SELECTED HIGH-IMPACT MEASURES

Reaching Ukraine's energy and climate targets

Georg Zachmann (editor)

Low Carbon Ukraine

Implemented by Berlin Economics

Supported by: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

Overview

List of abbreviations

Abbr.	Full name	Details
BEI	Burshtyn energy island	Electricity trading zone synchronised with ENTSO-e
BM	Balancing market	Last stage for trading electricity that allows to trade ancilliary services in addition to electric energy
CMU	The Cabinet of Ministers Ukraine	
DAM	Day-ahead market	Organised market segment where power for next day is traded
DSO	Distribution system operator	
EA	Energoatom	State-owned single operator of nuclear energy
EU	European Union	
FIT	Feed-in tariff	Policy mechanism that pays fixed prices to renewable energy producers
GB	Guaranteed Buyer	State-owned enterprise; off-taker of renewable energy and part of public service obligations for households
GHG	Greenhouse gases	
HUS	Housing and Utilities Subsidies	Welfare mechanism to support low-income households
IDM	Intraday market	Organised market segment where power with delivery at the same day is traded continuously
IEA	International Energy Agency	
IMF	International Monetary Fund	
IPS	Integrated power system	Ukrainian transmission grid synchronised with Russia
NERC	National Commission for State Regulation of Energy and Public Utilities	Energy market regulator
OECD	Organisation of Economic Co-operation and Development	
PSO	Public service obligations	Sector-specific regulatory tool for providing services of general economic interest
RES	Renewable energy sources	
TPP	Thermal power plant	
TSO	Transmission system operator	
UHE	Ukrhydroenergo	State-owned enterprise, operator of large hydro power plants
USS	Universal service supplier	Supplier at regulated prices
WTO	World Trade Organisation	

List of tables

List of figures

Motivation and project background

This series was elaborated in the framework of the project Low Carbon Ukraine (LCU) supporting more ambitious paths for selected energy and climate policy areas.

The idea to develop the present ten "Policy Proposals" arose in the course of LCU's support for the Ministry of Energy of Ukraine in setting up a National Energy and Climate Plan for Ukraine. While Ukraine's climate targets are partially very ambitious, we often observed a lack of underlying analysis and concrete policy measures to achieve those targets. For the most crucial topics, we provide a comprehensive analysis and propose concrete policy measures based on international experience.

Each Policy Proposal was written in a multi-stage process: a first draft of LCU experts or invited professionals was discussed over summer and early autumn 2020 with Ukrainian experts and stakeholders. Results of those discussions were taken into account when updating the Policy Proposals. It is important to note, that the presented results reflect the view of the authors and not necessarily the position of the BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety).

We hope that the present analysis and proposals will contribute to a fruitful and constructive discussion and help Ukraine to develop ambitious, yet realistic energy and climate policies.

Dr. Georg Zachmann, project leader
Ina Rumiantseva, project manager

Low Carbon Ukraine is a project with the mission to continuously support the Ukrainian government with demand-driven analysis and policy proposals to promote the transition towards a low-carbon economy. It is part of the International Climate Initiative (IKI) and is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) on the basis of a decision adopted by the German Bundestag. The project is implemented by BE Berlin Economics GmbH.

1. Financing options for ‘green’ policy measures

Authors: Manuel von Mettenheim, Stanislav Dubko

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Executive summary

Within our Policy Proposal series, we propose ambitious measures to reduce and curb greenhouse gas emissions in a variety of sectors of the Ukrainian economy. Since the proposed measures are capital-intensive, this paper aims at the capital markets and the unlocking of private capital. Therefore, we propose an overview of tailor-made green financing schemes consisting of public and private funding. We elaborate on certain financial instruments typical for green measures, such as green bonds, and potential ways of their correct implementation in Ukraine.

- For the transport sector, we propose to implement project finance for public private partnership in order to finance the capital-intensive monitoring and control infrastructure for congestion charging in Ukrainian cities. The scheme allows for the cooperation of the public and private sectors.
- To cushion the impact of a coal phase-out on regional socio-economic indicators, a transition fund could be established to finance retraining programs, pension schemes etc. A mix of grants on the one hand and loans on the other could then channel funds to regions and projects useful for an equitable transition.
- To finance an increase of renewable electricity generation, project finance and on-balance sheet finance are considered. High capital costs due to high perceived risks of such investments lead to a higher cost of electricity from renewable energy. Therefore, steps to reduce the risks are needed.
- We propose the use of green bonds to support energy efficiency retrofitting of public buildings as they offer secure options for large-scale projects and attract private investors. Nevertheless, government expenses will still be needed to accompany green bond financing.
- Our financing approach to support steel companies investing in new technologies and upgrades of their existing installations includes a modernisation fund and a credit from a multilateral development bank backed by a potential increase in carbon tax proceeds to front-load the fund. Then, the fund could provide grants to cover part of the investment into green modernisation projects with the company financing the other part of its project itself.
- To cover the expenses for Ukraine's ENTSO-E integration, Ukrenergo has to apply on-balance sheet financing with loans from international credit donors and higher tariffs with which Ukrenergo refinances itself.

Background

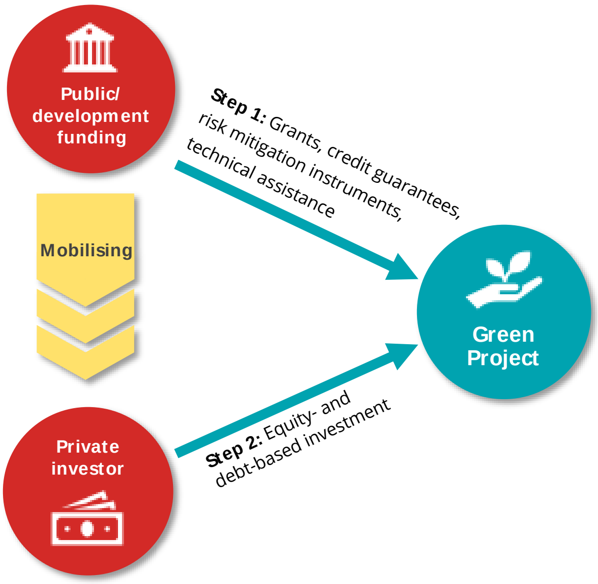
To conduct policy measures aimed at low-carbon, energy efficiency and renewable energy project, unlocking private capital is necessary.

In our Policy Proposal series, we propose several measures aiming at low-carbon, energy efficiency and renewable energy (RES) (hereinafter green) projects. Those green projects are capital intensive and cause a lot of upfront costs. Private investors are often hesitant to provide such capital-intensive investments because of low rates of return of long-term green investments and the associated risk (Sachs *et al.*, 2019). However, due to scarce public funds in Ukraine, the lion's share of climate financing will need to come from the private sector supported by public funding to mobilise and leverage private capital.

Ukraine suffers from a poor investment environment.

In Ukraine, capital costs are even higher and amortisation periods shorter than elsewhere due to a bad sovereign credit rating indicating a high risk for investors.[1] Furthermore, Ukraine suffers from an underdeveloped bond market and the contribution of banks and other financial institutions remains low.[2] In recent years prior to the Covid-19 crisis, however, stable economic growth since 2016 and the appreciation of the Hryvnia led the National Bank of Ukraine to loosen its monetary policy lowering the key interest rate from 18.0% in the beginning of 2019 to 6.0% as of today (September 2020).

Figure 1: Unlocking private capital



Public money should support the projects' cash flows.

The green measures we propose are all aimed at generating cash flows. To reduce the cost of capital for the projects, the cash flows must be improved, and their volatility reduced. Therefore, the government and development banks can start backing projects through market signalling, direct investment, risk mitigation instruments (such as RES auctions) and/or technical assistance.

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[1] The leading credit rating agencies rate Ukraine at B3 (Moody's), B (Fitch) and B (Standard & Poor's) with a stable outlook. The low speculative grade credit rating is due to a history of political instability, the conflict with Russian-backed forces in Donbas, weak institutional capacity, uneven application of the rule of law, high level of corruption and high external financing needs due to large government debt repayments. The significant impact of the Covid-19 pandemic even exacerbates the heightened macroeconomic and fiscal risks. https://www.fitchratings.com/research/sovereigns/fitch-revises-ukraine-outlook-to-stable-affirms-at-b-22-04-2020 (Accessed 28.09.2020)

[2] In January 2020, regulators approved the Strategy of Ukrainian Financial Sector Development until 2025. It aims at ensuring the sustained economic development and macro-financial stability, increasing the reliability and technological effectiveness of the financial system, reaching European standards on the financial market and increasing trust in the financial market. https://www.kmu.gov.ua/en/news/regulyatori-finansovogo-rinku-zatverdili-strategiyu-rozvitku-finansovogo-sektoru-ukrayini-do-2025-roku (Accessed 28.09.2020)

The proposed green measures involve different trade-offs between project economics and government support. Consequently, we present an overview of tailor-made financing mixes to unlock private investments for the measures.

We present tailor-made financing options to unlock private capital.

Financing policy measures

I. Congestion charge

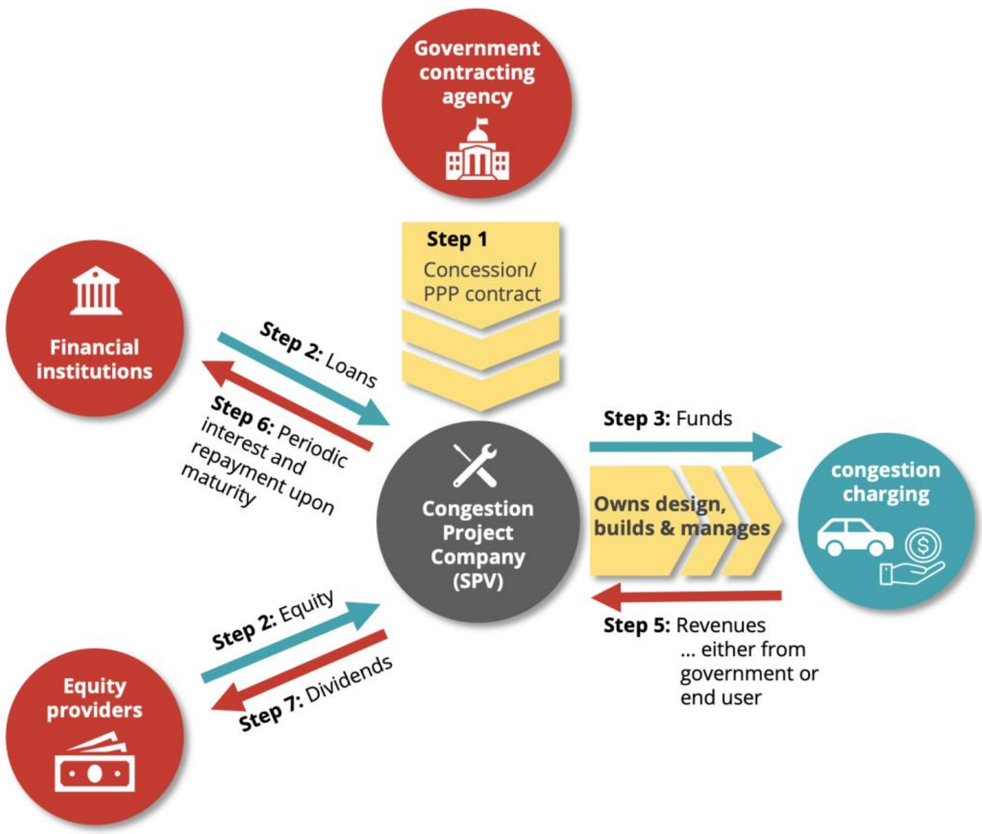
In the transport sector, a congestion charge could reduce road transport in Ukrainian cities and, thus, CO_2 emissions (see **"9. Low-Carbon Transport Policies for Ukraine"**). External identification and sensing technology, such as electronic road pricing gantries, have relatively high capital costs and induce operating costs which is why the Ukrainian municipalities might be reluctant to finance them with public funds. In order to reduce the dependency on the Ukrainian state-dominated funding models for road projects (World Bank 2018), we propose project finance for public private partnerships (PPP) to enable cooperation between the public and private sectors (Figure 2).

In the transport sector, project finance for PPP can break the state-dominated funding models.

According to Sachs *et al.* (2019), PPP schemes have a key role for low-cost finance, de-risking green infrastructure projects and crowding-in private finance. At the beginning, the project company (special purpose vehicle) concludes a PPP contract with the local government. Under a concession agreement, the local government enables it to design, build, finance and operate the project. The project company is responsible for raising and providing the funds to develop overhead gantries and cameras for licence plate recognition and street signs.

In a PPP scheme, the local government concludes a PPP contract with a project company.

Figure 2: Project Finance for Public Private Partnership



Similar Ukrainian road projects have a debt-equity ratio of 70:30 to 80:20.

The sources of capital are equity and a larger debt slice. Equity refers to capital invested by sponsors of the PPP project and other private investors acquiring a stake of the project company, while debt is borrowed capital from banks and other financial institutions. Typically, similar Ukrainian road projects are financed with a debt-equity ratio of 70:30 to 80:20 defining the financial risks of the project (World Bank 2018). The rate of return expected by equity providers is higher than interest rates of debt financing so that if the equity share decreases, the leverage increases. This leads to a reduction of capital costs, but it increases the financial risk due to a higher debt slice that requires larger cash flow for debt servicing.

Capital costs would amount to around 10-11%.

To determine the financing costs of the project, we apply the weighted average costs of capital. Given the 80:20 to 70:30 equity-debt ratio, 13% rate of return for equity providers and 8% interest, we obtain 11% and 10% rate, respectively, which the project company is expected to pay on average to all its security holders to finance its assets. Note that in a co-financing scheme, the local government could provide grants for the project. This could help to overcome the highest level of risk during the construction phase when delays and cost overruns can occur.

Public bodies can participate in the revenue structure of the congestion charge in order to carry some of the risk.

The revenues of the project are a key consideration for the investors and the financial viability of the project must be ensured. For providing the congestion charge, the project company is either paid by the government or the road users depending on the specific payment structure. The payment structure also defines the two main risks in the project scheme that must be shared among the actors: traffic risk (how many vehicles enter the congestion zone) and revenue risk (factor of traffic volumes/congestion charges and collection/enforcement risk). The municipality can support the revenues by applying an availability-based payment structure (Climate Bonds Initiative, 2015). In this case, the project company is paid for making the project/facility available for use even if the congestion zone is not used as much as anticipated. Thus, the public agency, namely the municipal Department of Finance, bears the traffic and the revenue risk, and misjudgement can lead to pressure on the public agency's budget. The public involvement could be necessary in Ukraine because average income levels limit the affordability of the charges (World Bank 2018). However, as the public agencies are not authorised to make such long-term commitments, an amendment in budgetary legislation would be necessary. Furthermore, the staff is not yet capable to assess the associated long-term fiscal risks with the conclusion of such contracts, so the necessary know-how must be developed.

Project is financed based on future cash flows.

In project finance, the project company usually repays when the congestion charge is up and running, and with the profits gained so that the lender has no or very limited claim on sponsor's assets. That is, the project would be financed based on the projected future cash flows. Past experiences with congestion charges have shown that, after a while, congestion fees can be a consistent source of revenue.[3] After interest payments and the repayment of the face value, political earmarking should be considered to enhance public transport and infrastructure upgrades in the congestion charging zones.

Ukraine is currently working on PPP legislation, but it has not yet been put into practice on a large-scale.

The Law of Ukraine on PPP was adopted in 2010.[4] Since then, the government has declared its support for this law, but without pursuing it further on a larger scale. On 3 October 2019, Ukraine updated the law on concessions to improve the legal regulation of concession activity and harmonise legislation in the sphere of PPPs paving the way for future projects[5] (Kyiv Post, 2019). The new law comprises guarantees for the protection of PPP participants aiming, first and foremost, at concessionaires and creditors. As there are still obstacles for PPP in Ukraine, the secondary PPP legislation is currently being updated with the assistance of the World Bank. It is important to note that PPP schemes only work for the benefit of the public if the

[3] In Stockholm, for example, the upfront costs for the congestion charge were recouped after four years (Provonsha & Sifuentes 2018).

[4] https://mtu.gov.ua/files/for_investors/Law%20of%20Ukraine%20on%20PPP.pdf (Accessed 28.09.2020)

[5] In June 2020, the Ukrainian government competitively tendered the first PPP designed in accordance with best international practice. It is aimed at transforming the Kherson port into a hub for cargo hauling operations on the Dnipro river (IFC 2020).

negotiators are highly professional, ethical and the project development is thoroughly followed by fair and transparent procurement for the benefit of the public interest.

II. Coal phase-out

In Chapter **"7. A socially sustainable coal phase-out in Ukraine"**, we propose accompanying social and structural measures for the coal phase-out. This would entail the closure of several of Ukraine's coal mines and related job losses. To avoid negative labour market effects, the structural change in the affected regions needs to be accompanied by well-designed policy measures.

Coal mining communities must be supported in case of a coal phase-out.

We propose a transition fund to reduce the socio-economic costs of the coal phase-out by supporting education programs, re-training opportunities, expansion of pension schemes[6] and structural improvements. The fund should be established in close cooperation with a multilateral development bank, such as the European Investment Bank (EIB). Similar to the EU's Just Transition Mechanism[7], the scheme should provide grants, crowd-in private investment and enable a public sector loan facility backed by the EIB or other multilateral development banks.

A just transition similar to that of the EU could be used to cushion negative economic effects on.

Figure 3 presents the scheme of the fund. To begin with, a front-loading of the fund's resources will be necessary. To improve the cash flow, a substantial part of the financing is obtained from grants. The grants used to boost investment could be partly financed by phasing out coal subsidies (see Chapter **"7. A socially sustainable coal phase-out in Ukraine"**. However, since the phase-out of those subsidies would extend over several years, it would be necessary to obtain a credit support from a multilateral development bank to provide the fund's initial funding.

The phase-out of coal subsidies could be used to provide grants.

Apart from that, the fund should leverage private capital from financial institutions that provide loans (incl. micro loans) and bank guarantees for business development. A loan requires periodic servicing of interest and repayment which means that it may be more suitable for low-risk projects that generate periodic cash inflows (Withana *et al.*, 2011). A competitive awarding of funding could be explored, where projects can apply stating the amount of co-financing they need. The use of grants for the project should always be accompanied by other financial contributions to ensure that the investments make sense commercially. Also, the fund should reach different social and economic projects implemented in the coal mining communities. On the local level, mining community stakeholders need to be informed on the funding and assistance programmes that are available for the respective community. The whole scheme would be designed and implemented in partnership between the Ukrainian state, regional authorities, NGOs, unions and other organisations.

In cooperation with financial institutions, the fund should also provide loans. The fund should then reach social and economic projects.

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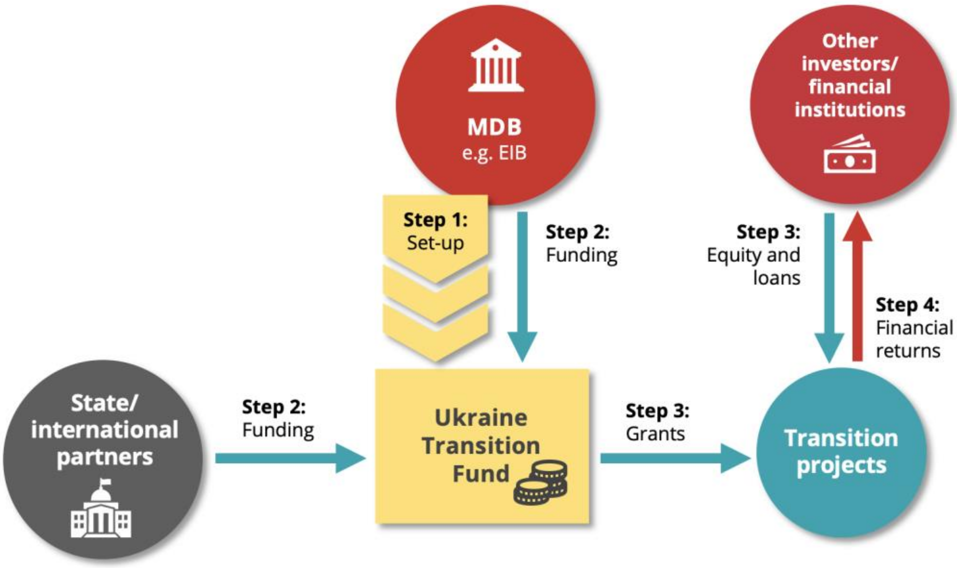
[6] The expansion of pension schemes is subject to a successful implementation of the pension reform in Ukraine.

[7] https://ec.europa.eu/commission/presscorner/detail/en/fs_20_39 (Accessed 28.09.2020)

Figure 3: Transition fund



III. Integration of renewable energy

For increasing the RES share in power generation, investment needs of EUR 19 bn are needed.

In order to achieve a more ambitious share of renewable energy sources (RES) in Ukrainian power generation of 30% in 2030, investments in new RES capacities and flexible generators to balance RES fluctuations will be needed. Given high capital requirements, a cost-effective way to raise funds is particularly important. Wind and solar projects incur the dominant part of their lifetime costs upfront, at the construction stage, not during the operating phase. From an investor's perspective this means an increase of investment risks (Noothout *et al.*, 2016).

The introduction of a fixed feed-in-tariff (FIT) for RES generation acted as the initial driver for investment into this sector, with around EUR 8 bn invested until 2020. However, the eligibility of new plants for FIT support ended in 2019 and FIT levels were retroactively restructured in 2020. From 2020 on, support for new plants will be determined via competitive auctions. In Chapter **5.** we show how Ukraine's RES auction design and support system can be improved in order to decrease risk premiums for RES investors.

To raise the funds for RES assets, either non-recourse project finance or on-balance sheet finance are common options.

According to FS-UNEP (2018), financing for RES assets of more than 1 MW can be subdivided into (a) non-recourse project finance (42% of all projects worldwide in 2017) and (b) on-balance sheet finance (56%). The share of green bonds and other finance options were negligibly small.

Project finance

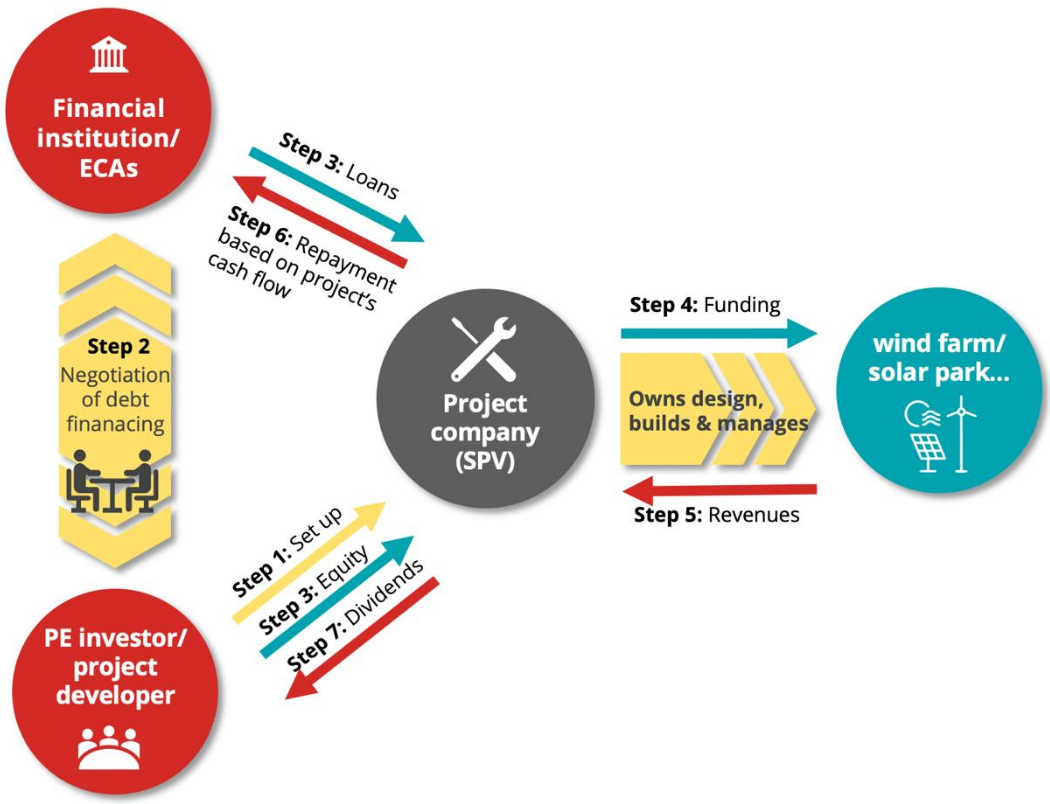
In the case of project finance, investors create a project company to incorporate the project. Figure 4 depicts a typical scheme for project financing. To begin with, the project company needs to negotiate building permits and power purchase agreements with the government. It is responsible for any further contracts and agreements concerning the RES project, such as supply contracts, off-take agreements, operating and maintenance contracts. It designs, builds and manages the RES project. In order to obtain additional funding, equity investors and financial institutions negotiate the debt financing conditions. RES projects are typically made up of a large debt slice from financial institutions, and a smaller equity slice from developers and other investors (FS-UNEP, 2018).

Project finance: a project company is responsible for the project and its funding.

In Ukraine, full-fledged non-recourse project finance (entitling the lender to repayment only from the profits of the project the loan is funding and not from any other assets of the borrower) is not possible due to the set-up of the current legislation that prohibits to prevent recourse to any assets of the borrower. However, financing a project company created specifically for RES generation with no other business activities/assets would essentially represent a non-recourse project finance transaction.

Current legislation prohibits non-recourse project finance. Solution: setting up a RES project company.

Figure 4: Project finance for renewable generation



The share of equity capital is at 30% while the debt slice accounts for 70% of the financing for Ukrainian wind and solar projects. The funding costs are quite high in Ukraine, given the country's political and economic risk in general and the risks specific to the RES generation sector where fixed FIT may be subject

The cost of capital (15%) is particularly high due to domestic risks.

to retroactive cuts and the risk of solvency of the Guaranteed Buyer[8] must be factored in. With a cost of debt of 20.5% in Hryvnia and an equity value of 13.5%, the weighted average cost of capital is set at around 15% taking into account the tax rate (Trypolska, 2019). Such capital costs are considered to be very high, as can be seen from the comparatively low capital costs in OECD countries, where they do not exceed 10%.

Risks can be reduced, e.g., by cooperating with export credit agencies in certain cases.

High capital costs lead to higher levelised cost of electricity for RES - and translate into higher auction bids. Further steps to reduce the risks are needed. For example, export credit agencies (ECAs) offering guarantees could be of use if private banks are unable or unwilling to finance certain projects due to market conditions. They take away some of the risks from the lenders and, thus, reduce the interest rate payable on debt (FS-UNEP, 2018).

On-balance sheet finance

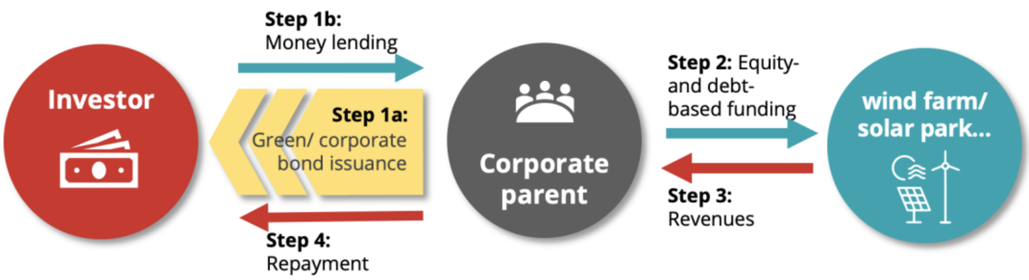
On-balance sheet finance is mostly conducted by independent power producers relying on debt-markets.

On-balance sheet financing is mostly conducted by utilities and independent power producers. The RES projects are financed from the owner's balance sheet. They, in turn, rely on debt markets to provide additional funding. Here, the package of equity is linked to the corporate developer of the project (not to the project vehicle itself), i.e., a project sponsor utilizes all assets and cash flows from the company to guarantee the credit provided by lenders.

Cost of capital amount to around 9%.

In November 2019, DTEK Renewables, DTEK's operating company managing its assets in the renewable energy sector, launched its first green bond worth EUR 325 m with a coupon rate of 8.5% and amortisation in 2024. For comparison, Italy based Enel issued EUR 1.25 bn 10-year bonds at a coupon rate of 1.4%.

Figure 5: On-balance-sheet finance for renewable integration



IV. Energy retrofitting of public buildings

We propose the use of green bonds to finance energy efficiency retrofitting of public buildings.

To improve energy efficiency in the Ukrainian building sector, we evaluate energy efficiency retrofitting of 50% of the public building stock until 2030 (Chapter **"10. Energy efficiency in public buildings – 50% retrofitting target until 2030"**). According to our estimations, investment needs amounting to app. EUR 10 bn are required until 2030 to achieve annual energy savings of up to 2,300 ktoe annually and related emission reductions of up to 5 Mt CO_2 annually from 2030 onwards. Therefore, we propose the use of green bonds, as they offer relatively secure options for large-scale projects.

[8] State owned enterprise responsible for payments to RES generators

A green bond is a fixed-interest security that serves to raise capital for activities aimed at reducing or preventing damage to the environment or climate. Compared to loans, green bonds can provide relatively cheap capital for specific green investment targets if well structured. Private investors get the chance to diversify their portfolios by tapping the green bond market.

Green bonds can provide relatively cheap capital for specific green investment targets.

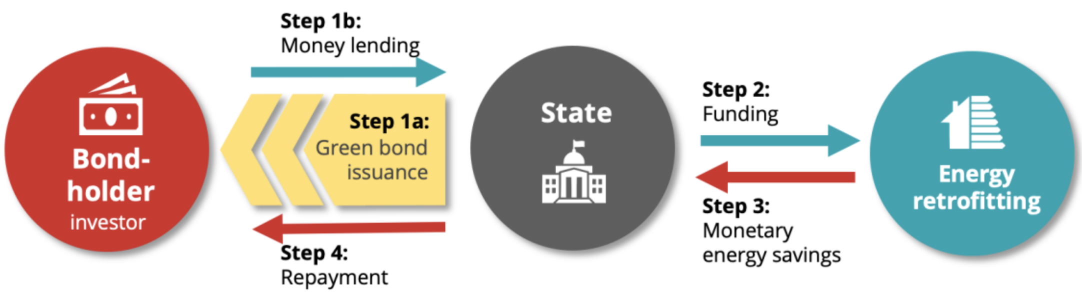
In the case of retrofitting public buildings, the state should be the issuer of the green bond while professional institutional investors should be the bond holders. The bond financing structure should cover EUR 8 bn while being accompanied by additional EUR 1.6 bn of governmental spending. The green bonds should be ring-fenced to the retrofitting of public buildings. Therefore, a clear definition of a retrofitting measure and the minimum target for an energy efficiency level must be established. Due to the outdated Ukrainian public building stock, energy efficient retrofitting could also be accompanied by structural non-energy-efficient renovations at the building.

The bond financing should cover most of the financing needs while being accompanied by governmental spending.

The balance of risk and return depends on the type of issuer, the strength of the economy and the cycle of the securities market. When it comes to domestic market Hryvnia denominated bonds, pricing should be similar to regularly issued bonds unless investors can gain some specific benefits from green bonds, e.g., if green bonds would be treated preferentially regarding the capital adequacy of banks. Using the government bond yield as a benchmark, Hryvnia-denominated bonds would yield around 12%. However, we assume Euro denominated bonds with a coupon rate of 7% and a lending period of 15 years through the reinvestment of bonds with a 5-year maturity. Thus, we obtain a Capex of EUR 19.6 bn. The debt can be serviced by monetary energy savings amounting to EUR 24 bn until 2059 (see Annex: **Methodology of Chapter "Energy efficiency in public buildings – 50% retrofitting target until 2030"**).

We assume Euro-denominated bonds with a coupon rate of 7%. Capex sums up to EUR 19.6 bn.

Figure 6: Green bonds for public buildings retrofitting



In June 2020, the amendments to the law on securities introducing green bonds were adopted.[9] However, it is still not possible for the state to extend its loans from the state budget to local budgets. Funding for locally administered buildings can only occur in the form of non-refundable subventions. At the same time, administrators of public buildings are not allowed to borrow. Moreover, the basis for calculating the expenses to support public buildings from public funds does not provide for the accumulation of monetary savings to be channelled to repay the investment. Therefore, a change in the budgetary legislation would be needed to use green bonds for public buildings that are owned by local authorities.

To use green bonds on municipal level, a change in the Budget Code must be conducted.

[9] https://zakon.rada.gov.ua/laws/show/738-20#Text (Accessed 28.09.2020)

V. Greening steel production

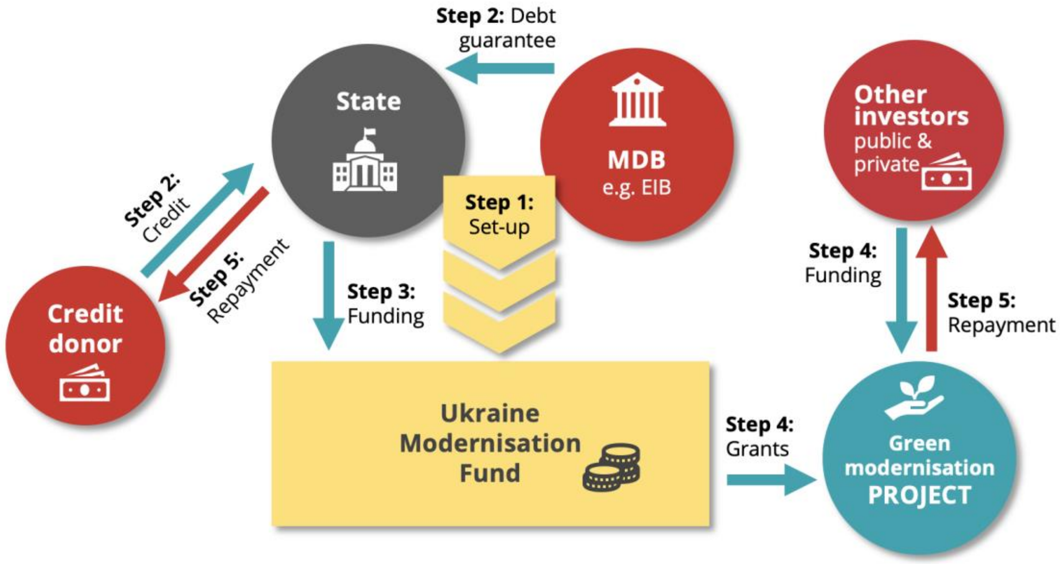
The Ukrainian steel sector must be modernised for decarbonising the production.

In Chapter **"8. Towards a decarbonisation of Ukraine's steel sector"**, we aim at a stricter climate policy to maintain or re-establish the competitiveness of the Ukrainian steel industry through modernisation measures for emission intensive steel assets. The CO_2 emission intensity of the steel industry can be reduced in three broad dimensions: optimising production processes for lower emissions without hardware changes, retrofitting existing production infrastructure and replacing equipment with newer and different technologies.

A modernisation fund similar to that of the EU should be established using funds from a potential increase of the carbon tax.

Our financing approach to support steel companies investing in new technologies and upgrades of their existing installations is twofold. Firstly, we propose the establishment of a modernisation fund (Figure 7) similar to that of the EU. A potential increase of the carbon tax could be used to provide funding (Chapter **"2. A Revision of Ukraine's Carbon Tax"**). However, as suggested in the Policy Proposal, the increase of the carbon tax would be implemented only gradually until 2030, so the fund would need front-loading to enable early grant provision. Therefore, secondly, to kick-start the fund, a EUR or USD credit should be obtained from a credit donor as part of the national debt that may be backed by future revenues through the carbon tax. Ideally, the credit would be supported by a guarantee from a multilateral development bank (MDB) (e.g. EIB) in order to lower the borrowing costs. Then, the fund could provide grants to cover part of the investment into green modernisation projects with the company financing the other part of its project itself.

Figure 7: Modernisation fund



Cost of capital amount to around 8%.

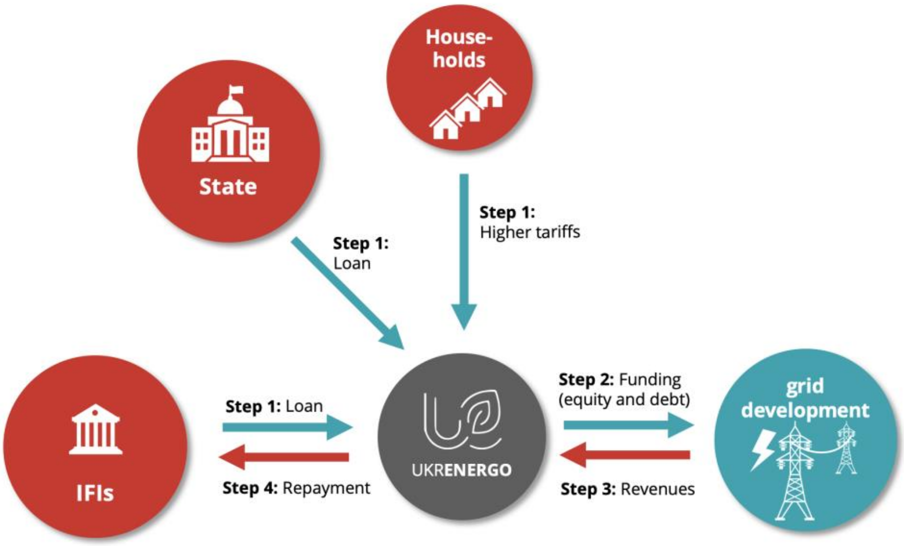
Currently, the capital costs for Ukrainian steel companies are quite high. Bonds from Metinvest, a Ukrainian steel company, have a coupon rate of 7.8% with maturity end in 2029 while ArcelorMittal, an international steel company, can tap the debt-market with a 4.2% coupon rate. Therefore, multilateral development banks should be approached to make credit available at improved conditions, meaning longer maturities and cheaper rate, for Ukrainian steel companies to unlock substantial investments.

VI. ENTSO-E integration

We support Ukraine's integration into the ENTSO-E synchronous area until 2023 (Chapter **"6. Synchronising Ukraine´s and Europe´s electricity grids"**). It includes a number of technical, political, legal and administrative requirements. Ukrenergo, the national power company, estimates costs of EUR 357 m of which EUR 130 m are intended for the grid development, EUR 130 m for generation readiness to ensure reserves and automatic voltage control, EUR 92 m for development of communication channels for dispatching operations, and EUR 5 m for additional studies on the static and dynamic stability implementation of the operation handbook. However, our estimates suggest that the cost will be about twice as high (see Chapter **"6. Synchronising Ukraine´s and Europe´s electricity grids"**).

To finance Ukraine's integration into the ENTSO-E synchronous area, around EUR 360 m of investment is required.

Figure 8: On-balance sheet finance for grid development



Since project finance is more complex and typically more costly, corporate finance is the predominating financing approach for electric power (Roland Berger, 2011). Note that the option of private sector investment is not feasible as Ukrenergo is a state-owned company (subordinated to the Ministry of Finance) which is allowed to finance its investments either from public sources such as electricity tariffs or via borrowing from international financial institutions for priority reconstruction (World Bank, 2014). According to Ukrenergo[10], they are expected to cover EUR 222 m by themselves. The remaining EUR 138 m of their own projections shall be provided by development banks such as the European Bank of Reconstruction and Development (EBRD), EIB and Kreditanstalt für Wiederaufbau (KfW).[11] Therefore, the launch of credit lines for Ukrenergo from the development banks are needed. EBRD and Ukrenergo already finalised a 15-year sovereign-guaranteed loan of up to EUR 149 m to finance the procurement of 26 new transformers and the automation upgrade of 12 high voltage substations.[12] The loan is accompanied by app. EUR 50 m of Ukrenergo's own resources. For facilitating the power system integration with Europe, Ukrenergo also obtained a loan of USD 240 m (EUR 205 m) from the International Bank for Reconstruction

Corporate finance is the predomi-nating approach for grid development.

[10] https://www.usubc.org/files/ENTSOE%20presentation%20(002).pdf

[11] Note that EUR 222 mn and EUR 138 m sum up to EUR 360 m (not 357 m as shown above) but both figures are taken from the official documents from Ukrenergo.

[12]https://www.ebrd.com/work-with-us/projects/psd/ukrenergo-transmission-network-modernisation.html

and Development (IBRD), additional funding from the Clean Technology Fund amounting to USD 30 m (EUR 25 m) accompanied with additional funding from the Government of Ukraine and other borrowers.[13]

Ukrenergo repays based on its business revenues from general activities.

Ukrenergo repays when due based on business revenues from general activities of the company. The additional costs used to finance capital expenses are then added to the tariffs with which Ukrenergo refinances itself. At the same time, Ukraine's integration into the more competitive European electricity market has a potential of reducing electricity prices for Ukrainian consumers.

[13] It is important to note that Ukrenergo does not recognise the funding from IBRD as necessary for ENTSO-E integration and, therefore, not as part of the related costs.

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Annex

Table 1: National and international credit donors

International donors				*National Donors*	
Banks	Credit and financial institutions	Agencies, facilities, and funds	Programmes and projects	Banks	Agencies and ministries
EBRD	IFC	GIZ	E5P	Ukreximbank	SAEE
EIB	NEFCO	GCPF	EU Horizon 2020	Ukrgazbank	Minregion
NIB		GEF	SUDEP		
KfW		SECO and SDC	MPSF		
		SIDA			
		USAID			

Table 1 presents a list of international and national green creditors for Ukraine assembled by Sokolova et al. (2019). Sokolova et al. (2019) conclude that the Ukrainian sustainable development strategy pre-dominantly depends on international creditors providing loans.

Source: Sokolova *et al.* (2019)

2. A Revision of Ukraine's Carbon Tax

Author: Julia Breuing

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Executive Summary

Among the countries that implemented a carbon tax, Ukraine's carbon price is one of the lowest. Studies have shown that it was virtually ineffective in strengthening energy efficiency and reducing carbon emissions, thus it does not support meeting international climate obligations. The country's current efforts to introduce a range of measures to achieve emission reduction goals call for a revision of Ukraine's carbon pricing strategy.

To avoid possible border-tax adjustment effects from the EU, we propose a price consistent with projections of the EU carbon price for 2030. Consequently, in the following, the implications of a carbon tax of EUR 39 /tCO_2 are discussed.

A poorly designed carbon tax can have negative effects on employment, competition and economic growth. Therefore, the OECD advises to respect the following principles: The carbon price should be phased-in over time in a predictable manner to support long-term investment decisions. The carbon policy should be transparent and fair. And it should be supplemented by measures that address the policy´s income effects as well as additional measures to support deeper emission reductions over time. In line with these recommendations, a gradual phase-in of the tax, starting in 2022 with a rate of EUR 4.3 /tCO_2 is suggested.

Further, supplementing measures are proposed. Experiences from other countries have shown that a (nearly) revenue neutral tax is commonly successful in reducing emissions without negatively affecting welfare. Therefore, the majority of tax income generated should be used to finance tax cuts or subsidies for households and businesses. These measures could be in the form of:

i. Support for the Housing and Utilities (HUS) scheme. By increasing energy prices, the carbon tax would automatically lead to an increase in subsidies under the current HUS scheme. Therefore, a share of the tax revenue should be dedicated to the Ministry of Social Policy for the HUS. Due the progressive nature of the programme, this would especially target low-income households.

ii. A reduction in indirect taxes, for example in the form of expanding the coverage of a reduced VAT rate. This could offset price increases in goods other than energy.

iii. A decrease in business taxes to reduce the burden carried by firms.

For the latter two, a separate, detailed assessment is required to identify the most efficient way of offsetting financial distress for consumers and producers. We do not propose legal earmarking but suggest political earmarking of revenues.

Within the first nine years after its introduction, in total, EUR 34.4 bn of carbon tax revenue can be redirected via these measures, with the highest annual tax revenue of EUR 6.2 bn achieved in 2030.

Still, the carbon tax should be regarded as only one piece of an effective climate package. To enable the price effects desired by setting a carbon price signal, a share of the tax revenue should be used to fund further projects targeting emission reductions. Therefore, this policy proposal constitutes only the first part of a series of 10 proposals, which altogether would likely have a high impact on Ukraine's climate action.

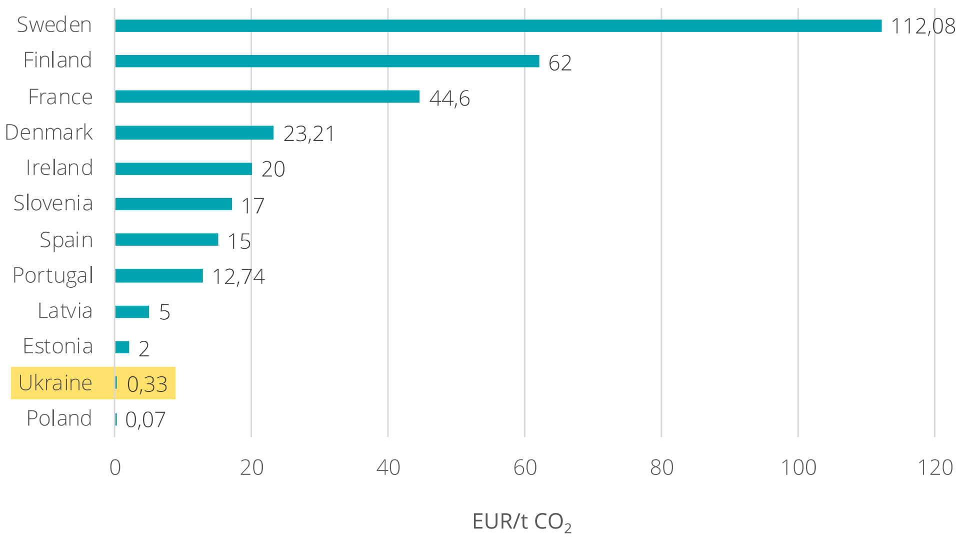
Current Carbon Taxing

Ukraine already has a carbon tax in place. But its rate is one of the lowest among countries that impose a tax on carbon.

Carbon pricing is a policy instrument that can induce broad, cross-sectoral climate mitigation measures. Ukraine's current carbon tax is part of the environmental tax, defined by Article 14.1.57 of the Tax Code (CMU, 2010). The tax rates for emissions by stationary sources are set by Article 243. The legislation targets emissions into the atmosphere, water and soil. The GHG taxes cover nearly all stationary sources of emissions, including the power sector and the metal, chemical and food industry. However, the carbon tax rate, which targets the largest share of GHG emissions, is too low to stimulate companies to implement energy saving or fuel switching technologies. Further, a lack of proper accounting, interaction of public authorities and control over pollution allowed eligible taxpayers to avoid paying the tax in past years (Romanko, 2018).

The tax was introduced in 2011 with a rate of EUR 0.003 /tCO_2 and was gradually increased by a rate not much higher than inflation until 2019 when a larger increase was implemented. Figure 1 displays carbon taxes (only taxes, not emission permit prices) in EU countries compared to Ukraine. With a carbon tax of EUR 0.33 /tCO_2 (as of 2019), Ukraine has one of the lowest carbon prices worldwide (World Bank, 2020). In comparison to other European countries, Ukraine is well below the median of EUR 17 /tCO2. Only Poland's tax rate was lower in 2019, with EUR 0.07 /tCO2. [14]

Figure 9: Carbon tax rates (excluding ETS) in Europe and Ukraine, as of 2019



Source: World Bank (2020)

Previous and current tax rates are too low to ensure consistency with the 1.5°C goal set by the Paris Agreement.

The National Ecological Centre of Ukraine (NECU, 2010) finds that the previous, low carbon tax rate does not lead to a reduction in the combustion of coal and associated carbon emissions. Frey (2016) further finds that the overall effects of the carbon tax were negligible. Despite the recent increase in the tax rate, Ukraine's current policy pathway would still lead to an emission level substantially exceeding levels required to maintain global warming below 2°C by 2030 – even when planned policies are taken into account (CAT, 2020). Moreover, the current carbon tax only covers stationary sources of emissions. The mobile sources diesel and gasoline are covered by an energy tax, which is however the lowest in Europe (Capros, 2020).

Effects of the harmful emission level are already noticeable. In 2016, Ukraine had the highest mortality from air pollution worldwide with up to 66'000 people dying annually because of air pollution (Heinrich Böll Foundation, 2019). Additionally, longer-term effects of climate change, like extreme weather conditions, have a negative impact on the country's agricultural sector (Polityuk, 2020). As these events are likely to become even more frequent and more extreme, this calls for a more ambitious carbon pricing and consequently a revision of Ukraine's carbon tax.

[14] Note, that large emitters in the EU (incl. Poland) fall under the EU Emission Trading System featuring prices around EUR 20/tCO2 in 2019.

Background info

Carbon Pricing in the EU

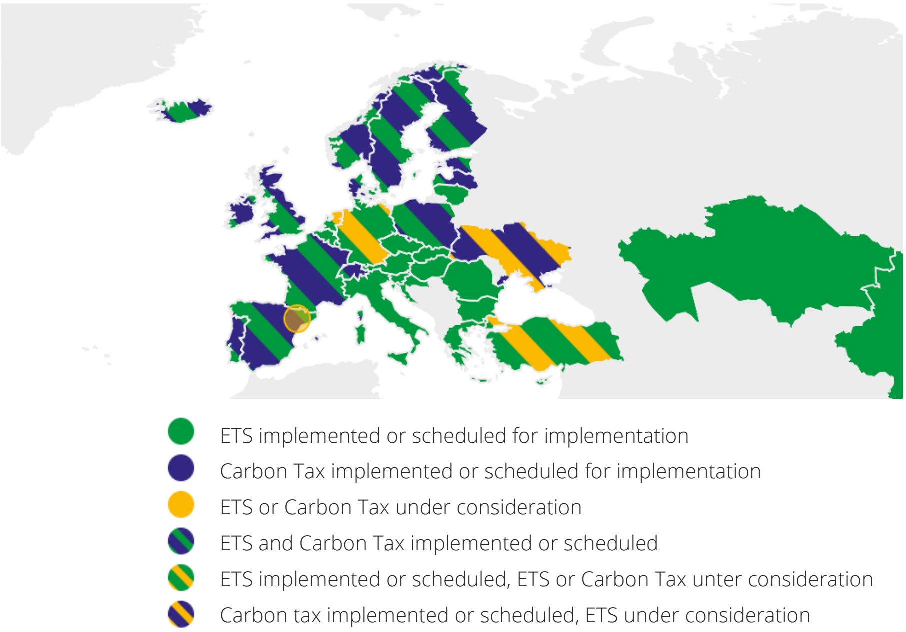
The Nordic countries are frontrunners in terms of carbon pricing. They introduced a carbon tax in the early 1990s. Their decision was built on ambitions to reduce income taxes and on their concerns about climate change. By both lowering income taxes and putting a price on carbon, they achieved a mainly revenue-neutral taxing scheme (Andersen, 2010). Soon after, the Netherlands and Slovenia followed. Since then, Portugal, Spain, Ireland, the UK, Poland, Latvia,and Estonia have also introduced carbon taxes, while the rest of the EU is covered by an ETS (see Figure 2).

Apart from different carbon tax rates, the countries' approach also differs in revenue recycling. Sweden and Finland lowered direct income taxes. Denmark and the UK on the other hand aimed at reducing inflationary pressure by lowering employer's social security contributions. Additionally, they contribute a share of their carbon tax revenue (5-20%) directly to energy efficiency subsidy programs. The Dutch similarly introduced a combination of both. In the first phase, they reduced income taxes , while lowering employers´ payroll and corporate taxes in the second phase.

In the EU-funded COMTER project Andersen (2010) found emission reductions of 6% in the period of the mid 1990s to 2004 under the early-movers, which can be attributed to the carbon tax. The results from the E3ME model, presented in Barker *et al.* (2009), lie in the same range. They attribute reductions of 4-6% of emissions to the carbon tax in the Nordic countries and of 2% in the Netherlands.

The difference can be explained by less ambitious tax shifts in the Netherlands. By investigating the mentioned EU countries, Hájek *et al.* (2019) find evidence that the long-term carbon tax in place in these countries is environmentally efficient (Was genau bedeutet das?). Further they find that a ceteris paribus increase of the carbon tax rate by one Euro per ton of CO_2 equivalent, would reduce per capita GHG emissions by 11.58 kg per year.

Figure 10: Carbon pricing in Europe



Source: World Bank (2020)

Proposed carbon pricing mechanisms

Carbon prices intend to internalise the costs of pollution imposed on society by the “polluter pays” principle and hereby incentivise low emission behaviour. The low level of effectiveness of Ukraine’s current carbon tax, however, calls the existing carbon pricing regime into question. Before a revised taxing scheme is proposed, different options of carbon pricing are therefore discussed.

In economic theory, an ETS is the first best policy choice if transaction costs are sufficiently low. As these are rather high in reality, a carbon tax presents an attractive, second best choice.

Two carbon pricing designs can be differentiated. Either, prices can be set directly by the lawmaker in the form of a carbon tax. Based upon this price, the level of carbon emissions will be determined by emitters. The lawmaker can also set quantities – in the form of caps – instead of prices. This is achieved through establishing an Emission Trading System (ETS). By this, the lawmaker has direct control over the amount of carbon that is allowed to be emitted. The carbon price is then determined by the demand for emission certificates. The Coase Theorem states that an ETS is the first best policy choice when externalities are tradable and transaction costs are sufficiently low (Capros, 2020). In reality, transaction costs can be rather high, such as: 1) Better-informed market participants may exploit information problems , leading to extra profits for those participants, 2) there is a risk of market power abuse, which poses a serious threat in Ukraine as large emitters usually highly influential and 3) uncertainty in prices makes it harder to foresee consequences and to offset negative effects (Andrew, 2008). A poorly designed ETS can thus encourage revenue-shifting to dominant players as well as a reduction in confidence of investors. A tax can be implemented more credibly and could hereby support Ukraine to attract capital. Despite being only the second-best policy choice, the arguments in favour of a carbon tax are simplicity, transparency and reduced regulatory uncertainty. Moreover, it could help Ukraine to act sooner than later, as a carbon tax requires less time for implementation than an ETS.

Previous studies favouring a downstream tax or an ETS in Ukraine, failed to take it’s administrative challenges and disadvantages into account.

Different projects have already evaluated potential carbon pricing strategies for Ukraine. The 'Preparedness for Emissions Trading in the EBRD Region I' (PETER I) evaluates how the current carbon tax can be improved while PETER II prepares a road map for a transition towards an ETS. For an improved carbon tax they propose a scheme with two tax bands. They neglect, however, mobile sources and rely on the current downstream[15] tax (EBRD, 2014). The Partnership for Market Readiness (PMR) compares different scenarios: a carbon tax, an ETS and a combination of a tax and an ETS (Vivid Economics, 2019). They find that an extended carbon tax covering all sectors has a larger negative effect on output and competitiveness than the ETS with similar emission reductions. However, they neglect the addressed institutional drawbacks of an ETS. While a carbon tax leads to larger costs for companies, it might provide easier access to capital to improve efficiency and install less emission-intensive technologies. Moreover, as in the EBRD (2014) study, the IPMR neglects the transport sector, which makes up 10% of Ukraine’s emissions (see the chapter on transport policies). The most recent study by Kantor & E^3M (2021) evaluates carbon pricing for Energy Community Contracting Parties, including Ukraine. Kantor & E^3M (2021) propose the introduction of a cap-and-trade system in the power and heat sector, while country’s could consider a carbon tax in the transport and building sector. The authors assess different policy options for this cap-and-trade system and conclude that a scenario encompassing a transitional period for carbon pricing and integrated power and gas markets with the EU presents the best policy option.

[15] A downstream approach taxes actual emissions.

Ukraine needs to establish plans for an ETS to meet obligations under the Ukraine-EU Association Agreement (icap, 2020). As a first step towards an ETS, in December 2019, a law on Monitoring, Reporting and Verification (MRV) of greenhouse gases (GHG) was adopted and should come into force in 2021 (CMU, 2019b). However, establishing an ETS is connected to a high administrative burden, as credible institutions have to be set up and market manipulation needs to be countered. As the design should be well thought-through, the implementation might take some time. Nevertheless, Ukraine should act rather sooner than later which is why this Chapter focuses on the easier-to-implement measure – an upstream carbon tax. In the long-run though, this should be complemented by an ETS to meet international obligations (see *Background Info – Transition to ETS* on page 33).

We prpopose an easier-to-implement upstream carbon tax, which should be complemented by an ETS to meet international obligations.

This paper further focuses on CO_2 emissions from the combustion of fossil fuels. These can be covered by levying an excise tax on coal, natural gas, oil and their derivatives. The point of taxation determines the distinct point in the supply chain the tax is raised. An upstream approach taxes the carbon content in raw fuels, whereas a midstream approach taxes fuels further down the supply chain and a downstream approach taxes actual emissions. In theory, the approaches should lead to equal results, at least in the "perfect" economic world (Hardistya *et al.*, 2019). However, there are several advantages of an upstream approach over the downstream tax, most of all its administrative simplicity and the broad coverage of fuels. With an upstream approach, the fuels are taxed at the point of extraction or importing, i.e. when entering the market. This has the following implications for different fuel types: Crude oil would be taxed as it reaches the refinery, natural gas as it enters the pipeline system, or if it bypasses the system[16] when it arrives at the end user and coal as it leaves the mine (Horowitz *et al.*, 2017). There can also exist a hybrid form, where coal and natural gas are taxed upstream, oil, however, is taxed midstream i.e. as it *leaves* the refinery. Consequently, different oil products, like gasoline, diesel and kerosene, are taxed differently and the different carbon intensities are accounted for. Further, imports of fossil fuels would be taxed whereas exports of coal, natural gas or oil products would be eligible for refundable tax credits. In comparison to the current downstream taxing scheme in Ukraine, an upstream/midstream approach reduces the administrative burden of accounting actual emissions in production processes. Moreover, when the tax is charged at the point of market entry, the collection of the tax might be easier than with the current scheme. Disadvantages of an upstream carbon tax are that it is less flexible and that it is more complex to exempt certain sectors – notably the ETS sectors once the market has been established. Still, some countries show that it is possible. France, Denmark and Sweden each apply an upstream carbon tax successfully exempting ETS sectors (World Bank, 2017).

Under the proposed upstream tax, fuels are taxed when they enter the market, which reduces the administrative burden in comparison to the current downstream tax.

Introducing a substantial carbon price in Ukraine could lead to carbon leakage, which means that a carbon tax imposed in Ukraine could lead to an increase in emissions in other jurisdictions. In theory, this could result if consumers turn to producers from countries where no tax is applied, as these face lower input-costs especially for carbon-intensive products, such as steel, electricity, or cement. To avoid a shift from locally produced goods to imports, a border carbon adjustment could be implemented. A standard border carbon adjustment corresponds to an estimation of how much higher goods prices would be, if the same carbon tax was applied in the country of production. It would apply the carbon tax to imports, based on an estimation of how much GHGs are emitted during the production of these products. This, however, is connected to high computational efforts, high administrative burden and legal risks. Moreover, there is no empirical study showing carbon leakage to actually occur and whether the carbon tax could not even have positive effects in the long-run through increased competitiveness (World Bank, 2017). Furthermore, the two most important trading partners of Ukraine, Europe and China, already imply (at least partly) a price for carbon in the form of emission trading schemes. Therefore, the benefits of introducing a border tax adjustment might be small.

Carbon border adjustments are connected to high computational efforts, while its positive effects are debateable.

[16] e.g. when large gas consumers are directly connected to gas extraction or landing points.

With the proposed uniform, upstream tax on fossil fuels exports would be eligible for exemptions. No carbon border adjustments are proposed. The steel sector would be eligible for partial exemptions, due to its importance for the economy and its vulnerability towards the tax.

Based on the presented arguments, a change of Ukraine's current downstream tax to a hybrid upstream-midstream, uniform carbon tax is proposed, where coal, peat and natural gas are taxed when they enter the market, whereas oil is taxed as it leaves the refinery, i.e. oil products are taxed when they enter the market. To allow for a clear distinction to the current downstream approach, where actual emissions instead of the carbon content is taxed, only the term 'upstream' will be used in the following. The tax would not be applied to biofuels. Furthermore, imported fuels would be taxed, whereas exported fuels would be eligible for exemptions. In law, the tax could be expressed in normal trade units (weight or volume), based on average, internationally acknowledged CO_2 emissions. No border tax adjustment for processed commodities or electricity is suggested.

Summarising, the tax would cover all sectors. This can be justified 1) by an equity point of view – by taxing all sectors, the "polluter pays" principle is preserved – and 2) by the significant administrative burden that would be required to exempt certain industries. Nonetheless, if the carbon tax faced by a certain sector, e.g. agriculture[17], would lead to a substantial negative effect for the population while the overall positive effects of taxing this sector are negligible, a tax refund could be discussed. This applies to the steel sector. Its exports accounted for 23% of Ukraine's total output in 2018, thus representing an important part of Ukraine's economy (German Advisory Group Ukraine, 2019). Moreover, it is strongly exposed to the world market, as the majority of the steel is produced for export. In addition to the lack of market-ready technologies that would allow for producing low-carbon steel as well as to the lack of innovation, this sector is especially vulnerable to the CO_2 tax and would lose its competitiveness with a carbon price of EUR 16 /tCO_2 (see chapter "Towards a decarbonisation of Ukraine's steel sector"). Exemptions could also be granted to companies that install carbon capture and storage technologies.

To avoid border adjustments from the European side, a tax corresponding to EU ETS price projections of EUR 39/tCO_2 in 2030 is proposed, which should be phased-in linearly over 9 years.

To avoid that Ukraine itself is affected by possible future carbon border adjustment mechanisms of the EU, the price for future ETS-sectors should be set in accordance with EU prices. To ensure consistency between sectors and to maintain the simplicity of a uniform tax rate, this is proposed to be applied to all sectors. The reference carbon price is retrieved from the updated ETS price trajectory of the EUCO3232.5 policy scenario[18] from the European Commission (2019). However, this scenario still assumes a 40% reduction in GHG emissions by 2030. As most recently European emission reduction goals have been revised to 55% below 1990 levels by 2030, a different price could result. Once a new policy scenario is published, the carbon price target should be updated. Until then, we calculate with the price stated in the EUCO3232.5 policy scenario of EUR 28/ tCO2 by 2030 in 2013 prices. Assuming a 2% inflation, this results in a carbon price of EUR 39/ tCO2 in 2030. To allow for a smooth adaption of consumer and producer behaviour, a linear phase-in is suggested, starting with a rate of EUR 4.3/ tCO2 in 2022[19]. To ensure that Ukraine complies with international obligations, a road map for a transition to an ETS is presented in the box. The steel sector is proposed to be partly exempted so that it is covered by an effective carbon tax of EUR 1.3 /tCO_2 in 2022 and reaches EUR 39/ tCO2 in 2050 (see the chapter on decarbonising the steel sector for more details on the reasoning).

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[17] A carbon tax faced in agriculture would increase prices for food, which could have a regressive effect. It should be evaluated with the help of appropriate models, if this is the case for Ukraine.

[18] The EUCO3232.5 policy scenario takes a renewable energy target of 32% and an energy efficiency target of 32.5% into account (European Commission, 2019).

[19] Given that changes to the current carbon tax law need to be made, 2022 is a more realistic starting point than 2021.

[B1] Alternatively, the steel sector could be granted a share of free allowances, where the share would decrease continuously. However, we deem that certainty about future prices is important in attracting investments in the sector, which is why a predetermined carbon tax trajectory is proposed instead.

Under the presented proposition, Ukraine's carbon pricing would be broader and more ambitious than in other Eastern European countries. It might even seem too ambitious, given its economy being among the weakest. Still, there are arguments in favour of this approach; If the tax revenue is efficiently used and redistributed, there should be no or minimal, negative effects on GDP (World Bank, 2017). In contrast to an ETS with free allowances, a simple, (nearly) revenue neutral carbon tax efficiently returns revenues to the economy. At the same time it ensures that the whole economy (not just some sectors) takes the costs of pollution into account. To reduce the tax burden, actors are incentivised for efficiency improvements, which can increase competitiveness and might help Ukraine to achieve a competitive advantage over countries that act later on climate-related issues. Moreover, the broad and ambitious tax would avoid locking-in emission-intensive technologies, that might lead to a competitive disadvantage in the future.

The broad and ambitious tax could grant Ukraine a competitive advantage in the long-term.

Background info

Transition to ETS

We propose a longer transition period than proposed by Vivid Economics (2019) to reduce institutional risks associated with an ETS. Moreover, an introduction with fixed price allowances is suggested:

1. Until 2025, the monitoring and reporting of emissions in MRV-sectors is tested and improved.
2. From 2025, fixed price allowances (as in the testing phase of Australia): MRV sectors are required to purchase allowances at a fixed rate which is set in accordance to the carbon tax rate. An unlimited amount of allowances is issued and MRV sectors are eligible for tax exemptions. The steel sector could be excluded from purchasing allowances and instead continue to be taxed with the reduced tax rate[B1].
3. After 2030, allowances will be gradually limited. A floor price could be set to maintain predictability of prices. Allowances are auctioned, while the steel sector is excluded and still covered by the carbon tax. An upstream carbon tax also remains in place for non-MRV sectors. The tax rate could either follow a separate trajectory or be set as an average ETS price of the previous year (as in Portugal). The latter ensures consistency between MRV and non-MRV sectors but could result in higher uncertainty as well as difficulties in budget planning for redistributive measures.

Apart from different carbon tax rates, the countries' approach also differs in revenue recycling. Sweden and Finland lowered direct income taxes. Denmark and the UK on the other hand aimed at reducing inflationary pressure by lowering employer's social security contributions. Additionally, they contribute a share of tax revenue (5-20%) directly to energy efficiency subsidy programs. The Dutch introduced a combination of both. In the first phase, income taxes were reduced, while employer's payroll and corporate taxes were reduced in the second phase.

In the EU-funded COMTER project, Andersen (2010) found emission reductions of 6% in the period of the mid 1990s to 2004 under the early-movers, which can be attributed to the carbon tax. The results from the E3ME model, presented in Barker *et al.* (2009), lie in the same range. They attribute 4-6% emission reductions to the carbon tax in the Nordic countries and 2% in the Netherlands. The difference can be explained by less ambitious tax shifts in the Netherlands. By investigating the mentioned EU-countries, Hájek *et al.* (2019) find evidence that the long-term carbon tax in place in these countries is environmentally efficient. Further they find that a ceteris paribus increase of the carbon tax rate by one Euro, reduces per capita GHG emissions by 11.58 kg.

Supporting measures

Efficient revenue recycling is crucial to avoid negative effects on the economy

The broader macroeconomic implications of a carbon tax depend on its design. A poorly designed carbon tax can have negative effects on competitiveness, employment and economic growth. Also, it can lead to higher price levels, due to higher fuel prices. Consequently, a carbon tax should be accompanied by supporting policy measures such as revenue recycling, which means to funnel the state's tax income back to citizens.

I. Compensation programmes

Producers are likely to pass a share of increased input costs on to consumers. The magnitude of the amount forwarded to consumers commonly depends on the sensitivity of demand to price changes, i.e. the price elasticity of demand. Additionally, environmental taxes that increase prices for heating and electricity tend to affect low-income households more than high-income households, because low-income households typically spend a larger share of their income on energy than richer households. This is termed 'regressive'. The effect can be counteracted by using a share of the carbon tax revenue to reduce the burden on low-income households. This can for example be achieved through a progressive[20] decrease of income taxes (Kosonen, 2012).

A commonly cited effect in combination with income tax relaxation, is the tax interaction effect, first presented by Bovenberg and de Mooij (1994). They show theoretically that the increase in fuel prices could lead to a loss in workers' purchasing power, despite income tax relaxation. This in turn would lead to lower labour supply or higher salary demands, in turn causing inflation.

Revenues could be returned by lowering income tax or VAT, whereas the option with the least distortion effects should be selected. It should be complemented by a reduction in corporate taxes.

To counteract this effect, cuts in labour costs can be implemented, for example in the form of reduced employers' social security contributions. Ekins and Barker (2003) argue that when the reduction in payroll taxes offsets the net increase by an environmental tax, a pass-over of increased fuel prices to product prices will not be necessary, thus labour market effects can be prevented. Another way of preventing an increase in product prices is to reduce indirect taxes, like the value added tax (VAT). Reducing payroll taxes and reducing indirect taxes can both lead to a so-called ´double dividend´ effect, where a distortionary tax is replaced by a tax, which corrects a market failure like the carbon tax (World Bank, 2017). Which one of the two options could reap the most benefits is, however, country-specific. A first assessment could be done by estimating the marginal costs of the different taxes.

The OECD (2015) argues that attributing only a portion of the tax revenue to targeted income tax adjustments is sufficient to counter negative effects on low-income households. This is proven by the example of British Columbia. The upstream carbon tax in British Columbia is perceived as the closest to the ideal carbon tax among economists (Metcalf, 2019). Here, the carbon tax is nearly revenue neutral. A combination of corporate and personal income tax cuts, low-income tax credits and targeted corporate as well as personal income tax credits ensured that a significant reduction in GHG emissions could be achieved with negligible effects on overall economic activity (Murray and Rivers, 2015).

Consequently, tax shifting programmes should consist of measures targeting progressive tax shifts for households as well as measures to decrease the burden carried by firms.

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[20] The terms regressive/progressive are commonly used in connection with taxes. For a regressive tax, the relative burden of households *decreases* with income, i.e. low-income households spend a larger share of their income on the tax. On the contrary, for a progressive tax, the relative burden for households *increases* with income, thus high-income households spend a larger share of their income on the tax than low-income households. This principle can also be applied to tax relief programs. If such a program is progressive, the relative relief for low-income households will be larger than for high-income households.

It should be kept in mind that a carbon tax is a transitory tax. Once CO_2 emissions have been reduced substantially, the government's revenue stream may dry out. Thus, constant monitoring is required, and the government needs to be able to shift back to the preceding system. Frequent monitoring additionally presents the advantage that compensation mechanisms can be adjusted so that revenue neutrality is maintained[21]. This can help to improve transparency and the political acceptance of the carbon tax, as it is emphasised that the goal of the tax is not to create additional revenue streams but to reduce emissions.

The carbon tax is a transitory tax and revenues may dry out when CO_2 emissions shrink.

II. Households

In Ukraine, a mechanism that could help to protect low-income households is already in place, namely the Housing and Utilities Subsidies (HUS) scheme. It has demonstrated its ability to counter effects of energy price hikes in the wake of gas price reforms (ESMAP, 2016). The HUS is a targeted social assistance programme and is one of the main mechanisms of social security in Ukraine, especially with regard to costs of energy (Ministry of Social Protection Ukraine, 2020). A detailed assessment of how the HUS works and an exemplary calculation is given in chapter 6.3 of the Annex. Under the programme, costs for housing services, utilities (gas, power, heat and water) as well as administrative costs are subsidised for households that pay more than a certain share of their income for these services. In 2019, 37% of households received housing subsidies (Ukrstat, 2020).

Low-income households in Ukraine are protected by the Housing and Utilities Subsidies (HUS) programme.

The subsidy is decoupled from actual consumption. By consuming less energy, a household would have to pay less for energy with receiving the same amount of subsidy. Hereby, households are incentivised to achieve efficiency improvements. Also, a higher share of the bill is covered for low-income households. By its progressive design, the programme helped protect vulnerable groups of the population from the price increase of natural gas and district heating and thereby had a substantial impact on poverty.

The programme can support the implementation of a carbon tax in the same way. As the payment within the social norm is influenced by energy prices, the subsidy will increase with a rise in energy prices. Low-income households are protected from price changes of electricity and heating. Still, it should be evaluated whether an adjustment of the formula for the share of contribution is required to maintain the HUS's effectiveness.

Furthermore, households would only be protected from rising electricity and heating prices, but not from any other price increase – energy or non-energy. Frey (2016) proposes a decrease in indirect taxes for Ukraine, which constitutes the largest position in government income (Ministry of Finance of Ukraine, 2020). With a VAT of 20%, Ukraine is at the lower end in comparison with other European countries. But other countries commonly have a broader application of reduced VAT rates for specific products. Ukraine only lowers its VAT for pharmaceuticals. Thus expanding reduced VAT rates to more products could be an option in the country. However, as explained in the previous section, the most efficient revenue recycling can be achieved by reducing the most distortionary taxes. Thus, first an analysis on the marginal costs of different taxes should be carried out.

Further measures are required to protect low-income households from price hikes of non-energy products.

[21] In British Columbia, for example, the Ministry of Finance is required to develop a plan that ensures revenue-neutrality each year. If the target is not met, a penalty in the form of salary reduction can be placed upon the minister.

III. Businesses

An assessment in close consultation with the Ministry of Finance is required to find efficient ways of reducing a carbon tax's burden for businesses.

To avoid negative labour market or investment effects, not only households but also businesses should be reimbursed. Studies often find that corporate income taxes are among the most distortionary (Marron and Morris, 2016). Reducing corporate income taxes, however, presents certain difficulties in Ukraine. A large informal sector and undeclared work pose a problem in Ukraine. Consequently, the corporate profit tax revenues are low in relation to international standards, despite its rate of 18%, which is well in the range of other European countries. In the 2020 budget, the corporate income tax only makes up for 6.5% of total revenue from income taxes – 93.5% is accounted for by the personal income tax (Ministry of Finance of Ukraine, 2020). An alternative option to decrease the burden for businesses is in the form of reduced employer social security contributions. Nonetheless, a shift away from labour taxation has already been addressed in past reforms. Since 2016, the social security contribution was significantly reduced. Now employers are liable for a single contribution of 22% of the gross earnings of employees. Before the reform, a share of 3.6% had to be carried by the employee, while the employers' share ranged from 36.7%-49.7% (IMF, 2016).

In order to make a well-informed decision on the most efficient way of reducing the carbon tax's burden for businesses, an assessment in close consultation with the Ministry of Finance of Ukraine should be performed. A first high-level assessment based on an input-output multiplier approach by Kantor & E^{3}M (2021) implied that targeting support to trade exposed firms might be superior to generally lowering taxation or labour costs in Ukraine.

IV. Other measures

A share of the revenue can be used to fund low-emission measures.

Besides tax-shifting programmes, a share of the carbon tax revenue should be used to support energy projects. For example, with assistance programmes for transport and the energy performance of buildings, the welfare of low-income households can be improved. Further, targeted programmes that remove hidden costs and risks for energy efficiency projects, increase the responsiveness of consumers to the carbon price signal and thus support consumers and producers to switch to low carbon fuels and/or technologies (OECD, 2015). Policies should, however, be market based, i.e. not favour specific technologies, to leave room for adaption (Andersen, 2010). Moreover, an efficient carbon pricing policy requires the existence of competitive market structures to pass on costs. In the case of Ukraine, this is especially relevant in power and gas markets. In both markets, final consumer prices should be market-based and reflect actual costs.

The following measures, which are covered in separate chapters, are proposed:

i. Phase-out of energy subsidies;

ii. Further liberalisation of the gas and electricity market;

iii. Energetic retrofitting of buildings;

iv. Coal sector transition.

Political – but no legal – earmarking is desirable.

Due to the volatile political setting in Ukraine, earmarking for both redistributive and energy efficiency/fuel switching measures might be required. Earmarking is the political or legal commitment to use revenues from specific sources for specific purposes. Rather political than legal earmarking is desired here as it ensures efficiency and political support but at the same time allows to determine each year anew, how revenues can be used most effectively. For a detailed discussion on this topic see Saha, Poluschkin and Kirchner (2019).

Assessment of Carbon Tax Effects

The effects of the tax are evaluated with short- and long-run price sensitivies of demand.

The methodology with which the effects of a carbon tax of EUR 39 /tCO_2 on Ukraine's tax revenue, carbon emissions and consumer costs are evaluated, is presented in the Annex. The following results take short-run as well as long-run price sensitivities of energy demand into account. The short-run sensitivities reflect consumers' immediate response to higher energy prices within one year. In the long-run, these responses are likely to be more pronounced as they take gradual changes in the capital stock over several years into account (Huntington, Barrios and Arora, 2019). The time scope of the expression "long-term" is not predefined, though and varies between studies. It should allow for the time necessary to do significant capital investments, i.e. several years. Here, we define the long-run as 3 years, as in Deryugina, MacKay and Reif (2017). However, this should be seen as a lower bound and depending on the sector, adjustments might take considerably longer. Furthermore, it should be noted that only price effects are considered here and no income or substitution effects.

I. Tax revenue

A revision of Ukraine's carbon tax to an upstream tax with a phase-in of a tax rate up to EUR 39 /tCO_2 in 2030 is proposed. For a smooth implementation of the final target, a tax of EUR 4.3 /tCO_2 should be levied on all fossil fuels in 2022 and increased linearly by the same rate of EUR 4.3 /tCO_2 each year afterwards.

Under the upstream approach, each fuel is taxed at the point of entry into the economy. Consequently, primary energy is taxed. Due to different implications for consumer prices, in this analysis it is still differentiated between consumption of primary energy of natural gas, coal and oil and the consumption of secondary energy like electricity and heat. Fuels like coal and gas used for the production of heat and electricity are deduced from primary energy consumption. Consumption data from the energy balance from Ukrstat (2020) is used as an initial starting point, while assumptions about future energy demand are adopted from Scenario 2 of Ukraine's draft NDC[22]. Figure 11 displays the annual revenue from the carbon tax.

EUR 34.4 bn could be raised in tax revenue over nine years.

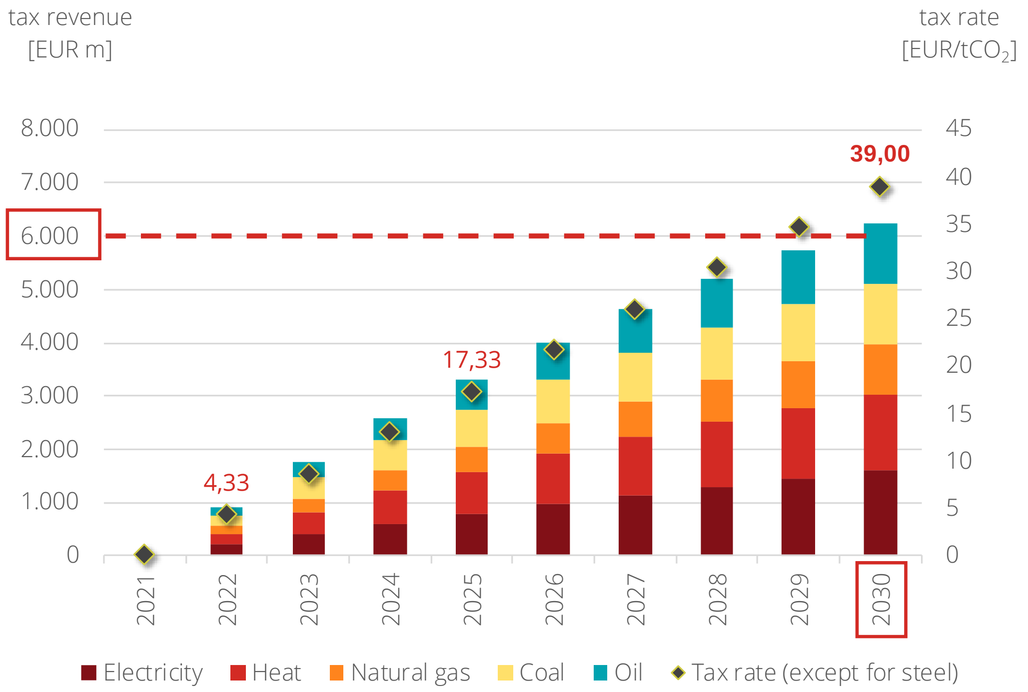
With an initial tax rate of EUR 4.3 /tCO_2 in 2022, a tax revenue of EUR 905 m is generated. This increases to EUR 6.2 bn in 2030, when the full EUR 39 /tCO_2 are levied. In total, EUR 34.4 bn are generated in the period from 2022 to 2030.

Revenues resulting from secondary energy consump-tion constitute the largest share.

Revenues from heat and electricity consumption exceed those from natural gas, despite higher total energy consumption of natural gas. Even though carbon neutral energies account for the majority of power production, the carbon emissions per energy output is higher than per primary energy input, because losses occur when thermal energy is transformed to electrical energy. The same holds for heat production. Here however, a larger share of energy is produced from coal or gas. The third largest source of revenue is coal due to its high carbon content and due to its importance for Ukraine's industry in steel production.

[22] The NDC2 Scenario assesses the impact of a timely implementation of all existing legislation as well as drafted climate related legislation. It implies a 1% increase in coal demand, a 36% increase in electricity demand and a 22% increase in heat demand compared to 2019 levels. Gas demand is specified to fall by 23% and oil demand by 20%. In the NDC2 Scenario, only the currently implemented carbon tax is taken into account. Its effects on energy demand can be neglected due to its low value.

Figure 11: Approximately 6 bn EUR carbon tax revenues by 2030



Source: Based on Own calculation

II. Effects on CO_2 Emissions

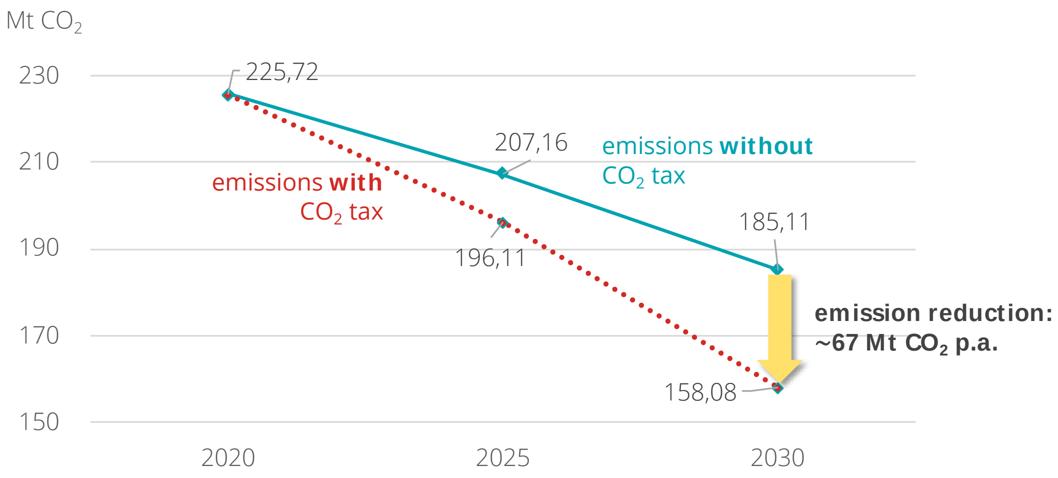
Emission reductions are achieved through energy demand reductions in the short-run and efficiency improvements in the long-run. In total, 27 Mt could be saved over 9 years.

To evaluate the emission reduction potential two scenarios are compared: a reference scenario and a carbon tax scenario. The reference scenario is based on the 2nd policy scenario of the NDC. It takes the implementation of currently addressed policies into account (for more details see **Annex: Evaluating the impact of a carbon tax**). These would lead to a decrease in emissions. But planned and current measures are not sufficient to comply with the goal set in the Paris Agreement to keep global warming below 1.5 °C (CAT, 2020). A revised carbon tax can support the reduction of CO_2 emissions.

The dotted line in Figure 12: Carbon tax would lead to an additional decrease of CO2 emissions from fossil fuel consumption by 67 Mt p.a. represents CO_2 emissions under the carbon tax scenario. The difference between the two scenarios results from the decrease in energy consumption and long-run efficiency improvements induced by the internalisation of emission costs. As energy demand is rather price inelastic in the short-run and the carbon tax is introduced with a low rate of EUR 4.3 /tCO2, this difference is rather small in the beginning. After four years, 11.0 Mt can be saved compared to the NDC2 scenario. In 2030, an emission reduction potential of 27.0 Mt could be realized.

Coal consumption contributes the most to CO_2 emission savings. On the one hand, this is because of the high emission factor of coal, which causes a comparably higher increase in fuel prices. On the other hand, this effect is caused by the comparably higher price sensitivity of coal demand. This leads to a reduction in coal demand by up to 40% in 2030 under the carbon tax scenario, compared to a baseline scenario.

Figure 12: Carbon tax would lead to an additional decrease of CO_2 emissions from fossil fuel consumption by 67 Mt p.a.



Source: Own calculation

Due to the underlying price assumptions, which are based on the NDC, that coal prices decrease by 7% while gas prices increase by 37% until 2030, the carbon tax does not lead to fuel switching in the electricity sector. Under these assumptions a carbon price of EUR 58 /tCO_2 would be necessary for gas to become cheaper as a power source than coal. Under the assumption that fuel prices stay constant at the 2020 level however, a carbon tax of EUR 25 /tCO_2 would be sufficient.

Under underlying fuel price assumptions, a carbon price of EUR 58/tCO_2 would be required for gas power to become cheaper than coal.

It should be noted that the discussed figures present rough estimates. The results heavily depend on assumptions regarding fuel prices, future energy demand and elasticities. Additionally, substitution effects were neglected in this analysis.

Consumer costs

With an upstream tax, the tax authority does not decide on who pays the final price of the tax. The price increase through the carbon tax could be passed forward to consumers, backward to producers, or shared between both, depending on the price elasticity of demand. Therefore, consumers likely do not only face an increase in energy prices themselves, but also an increase in prices of consumer goods. The two effects should be separated. First, the implications are different. For an increase in household's energy prices, the "polluter pays" principle can be applied. Here, the consumer can directly influence the level of emissions by investing into energy efficiency measures. This is not the case for consumer goods. Second, the compensation mechanism differs. While the increase in energy prices is mainly covered by the HUS (except for oil and oil products), the increase in consumer good prices requires other mechanisms, like the proposed changes to the VAT.

Under a carbon tax, consumers face higher costs from energy as well as non-energy products, as a share of the burden of firms is likely passed forward to customers.

I. Households

In this section, we analyse the consumer costs resulting from residential energy consumption. As energy demand is commonly very inelastic, it is assumed here that the price increase is passed forward to consumers for non-regulated as well as regulated energy markets. Even though prices for electricity are assumed to remain constant until 2030 (assuming Ukrainian energy subsidies stay in place), it is assumed that the increase in wholesale electricity prices through the carbon tax is passed on to end consumers. This implies that the government increases the politically determined price for regulated consumer groups by the carbon tax costs arising for the marginal power plant. The same holds for heat prices.

It is assumed that the costs of the carbon tax in energy and heat supply are fully passed on to consumers.

The price increase in electricity and heat present the largest burden for household.

The increase in household prices is determined by the carbon content of each fuel type. Coal prices increase more than oil or natural gas prices, due to the high emission factor of coal. However, the largest increase in the price per energy unit consumed has to be faced from electricity and heat consumption. Here, up to EUR 25 /MWh for electricity and EUR 15 /MWh for heat would need to be paid additionally, if a carbon tax was introduced. This can be traced back to high energy losses in the transformation process from coal and gas to secondary energy.

Households have to pay up to EUR 3 bn additionally for energy consumption, contributing 44% of the tax revenue.

Even though natural gas consumption exceeds electricity consumption, the latter makes up for a larger share of the increase in household expenditure (Table 2). Increased costs from electricity consumption contribute EUR 1.4 bn to the change in household expenditure on energy by 2030, which is more nearly half of the total costs of EUR 3.3 bn faced by households from direct energy consumption. This is followed by consumption of natural gas, oil and heat. Coal makes up only a minor share. In total, consumers contribute on average 44% to the revenue collected with the carbon tax.

Table 2: Increase in household expenditure for energy consumption (EUR m.)

Energy type	2022	2025	2030
Electricity	144	604	1418
Heat	65	234	422
Natural Gas	81	298	559
Coal	5	16	26
Oil/Oil products	71	264	517
Total	366	1’417	2’942
Tax revenue	904	3’323	6’234

Source: Own calculation

HUS compensation

Vulnerable households are protected by the HUS.

The HUS mechanism constitutes one part of the compensation scheme. It progressively protects households from increased electricity, heat and natural gas prices by subsidising a share of the costs, depending on the income. As the subsidy paid to households depends on energy prices, the compensation increases with the carbon tax. Consequently, households eligible for HUS will be protected from the price increase of residential energy consumption. As electricity, heat and natural gas make up around 80% of increased expenditure, this protects vulnerable households from the lion’s share of increased costs from energy consumption. In the Annex **(Housing and Utilities Subsidies)** it is explained in more detail, how the HUS works and how the compensation paid to households is calculated.

Figure 4 illustrates the costs for the government resulting from increased subsidies under the HUS as well as the number of households receiving subsidies. Fuel prices for 2025 and 2030 correspond to prices assumed in the NDC, based on the IEA World Energy Outlook 2018 (IEA, 2018). A summary is given by Table 3 in the Annex. In between those years, a linear increase is assumed. The annual 5% growth rate of income is based on the NDC Baseline Macroeconomic Scenario.

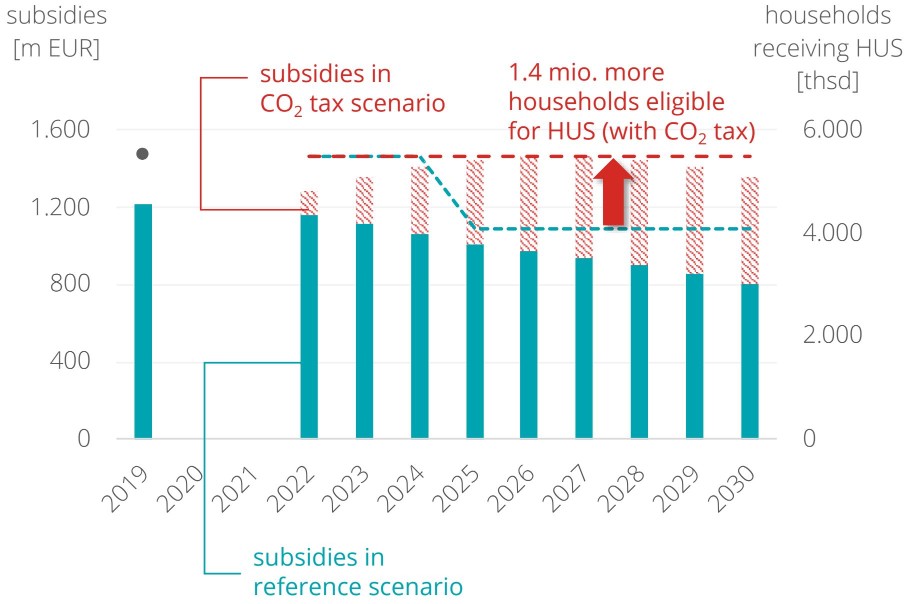
From 2027, the increase in household expenditure offsets increased costs from the tax.

The increase in household income results in a decrease in HUS paid under the reference scenario. Annual HUS would decrease from EUR 1.2 bn in 2019 to EUR 0.8 bn in 2030. Under the carbon tax, the costs of the HUS for the government would increase until 2027. After this year, the exponential growth in income offsets the linear growth in energy costs from the carbon tax. With EUR 1.4 bn, HUS payments would be only slightly above the 2019 payments by 2030.

By increasing the payment under the social norm (see the carbon tax also affects the number of households eligible for the HUS. In 2019, around 5.4 m households (37% of total) received subsidies. This would remain the same under the carbon tax scenario. For the reference scenario on the other hand, the number of households decreases to 4 m households. The number of households receiving subsidies does not decrease smoothly due to i) the definition of income groups as ranges, ii) the income distribution and iii) the progressive nature of the determination of subsidies. A detailed description on the income groups receiving subsidies as well as the amount of subsidies paid per income group can be found in Table 5 in the Annex.

The number of households eligible for the HUS would remain constant under the tax.

Figure 13: The CO2 tax would offset the drop in the number of households receiving subsidies (HUS) that would result from increased income



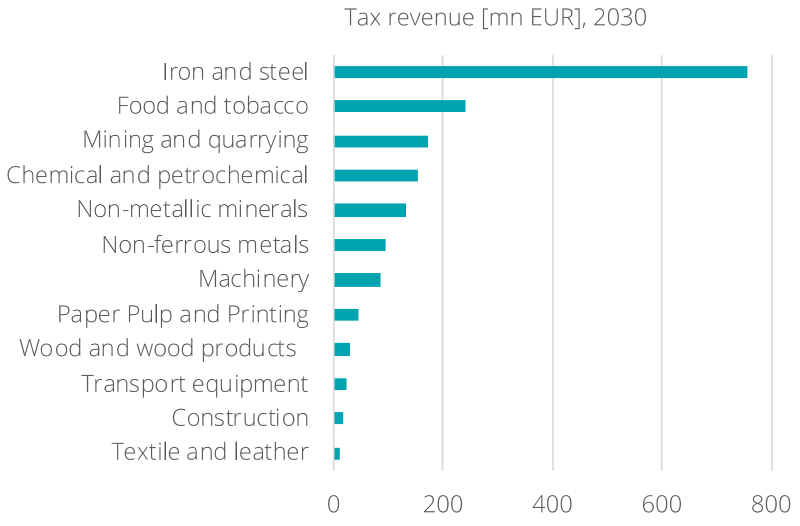
Source: Own calculation

II. Industry

Despite the reduced tax rate, the steel sector carries the largest burden.

The increase in household's energy expenditure represents only 44% of the tax revenue. 34 p.p. of the remaining 56% will be borne by the industry. Despite enjoying a lower tax rate, the majority of these costs are borne by the steel sector. Its costs increase from EUR 100 mn in 2022 to EUR 750 mn in 2030. The steel sector is followed by the food, the mining and the chemical industry (see Figure 14).

Figure 14: Iron and steel sector would pay significant amount of CO_2 taxes in 2030



Source: Own calculation

As previously explained, a share of the costs borne by the industry is likely to be passed forward to final consumers, depending on the price elasticity of demand. Thus, households will also face higher prices from consumer goods. Evaluating the overall costs for households should capture the effects on different industries in Ukraine, as the demand elasticity differs depending on the product. To take the interaction of supporting measures with the carbon tax as well as the interaction between different sectors into account, an assessment with the help of e.g. a constant general equilibrium model should be performed. This, however, would exceed the scope of this policy proposal and should be part of a separate assessment.

Employment effects

Employment effects in the past have been positive, but can be negative for specific emission-intensive industries.

Employment effects can be ambiguous and depend on the specific industry as well as on the design and revenue recycling of the carbon tax. In British Columbia, the revenue-neutral carbon tax led to an increase in overall employment (Yamazaki, 2017). Nonetheless, negative employment effects can arise for emission-intensive industries, for example the coal sector and the steel industry. Structural measures to support employers in the coal sector as well as in the steel industry are addressed in Chapter **"A socially sustainable coal phase-out in Ukraine".**

Energy Efficiency

The carbon tax incentivises energy efficiency improvements through price signals. These effects are captured in this analysis by the long-run elasticity. The effects vary drastically between the different energy types. The least efficiency improvements are realised for electricity and petroleum consumption. Here, up to 4% of consumption are saved in the long-run. While electricity demand is very inelastic, this is not the case for petroleum (see Table 3 in the Annex). However, the price increase of gas and diesel induced by the carbon tax is comparably lower. By funding energy efficiency programs with tax revenue, a higher decline in energy consumption and consequently GHG emissions could be achieved. In the transport sector these could include the promotion of alternative engine technologies, by which the responsiveness of petroleum demand to the carbon tax would be intensified. Natural gas and heat consumption lie in the middle, with efficiency improvements of 8% and 9% respectively. Due to the internalisation of the high environmental costs, the largest efficiency improvements are realised for coal, with up to 40% in 2030.

The least efficiency improvements are expected for electricity consumption, the most for coal.

Research, innovation & competitiveness

The effects of carbon pricing on competitiveness can be adverse. In theory, carbon pricing leads to an increase in production costs, causing a disadvantage compared to countries without a carbon price. Given, however, that the price is set in accordance with Ukraine's largest trading partner – the EU – and that other countries are likely to follow, this effect might not be decisive.

A gradual phase-in should allow companies to adapt and help to counter negative effects on competitiveness.

Further, there is little empirical evidence that carbon pricing has actually led to reduced economic competitiveness in countries that have already introduced a carbon price. On the contrary, it provides a stimulus to diversify, innovate and invest. Still, this requires a smooth transition, thus a gradual phase-in is recommended, so that firms can adapt (World Bank, 2016). Additionally, a carbon tax can create a competitive advantage for low-emission companies, whereby more financial resources are attracted to these sectors.

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Annex: Evaluating the impact of a carbon tax

A carbon tax affects behaviour by increasing fuel prices. Therefore, at the heart of the evaluation of a carbon tax lies the determination of the increase in prices through the tax and the change in consumer behaviour due to this increase. From this, important figures on tax revenue, change in household expenditure and carbon emissions can be estimated.

I. Data

The calculations are based on assumptions about future fuel prices as well as assumptions about the carbon tax. Estimated fuel prices for the years 2020, 2025 and 2030 correspond to prices assumed in the NDC, based on the IEA World Energy Outlook 2018 (IEA, 2018). In-between, a linear increase is assumed. The carbon tax is also assumed to increase linearly until it reaches a final carbon price of 39 EUR/tCO_2 in 2030. A summary of fuel prices and the carbon tax rate for each year is presented in Table 3.

Table 3: Assumptions about energy demand and prices

			2022	2025	2030
natural gas	price [EUR/MWh]	residential	23.4	26.3	26.4
		non-residential	24.8	28.0	28.0
	demand [TWh]		150.9	141.5	125.8
coal	price [EUR/MWh]		9.4	8.9	9.2
	demand [TWh]		134.7	135.1	135.8
oil	price [EUR/MWh]		42.2	50.0	54.6
	demand [TWh]		138.2	127.7	114.6
electricity	price [EUR/MWh]	residential	35.0	35.0	35.0
		non-residential	62.5	62.5	62.5
	demand [TWh]		170.5	181.9	200.8
heat	price [EUR/MWh]	residential	36.3	40.0	46.2
		non-residential	38.8	45.0	47.3
	demand [TWh]		93.7	98.5	106.5
carbon tax	EUR/tCO2		4.3	17.3	39.0

Source: NDC and Own calculation

For coal and oil, the presented fuel prices correspond to consumer prices in the reference scenario. Natural gas prices, however, differ from raw fuel prices due to costs of transmission, distribution and supply. Further, it is differentiated between prices for households and non-households for gas as well as electricity.

Moreover, assumptions about fuel demand for the baseline scenario are required. For this, energy demand projections are retrieved from Scenario 2 in the NDC. The NDC Scenario 2 builds on the assumption that all legislation adopted as of September 1st, 2019, as well as drafted climate-related legislation will be implemented. Based on this scenario, the share of coal in electricity decreases from 35% to 18%, whereas the share of gas increases from 5% to 7%. In district heating, the policy focus of stimulating biomass heat production is captured, by which the share of renewables in district heat production increases to 35% in

2030. The exact composition of heat production is not specified. Here, it is assumed that coal will be phased-out completely, thus gas makes up for the remaining 65% of heat production.

Another key parameter in the calculations is the elasticity of demand. Unfortunately, there is a lack of reliable data for price elasticities of energy demand in Ukraine. This issue was also addressed by The World Bank (2005), who argues that average OECD elasticities can be used for Ukraine instead. Following this approach, average OECD elasticities for residential and non-residential demand are retrieved from Liu (2004). For heat, the same price elasticity as for residential natural gas demand is used.

Table 4 summarises the price elasticities for different energy types. The price elasticity of demand for each energy type is inelastic. The price elasticity of the electricity demand presents the lowest value, demonstrating that an increase in the electricity price is likely to have only very limited effects on demand, at least in the short run. Residential demand for gasoline presents a higher elasticity. This can be drawn back to the fact that for this energy it is easier to switch to alternatives. For high gasoline prices, consumers might switch to public transport for distances they would have travelled by car otherwise.

Table 4: Price elasticities of demand

Energy type		short-run	long-run
Electricity	residential	-0.03	-0.16
	non-residential	-0.01	-0.04
Natural gas	residential	-0.10	-0.36
	non-residential	-0.07	-0.24
Petroleum	residential (gasoline)	-0.19	-0.60
	non-residential (diesel)	-0.09	-0.17
Coal		-0.23	-0.40

Source: Liu (2004) and Burke and Liao (2015)

II. Methodology

a. Change in prices

Primary energy price increase

First, the increase in fuel prices needs to be calculated. It should be distinguished between primary and secondary energy consumption as there are different implications for prices. For both types, it is differentiated between two scenarios: Scenario 1 is a reference scenario without a carbon tax. Scenario 2 is based on the same assumptions as Scenario 1, but includes a gradual increase of the carbon tax.

By imposing a price on carbon, the prices of primary energy changes, depending on the amount of carbon emitted per energy unit consumed. Consequently, the increase in primary energy prices can be calculated, based on their carbon content:

$$P_{t,1} = P_{t,0} + CO_2\ content\ \times tax\ rate \qquad (1)$$

The carbon content is based on emission factor assumptions in the Policy Oriented Tool for Energy and Climate Change Impact Assessment (POTEnCIA), retrieved from the JRC Integrated Database of the European Energy System (European Commission, 2020).

Electricity price increase

In the electricity consumed in Ukraine, there are two sources of emissions: coal and natural gas. The increase in power prices depends on the *marginal* power plant. If the marginal power plant is a coal-based plant, electricity prices will increase based on the carbon content of coal. If the marginal power plant is a natural gas-based plant, it will change on the basis of the carbon content of natural gas.

Currently, the marginal power plant is a coal-fired power station. This, however, depends on the marginal costs (MC) of power production. The marginal costs are not constant, but depend on plant efficiency, fuel costs and the carbon price.

$$MC = \frac{Fuel\ costs}{Efficiency} + \frac{CO_2\ content}{Efficiency} * carbon\ tax \qquad (2)$$

It is assumed that coal-fired power stations have an efficiency level of 35%, while gas turbines are assumed to have an efficiency level of 45%.

Even though coal prices are assumed to decrease until 2030, while natural gas prices are assumed to increase, marginal costs of gas fall below those of coal when carbon prices reach a certain level. This can be explained by the higher efficiency of gas plants and by the lower carbon content of natural gas. When carbon prices reach a certain level, their costs outweigh the fuel costs. Under the previously mentioned assumptions, the marginal costs of coal are lower than those of gas. Only if the carbon price would be raised to EUR 58/ tCO2 the marginal costs of coal would exceed those of gas by 2030.

c. Change in demand

Based on the fuel demand of the baseline scenario and after-tax prices, the change in demand due to the introduction of the carbon tax can be calculated. The methodology refers to Ouyang and Lin (2014). A constant-elasticity inverse demand function is assumed, as proposed by the (IEA, 1999):

$$q_t = {p_t}^{\varepsilon} \tag{3}$$

where q_t is energy demand in t, p_t the price for energy in t and ε is the price elasticity of demand. The change in demand can then be calculated by:

$$\Delta q_t = Q_{0,t} - Q_{1,t} \tag{4}$$

With

$$Q_{1,t} = exp\,(\varepsilon \times (ln\,P_{1,t} - ln\,P_{0,t}) + ln\,Q_{0,t}) \tag{5}$$

where the index 0 indicates that the quantity/ price corresponds to the baseline scenario without the carbon tax, while the index 1 indicates the quantity/ price corresponding to the carbon tax scenario levels.

The presented methodology can only account for a demand reduction in CO_2-intensive sectors. Frey (2016) demonstrates that a carbon tax can also lead to an increase in production of less carbon-intensive products. She uses a CGE model and finds that in Ukraine, raising the CO_2 tax could increase output in the textile industry, which hardly uses any fossil fuels as an input of production.

As there are different elasticities for residential consumers and non-residential consumers, it is distinguished between households and non-households.

Petroleum demand

In the energy balance of Ukraine, it is not differentiated between petroleum consumption from private and non-private cars. To evaluate the impact on household expenditure, it is however necessary to differentiate between these two categories.

To approximate this, wholesale as well as retail petroleum sales from Ukrstat (2020) are aggregated and multiplied by the share of private passenger cars of 0.9, 0.58 and 0.79 for gasoline, diesel and LPG respectively.

d. CO_2 emissions

Once the change in demand has been calculated, the difference in carbon emissions between Scenario 1 and 2 can be calculated by:

$$\Delta CO_2 = \sum_t \Delta CO_{2,t}\ with\, \Delta CO_{2,t} = \sum_i \Delta q_{i,t} \times CO_2EF_i \tag{6}$$

III. Housing and Utilities Subsidies

The HUS protects vulnerable groups of the population from energy price increases by subsidising a share of the utility bill exceeding a certain income share. While the subsidy depends on prices, it is detached from actual consumption. Due to this – and due to its recent monetisation – incentives for increasing energy efficiency and decreasing energy consumption are kept intact.

The subsidy (S) granted to a household is determined by the difference between the payment within the social norm (SP) and the share of contribution (Sh) multiplied with the household income (HI) (CMU, 2020b):

$$S = SP - Sh * HI$$

The social norm defines how much an average household would consume. It takes the equipment of a household into account. For example, for a household equipped with a stationary electric stove and centralised hot water the social norm defines an electricity consumption of 110 kWh per month per household with an additional 30 kWh for every other member of the household but not exceeding 230 kWh per month (CMU, 2019a) (see Table 5). The share of contribution is determined by the household income per capita (HI/N) and the subsistence level (SL) (CMU, 2020a):

$$Sh = \frac{HI/_{N}}{2 * SL} * 20\%$$

The calculation of the subsidy can be illustrated by the following example; With a subsistence level of UAH 1’700 and an average monthly income of a two-person household of UAH 4’000, the share of contribution would be:

$$\frac{UAH\ 4'000/_{2}}{2 * UAH\ 1'700} * 20\% = 12\%$$

A contribution payment of 12% * UAH 4’000 = UAH 470 would result. If the total bill for housing and communal services based on the social norm would amount UAH 1’500, a subsidy of UAH 1’500 – UAH 470 = UAH 1’030 follows.

The HUS covers expenses for electricity, gas, heat, cold and hot water, waste and building management. The social norm is defined by housing characteristics. Table 5 summarises the different increments for the relevant categories affected by the carbon tax, namely electricity, gas and heat.

Table 5: Social norm consumption

Category	Housing characteristics	base	additional for each person	max
Electricity [kWh/month]	no stove, centralised hot water	70	30	190
	electric stove, centralised hot water	110	30	230
	electric stove, no centralised hot water	130	30	250
	no stove, no centralised hot water	100	30	220
Heat [sqm]		62.52		
Gas [cm p.p.]	gas stove, centralised hot water	3.3		
	no gas stove, gas water heater	5.4		
	gas stove, gas water heater	10.5		

Source: (CMU, 2019a)

Consequently, to determine the increase in subsidies resulting from the carbon tax, knowledge about the distribution of housing characteristics in the Ukrainian population is required. This information is made public by the State Statistic Service (Ukrstat, 2020). However, this information is only available for the total population and does not differentiate between income groups. Lower income households are more likely to be equipped with less advanced technologies, thus it should be noted that the presented estimations only reflect approximations.

As the payment under the social norm depends on the number of persons living in a household, the average household sise (2.58) is retrieved from the State Statistic Service of Ukraine. Further, heat consumption is defined per square meter, thus information on the amount of heat consumed per square meter are required. The average weighted consumption for an apartment building is 156 kWh/sqm per year and for an individual house 240 kWh/sqm per year. As 51% of Ukraine's population are living in an individual house (or as part of an individual house) and 49% in an apartment building, the overall weighted average consumption is 198 kWh/sqm per year.

Based on the distribution of household characteristics, the average social norm consumption for a household is 134 kWh of electricity, 9 m^3 of gas and 1'ooo kWh of heat per month. These are multiplied with the respective fuel prices. Further, the cost for water supply, waste and building management are taken into account. In total, in 2019 the payment for housing and utilities based on social norm amounted to EUR 61 per month per household.

A share of these costs has to be carried by households. This share depends on the household income and the legally determined subsistence level. Information on both is retrieved from the State Statistics Service. To calculate the HUS when a carbon tax is phased in, potential commodity price changes are disregarded to extract the effect of the carbon tax. Table 6 presents the subsidies paid for different income groups. In the calculation, the average of the income range is used. The HUS paid per household increases by the same amount as the social norm utility bill (differences in Table 6 might result due to rounding).

Table 6: HUS for different income groups

monthly household income [EUR]	share of house-holds	HUS per household [EUR/month]								
		2022	2023	2024	2025	2026	2027	2028	2029	2030
below 170	3%	45	47	49	51	53	54	55	56	56
170 – 204	4%	41	43	45	46	47	48	49	50	50
204 - 235	7%	31	33	34	35	36	36	36	36	36
235 - 266	8%	20	21	22	23	23	22	22	20	19
266 - 299	9%	8	8	8	8	7	6	5	3	0
299 - 330	9%	0	0	0	0	0	0	0	0	0
330 - 361	9%	0	0	0	0	0	0	0	0	0
361 - 395	9%	0	0	0	0	0	0	0	0	0
395 - 426	7%	0	0	0	0	0	0	0	0	0
426 - 459	7%	0	0	0	0	0	0	0	0	0
above 459	29%	0	0	0	0	0	0	0	0	0
Social norm utility bill [EUR/month]		66	69	72	76	79	81	84	86	88
Carbon tax [EUR/tCO2]		4	9	13	17	22	26	30	35	39

Source: Own calculation

3. Phasing-Out Consumer Subsidies. Prospects and Challenges for Ukraine's Natural Gas and Electricity Sector

Author: Julia Breuing

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Executive summary

Fossil fuel subsidies have been a popular measure for governments all around the globe. However, subsidies can have a range of adverse effects on the economy, which is why large international organisations, like the World Bank, the OECD as well as the IMF, advice to phase-out these subsidies.

By promoting wasteful consumption and discouraging the implementation of low-emission production technologies, energy subsidies can lead to an increase in Greenhouse Gas (GHG) emissions. Further, the IEA (2019) demonstrated that they rather benefit wealthy recipients and that only a small portion arrives at low-income households, thus they can even promote income inequalities. Further, subsidies can pose a substantial burden to government budgets – and consequently taxpayers.

This paper focusses on consumer subsidies in the natural gas and electricity sector. Producer subsidies in the coal sector are covered in a separate proposal and are proposed to be phased-out in accordance with the coal transition.

Substantial steps were pursued in Ukraine's gas market, leading to (nearly)[23] market-based pricing. While the gas market Public Service Obligations (PSO) regime was abandoned in 2020 (ICIS, 2020), there is a threat of returning to politically determined prices when gas prices pick up and/or the economic situation deteriorates, as was demonstrated by actions taken by the Government in light of the COVID-19 pandemic (CMU, 2021). In line with the IMF recommendations, prices should be permanently de-politized. Still, the progress in this sector demonstrates that if a subsidy phase-out is accompanied by appropriate measures, it is publicly accepted and can lead to a functioning market.

The electricity sector is yet to follow, which is why a gradual phase-out of consumer subsidies – i.e. an elimination of the price gap between actual and efficient prices – until 2022 is proposed and discussed here. The phase-out should happen in the form of a liberalisation of final consumer prices together with a phase-out of the PSO scheme. It should be accompanied by a clear energy sector strategy and by increasing the support for the Housing and Utilities Subsidies (HUS) programme. Overall, economic savings from the phase-out of consumer subsidies in the electricity sector could reach on average EUR 1.6 bn annually over the next ten years, whereas the increase in HUS payments is estimated to amount to an average of EUR 285 m annually.

This paper is part of a series of policy proposals which pose the potential of having a high impact for reaching Ukraine's energy and climate goals. It presents a first proposition as well as first back-of-the-envelope calculations. For a detailed evaluation of the consequences for Ukraine's economy and emissions, more detailed modelling is required. All ten propositions of the policy paper series should then be considered to take reciprocal effects into account.

[23] In past years, natural gas prices fully reflected market prices for certain months and years (IEA, 2020). However, this was not always accurately transferred to households or transferred with delay, thus the natural gas pricing mechanism did not work perfectly.

Current state of energy subsidies in Ukraine

I. Preliminary considerations

Fossil fuel subsidies cause a range of inefficiencies and can present a burden to public finances.

Energy subsidies have been a popular measure for governments all around the globe to address job creation, energy access and poverty. However, fossil-fuel subsidies encourage wasteful consumption, slow down technological innovation and renewable energy development and can potentially present a burden to government budgets – and therefore to taxpayers. Accordingly, the OECD (2019) names energy subsidies as an important reason for (1) limited investments in the energy system and (2) low levels of energy efficiency as well as a burden on public finances in Ukraine. Moreover, the efficient introduction of carbon pricing – as proposed in the policy proposition "A Revision of Ukraine's Carbon Tax" (part of the policy paper series) – calls for a phase-out of subsidies to achieve responsiveness to price signals. The Box on page 5 summarizes the main arguments of why Ukraine should phase-out energy subsidies.

Subsidies can take on many different forms; hundreds of different measures were identified as subsidies by the OECD.

However, the identification of fossil fuel subsidies can be very complex. The OECD "Inventory of Support Measures for Fossil Fuels" (2015) identified about 800 different measures as fossil fuel subsidies. They base their inventory on the cross-sectoral definition of subsidies set in the Agreement on Subsidies and Countervailing Measures (WTO, 1996)[24]. This subsidy definition sets a standard for all WTO members. However, not all of the measures characterised as subsidies by this definition are classified as such under Ukrainian national law (OECD, 2018a). The OECD "Inventory of Energy Subsidies in EU's Eastern Partnership Countries" (2018) presents estimates for energy subsidies in Ukraine on the basis of the WTO definition. The Bottom-up inventory classifies subsidies into four different categories: direct transfers, tax expenditure and other government revenue forgone, induced transfers and transfers of risk to government. The most straightforward types of mechanism – direct transfers and tax breaks – directly affect government budgets. However, this is not necessarily always the case. A demonstration of the complexity of measures is given by the overview of examples for measures belonging to the four categories presented in Table 2 in the Annex.

Subsidies can benefit energy producers and/or consumers.

Apart from categorising subsidies according to the type of mechanism, subsidies can also be categorised along the type of energy subsidised or along the beneficiary – i.e. producer or consumer subsidies. This is reflected in the IEA's (1999, p.43) definition of energy subsidies: "An energy subsidy is any government action that concerns primarily the energy sector and that lowers the costs of energy production, raises the price received by energy producers, or lowers the price paid by energy consumers".

Only subsidies affecting consumer prices are regarded here.

Instead of using a bottom-up inventory approach, here, a more pragmatic, top-down approach is used. The IEA's (1999) price-gap approach is applied, which compares consumer prices to a reference price[25]. It only captures those subsidies that reduce observable, cumulative prices for consumers. It thus only refers to the third part of the IEA's definition. Moreover, it does not allow to draw any conclusion about the source of the subsidy or whether it affects government budget. Still, the approach is able to identify the costs for the economy which is caused by an inefficient level of consumption due to under-pricing of energy[26].

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[24] According to Article 1.1. a subsidy exists if 1) there are direct transfers of funds by the government, 2) there is government revenue forgone or not collected, 3) the government provides goods or services (other than general infrastructure) or purchases them, or 4) the government provides price support, and hereby a benefit is conferred.

[25] In contrast to the IMF, the IEA's estimations do not include externalities, such as CO_2 emissions that are not internalised due to a lack of proper CO_2 pricing. It is also refrained from including externalities in this paper as a) environmental costs – which constitute the main form of non-internalised costs – are covered in the proposal on CO_2 pricing, and b) it is controversially discussed whether subsidies estimates should include the costs of externalities.

[26] Efficiency costs result from pricing below opportunity costs, which leads to a misperception of scarcity of energy and thus to a level of consumption above economic efficiency. When evaluating the justification of a subsidy, these costs need to be compared

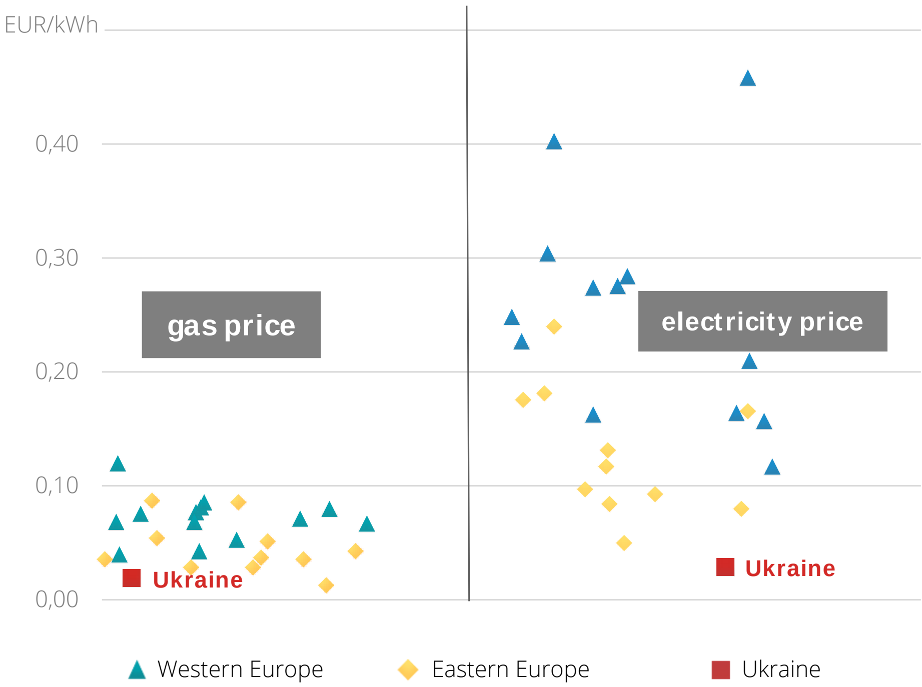
Furthermore, the price gap approach is able to capture effects on energy intensity as well as on the choice of technologies and thus the effects on CO_2 emissions, which is at the heart of this policy paper series.

According to the IEA's estimations, Ukraine's energy subsidies rank the 20th globally with subsidies of EUR 1.9 bn, making up 1.4% of its GDP. The subsidies identified by the IEA in Ukraine solely comprise the electricity sector. However, in past years, there were subsidies present also for natural gas (IEA, 2020). Therefore, this paper focuses on subsidies for electricity as well as natural gas consumption. Oil prices are fully liberalised in Ukraine (OECD, 2018a). Subsidies directed to the coal sector are analysed in Chapter **"7. A socially sustainable coal phase-out in Ukraine"** in the coal sector, producers instead of consumers are subsidized. Subsidies amounted to EUR 407 m in 2019. However, a bottom-up inventory approach was used to quantify these subsidies, thus the magnitude of subsidies identified cannot be compared directly to the results presented in this paper.

Ukraine ranks the 20th among the countries with the highest energy subsidies globally.

Figure 15 illustrates that Ukrainian consumer prices are low in European comparison for both natural gas and electricity. Reasons for that can be differences in taxes (which were excluded in the graph, though)[27], tariffs or underlying energy prices. In the following, the reason for the price difference will be analysed.

Figure 15: Gas and electricity prices for households in Ukraine - among the lowest in Europe (excluding taxes, 2018)



Note: 2018 prices are presented for illustrative purposes, as the IEA does not identify any subsidies for natural gas for 2019 in Ukraine.

Source: European Commission (2020)

to the public-good benefits. Furthermore, in economic theory these efficiency costs should only be accepted if subsidising energy is the most efficient way to reach a certain public policy goal, which is however hard to prove in reality (IEA, 1999).

[27] Different energy or carbon taxes can also result in differences in prices. However, this topic is addressed in the paper "A Revision of Ukraine's carbon tax".

Background info

Why should fossil fuel subsidies be phased-out?

Apart from encouraging wasteful consumption, slowing down technological innovation and renewable energy development and potentially presenting a burden to government budgets, energy subsidies are also often inefficient in achieving their re-distributional policy objective (IEA, 1999). They are often badly targeted and further reinforce existing inequalities (IMF, 2020). Estimations of the IEA (2019) show that in 2019, global fuel subsidies amounted to USD 400 bn. However, only 8% of these subsidies reached the poorest 20% of the population.

Additionally, subsidies emphasise dead-weight losses in the subsidised sector (ESMAP, 2010). Also, in the case of Ukraine, consumer subsidies in the gas and electricity sector are badly targeted. They do not only benefit vulnerable consumers – in the sense of low-income households – but benefit all households. Consequently, even wealthy households are subsidized, who commonly consume more energy and thus benefit more from these subsidies than low-income households.

Moreover, energy subsidies increase emissions, decrease the responsiveness of demand to price changes (which is inter alia required for efficient carbon pricing) and can lead to losses for energy companies due to under-priced commodities resulting in under-investment.

Phasing-out subsidies can present substantial benefits for the economy. By phasing-out fuel subsidies, Ukraine could incentivise households to reduce energy consumption, which would lead to a decreased dependency on energy imports. Further, there would be higher incentives to improve efficiencies, presenting environmental benefits in the form of reduced GHG emissions. Additionally, the phase-out could lead to fiscal and welfare benefits and if designed thoughtful, even reduce inequalities.

But phasing-out subsidies also presents challenges. Energy prices will increase, which is not only politically unpopular, but could also be regressive, if no additional policies to offset this effect are implemented. Compensating vulnerable groups of the population with cash or non-cash transfers, can not only help to address adverse effects of a subsidy removal but also improve public acceptance of the reform.

II. Sector analysis

The IEA's price gap methodology is adopted to identify subsidies.

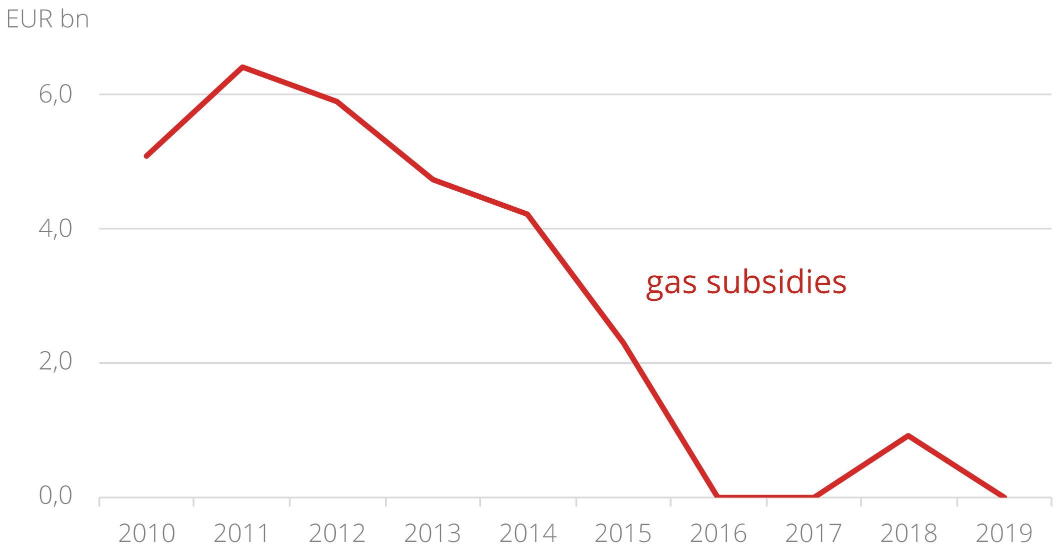
In this paper, subsidies are approximated via the price-gap-approach, as proposed by the IEA (1999) and applied to Ukraine by Ogarenko and Hubacek (2013). The "price gap" is defined as the difference between end-user prices and a reference price that would prevail in competitive, undistorted markets where no subsidies are provided. A detailed description of the methodology and data used can be found in chapter 5.2.2 of the Annex. While the price gap approach likely understates fossil fuel subsidies, as it only captures those that affect consumer prices (IEA, 2020), applying this approach can be justified by the following: first, this approach is able to identify emission savings from removing subsidies, which is of main concern in this policy paper series. Second, underpriced natural gas and electricity for households were/are the main reasons for inefficiencies in both sectors, as regulation, market design, taxation and laws enabling the subsidies are shaping revenue streams in the system (see the subsequent analysis).

In the following, subsidy estimates by the IEA for past years are presented and regulatory developments that shaped these subsidies are addressed. In the end, own estimates for subsidies in the electricity sector are given for 2019, to evaluate the effects of phasing out these subsidies in the subsequent sections. For natural gas, the IEA does not identify consumer subsidies for 2019 anymore.

a. Natural gas

The main challenge in the price gap approach is to find a good reference point – as in different countries, different sharing of cost/benefit in the sector are hardwired through regulation and it is not clear which one is the most cost-reflective. Natural gas is extensively traded in Ukraine with other countries and Ukraine is a net-importer of natural gas (Ukrstat, 2020). Thus, the import parity price is used as a reference price in this case, adjusted by transportation and distribution costs. Figure 2 presents the IEA estimates until 2019.

Figure 16: Natural gas subsidies in Ukraine significantly decreased over the last decade



Source: IEA (2020)

Natural gas price subsidies substantially declined in past years.

In 2014, households paid around EUR 22 for thousand cubic meters. In contrast, industrial consumers paid EUR 222[28] (Bayramov and Marusyk, 2019). Since then, the graph depicts a steep decline in subsidies for naturals gas due to a combination of factors: A decrease in gas prices at the international market, reduced domestic consumption and revision of tariffs.

But the subsidisation left its marks: it costs the government billions of Euros between 2012 and 2015.

The drastic consequences of such high subsidies that were previously in place could be illustrated on the example of Naftogaz, which received compensation with a complex mechanism of inter-budget transfers (subvention) until 2012 (OECD, 2018). These transfers were not sufficient to maintain liquidity and recover the deficit resulting from the difference of import prices and consumer prices. In order to timely pay for imported gas, the company had to take on loans. However, Naftogaz would not have been able to pay back loans without government support. Therefore, the Cabinet of Ministers developed special state bonds, that were issued from 2012 to 2015, to recapitalise Naftogaz (OECD, 2018a). All in all, bonds worth UAH 142 bn (EUR 5 bn) were issued for capital injection into Naftogaz. This demonstrates that subsidies are not only counterproductive for the energy transition, but that they can also present a high financial burden to governments.

[28] Conversion based on 2014 exchange rates.

Consequently, the IMF set the deregulation of natural gas prices as a precondition to receive loans.

Nonetheless, in 2015 the government took steps to deregulate pricing in wholesale and retail gas markets and raised tariffs for regulated consumers. This was a precondition to receive IMF loans. To reduce the burden for households, the reforms were accompanied by progressive changes to the Housing and Utilities Subsidies (HUS) mechanism. By the redesign, the coverage of poorer households was increased (Dodonov, 2018).

While large subsidies were abolished and import-parity pricing was introduced in 2016, the revision of tariffs for households to reflect price increases at the international market was often delayed for political reasons. Since then, there have been several attempts to further reform gas prices. In May 2019, it was decided on a regulation for residential gas prices consisting of two options. Under the first option, gas prices were determined by a PSO-formula, whereby a 20% discount was applied as a price cap to an import parity price average for the period of November 2018 to January 2020. Under the second option, prices were determined by current import prices.

The government of Ukraine could switch between both options and choose the option that presented the smaller prices for end-consumers. This allowed to benefit from low international gas prices in summer 2019 and to switch back to the price cap as soon as import prices picked up.

In the beginning of January 2020, the first option was replaced by a temporary guaranteed gas price, which was set at UAH 5500 /tcm (around EUR 200 /tcm). At the end of January, the temporary guaranteed gas price was changed again to a price cap determined by four components; The average end-of-day prices at TTF and NCG gas hubs for the first 22 days of the gas delivery month, the spread between average end-of-day and actual prices at these hubs, the Ukrainian gas entry fee at the European border and a regulated Naftogaz mark-up (Naftogaz, 2020). In summer 2020, the PSO scheme for gas supplied to households (not yet for district heating purposes) was removed (ICIS, 2020). Still, due to the COVID-19 pandemic and the related quarantine measures, the government returned to regulated prices at the beginning of 2021, which it set below market prices and hereby returned to gas price subsidies (CMU, 2021). Nonetheless, the government emphasized that this was a short-term, quarantine-related measure only.

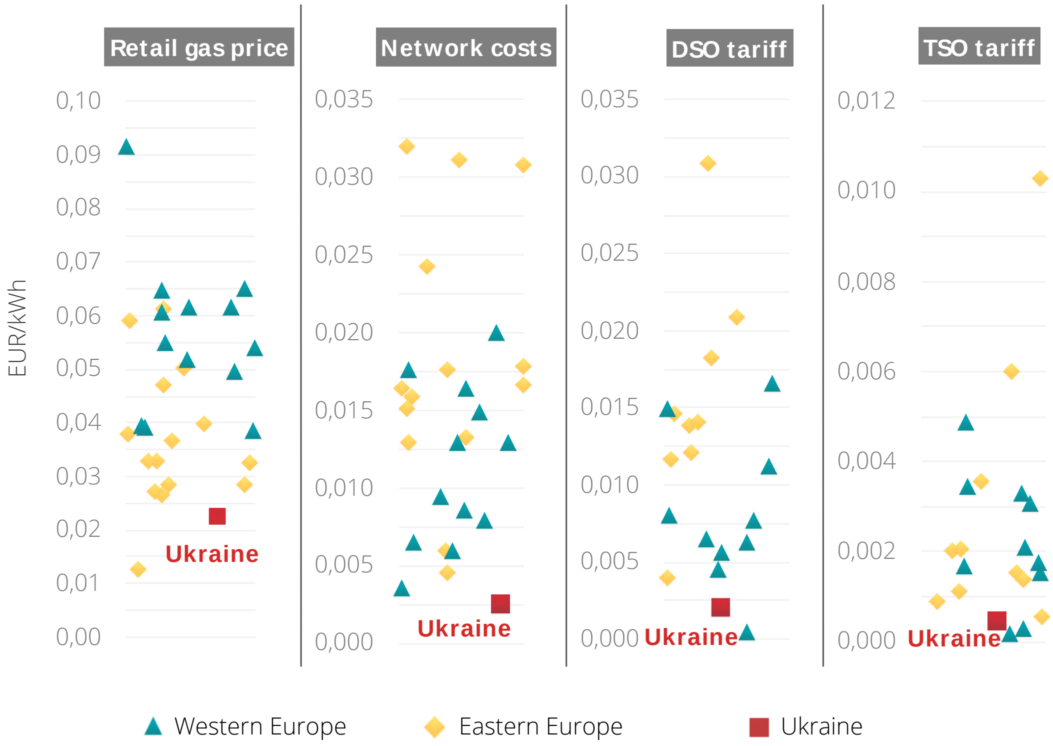
In 2019, the IEA did not identify any natural gas price subsidies.

For the most recent year – 2019 – the IEA (2020) does not find any consumer subsidies for natural gas. Still, Figure 3 illustrates that the retail household gas price is below European levels, which could result from lower network costs. Low TSO and DSO tariffs could lead to under-investments into the pipeline system, which could on the one hand pose a risk to security and on the other lead to higher costs of supplying gas in the future. The median European margin between wholesale and retail prices is EUR 31.5/ MWh (Own calculation based on European Commission, 2020). In contrast, the Ukrainian margin corresponded to EUR 4.3/ MWh in 2019. As the same technological costs of supplying gas should apply in European countries and in Ukraine, there might still be implicit subsidies.

Natural gas price components are still low in European comparison.

However, Dixi (2017) illustrate that labour costs made up around 30% of DSO tariffs in 2017. As these are considerably lower in Ukraine than in other European countries, wages might be the source of lower tariffs. To take this into account, it is differentiated between western and eastern European countries in the graph. Nonetheless, data was retrieved from European Commission (2020), where consistent data is mainly available only for EU countries. Eastern European countries being part of the EU still present higher wages than Ukraine or its direct non-EU neighbours Moldova or Belarus. To control for country-specific effects, such as wages, a detailed benchmarking analysis would be required, which exceeds the scope of this policy note.

Figure 17: Gas price components are among the lowest in Europe (for households, 2019)



Source: European Commission (2020), NERC (2019) and NERC (2020)[29]

Summarizing, the reforms in the gas market demonstrate that liberalising energy markets is possible in a socially sustainable way. In addition to cost covering prices the reforms also helped to fight corruption and set new rules to the game. The sector hereby sets an example for the electricity market. It has to be noted, though, that a shift to import-parity was politically eased by the favourable circumstance that gas prices were low at the international market (compared to previous years) and thus these changes did not imply drastic price increases for the population. Moreover, the sector is still missing sufficient competition in the retail segment and the praise of the progress in the gas sector should only be kept up, if the recent moves back towards subsidization truly are only a temporary measure.

b. Electricity

Before the market opening, electricity prices were cross-subsidized. This means that certain consumer groups – in the case of Ukraine non-household consumers as industry, railway transport and state-funded institutions – pay a higher price to subsidise preferential consumer groups, like households. In 2019, the average price for non-households was 78% (28 EUR/MWh) higher than the average regulated household price (Ukrstat, 2020). Consequently, neither group payed the “correct” price, in the sense of the true opportunity costs, as the former payed a price supposedly exceeding the costs of supply and the latter a price lower than costs of supply. This can distort the market and obstruct competition in the retail segment. Also, the higher price that has to be borne by the industry can be regarded as an implicit tax, which increases production costs. The burden, that has to be carried by the industry, is likely to be distributed between the demand and supply side, depending on the relevant elasticities. This can in turn again negatively affect

[29] Network costs is the sum of DSO and TSO tariffs.

households. In Belarus, for example, the cross-subsidisation of residential heat-prices had a regressive impact (Grainger, Zhang and Schreiber, 2015).

A complicated Public Service Obligations (PSO) scheme to finance consumer subsidies is still in place in the electricity sector.

Steps towards market liberalisation were taken with the liberalisation of wholesale markets in July 2019. Nevertheless, there is no full competitive market structure yet[30]. To enable low rates of electricity supply for households, the Resolution No. 483 from June 2019 (CMU, 2019c) established the following PSO scheme:

i. The Guaranteed Buyer (GB) buys a regulated share of electricity from Ukrhydroenergo (UHE) (35%) and Energoatom (EA) (85%) at regulated rates. He then sells power required to cover household demand to the Universal Service Suppliers (USSs) who sell to households. However, this only holds in the IPS-zone. In Burshtyn Energy Island (BEI) neither UHE nor EA have power plants. Instead, the GB has to buy electricity from privately owned coal power plants. As these do not belong to the PSO, the GB has to buy electricity at much higher prices here.

ii. Households pay a regulated rate to USSs, while the USSs buy it from the GB for:

iii. average household price – (TSO tariff + DSO tariff + USS margin), where all four components are regulated. Some USSs pay to the GB and some receive money due to differences in DSO tariffs. Moreover, The GB incurs losses here, because the total average price he receives from the USSs is below what he pays for electricity (see Figure 18).

iv. To cover the losses accrued for selling at regulated rates to households, the GB sells excess power on the wholesale market. In 2019, the GB made enough profits to cover these losses, however since January 2020, the revenues made at the wholesale market are no longer sufficient to cover all losses. Therefore, some losses remained at this stage.

v. After some regulatory changes, the law obliges Ukrenergo to not only finance the green tariffs via transmission tariffs but also to fund the remaining losses incurred by the GB (CMU, 2019a). The tariff increase is set by the regulator and affects final electricity prices for non-residential consumers.

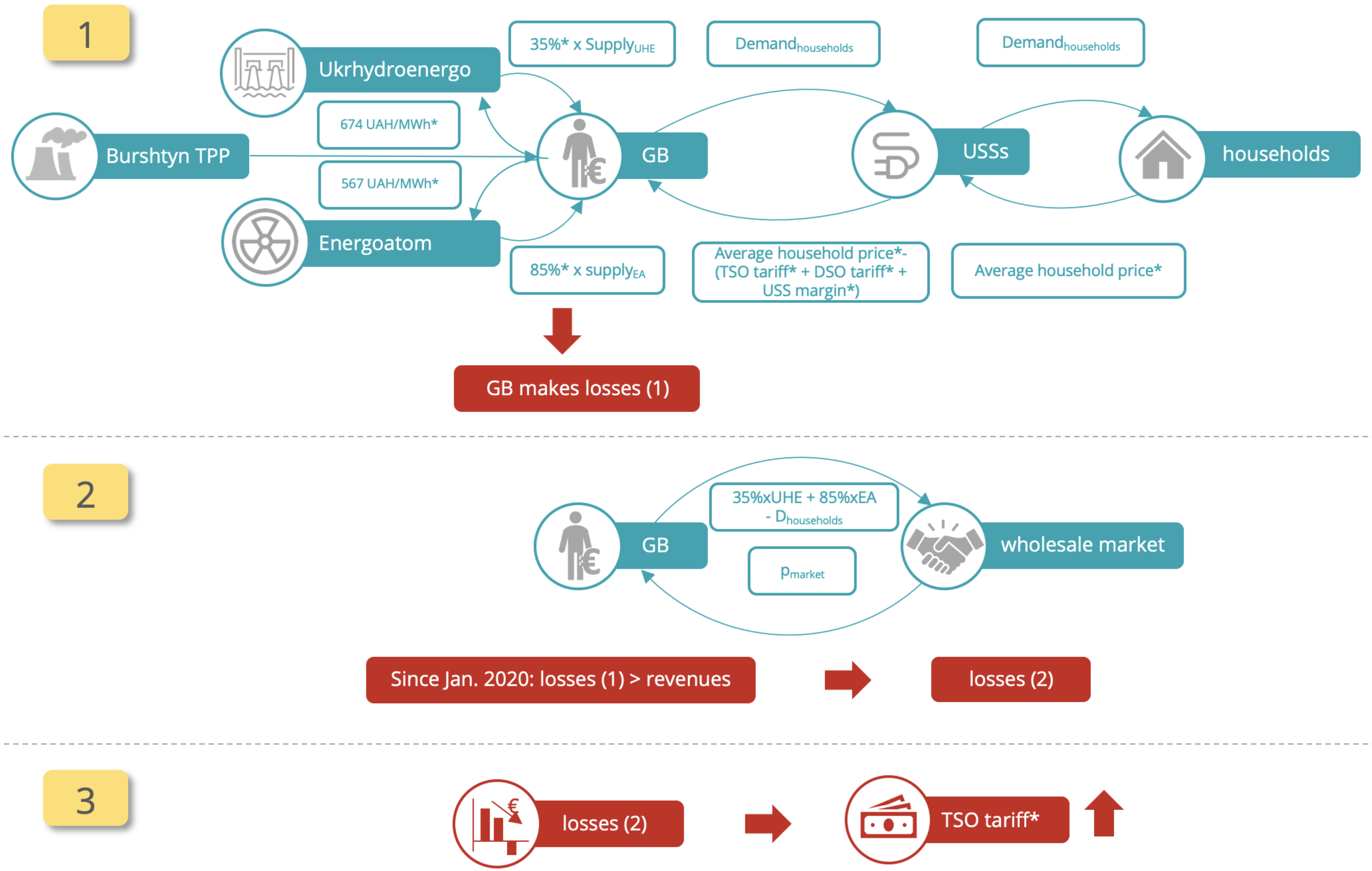
The increase in TSO tariffs, does not only lead to higher costs faced by non-regulated consumer groups, but also to a decrease in revenue of the GB in step 1). Additionally, the TSO tariff increase does not necessarily cover all losses of the GB, as was the case in recent months, where the GB failed to pay EA (Zachmann, Mykhailenko, Meissner, *et al.*, 2020). Household subsidies are consequently financed a) by the low, regulated rates from which the GB bought electricity from UHE and EA, b) by the increase in TSO tariffs, borne by non-household consumers, and c) by the government in case the debt accumulated in the system leads to the failure of the GB, Ukrenergo, UHE or EA.

The PSO scheme causes a range of inefficiencies in the Ukrainian electricity market.

This complicated scheme of redistributing flows in the electricity system also negatively affects other segments as it virtually separated the market into self-contained territories (Zachmann, Mykhailenko, Vereshchynska, *et al.*, 2020). Figure 5 illustrates all flows in Ukraine's electricity market. Thermal Power Plants (TPPs) sell the largest share of their power with little to no competition via bilateral agreements. The organised market segments – day-ahead (DAM), intraday (IDM) and balancing market (BM) – are dominated by nuclear power from the two main players EA and the GB. This limits competition. Moreover, the PSO scheme withholds demand from the organised market segments as around one third of the market is determined by bilateral contracts between the GB and USSs.

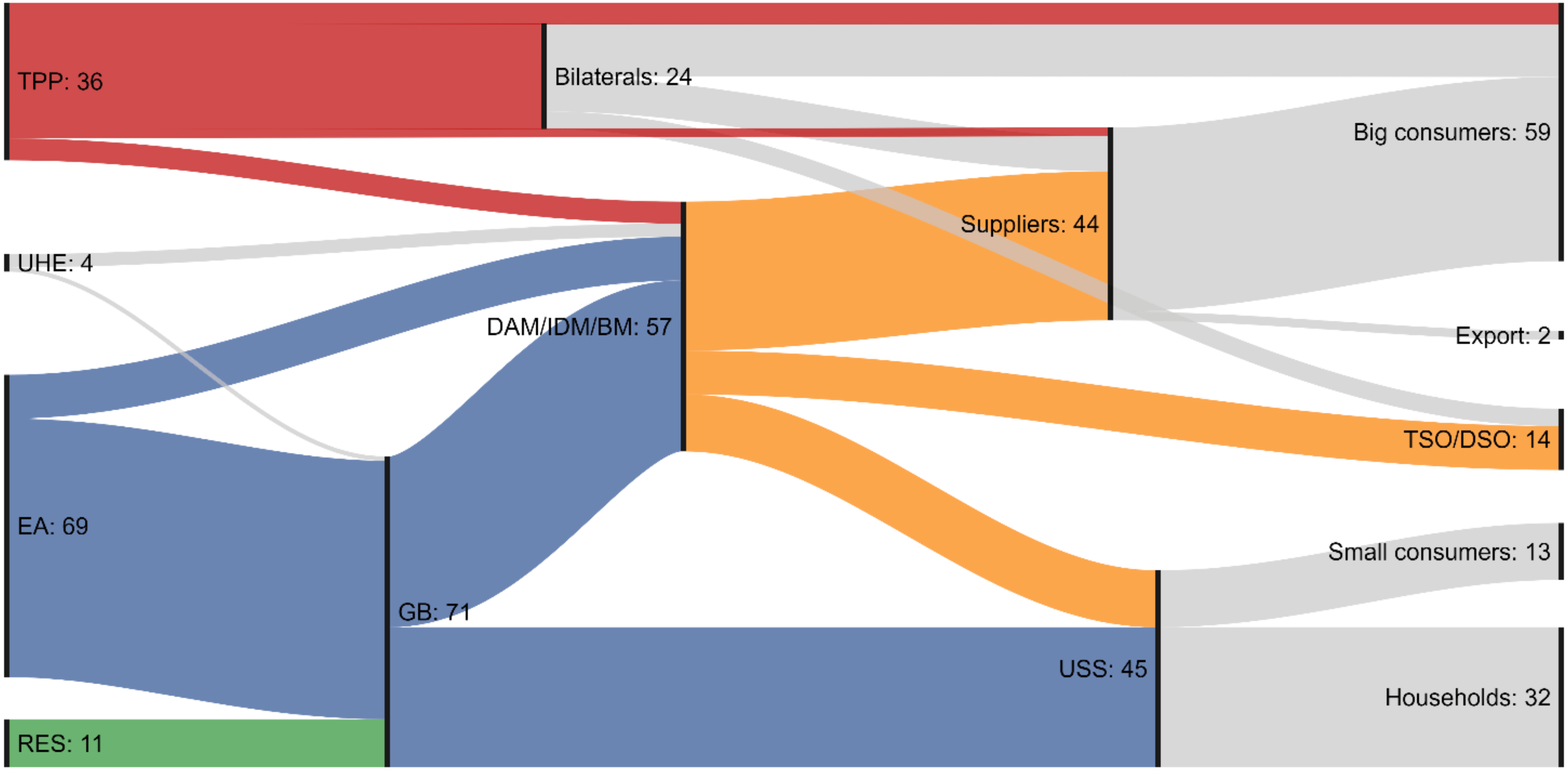
[30] For a detailed analysis of the wholesale market since its opening, see Zachmann *et al.* (2020).

Figure 18: How the PSO scheme for households led to losses and increased non-household tariffs (before May 2020)



Source: Own illustration based on CMU (2019) and Zachmann *et al.* (2020)

Figure 19: Electricity volume flows in the IPS market [TWh]



Note: The flowchart is read from left to right. On the left, energy producers are shown, followed by market segments and intermediaries where electricity is sold to, and on the right final consumers. The size of the lines corresponds to volumes

Source: Zachmann *et al.* (2020)

All in all, the PSO scheme created a string of debts, massive distortions to the market, and non-functioning organised market segments due to the lack of competition. Consequently, the true costs of the subsidies likely substantially exceed the economic costs that result from overconsumption caused by inefficient household pricing.

Moreover, the current form of Ukraine's PSO scheme contradicts the rules to PSOs, set by Article 3 in the EU's Electricity Directive (European Commission, 2009). Here it states, that the public service obligation shouldn't affect the liberalisation process in the electricity market. This is even captured by CMU (2019), which established the PSO, as it acknowledges that ensuring the special obligations should not compromise the primary goal of creating an electricity market based on free competition. Free competition is, however, hard to achieve under the above stated market conditions.

Additionally, it contradicts the rules to the PSO themselves.

To address competition issues, improve liquidity, reduce imbalances and reduce the financial burden of EA, GB and others, changes to the PSO Resolution were made in May 2020 (CMU, 2020b). The compulsory sale of power by EA was reduced from 85% to 80%. Additionally, the changes allowed EA to sell up to 5% of its forecasted supply under bilaterals at special sessions of electronic auctions. In August 2020, a transitional PSO was adopted (CMU, 2020a). EA is now only obliged to sell the volumes claimed by the USSs for household consumption to the GB, while UHE is obliged to sell 30% to the GB. UHE sells at UAH 10/MWh (around EUR 0.3/MWh) whereas EA sells at UAH 150/MWh (around EUR 5/MWh) to the GB. However, UHE and EA have to make sure that their overall average selling price (including prices achieved at the market) is not below their cost of supply, which virtually sets a minimum price cap.

Several changes to the PSO were made to address its flaws.

Nonetheless, the PSO mechanism is still in place and the time scope of the "transition" is not defined. While the regulated prices will likely stop debt being accumulated further by the GB, it is not clear how old debt will be repaid. Additionally, this will likely drive the price for other market participants up as it sets a minimum price cap for EA and UHE. Summarizing, as household tariffs are still subsidized, these costs will have to be borne somewhere along the supply chain or by the government. To approximate the costs of these subsidies, the price gap approach will be applied to the electricity sector next.

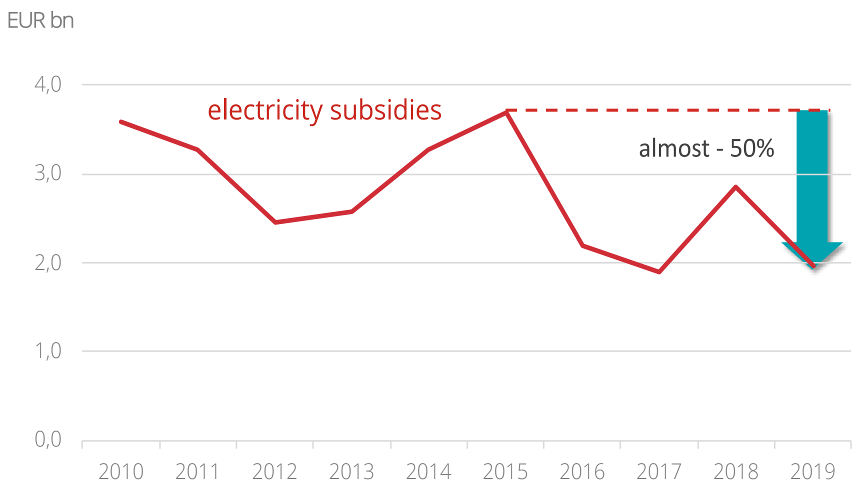
But these will likely not solve the underlying problem and subsidies should be abolished.

SUBSIDY ESTIMATES

In contrast to natural gas, subsidies in the electricity sector were not reduced as much. Figure 20 illustrates the IEA's (2020) estimates for consumer subsidies for electricity. Subsidies still amounted to EUR 2 bn in 2019.

The IEA estimates EUR 2 bn in electricity price subsidies for 2019.

Figure 20: Electricity subsidies in Ukraine almost halved over the last decade, but are still substantial



Source: IEA (2020)

Therefore, the consequences of phasing-out these subsidies will be evaluated in this policy note. The price-gap methodology employed by the IEA is adopted here. Electricity is not extensively traded across-borders. Therefore, the reference price is based on annual average-cost pricing of electricity, weighted according to output levels. The annual average-cost pricing takes reference prices for fossil fuels and efficiencies of power generation into account (IEA, 2020). A price of EUR 47 /MWh is obtained. A detailed description of how the average-cost pricing is obtained is given in the Annex.

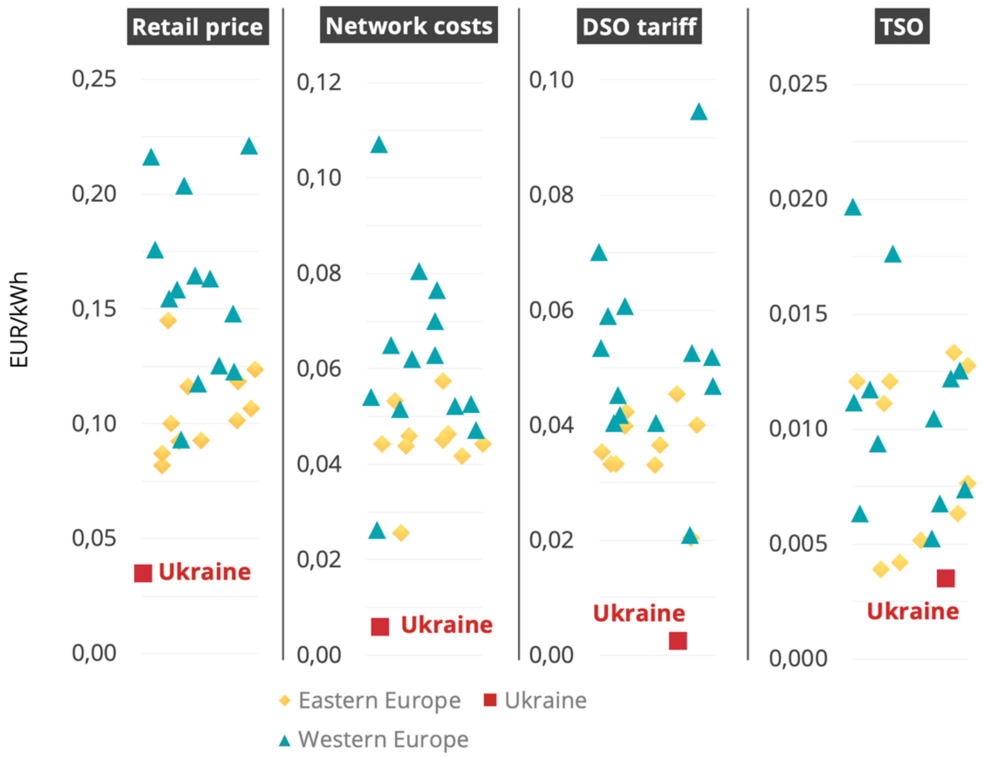
Comparing the different price components of household electricity prices reveals that not only final electricity prices for households are substantially below the level of other European countries, but also network costs.

This could be an indicator that DSO/TSO tariffs are also below efficient prices and contain implicit subsidies. Consequently, the IEA's approach of including an allowance for transmission and distribution costs of USD 40 /MWh (EUR 35 /MWh) for household and USD 15 /MWh (EUR 13 /MWh)[31] for industry is adapted instead of relying on current domestic DSO/TSO tariffs.

Consumer subsidies of EUR 1.4 bn are estimated, from which EUR 200 m are financed via cross-subsidisation by industry.

Based on these assumptions, consumer subsidies of EUR 1.4 bn are obtained. Parts of it (EUR 200 m) were financed through cross-subsidisation by industry prices, which were EUR 4 /MWh above the reference price. The subsidy estimation is 30% below the IEA estimations which may result from different assumptions used for calculating the average-cost pricing.

Figure 21: Electricity price components are the lowest in Europe (for households)



Source: European Commission (2020), NERC (2019) and NERC (2020)[32]

[31] As industry commonly purchases larger volumes of electricity, it can be supplied at higher voltages, which is more efficient. Therefore, supply costs for industry are less than for households and industry prices are usually closer to wholesale prices (eia, 2020).

[32] Network costs is the sum of DSO and TSO tariffs.

c. Other subsidies

Subsidies directly affecting final consumer prices constitute only one form of energy subsidies in Ukraine. Producer subsidies present a second category. These are not the focus of this policy note but will be quickly addressed in the following. Thermal heat and power producers were recipients of de-facto subsidies due to the formation of the forecasted wholesale market price of electricity – a procedure popularly known as "Rotterdam+". For a more detailed description of "Rotterdam+", please refer to the Chapter "A socially sustainable coal phase-out in Ukraine".

Not only consumers, but also producers are subsidised in Ukraine's electricity sector.

Also, renewable energy is subsidized. Since 2009 there are subsidies for certain types of renewable energy installations in the form of feed-in tariffs (FIT). Since July 2019, eligible producers sell their electricity to the Guaranteed Buyer for FIT, who then resells RES electricity at the organised market segments. Therefore, the actual subsidy is variable and depends on the difference between the FIT level and the average GB selling price on organised market segments.

Renewable energy subsidies correct a market failure instead of creating one and should thus not be abolished.

While inefficient fossil-fuel subsidies that were addressed above contribute to CO2 emissions, this is not the case for renewable energy subsidies. Furthermore, there are valid arguments for renewable energy subsidies, as long as related technologies are not yet competitive due to high upfront investment costs. Apart from improving the competitiveness of clean energy technologies, RES subsidies also correct for market failure. Social benefits of clean energy in the form of lower GHG emissions and cleaner air are disregarded in the investment decision of private investors, leading to an underinvestment in RES technologies.

Consequently, a phase-out of renewable energy subsidies is not proposed. Instead, a redesign of renewable energy support that aims at improving the efficiency and reducing costs for consumers is covered in Chapter "Increase RES electricity generation through competitive auctioning of FIPs".

Background info

IMF reform plan

The IMF (2020) presents recommendations for a reform plan to phase-out energy subsidies, derived from country experiences:

i. Comprehensive energy sector plan

ii. Phase-in of price increases over time

iii. Measures to protect low-income households, e.g. near-cash transfers or expansion of existing, targeted programmes

iv. De-politisation of energy prices, e.g. automatic pricing mechanisms

Also, the process should be accompanied by transparent communication and consultation with stakeholders.

Phasing out energy subsidies

The previous section illustrated some estimates for energy subsidies in Ukraine. Now it will be addressed, how the Ukrainian government can abolish energy subsidies in a socially sustainable way.

The government has pursued steps to liberalise the natural gas market that are close to IMF recommendations and phased-out natural gas subsidies over time. Only a full de-politisation of prices should be achieved, to impede a return to subsidised household prices once international gas prices pick up or the economic situation deteriorates. In contrast, the electricity sector is yet to follow. In line with the IMF-recommendations, the following steps are proposed.

I. Comprehensive energy sector plan

Along with subsidies, the PSO scheme should be phased-out.

Subsidised household prices and the connected PSO scheme are the root of several inefficiencies in the electricity market. Consequently, the redistribution of financial flows between the Guaranteed Buyer and other market players should be faded out along with a phase-out of subsidies itself. One proposal, how this can be achieved, is given by USAID (2020) and presented in the Box on page 15. However, as this is a large topic, it will not be covered in detail here and should be part of a separate analysis.

Background info

PSO phase-out: USAID proposal

USAID (2020) proposed an improved financial PSO-structure in response to a proposal made by the Energy Community. Under USAID's proposal, the state-owned company EnergoAtom should sell all its electricity on the wholesale market in contrast to the current scheme of selling a volume corresponding to household demand to the Guaranteed Buyer at fixed prices.

In the proposal, volumes would be sold on the market. The USSs would then sell electricity to households, who pay a fixed rate. Energoatom would be obliged to compensate the USSs by "quasi" swaps for the difference of the market price and fixed rates, while the fixed price increases and gradually reaches market prices by 2028. Consequently, the proposition of USAID implies a subsidy phase-out in the electricity sector.

II. Phase-out over time

Subsidy phase-out until 2022

For the time scope of the subsidy phase-out there is a trade-off between choosing a time scope long enough to allow for households to adapt, minimise negative welfare effects and enable reforms in the market and between choosing a time scope short enough to allow for a credible commitment by the government that is not threatened by a shift in the political agenda. The analysis in section 3 (Assessment of the effects of a phase-out) shows that negative effects for households are likely not substantiate, even if a shorter time scope is envisioned. Therefore, a time scope of 2 years is proposed. Household prices should be increased linearly each month starting in 2022 until the reference price is reached in 2023. When the final price is reached, households would need to attribute EUR 9 additionally to electricity bills per month which corresponds to approximately 0.5% of the average household income.

III. Compensation schemes

As electricity bills are covered under the HUS mechanism (CMU, 2020c), which has been improved in light of the phase-out of subsidies in the gas sector, low-income households would be protected from an energy price increase. Under the HUS, the difference between norm-based consumption and the household contribution share is covered by the state, while the obligatory contribution depends on household income.

Low-income households would be compensated by Housing and Utilities Subsidies (HUS).

The subsidy (S) granted to a household under the HUS is determined by the difference between the payment within the social norm (SP) and the share of contribution multiplied with the household income (HI). The share of contribution depends on the household income per number of people living in the household (N), as well as on the subsistence level (SL) (CMU, 2020c):

$$S = SP - \frac{HI/_N}{2 * SL} * 20\% * \ HI$$

The subsidies paid by the state increase with energy prices. Consequently, households eligible for these subsidies – 37% of households in 2019 (Ukrstat, 2020) – will be largely compensated for the price increase. Moreover, an increase in power prices is likely to increase the number of households receiving subsidies, because those households that were close to thresholds before are likely to be pushed above. However, an increase in income during the next decade could mitigate this. Section 3 (Assessment of the effects of a phase-out) investigates this in more detail. Due to norm-based payments and monetisation of the subsidies in March 2019 (DiXi Group, 2019), the incentives for energy savings are kept intact with this compensation scheme as the recipient has unused subsidies at his/her own disposal.

IV. De-politisation of energy prices

The goal of the sector should be market-based prices. As for natural gas, electricity prices should be fully detached from governmental influence. Prices should be allowed to fluctuate freely as soon as they reach the market level. This would also support the introduction of carbon pricing, as this requires that the price signal depending on the carbon content of fuels is forwarded to consumers so that these are incentivised to adapt their consumption behaviour.

Moreover, electricity – but also natural gas – prices should be fully de-politized.

Assessment of the effects of a phase-out

I. Costs of subsidies

To quantify effects, a phase-out scenario is compared to a reference scenario where electricity prices are still subsidized.

To quantify potential effects of the subsidy phase-out, a scenario with price subsidies and one with a gradual phase-out are compared. In the reference scenario, household prices are kept constant at the subsidised levels. In the phase-out scenario, subsidies in the electricity sector are phased out linearly thus consumer prices approach the benchmark price by 2023. As natural gas prices were close to market levels already before the recent, temporary changes, no phase-out is regarded here. Nonetheless, it should be noted that the phase-out of subsidies for natural gas was accompanied by favourable conditions of low international gas prices in past years. The IEA (2018b) projects an increase in natural gas prices until 2030, thus there is a threat of permanently returning to subsidised prices once gas prices pick up. Still, it is assumed here that the government will adhere to its long-term strategy for natural gas prices.

The benchmark price for electricity is kept constant.

The benchmark price for electricity is kept constant at the 2019 level despite a projected increase in natural gas and coal prices, which could lead to higher power prices in the coming years. However, power prices depend on several, uncertain factors – such as the generation mix, investment costs of new capacities and renewable subsidies. As these can also work in opposite directions, making an educated guess about future electricity prices in Ukraine would not be appropriate. Still, it should be kept in mind that a change in power prices could increase or decrease the costs of subsidies in the reference scenario.

Future electricity demand trajectories are retrieved from the NDC Scenario 2. This scenario was developed within the drafting process of Ukraine's second NDC in 2020. It describes Ukraine's development for a timely implementation of all drafted and passed climate-related legislation. It takes current as well as planned climate measures into account. It projects an increase in electricity demand by 29% compared to 2019 levels.

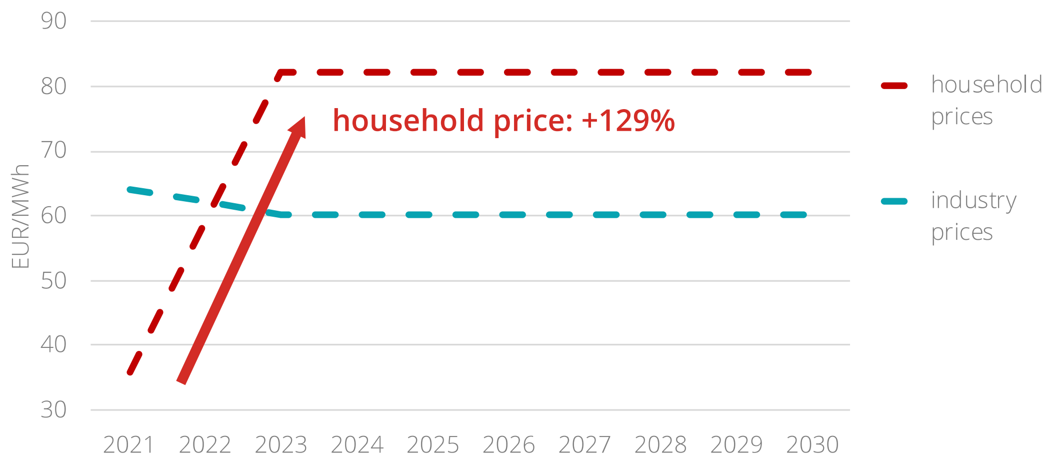
Costs of subsidies would increase to nearly EUR 2 bn in 2030 if they are not phased-out.

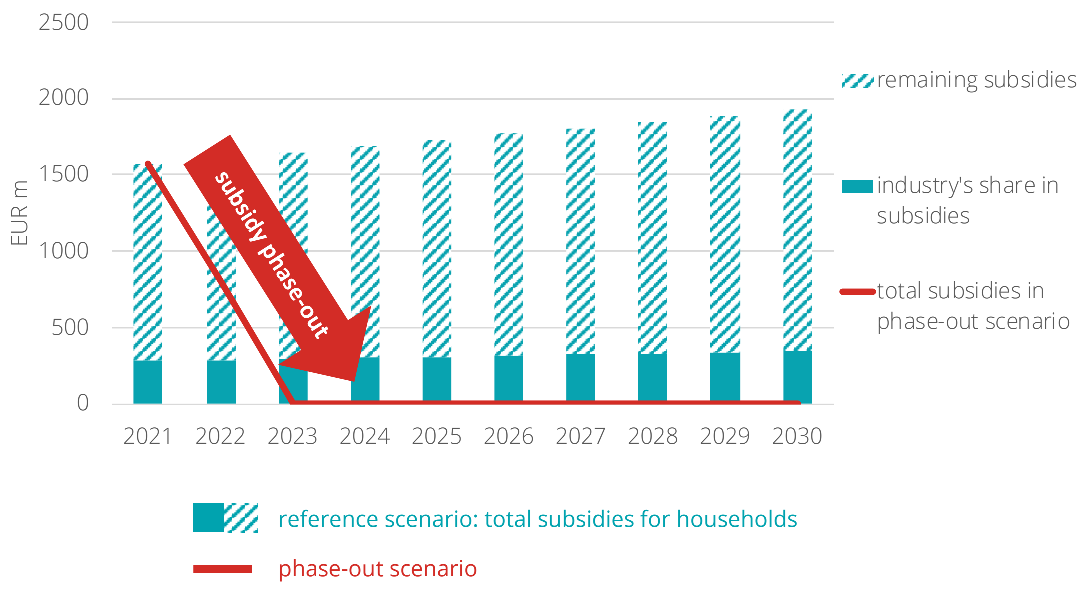
In the subsidy phase-out scenario, subsidies are gradually removed. Figure 8 displays the costs of the subsidies as well as electricity prices for industry and households. Industry prices are already close to their reference price thus the majority of the costs of the subsidies are borne by revenue shifts in the electricity market. Due to the assumed increase in electricity demand, these costs would increase from EUR 1.5 bn in 2021 to nearly EUR 2 bn in 2030. These costs could be avoided by 2023 if electricity price subsidies are phased-out. 20% of the costs of subsidies would be covered by the cross-subsidisation through industry. As discussed in Section II ("Electricity"), it is virtually impossible to pin down who exactly bears what share of the remaining 80% of the costs. Nonetheless, it is likely that some costs are borne by the state, as EnergoAtom and the Guaranteed Buyer would finally be backed by the state.

Household prices need to increase to around EUR 80/MWh.

Electricity prices would more than double until 2023 to reach the reference price. Also, instead of having cheaper retail prices, households would pay EUR 22 /MWh more than industry. Nonetheless, with EUR 82 /MWh (EUR 0.08 /kWh), Ukraine would still have the cheapest household electricity prices compared to European countries (Figure 15, section 1.1.2). Industry prices would slightly decrease to EUR 60/MWh.

Figure 22: Phase-out of electricity price subsidies for households would cause an increase of 129% in household electricity prices, but the costs for the economy are substantially reduced





Source: Own calculation

II. Effects

The effects of a subsidy phase-out can be classified in two categories; direct and indirect effects. In the short run, the phase-out directly affects consumer income and spending. By the increase in prices, consumer will decide to spend less for certain fuels, depending on their short-run price sensitivity. Short-run price sensitivities thus reflect consumer's immediate response to higher energy prices within one year. A description of the methodology to evaluate the effects is presented in the Annex.

The increase in household prices will affect household's current spending level but will also influence their future investment decisions.

While in the short-run, this directly leads to a decrease in GHG emissions through decreased consumption, in the long-run consumers tend to adopt their behaviour. These responses are likely to be more pronounced as they take gradual changes in the capital stock over several years into account (Huntington, Barrios and Arora, 2019). Hereby further GHG emission reductions can be achieved. This effect can be quantified by long-run price elasticities.

The presented estimates should be regarded as first approximations instead of a final analysis. As this paper is part of a series of ten policy proposals, all measures should be modelled simultaneously to account for reciprocal effects.

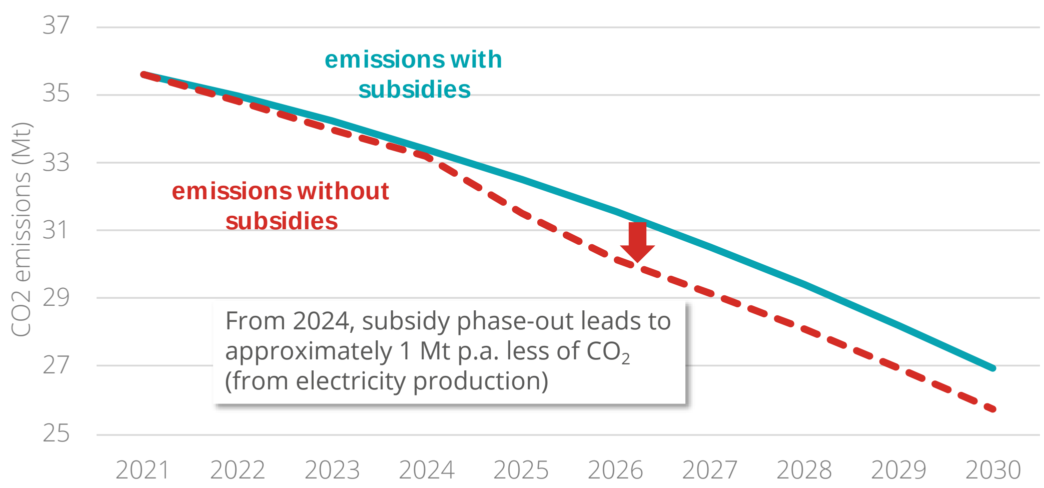
a. Decarbonisation

The following estimations for GHG emission reductions take short-run as well as long-run price sensitivities of energy demand into account. The time scope of the expression "long-term" is not predefined though and varies between studies. It should allow for the time necessary to do significant capital investments, i.e. several years. Here, we define the long-run as 3 years, as in Deryugina, MacKay and Reif (2017). However, this should rather be seen as a lower bound and depending on the sector, adjustments might take considerably longer. Further, it should be noted that only price effects are regarded here and no income or substitution effects.

CO_2 emissions of up to 1.2 Mt could be saved by 2030. This could be intensified through complementary measures like a more ambitious carbon tax.

Since demand for energy, especially for electricity, is rather inelastic, and only one third of Ukraine's electricity is produced from carbon-intensive fuels (Ukrenergo, 2020) the emission reductions are likely to be small. Based on the presented calculations a reduction of up to 1.2 Mt in CO_2 emissions in 2030 is estimated. However, the subsidy phase-out is necessary for the efficient introduction of carbon pricing, which in turn likely leads to substantial emission reductions.

Figure 23: CO_2 emissions from natural gas consumption and electricity production



Source: Own calculation

b. Consumer costs

Due to the nearly perfectly inelastic residential electricity demand, in the short-run households will only slightly react to the price increase by a reduction in demand. Instead, the subsidy phase-out will mainly increase the cost-of-living. Formerly regulated electricity prices would increase by 130% over two years. This substantial increase emphasizes the drastic subsidisation of current residential power prices.

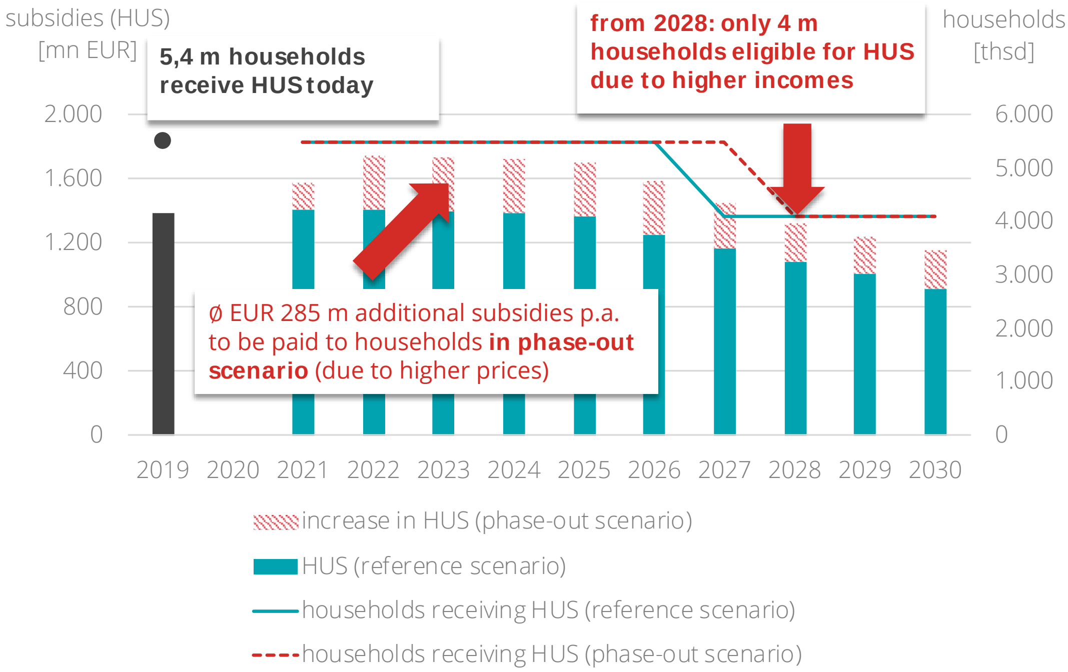
Low-income households would be protected by the HUS scheme. A detailed description of how the HUS works is given in chapter 5.3 of the Annex. Figure 10 compares payments under the HUS as well as the number of households receiving subsidies for the reference and the phase-out scenario. Natural gas price assumptions are based on IEA (2018). Heat prices are assumed change with natural gas prices while the remaining utilities costs covered by the HUS are assumed to be constant. For household income, the NDC Baseline Macroeconomic Scenario assumption that household income increases by 5-6% annually is adopted. Until 2025, natural gas prices increase by 30% compared to 2020. However, afterwards the effect of rising natural gas prices diminishes with an assumed annual increase of 1%. This is more than compensated by the increase in income, thus less subsidies would need to be paid under the reference scenario in 2030. The increase in income even offsets the increase in payments resulting from increased electricity prices.

Low-income households are protected by the HUS. But an increase in household income likely offsets increased HUS from the electricity price subsidy phase-out.

In 2023, EUR 338 m would need to be attributed *additionally* to the HUS due to the phase-out of electricity prices subsidies. This would decrease to EUR 233 m by 2030, as less households would be eligible for HUS resulting from the increase in household income. However, it should be noted that the results are based on the assumption that each income group benefits equally from the increase in income. An increase in inequality could alter the results. On average, EUR 285 m would need to be attributed additionally to the HUS in the next ten years under the phase-out scenario. This corresponds to 20% of the average increase in household expenditure until 2030.

EUR 338 m would need to be attributed additionally to the HUS in 2023.

Figure 24: Annual HUS payments under the subsidy phase-out scenario



Source: Own calculation

Taking the HUS into account, household expenditure would increase by EUR 600 m in 2022 and EUR 1.2 bn in 2023. This corresponds to EUR 5/month in 2022 and EUR 10/month in 2023 for households not eligible for the HUS.

c. Employment effects

No direct negative effects on employment are expected.

As there are no subsidies for industrial gas prices and industrial electricity prices would even decrease when cross-subsidisation is removed, there are no direct implications for input costs of production in the industry. Therefore, no adjustments to labour input are required. However, households are likely to spend less for non-essential goods when energy bills increase, which may pose a threat to certain industries and consequently to employment in these industries. To evaluate these effects, comprehensive modelling of cumulative effects is needed.

d. Energy Efficiency

Efficiency improvements of up to 12% are estimated for electricity by 2030.

A removal of energy subsidies leads to an improvement of energy efficiency via price signals. Through an increase in energy prices, households are incentivised to take measures that improve energy efficiencies in order to decrease expenditure for electricity. This effect is deepened by a transparent and gradual phase-out of subsidies as well as by tax (or in the case of the HUS, subsidy) shifting programs that enable investments also for low-income households. The effects on energy efficiency are represented by the long-run price elasticities presented in Table 7. Basing the estimation on these elasticity assumptions, efficiency improvements of up to 12% can be realised for electricity by 2030.

Table 7: Price elasticities of demand

Energy type		Short-run	Long-run
Electricity	residential	-0.03	-0.16
	Non-residential	-0.01	-0.04

Source: Liu (2004)

III. Energy security

Additionally, the phase-out could help improve energy security.

Achieving market-based prices would allow energy companies to make profits again sector. This would in turn enable investments in capacities and infrastructure, which suffered from severe under-investments due to the highly subsidised prices. Consequently, the reliability of electricity systems would be improved, and the risk of outages reduced.

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Annex

I. Types of subsidies

Table 8: Types of subsidy – OECD

	Types of subsidies	Examples
Direct transfer of funds	direct spending	earmarks and agency appropriations: Targeted spending on the sector through government budgets of different levels and budgets of individual government agencies
		research and development support
		contracts and government procurement of energy at above-market rates
	Government ownership of energy-related enterprises if on terms and conditions more favourable for business than in case of private ownership	equity injection in the energy sector from government budgets (e.g. strategic petroleum reserve, electricity plants...)
		Government ownership of strategic and other energy assets that otherwise would not be viable
Tax expenditure and other government revenue forgone	Tax breaks	Tax expenditures: foregone tax revenues due to special exemptions, deductions, rate reductions, rebates, credits and deferrals
		Reduced overall tax burden by industry: marginal tax rates lower than for other industries (e.g. non-application of VAT)
		Exemptions from excise taxes/special taxes
	Foregone revenue from government-owned energy resources	Process for energy resource leasing: Auctions for larger sites; sole source for many smaller sites
		Royalty relief or reductions in other taxes due on extraction: Reduced, delayed or eliminated royalties
		Process of paying royalties due: Allowable methods to estimate and pay public owners for energy minerals extracted from public lands
	Foregone revenue from non-energy government-owned natural resources or land	Access to government-owned natural resources such as water and land: At no charge or for below fair-market rate

	Foregone revenue from government-owned infrastructure	Use of government-provided infrastructure: At no charge or below fair-market rate
	Foregone revenue from other government-provided goods or services	Government-provided goods or services at below-market rates
Induced transfers (income or price support)	Income or price support and market regulation	Consumption mandates and mandated feed-in tariffs: fixed consumption shares for use of a specific energy type
		Border protection or restrictions: controls (tariff and non-tariff measures) on imports or exports leading to unfair advantages
		Regulated (consumer) prices set at below-market rates
		Regulated (producer) prices set at above-market rates
		Cross-subsidies in the electricity sector
Transfer of risk to government	Credit support	Government loans: Below-market lending to energy-related enterprises, including loans to energy exporters
		Loan guarantees: At below-market rates
	Insurance and indemnification	Government insurance/indemnification: Market or below-market risk management/risk shifting services
		Statutory caps on commercial liability: Can confer substantial subsidies if set well below plausible damage scenarios
	Occupational health and accidents	Assumption of occupational health and accident liabilities
	Environmental costs	Responsibility for closure and post-closure risks: Facility decommissioning and clean-up; long-term monitoring; remediation of contaminated sites
		Waste management and environmental damages: Avoidance of fees payable to deal with waste

Source: OECD (2018a, p.33)

II. Evaluating the impact of a subsidy phase-out

An energy subsidy phase-out affects behaviour by increasing fuel prices. Therefore, at the heart of the evaluation is a determination of the increase in prices through the subsidy removal and the change in consumer behaviour due to this increase in prices. From this, important figures on revenue, change in household expenditure and CO_2 emissions can be estimated.

Data

The calculations are based on assumptions about future energy demand. Energy demand projections are retrieved from Scenario 2 in the NDC. The NDC-Scenario 2 builds on the assumption that all legislation adopted as of September 1st, 2019, as well as drafted climate related legislation will be implemented. A summary of electricity demand and prices is presented in Table 9.

Table 9: Assumptions about energy demand

Energy type			2021	2025	2030
electricity	price [EUR/MWh]	residential	40.5	59.0	82.0
		non-residential	63.7	62.0	60.0
	demand [TWh]	residential	33.9	37.2	41.5
		industry	72.4	117.0	130.3

Source: NDC, Ukrstat (2020) and Own calculation

Another key parameter in the calculations is the elasticity of demand. Unfortunately, there is a lack of reliable data for price elasticities of energy demand in Ukraine. This issues was also addressed by The World Bank (2005), who argues that average OECD elasticities can be used for Ukraine instead. Following this approach, average OECD elasticities for residential and non-residential demand are retrieved from Burke and Liao (2015) and Liu (2004).

Demand for each energy type is inelastic, but there are differences between energy types. Residential demand for gasoline for example presents a comparably higher elasticity. This can be drawn back to the fact that for this energy type it is easier to switch to alternatives. For high gasoline prices, consumers might switch to public transport for distances they would have travelled by car otherwise. The price elasticity of the electricity demand presents the lowest value, demonstrating that an increase in the electricity price is likely to have only very limited effects on demand, at least in the short run.

Table 10: Price elasticities of demand

Energy type		short-run	long-run
Electricity	residential	-0.03	-0.16
	non-residential	-0.01	-0.04
Natural Gas	residential	-0.10	-0.36
	non-residential	-0.07	-0.24
Petroleum	residential (gasoline)	-0.19	-0.60
	non-residential (diesel)	-0.09	-0.17
Coal		-0.23	-0.40

Source: Liu (2004), Burke and Liao (2015)

Price-gap approach

The estimation of consumer subsidies in the electricity and gas sector is based on the price-gap approach, used by the IEA, which has already been applied to the case of Ukraine in 2013 by Ogarenko and Hubacek (2013). Hereby, end-user prices by fuel are compared to a reference price:

$$Subsidy = P_{ref} - P_{act} \quad (1)$$

A subsidy removal corresponds to an elimination of this difference – or price gap.

For net importers, the reference price is based on the import parity price at the border, adjusted for any transportation, distribution and supply fees as well as general consumption taxes. If a product is imported, the price-gap approach presents explicit subsidies, because products are sold at a lower rate than they are bought.

For an exporter, on the other hand, the price gap approach presents implicit subsidies, because it largely captures revenue loss for producers. In this case, the price gap represents the opportunity costs of selling the gas in the domestic market at the level of exported energy prices . When a product is imported as well as exported, the price gap can represent both actual budgetary expenses as well as opportunity costs (OECD, 2018b).

For products that are not extensively traded internationally, like electricity, the IEA bases the reference price on generation-weighted annual average-cost pricing. The reference price reflects the costs of production, transmission and distribution and incorporate a margin.

Average-cost prices are based on fuel costs, plant efficiencies, operation and maintenance costs, carbon prices, and investment costs. Assumptions about plant efficiencies and technology costs are based on technology assumptions from the JRC POTEnCIA Central Scenario (European Commission, 2020a). Due to the age of nuclear, thermal and combined heat and power plants in Ukraine, it is assumed that their costs only comprise variable costs and no fix costs. In contrast, the average costs of hydro power mainly consist of fixed costs from annuities, as their variable costs are close to zero. For the annuities, an interest rate of 12% is assumed, based on current bond rates (Cbonds, 2020). The average costs of RES are approximated by the average green tariff paid in 2019 (NERC, 2019). Finally, the average costs of the different production technologies are weighted according to their power generation share based on data published by Ukrenergo (2020).

Change in demand

Based on the fuel demand of the baseline scenario and after-tax prices, the change in demand due to the removal of energy subsidies can be calculated. The methodology refers to Ouyang and Lin (2014). A constant-elasticity inverse demand function is assumed, as proposed by the IEA (1999):

$$q_t = {p_t}^{\varepsilon} \qquad 2$$

where q_t is energy demand in t, p_t the price for energy in t and ε is the price elasticity of demand. The change in demand can then be calculated by:

$$\Delta q_t = Q_{0,t} - Q_{1,t} \qquad 3$$

with

$$Q_{1,t} = \exp\left(\varepsilon \times (\ln P_{1,t} - \ln P_{0,t}) + \ln Q_{0,t}\right) \qquad 4$$

where the index 0 indicates that the quantity/ price corresponds to the baseline scenario including energy subsidies, while the index 1 indicates the quantity/ price corresponds to the energy subsidy phase-out levels.

CO_2 Emissions

Once, the change in demand has been calculated, the difference in CO_2 emissions between Scenario 1 and 2 can be calculated by:

$$\Delta CO_2 = \textstyle\sum_t \Delta CO_{2,t} \text{ with } \Delta CO_{2,t} = \sum_i \Delta q_{i,t} \times CO_2EF_i \qquad 5$$

III. Change in Housing and Utilities Subsidies

The HUS protects vulnerable groups of the population from energy price increases by subsidising a share of the utility bill exceeding a certain income share. Subsidies are calculated by the following formula:

$$S = SP - \frac{HI/N}{2 * SL} * 20\% * HI \qquad 7$$

Where S represents the subsidy, SP the payment under the social norm, HI the household income and SL the subsistence level. The subsidy phase-out increases the payment under the social norm and would increase the subsidies paid. However, the assumed increase in household income more than offsets this on a nationally aggregated level.

The HUS covers expenses for electricity, gas, heat, cold and hot water, waste and building maintenance. The social norm is defined by housing characteristics. Table 11 summarizes the different increments for the relevant category affected by subsidy phase-out, namely electricity.

Table 11: Social norm consumption

Category	Housing characteristics	base	additional for each person	max
Electricity [kWh/month]	no stove, centralised hot water	70	30	190
	electric stove, centralised hot water	110	30	230
	electric stove, no centralised hot water	130	30	250
	no stove, no centralised hot water	100	30	220

Source: CMU (2019a)

Consequently, in order to determine the increase in subsidies resulting from the subsidy phase-out, requires knowledge about the distribution of housing characteristics in the Ukrainian population. This information is made public by the State Statistic Service (Ukrstat, 2020). However, this information is only available for the total population and not differentiated between income groups. Lower income households are more likely to be equipped with less advanced technologies, thus it should be noted that the presented estimations only reflect approximations.

As the payment under the social norm depends on the number of persons living in a household, the average household size (2.58) is retrieved from the State Statistic Service of Ukraine. Further, heat consumption is defined per square meter, thus information on the amount of heat consumed per square meter are required. The average weighted consumption for an apartment building is 156 kWh/sqm per year and for an individual house 240 kWh/sqm per year. As 51% of Ukraine's population is living in an individual house (or as part of an individual house) and 49% in an apartment building, the overall weighted average consumption is 198 kWh/sqm per year.

Based on the distribution of household characteristics, the average social norm consumption for a household is 134 kWh of electricity, 9 cm of gas and 1'ooo kWh of heat per month. These are multiplied with the respective fuel prices. Further, the cost for water supply, waste and building maintenance are taken into account. In total, in 2019 the payment for housing and utilities based on social norm amounts to EUR 61 per month.

A share of these costs has to be carried by household. This share depends on the household income and the legally determined subsistence level. Both information are retrieved from the State Statistics Service. The projection of the HUS for the next ten years is based on energy price forecasts by (IEA, 2018) and income assumptions. The social norm consumption is assumed to remain constant. Under the phase-out scenario, an increase in household electricity prices is taken into account.

4. Reforming Ukraine's electricity market

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Executive summary

The Ukrainian electricity market opened in July 2019. The market started with limited functionalities as some elements were not yet operational while others where constrained to address structural shortcomings.

In this Chapter, we assess the recent market development based on the experience of the first year of market opening. After looking into the **History of market opening and exploring** and **Why it is important to have an EU-compatible electricity market in Ukraine**, we address a number of issues that we deem critical for ensuring the development of a stable, transparent and competitive market.

Summary of key challenges and recommended measures

i. Improving monitoring and regulation

Perhaps the biggest problem in Ukraine's electricity market is the lack of *regulatory stability* in a often uncertain business environment. This hinders, consequently, major foreign investments in the electricity market. While this is not surprising for a young market and it is important to implement corrective actions when needed, it is now time to consolidate the market - especially since prolonged uncertainty favours big players and keeps foreign investors out of the market.

Most importantly, Ukraine should gradually remove *price caps* and replace them by implementing a robust market monitoring system, supported by tools provided in the REMIT legislation: In section "**Addressing anticompetitive behaviour in a highly concentrated market"** we shed light on how to enable effective and transparent monitoring and regulation. Proper market monitoring requires putting the monitoring infrastructure in place and providing the independent regulator with sufficient investigation resources and sanctioning powers to fulfil its role effectively and to ensure the success of the market. Assistance from outside is important for a young regulator (see section "**Strengthening regulatory authority"**).

The implementation of a robust market monitoring system should be supported by "**Introducing REMIT regulation to improve transparency"**. This is important:

- to prevent generators from abusing their dominant position, which is a considerable risk in Ukraine's highly concentrated market;
- to create trust in the market for existing and potential new actors.

Implementing the EU REMIT regulation might be even more important than fundamental data transparency in the Ukrainian.

ii. Power generation sector: Tackling overcapacities, market concentration and security of supply

The Ukrainian electricity market is characterised by *considerable overcapacity* (see section **"The problem of excess capacity"**). The Ukrainian government should therefore introduce a programme to dismantle obsolete or mothballed old power plants, that due to high subsides significantly distort prices. Their reappearance in the market should be prevented. The programme, moreover, should include measures to alleviate the social and economic consequences of closing old coal-fired plants and coal mines. Part of the jobs lost in the coal sector can be transferred to the energy sector, but new jobs also need to be created.

High *market concentration* in the Ukrainian electricity market makes it vulnerable to anticompetitive behaviour (see section **"Market concentration in Ukraine's electricity market"**). A small number of private players owns the price-setting power plants. Reducing market concentration should thus be a priority and considered in any merger or privatisation case. Foreign investments should be promoted. There should be a roadmap for *removing price caps* and replacing them with active market monitoring to detect and sanction anticompetitive behaviour.

The *Generation Adequacy Report* that is set up by the TSO should encourage the right kind of investments and should be based on transparent modelling and wide stakeholder involvement to be a credible base for decisions. Attracting foreign investors would be particularly important and could be achieved by a Generation Adequacy Report based on transparent modelling and wide stakeholder involvement (see section "**Fostering security of supply and investment certainty through a transparent Generation Adequacy Report"**).

iii. Trading electricity and providing services

The Ukrainian market is *heavily regulated with price caps and with public service obligations (PSOs)*. Therefore, room for non-distorted market-based price formation is limited. A big share of electricity is supplied to the end customers through a PSO at fixed prices, bypassing the market but still influencing the market outcome. It is thus important to make PSOs selective, addressing the consumers who really need them. They also should be gradually replaced by social measures made outside the electricity market.

Though the opening of the electricity market led to the creation of many independent *retail supply* companies (see section "**Making retail supply competitive – a look into DSOs, PSOs, the need for long-term contracts and competition"**), retail sales are currently dominated by companies linked to the regional distribution system operators (DSOs). Thus, it is important to unbundle retail suppliers from DSOs, since the DSO activity might subsidise the retail supply arm of a company. Also, authorities should invite more market players, in particular owners of price setting thermal plants to participate in the spot market.

The retail market development is currently also slowed down by *missing metering infrastructure*. Additionally, the regional distribution companies are responsible for the settlement of all supply contracts in their grid - also for their competitors. This gives them an advantage over independent suppliers.

Day-ahead and intraday markets are fundamental for any electricity market. They give the price signal for dispatching of power plants. Ukraine should undertake several measure to make those markets more competitive (see section **"Making day-ahead and intraday markets competitive"***)* by inviting more market players, in particular owners of price setting thermal plants to participate in the spot market.

Forward markets are not developed either due to lack of trust in the short-term market, immaturity of the financial market and limited enforceability of contracts. To promote long-term markets, the Ukrainian government could invite the big international exchanges to set up a branch in Ukraine. This would bring know-how and credibility to the country's power trading. The government should then increase volumes in the long-term market by various measures, such as using market makers (see section **"Developing long-term markets"**).

A *balancing market* allowing wide participation is not yet operational. We recommend to swiftly implement a balancing market open to all potential participants. Consumers should receive smart meters, starting with customers who have the biggest potential to benefit from competition or who have potential to be active customers with self-production, self-consumption and storage. The balancing markets should be aligned with EU rules as soon as possible (see section **"Improving balancing markets and ancillary services"**).

iv. Re-structuring cross-border supply

Synchronisation with the central European system should be energetically pursued. In the meantime, the Ukrainian government should investigate the possibility to introduce a market-coupling type of capacity allocation for the trade between the Burshtyn Electricity Island and the EU. *Changes in the import rules regarding Russia* have created uncertainty. This is important as the potential import capacity from Russia is high enough to have a significant influence on market prices in Ukraine (see section **"Re-structuring cross-border supply").**

Background

I. History of market opening

Though market opening took place in 201, the market is still characterised by regulatory features (PSO, price caps) dealing with country-specific problems.

The Ukrainian electricity market was opened 1 July 2020 after quite some debate on whether the necessary preconditions to open the market were in place. The market rules are following EU legislation. However, the market contains many unique features which intend to take the Ukrainian special conditions into account. Most of these features are regulatory measures; most important are the price caps and public service obligations to sell to household and small consumers at a regulated price.

Unbundling of the electricity system in Ukraine took place by creating Ukrenergo for transmission, regional grid companies for distribution, Energoatom for producing nuclear power and Ukrhydroenergo for producing most of the hydropower. Other power production assets are in the hands of both state-owned and privately-owned companies.

Unbundling left large market power for regional distributors, who still also act as suppliers.

One important feature in the unbundling was to allow the regional distribution companies to continue to supply electricity, side-by-side with independent, mostly new electricity suppliers. This situation, not unknown from EU electricity markets, creates tensions in the retail sector. The problem is aggravated by the fact that the metering infrastructure is still in development. This gives a central role to the regional distribution companies, themselves suppliers, to settle the sales of competing suppliers. It creates a conflict of interest in which the distribution company might be tempted to cross-subsidise the sales activities from grid activities.

Market faces legacy problem: large unpaid debt of public utilities.

The open market inherited several legacy issues from the past. A financially important legacy issue is the debt that has accumulated mainly from the unpaid bills by public utilities who could not pay for their electricity and from supplying electricity in the occupied areas. Collecting money to cover this debt is important for the market because, depending on the way it is done, it might have a big influence on how the market is working.

This paper discusses how well the market has developed based on the experience of one year of market opening.

II. Why it is important to have an EU-compatible electricity market in Ukraine

Ukraine is committed to implement the EU's so-called third energy package rules from 2013, being a member of the Energy Community. There is a plethora of rules which need to be transposed into national legislation. Even if the rules are the same for each country, how well the idea of the market is implemented can vary considerably. Some member states try to take all the benefits from the market, while others rather try to just implement the minimum, conserving the old structures as much as possible.

For Ukraine, it could be argued that a modest level of ambition in implementing the EU electricity market rules has some advantages. The EU electricity market is a complex system requiring a lot of effort to follow the current rules and their development in the future. There is a risk that the implementation becomes just a bureaucratic effort, creating a lot of rules on paper but not actually impacting the electricity system.

There are also arguments which speak strongly in favour of a wholehearted implementation of the EU legislation. The perspective of Ukraine becoming a full member of the EU speaks for itself. This would also mean that Ukrenergo becomes a full member of ENTSO-E. An EU-like electricity market would also attract international investors and would lead to better investment decisions overall.

Ukraine is already an important node in the Central European electricity system. With synchronisation it will become even more important. To take full benefits of cross-border trade, Ukraine needs to be integrated to the European-wide market coupling system in one way or another. This is not possible without applying the EU electricity market rules, at least the essential parts of them.

Ukraine needs to implement essential EU market rules to become member of the EU.

For any open market competition is the aim that justifies introduction of markets to formerly fully regulated sectors. Competition is supposed to bring the benefits to the end consumers through efficiency gains in electricity production and sales. Being part of the European electricity market would dramatically reduce the market power of incumbents and would make it more likely that also Ukrainian suppliers would compete to deliver the best service at the lowest price to consumers.

With a proper implementation of the electricity market the system costs would be lower, and this benefit can be passed on to consumers.

Improving monitoring and regulation

I. Addressing anticompetitive behaviour in a highly concentrated market

The electricity market is a complex market which is split into several markets based on products of different time horizons, interacting with each other. It strongly differs from other markets due to the need to always balance production and consumption, because storing electricity is very expensive and technically difficult. Anticompetitive behaviour is a serious concern in electricity markets, proven by countless past examples.

The usual categories of anticompetitive behaviour are:

a. abuse of market power through capacity withholding or abusing bidding behaviour,

b. missing transparency or use of *insider information*,

c. anticompetitive agreements with competitors and

d. reducing customers' choices with *anticompetitive contracts* (foreclosure).

Large market concentration gives Ukrainian actors the power to influence and abuse their market position.

The risk of anticompetitive behaviour is especially high in the power generation part of the market. This becomes clear when looking at the marginal price setting plants and can be explained by the *high market concentration* in Ukraine's power generating sector. Two companies, Energoatom and DTEK, are in a pivotal position which means that their capacity is most of the time needed to meet the demand. In peak demand situations, smaller companies may also temporarily be in a pivotal position. Similarly, Ukrhydroenergo is providing much of the balancing power and is in a pivotal position regarding balancing markets.

Insider information is another important issue in Ukraine stemming from the high market concentration and giving the large players a big advantage over many small players in the supply market.

However, (potential) anticompetitive behaviour is not limited to the power generating sector but is rather possible for most of the actors in the market. Even a regulated company such as the TSO can abuse its position. For example, while the TSO has the obligation to provide transparent and market-relevant information, the TSO acts at the same time as the sole buyer of balancing power.

Regarding end customers, it is worth noting that several power-intensive customers belong to a major power producing group (DTEK), while trading of certain state-owned generators appears to be coordinated with major private consumers. This presents an extra challenge regarding transparency of the market.

II. Introducing REMIT regulation to improve transparency

Transparency is an important element for any market to function. The availability of information on the market's products and prices is a crucial requirement for efficient and precise decision-making by market participants. A lack of transparency on the other hand has negative economic implications, such as inefficient investments and daily dispatch decisions. Transparency furthermore helps to remove information asymmetries and thus raises incentives for market entry and investments. It makes market monitoring more efficient, thus allowing to detect and prevent misbehavior on the market more easily. Transparency also allows consumers, their political representatives and market participants to easier react on what is happening on the market.

In the EU, there is extensive legislation requiring transparency in the form of a variety of market information. This holds true especially for markets with either an obvious need for consumer protection, for example for food or medical devices, or markets of outstanding economic importance, for example financial markets.

Challenge: electricity markets are highly complex with many kinds of actors and different time horizons

Electricity markets are demanding regarding transparency for several reasons. Firstly, the electricity system involves many kinds of parties: generators, consumers, grid companies, traders, service providers and regulators. To ensure an efficient coordination of actions in this complicated system, information needs to be shared timely between parties. Secondly, electricity markets involve trading in several time periods from long-term products of several years to real-time balancing products. The price level and dynamics depend on the product, thus having different requirements for transparency information. Thirdly, the system itself is complex which makes it difficult to understand even for large players. Providing reliable publicly available information would allow individual parties to save in data collection and to invest in making best use of that information.

The EU electricity market transparency requirements have developed alongside with the progress of opening the market for competition. At the market opening in 1999, the transparency rules were still of a very general nature. In 2006, together with the rules on congestion management (Regulation 2006/770/EC), a set of rules on information to be published by the TSOs entered into force. These were enhanced and updated in 2013 in a separate legislation (Regulation 543/2013). This regulation required market participants to publish market relevant information, including on availability and use of their power plants. ENTSO-E (European Network for Transmission System Operators) was given the responsibility to develop a platform to publish this data.

The EU requires its members to publish data via the REMIT regulation with ENTSO-E (does not yet apply to Ukraine).

A major step to improve transparency in energy markets was taken in the aftermath of the financial crisis in 2011. The so-called **REMIT regulation** (Regulation 1227/2011 on Wholesale Energy Market Integrity and Transparency) is meant to prevent market manipulation in electricity and gas markets. REMIT requires market participants to report all trades to the regulator and ACER (Agency for Cooperation of Energy Regulators). The national regulators and ACER analyse the information and start investigations if something strange is detected. Most of this information is not publicly available but is only available to the national regulator and ACER.

As a member of the Energy Community, Ukraine is committed to implement the EU electricity market legislation, including Regulation 543/2013 on fundamental data transparency. However, REMIT does not yet apply to Ukraine.

Ukrenergo, as the Ukrainian TSO, has the key role in implementing the EU rules on fundamental data transparency on the electricity market by collecting and publishing data on the ENTSO-E transparency platform. Still, some key data, for example on power plant availability, is missing. REMIT is not yet implemented.

III. Strengthening regulatory authority

The Ukrainian energy regulator **NEURC** is young but already loaded with an impressive set of tasks. The anti-monopoly commission and the financial regulator also have important tasks regarding the electricity market's surveillance. The government's most important concerns should be these regulators' resources and independence.

Ukraine's regulator NEURC must be well-equipped and independent.

The Ukrainian regulator has limited resources compared to many of its European colleagues even if the number of employees is among the highest in Europe. The energy market is relatively large with many regulated companies and organisations.

Another important topic is the independence of the regulator. The nomination of the regulator is a political subject in most European countries. What makes the difference is the independence of the regulator *after* it has been nominated. Examples of political influence on the NEURC´s task of setting distribution tariffs indicate substantial room for improvement in the independence of Ukrainian regulators.

It remains to be seen where the Ukrainian regulator is situated on this scale. The recent example of political influence on NEURC´s task of setting distribution tariffs is not very encouraging in this respect. Similar cases exist in the EU; there is a court case against Germany and Hungary on excessive involvement of the governments in setting tariffs.

IV. Recommendations

To Do's: strengthen transparency through implementation of REMIT and a transparent Generation Adequacy Report, limit concentration, create an effective authority to monitor market players

Publishing of data on the transparency platform should help Ukraine to fully meet European requirements. This will increase confidence in the market overall, and among potential newcomers and foreign investors. Ukraine should **implement the REMIT regulation without delay**. Implementing REMIT is particularly important to enable the regulatory authorities to monitor the transactions made by dominant incumbent companies.

Especially in the context of a highly concentrated market as in Ukraine, it is decisive that a **competent authority** gets all the information from the behaviour of the companies as required by the REMIT regulation to enable detecting any abuse. In addition of the possibility to sanction anticompetitive behaviour, this would also have an important preventive effect.

The authority should have **enough resources and sufficient power** to investigate and to sanction when necessary. As the electricity market is young, it is difficult to find skilled and experienced people for the different tasks at the regulator. It is noteworthy, that power companies are able to attract experienced people with significantly higher salaries than in the state sector. Thus, it is extremely important to seek help for example from the European colleagues in order to educate young people and to provide assistance in the most complicated tasks.

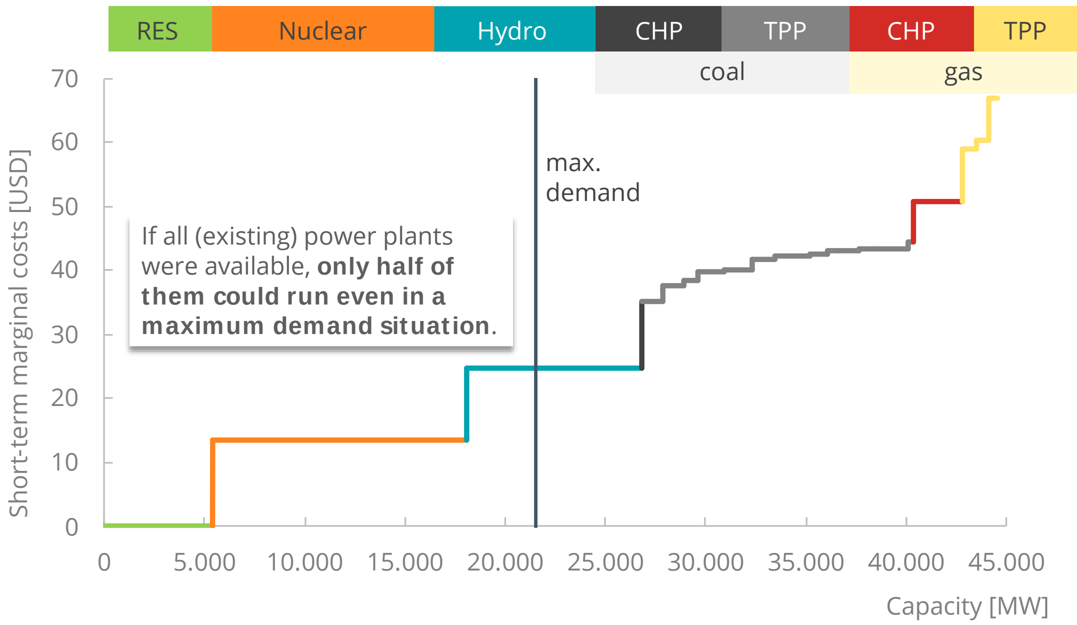
Power generation sector: Tackling overcapacities, market concentration and security of supply

I. The problem of excess capacity

From Figure 25, depicting the merit order (see below: Background info – Merit Order), we can clearly see a problematic feature of Ukraine's electricity market: a significant overcapacity in electricity production, meaning that there is too much offer in the market. The marginal costs of all plants above the price-setting power plant cannot be covered. In other words, prices are not high enough to pay back investments of those plants.

Ukraine's over-capacity causes prices to be too low for a financially sustainable energy system. Thus, coal plants must be shut down.

Figure 25: Merit order - electricity production capacity in Ukraine ranked by (increasing) short-term marginal costs of production



Note: This is a simplified representation of the merit order in Ukraine. Nominal capacities are displayed. See Annex for details.

Source: Own calculation based on World Bank (2007) and Low Carbon Ukraine (2020)

A closer look reveals that, if all power plants were available, only half of them could run even in a maximum demand situation. The overall installed capacity in Ukraine is 47.000 MW while the maximum demand by mid-2020 was 22.000 MW. It has to be noted, that wind, solar or hydro power plants can obviously run only when their respective power source is available. But even taking this into account, there is much more excess capacity in Ukraine than we usually observe in other European countries.

In Ukraine, the problem of overcapacity aggravated as demand declined dramatically (by approximately 50%, 300 TWh) from 1990 until today. Consequently, many power plants are forced to stay idle. At the same time, a significant amount of renewable energy capacity is built supported by government programmes. Taking into account aspects of efficiency and climate protection, there is only one conclusion to draw: there is a strong need to close the oldest coal power plants.

Background info

Merit Order

Electricity production capacity needs to be constantly adjusted to the demand fluctuating between minimum and maximum demand. The so-called merit order (see Figure 25) represents the idea that power plants with lower short-term marginal cost are the first to be used to meet (low) demand, while power plants with high short-term marginal costs will only run when the demand is high. Respecting the merit order in general will minimise the overall cost of electricity production.

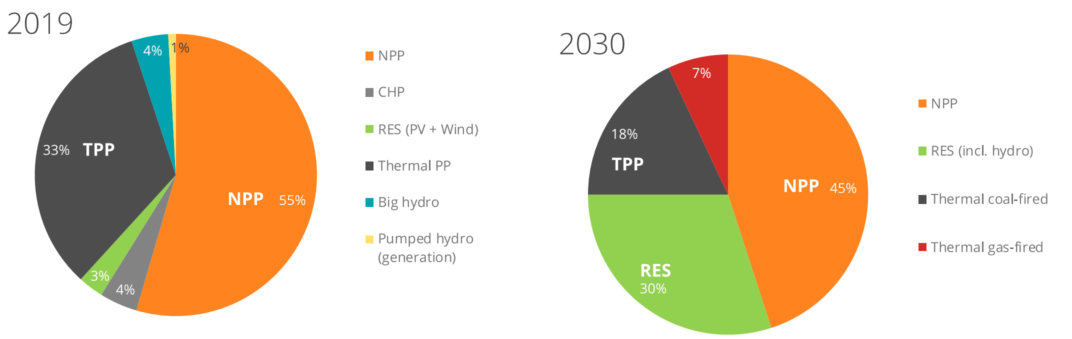
A specific feature of Ukraine's market is the high share of nuclear electricity production (55% of electricity production in 2019, Ukrstat, 2020). Nuclear has high capital costs but low short-term marginal costs. This means that nuclear power plants tend to run as many hours as they can. They stop only for service periods used for maintenance and refuelling, or because of an incident.

The share of nuclear in Ukraine is so high that nuclear plants sometimes need to reduce their power in order to avoid too much electricity in the grid (leading to network congestion). This is visible in international statistics: the forced reduction in Ukrainian nuclear power plants at low demand periods lead to an overall reduction of their annual utilisation ratios. The same phenomenon an be observed in France where the share of nuclear is even higher than in Ukraine (71% of electricity production in 2019).

The merit order for Ukraine is depicted in Figure 25. It is clearly visible that coal fire-plants are the marginal plants, featuring the flexibility that is needed to meet the fluctuating demand. This means that coal-fired plants are most of the time the price-setting plants.

According to own calculations, coal-fired thermal capacity could be strongly reduced by 2030 while renewable capacity could grow considerably (see Figure 26). Gas-fired generation would gain an important share to provide more flexibility in power generation.

Figure 26: Electricity generation mix in Ukraine, 2019 and the potential 2030 electricity generation mix



Within a decade, coal-fired thermal power plants could be largely replaced by RES and gas-fired plants

Source: Own calculation

II. Market concentration in Ukraine's electricity market

For any open market **competition** is the aim that justifies introduction of markets to formerly fully regulated sectors. Competition is supposed to bring the benefits to the end consumers through efficiency gains in electricity production and sales. It requires a reasonable number of players in the market. Consequently, market concentration limits competition and makes market outcomes less favourable.

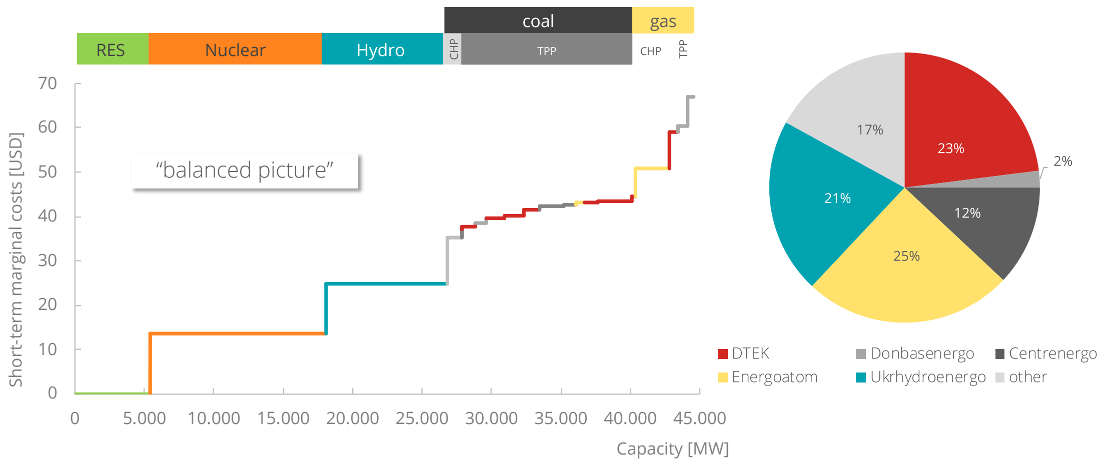
Many **power markets** in Europe are **oligopolistic**, which means that there are only a few players in the market. Ukraine is in this respect an extreme case. Energoatom and Ukrhydroenergo have technology-specific portfolios and have only low marginal cost production capacity. They are influencing the market through the volumes they offer, but they are not setting the price. Prices are set most of the time by hard coal plants, and they are owned by only a few companies.

A few companies owning Ukraine's hard coal plants determine the electricity price. Together, they form a strong oligopoly.

Ukraine's high market concentration is clearly visible from Figure 27 and Figure 28. If all capacity is considered, the situation looks relatively balanced, see Figure 27. However, if we instead look only at *marginal cost plants*, the situation looks completely different, see Figure 28. Among the marginal cost plants, DTEK represents 2/3 of the production capacity. The only other company that owns a significant amount of coal fired power production, is Centerenergo.

Figure 27: Market concentration in Ukrainian power production

Simplified representation of the merit order in Ukraine (left) and ownership structure of plants (capacities) by companies (right)

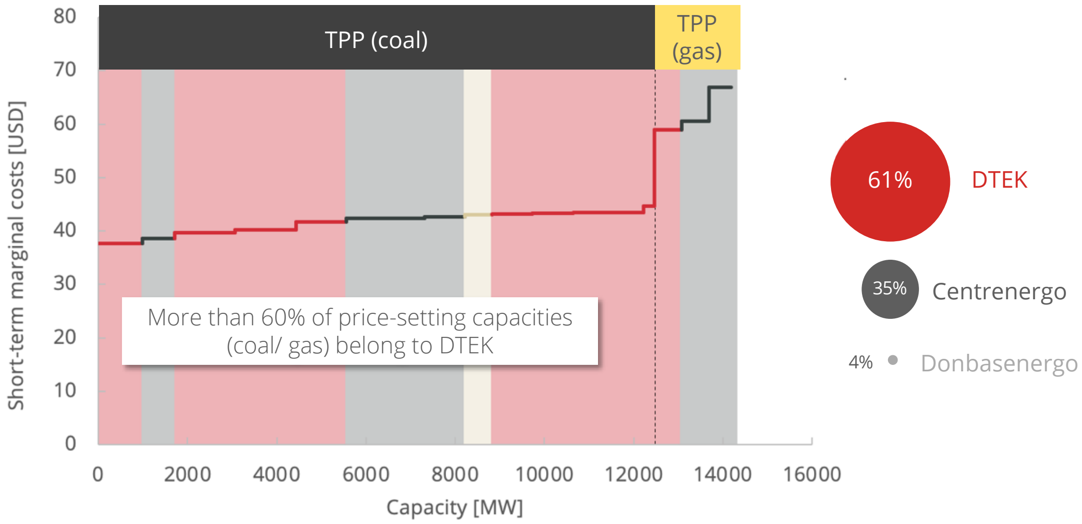


Note: See Annex: Construction of the merit order for details on the merit order in Ukraine.

Source: Own calculation based on World Bank (2007)

Figure 28: Market concentration in the Ukrainian thermal power generation

Excerpt of the merit order showing price-setting capacities (left) and respective ownership of those capacities (right)



Note: This is a simplified representation of the merit order in Ukraine. See Annex for details

Source: Own calculation based on World Bank (2007) and Low Carbon Ukraine (2020)

DTEK's dominant position in the power market is obvious and well-known. The question is whether sufficient tools are in place to monitor its behaviour, and whether authorities are ready to act when they detect any misbehaviour by DTEK.

III. Fostering security of supply and investment certainty through a transparent Generation Adequacy Report

Many Ukrainian power plants are old and need to be (partly) replaced.

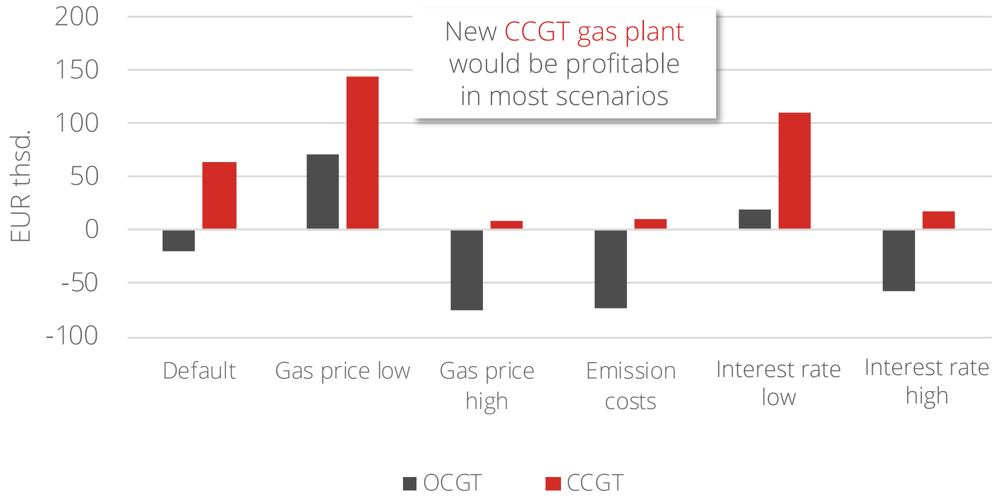
At the moment, Ukraine has a relatively high share of electricity production capacity compared to actual consumption. Thus, a security supply risk related to available power generation capacity does not exist. However, many power plants are old and will probably not be renovated due to high costs and environmental concerns. The question is, to what extend and by which technologies this outdated capacity will be replaced in the future.

Renewables and Combined Cycle Gas Turbine power plants would be the preferred technologies for a low-carbon replacement of outdated capacity.

It is obvious that renewables will (and should) play a role in this process: renewable energy support programmes have already brought a considerable amount of renewable capacity into the market. Another technology to be considered are Combined Cycle Gas Turbine (CCGT) power plants, as this could be (beside renewables) another means to rapidly reduce greenhouse gas emissions in Ukraine. Calculations based on current market prices indicate that, in most scenarios, investment in Combined Cycle Gas Turbine (CCGT) power plants would be profitable (see Figure 29 and Table 12).

Figure 29: Calculation of the profitability of a new CCGT gas plant in Ukraine

hypothetical, annual net profits: July 2019-June 2020)



Source: Own calculation based on ENTSO-E (2020)

Table 12: Assumptions for scenarios of gas plant profitability

Scenario	Industrial gas price [EUR/tcm]	Emission costs [EUR/tCO2]	Interest rate
Default	218	0.4	10%
Gas price low	150	0.4	10%
Gas price high	280	0.4	10%
Emission costs	218	30	10%
interest rate low	218	0.4	5%
interest rate high	218	0.4	15%

Crucial role of Ukrenergo's Generation Adequacy Report

Whether or not a certain investment will be done in the future strongly depends on the available information to enable investors making sound and rational decisions. In this context, the **Generation Adequacy Report** is of high importance for both Ukraine's future security of supply and for investors seeking information on the future energy system of Ukraine. The Report is being prepared by Ukrenergo and presents scenarios of electricity generation capacities in Ukraine in 10-year perspective. It considers planned activities for the generation development, introduction of demand response systems, ensuring the operational security and the analysis of disruptions in the grid's operation.

It is important that this strategic document is set up with utmost transparency and stakeholder involvement to gain the trust of all market players needed for future investments.

IV. Recommendations

Old coal power plants must be not only mothballed, but shut down to prevent market uncertainty.

Due to massive *overcapacity*, many power plants stay idle or are mothballed. Idle power plants, however, are an obstacle for new investments, as they create uncertainty for the profitability of new plants. It would be better to dismantle old power plants so that there is no more threat that they reappear in the market. Thus, government policy needs to close much of the outdated, inefficient and emission intense coal-fired capacity.

Support for hard-hit coal regions required

As many coal mines and coal plants are situated in economically vulnerable areas, a programme to alleviate the consequences of closing old coal fired plants and mines is necessary (see Chapter **"7. A socially sustainable coal phase-out in Ukraine"**). Part of the jobs lost in the coal sector can be transferred to the energy sector, but new jobs also need to be created. Lessons from EU countries with similar challenges could be valuable for Ukraine.

Any more mergers must be prevented if they make market concentration worse

The first thing to do regarding *market concentration* is to make sure that the situation does not become worse. This means that no more mergers and acquisitions should be approved if they worsen market concentration.

Either break up existing companies or support new electricity business-ses from Ukraine and abroad

The government could also actively reduce market concentration. In extreme cases it should take measures to structurally reduce market concentration. Examples of this kind can be found in the UK during the beginning of market liberalisation when the whole sector was reorganised into six generating companies. In Italy, the dominant incumbent company was obliged to sell an important share of its capacity. Other measures have been taken in France and Belgium, such as obliging the dominant company to sell capacity to its competitors in the form of virtual power plants.

Another way to reduce market concentration is to favour investments by newcomers, i.e. applying *positive discrimination to attract new players.* Attracting foreign investors would be particularly important as they require more transparency, tend to scrutinise the market rules and challenge anticompetitive features of the market. The Ukrainian government should thus invite foreign investors by identifying and supporting suitable projects.

Base Generation Adequacy Report on transparent modelling to create trust and lay open investment needs.

In the EU, the *Generation Adequacy Report* is set up by the TSOs together with ENTSO-E and is an important tool to inform the market players, stakeholders, authorities, and potential investors about the actual state of the electricity system. This increases transparency and provides a better base to consider investments in the power sector. Ukraine should follow this example. A Ukrainian Generation Adequacy Report should be based on transparent modelling and wide stakeholder involvement in order to be a credible basis for decisions. One should also consider other measures, for example applying positive discrimination to attract new players to become electricity producers and to enter the market. Attracting foreign investors would be particularly important as they tend to require more transparency and challenge the anticompetitive features of the market.

Trading electricity and providing services

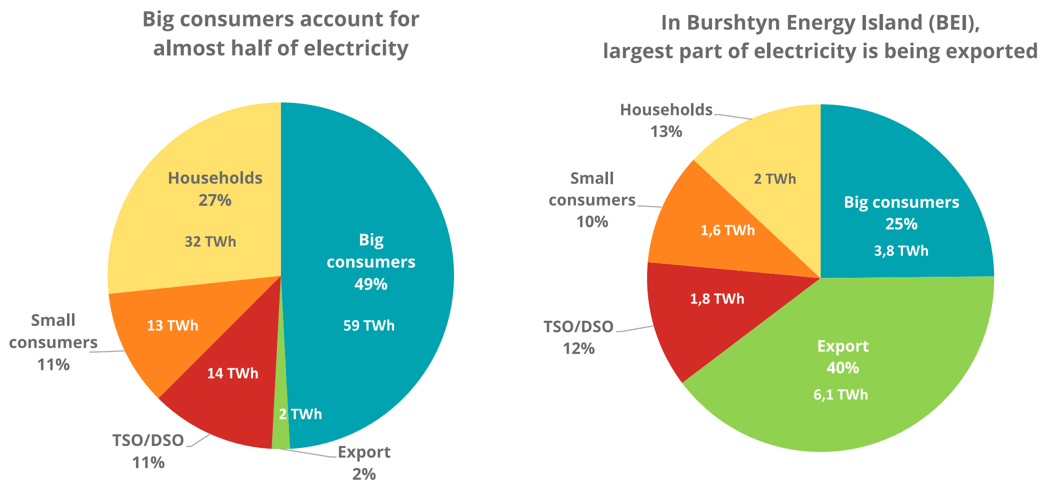
I. Making retail supply competitive – a look into DSOs, PSOs, the need for long-term contracts and competition

In Ukraine, big consumers cover almost half of the electricity consumption, which is a high share compared to other European countries. Heavy industry is in large parts vertically integrated, i.e. companies receive electricity from power production facilities inside the own industrial group.

Large industrial companies often receive cheap electricity from other companies within the same group, while households benefit from cheap PSO prices.

Household consumption represents about 25% (see Figure 30). Electricity for households is significantly subsidised, because many households are socially vulnerable. All households (as most small consumers) enjoy a heavily subsidised PSO price. In result, household tariffs for electricity are among the cheapest in Europe.

Figure 30: Electricity volumes and shares per customer group based on forecasted electricity balance for 2020 (left: IPS, right: BEI)



Source: Mykhailenko, Vereshchynska, Mukha, Avetyan and Zachmann (2020)

The opening of the electricity market created many independent retail supply companies. This is potentially good news regarding competition. However, retail sales are dominated by companies linked to the regional *DSOs (distribution system operators)*, and it is not uncommon that power production cross-subsidises sales activities, because margins in the retail supply are generally small. It remains to be seen how independent suppliers manage to gain market share from the regional DSOs and from the vertically integrated companies who own electricity generation. Even if most suppliers buy their electricity from the same sources, small differences in prices can be crucial as the margins in retail supply are generally small. Captive customers acquired through network activities or own power production can grant distribution companies and incumbent generators a competitive advantage.

Regional DSOs control retail market due to influence on consumers via their grid and power over producers.

Independent retail suppliers cannot rely only on the *day-ahead market* as this would expose them to a mismatch between the contract period in buying and selling electricity. Electricity contracts based on *hourly spot markets* require smart metering with at least hourly resolution – this kind of contract is increasingly popular in the EU. However, smart metering is not widely in place yet in Ukraine. There is thus a need to have *long-term products* as the price reference for selling to end customers. Consequently, from an independent retail supplier's point of view, it is crucial to get access to long-term electricity.

Retail suppliers need long-term contracts to secure their operations.

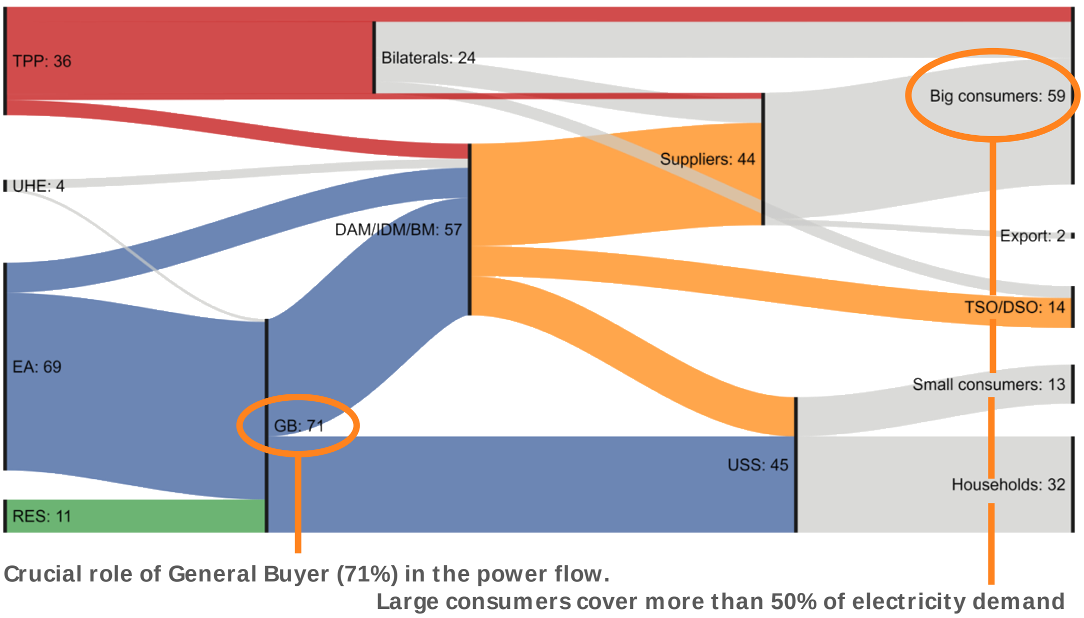
Crucial role of the General Buyer in the retail market

The *General Buyer* plays a crucial role in the retail market, what is clearly visible from Figure 31. In Ukraine, large consumers cover more than 50% of electricity demand, more than in most EU countries.

Figure 31 schematically explaining power flows from production to end customers in Ukraine. One can also see that to be competitive in retail it is most important to get access to electricity passing through the General Buyer.

In Ukraine, large consumers cover more than 50% of electricity demand, more than in most EU countries

Figure 31: Power flow from production to end customers in Ukraine, projection for 2020



Note: BM = Balancing Market, DAM = Day-Ahead Market, DSO = Distribution System operator, EA = Energoatom, IDM = Intraday Market, RES = Renewable Energy Sources, TPP = Thermal Power Plants, TSO = transmission System Operator, UHE = Ukrhydroenergo, USS = Universal Service Supplier

Source: Mykhailenko, Vereshchynska, Mukha, Avetyan and Zachmann (2020)

The Ukrainian PSO is discriminatory and harmful to competition.

The *Public Service Obligation (PSO)* to sell to households and small customers at a subsidised price is understandable as a transitional measure. However, Ukraine's public service obligation is based on cross-subsidisation which is discriminatory:

- The measure *lacks selectivity* as even wealthy consumers have access to subsidised electricity.
- Low prices also reduce the incentive for end customers to save electricity.
- It *harms competition* because households and small customers have no incentive in seeking new suppliers as the price would not change anyway.
- The *incumbent companies* (that currently supply PSO customers) have less incentives to be active on the market. They *would like to avoid competition* and just keep the customers in the portfolio as passive as possible. We observe such a phenomenon also in EU countries: In France, for example, the heavily regulated prices have reduced competition in the retail market among households and small customers to a minimum.

Price-comparison portals are mandatory in the EU and a great tool to foster competition in the retail market.

In many EU countries, the retail market started very slowly. It took time before the customers started to switch the supplier. Little by little, the incumbent players began to lose their customers to competitive suppliers. There were several reasons for this. To maximise profits, the incumbents kept prices relatively high for the historical customers. This gave an opportunity for newcomers to propose attractive contracts. High prices appeared regularly in the press causing customers to switch in waves towards newcomers. The regulators started *price comparison portals* (which are now mandatory in the EU). These portals facilitated the comparison between different offers, overcoming the jungle of different terms and clauses included in the contracts.

Finally, it is important to understand that the fundament to get competition into the retail market is to improve ***the liquidity of the long-term market*** in various timeframes: this allows incoming retail companies to source their electricity at a competitive price.

Liquidity of the long-term market needed for competition in the retail market

II. Making day-ahead and intraday markets competitive

The day-ahead and intraday markets are fundamental for any electricity market. They give the price signal for dispatching of power plants. By bidding into the day-ahead market, the power plant owner can ensure that she is not running the power plant at loss but gets at least the short-term marginal costs covered. In the intraday market companies can further adjust their positions acquired in the day-ahead market to optimise their power plant portfolio.

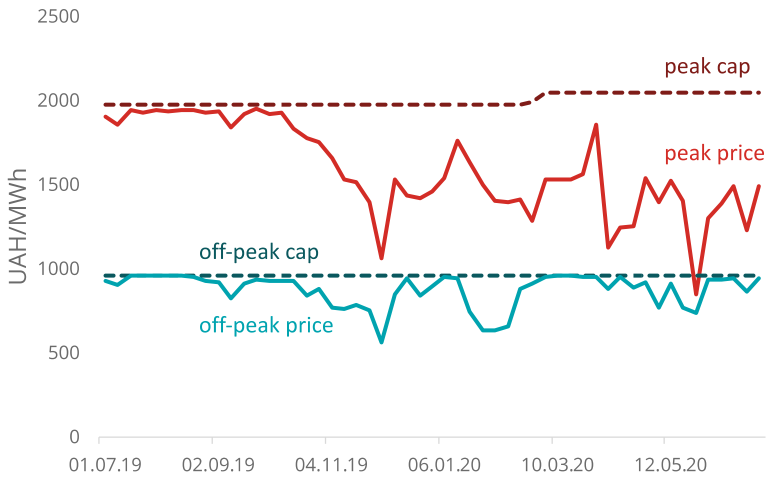
Day-ahead and intraday markets are needed to form the price and give certainty to elec-tricity producers.

In addition of being instrumental for dispatch decisions, the day-ahead market is the reference for long-term markets. The long-term markets are in fact based on expectations of future day-ahead market results. They are also the building block for financial markets for electricity. In a financial market no physical electricity is traded, but the price of electricity is locked in by buying hedging products. Hedging is beneficial for both power producers and power consumers. It gives certainty over production revenues or consumption costs for the chosen hedging period.

Regulations like price caps and obli-gations for the Ukrainian single buyer to trade on the day-ahead market make prices rather volatile around the caps.

The Ukrainian electricity market itself resembles very much the day-ahead and intraday markets as we know them from other European countries. However, the prices are heavily regulated which means that there is a strong government interference in the market price. Also, there is an obligation for the so-called 'single buyer' to trade in the day-ahead market which brings a lot of electricity to the selling side of the market. This could be one of the reasons why the prices have been rather volatile. Peak prices remained close to the price caps in the beginning. However, from October 2019 on, the peak prices have decreased while off-peak prices remained close to the cap, see Figure 32.

Figure 32: Average weekly day ahead prices of electricity in IPS



After October 2019, peak prices decreased, while off-peak prices remained close to cap.

Source: Mykhailenko *et al.* (2020)

Price cap kills incentives for potentially needed investments in peaking capacity.

The effect of price caps is clearly visible in Figure 33 that compares the Ukrainian day-ahead prices to prices in neighbouring countries. The so-called duration curve of the day-ahead price is smooth for all countries except for Ukraine. In Ukraine, the curve is clearly influenced by the price caps: Flat horizontal parts of the curves represent prices close or equal to price caps – they dominate Ukrainian market results. Consequently, there are periods when the price cap leads to an increase of prices, and periods when the tight cap pushes them down. The price duration curve also indicates that the price cap kills incentives for potentially needed investments in peaking capacity such as peaking power plants, batteries or flexible demand. From the curve for Ukraine, the usual high price zone due to scarcity, on which providers of peaking capacity make their revenue, is totally cut off due to the price cap.

Figure 33: Hourly day-ahead prices of Ukraine and neighbouring countries (July 19 to June 20; sorted in descending order)

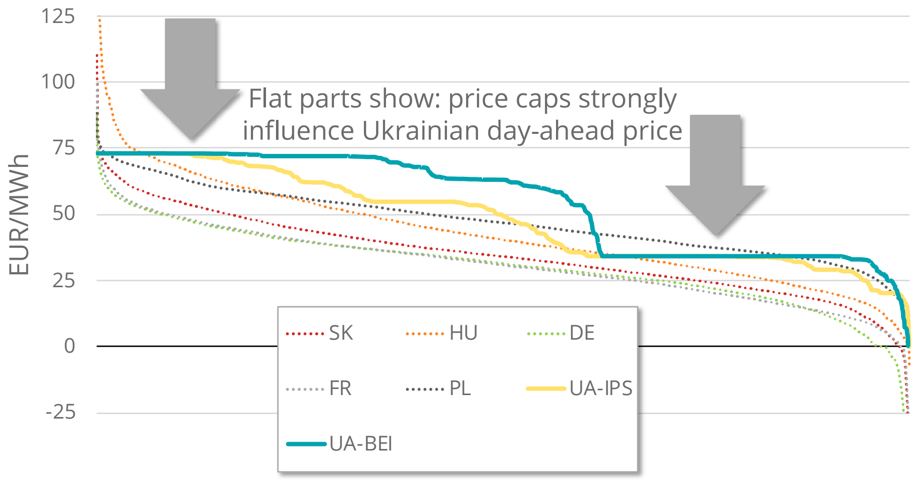
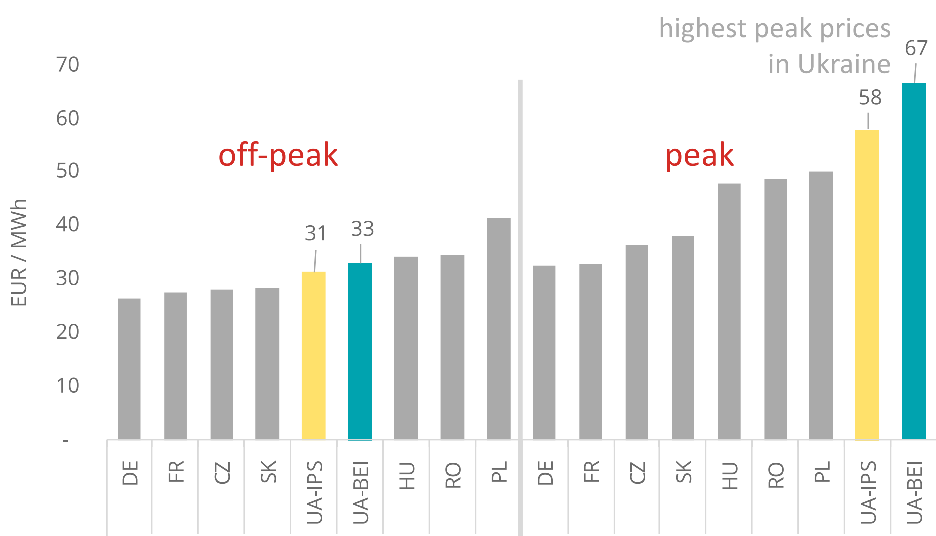


Figure 34: Average peak and off-peak day-ahead prices of Ukraine and neighbouring countries (July 19 to June 20)



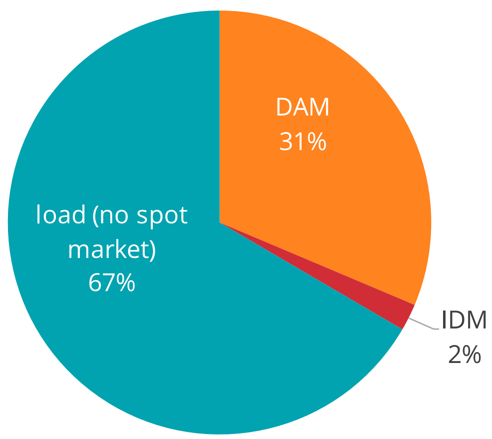
Source: Mykhailenko *et al.* (2020)

Under normal circumstances, companies have a natural interest in trading in the spot market. In most European countries, day-ahead markets are voluntary and part of the overall consumption is traded in the day-ahead market. If the volume is reasonable, let us say 20% of total load, this gives a price signal upon which also bilateral trades are concluded. In principle, this criterion is fulfilled in the Ukrainian electricity market. However, the Ukrainian market has many special features, including the price caps, which make companies hesitant to participate in the spot market.

Another issue is the volume traded in the day-ahead market (see Figure 35). In most European countries the day-ahead markets are voluntary. This leads to the fact that only a proportion of the overall consumption is traded in the day-ahead market. If the volume is reasonable, say 20% of total load, this gives a price signal upon which also bilateral trades are concluded. In principle, this criterion is fulfilled in the Ukrainian electricity market. However, the fact that on the selling side the main actor is the single buyer, distorts the price signal. It would be most important that the owners of marginal cost power plants, which are mainly coal-fired plants, would participate in the market. Thus, the day-ahead market does not truly reflect the market situation and does not give a trusted price signal.

Day-ahead market does not give true price signal, since the usually price-making thermal power plants do not participate in it.

Figure 35: Average traded volumes of electricity in relation to load in the day-ahead and intraday market in IPS (Jul.19-Jun.20)



Source: Mykhailenko *et al.* (2020)

In a well-functioning market, the volume traded in the day-ahead market would give a reliable price signal for both forward and bilateral markets. However, as Ukraine's day-ahead prices mostly follow the price caps, forward and bilateral markets are seemingly disconnected from the short-term markets. This is a serious handicap for reaching an efficient market. Volumes in intraday markets are insignificant, but this could be a temporary situation before market players understand the benefits of the intraday market.

The consequence of this heavily constrained market is that it does not fulfil its primary task to reveal the efficient price which would optimise the use of resources. In fact, the price caps are too high in average situations, and thus grant windfall profits to the producers, and too low in situations of scarcity thereby preventing entrance of the needed flexible units and hence endangering security of supply in the long run.

Main goal of day-ahead market: price signal for an effective use of resources – Ukraine's market can't fulfil this function due to price caps.

Rigid stepwise price caps also potentially distort the optimal dispatch within the 24-hour cycle. Based on the analysis of production costs (reference) it seems that coal-fired power plants, which should usually be the marginal producers, make considerable profits at the peak price cap but cannot cover their marginal cost at the off-peak price cap. This might lead to capacity withdrawal in the off-peak hours. If generators find the bidding cap too low, they might simply abstain from bidding, causing lower supply and higher prices. The low off-peak price cap might also lead to excess demand in off-peak hours. All potential buyers will not get electricity at the regulated price, but must seek it from bilateral markets, at a higher price.

Burshthyn Energy Island does not benefit from lower prices in neighbouring countries due to low import levels.

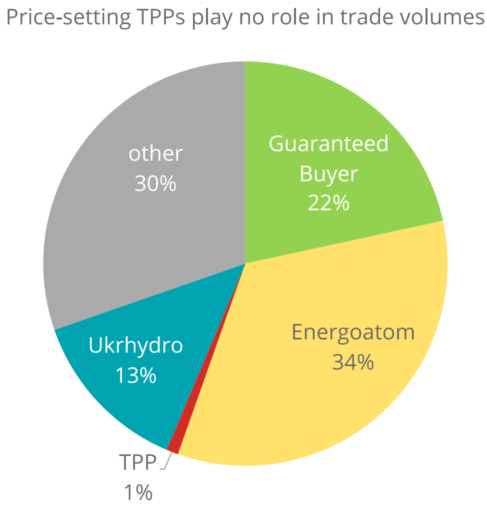
Regarding competition, the price caps are a double-edged sword. On the one hand they prevent bidding at a high price, but on the other hand they might guide bids to be aligned to the caps even if the market situation would suggest lower bids. The dominant position of some companies allows this to happen. In the Burshtyn Electricity Island there is a stable increase in average prices, probably due to capacity withdrawal during off-peak hours. Thus, peak hours have a higher share in overall trade volumes. Imported electricity volumes continue to be negligible and therefore do not have a major influence on the price.

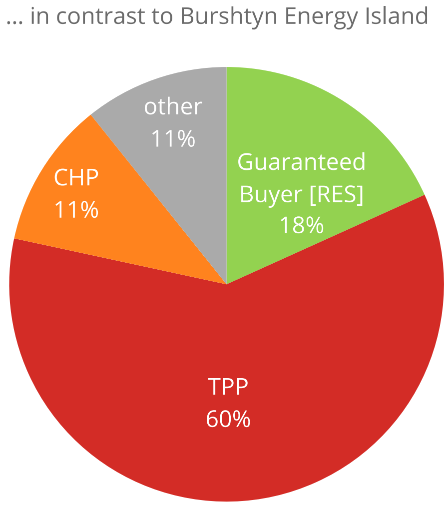
Ukraine has highest prices in the region, due to ineffective market regulation.

The reasons above contribute to the fact that Ukraine has the highest electricity prices in the region.

Figure 36 confirms that the spot market is dominated by a few players: while marginal costs of TPPs prevalently determine the supply price, the volume of bids of these "price-setters" is negligibly small. For proper market functioning, coal fired power plants should be more active in the spot market.

Figure 36: Trade volume shares in the day ahead market in IPS (*top*) and in the Burshtyn Electricity Island (*bottom*) in June 2020





Source: Mykhailenko *et al.* (2020)

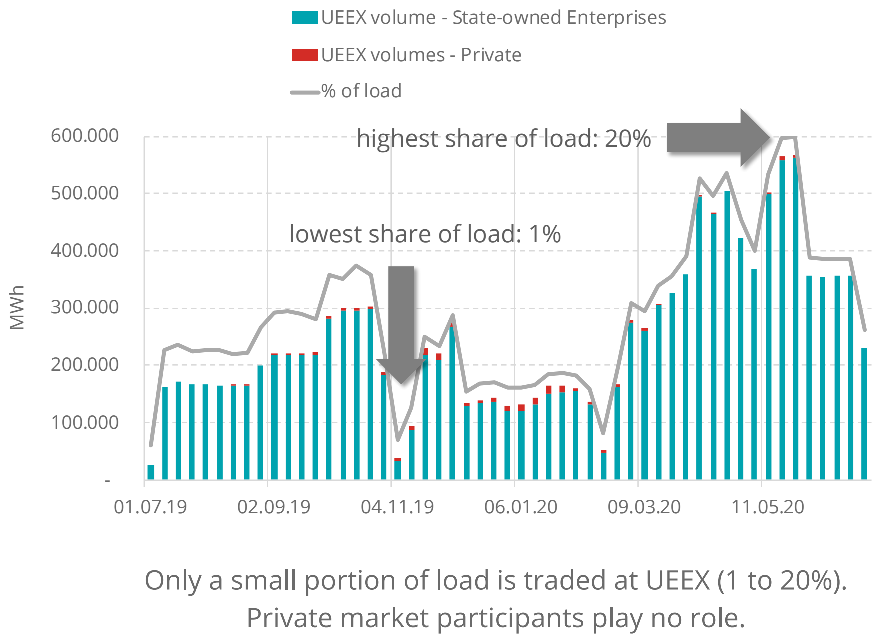
III. Developing long-term markets

In the EU, the bulk of electricity is traded in long-term contracts. The link between long-term contracts and day-ahead and intraday markets was explained in the previous section on day-ahead and intraday markets. The way the long-term contracts are made differs from country to country. In most developed markets, the long-term contracts are financial, and traded and settled in power exchanges. In other countries, bilateral contracts are common. Bilateral contracts include less trading fees, but they can be less secure regarding counterparty risks etc.

Since the start of the market in July 2019 the Ukrainian Energy Exchange (UEEX) has conducted bilateral auctions as an interim provider upon a decision of the Ukrainian government. Long-term contracts represent only about 10% of consumption at UEEX. State-owned generators have been most active in trading in the UEEX. While the UEEX is open for any private market players, their interest has been limited so far: the share of private market participants was about 1% of consumption (see Figure 37). This means that most of the electricity is traded bilaterally outside the organised market or inside industrial groups.

Ukraine's long-term market open since July 2019, so far only represents 10% of consumption.

Figure 37: Traded volumes at the UEEX bilateral exchange (IPS)

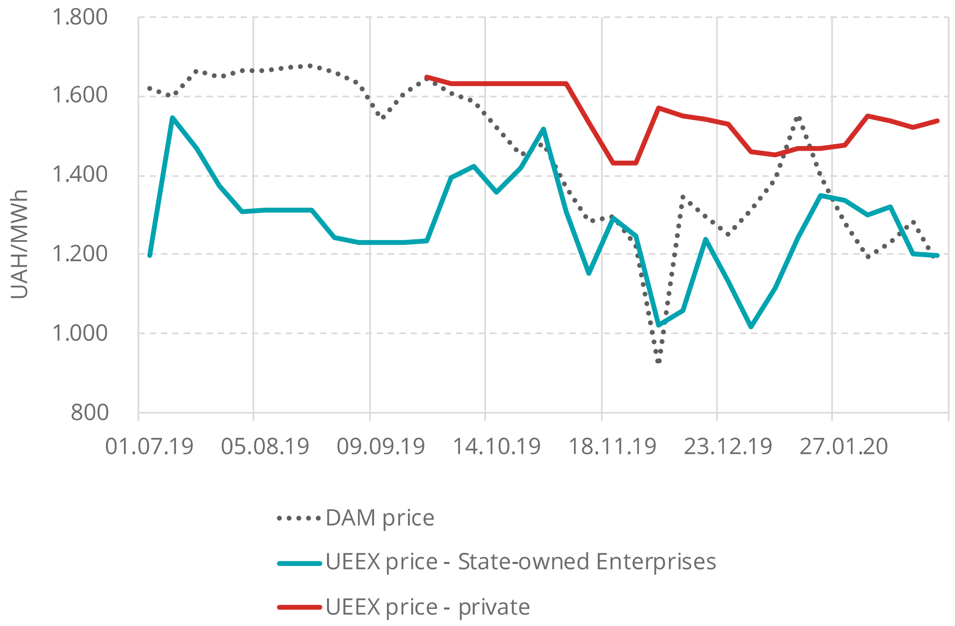


Source: Mykhailenko *et al.* (2020)

Figure 37 compares UEEX prices with day-ahead and intraday prices. Usually, clearing prices for bilateral agreements auctions should not be higher than the day-ahead and intraday prices. The figure confirms the previous statement that the off-peak price cap seems to be (too) low.

Off-peak price cap on DAM and IDM too low.

Figure 38: Price comparison between the day-ahead market and UEEX bilateral contracts



Source: Mykhailenko *et al.* (2020)

IV. Improving balancing markets and ancillary services

The balancing and ancillary services market was opened in only 2020, i.e. *after* the day-ahead and intraday markets. This is understandable because of the complexity of balancing markets. Balancing markets gain importance with increasing amounts of variable renewable energy coming into the system.

In case of integration with European electricity grid, balancing markets will also be integrated.

Balancing markets play a crucial role in the integration into the EU, because automatic and manual frequency restoration reserves are subject to central coordination on common platforms. The principle is that the cheapest available bids in the balancing market are activated to the extent as interconnector capacity allows this to happen. Currently, Ukraine cannot yet participate in this initiative because of lacking transmission capacities. Once the synchronisation is realised, Ukraine will naturally seek for full integration into these platforms.

Large imbalances point to either large profits in selling balancing services or insufficient balancing on the generators' side.

Since market opening, mandatory balancing measures have been regularly carried out to compensate for large imbalances of up to 4GW. This indicates either missing incentives to keep the balance or excessive profits in selling balancing services. This anomaly should disappear when the EU rules on balancing are fully implemented. Then the market players do not have incentives to create large imbalances on the balancing market as this would be more expensive than trading on the day-ahead and intraday markets.

V. Recommendations

Making retail supply competitive – a look into DSOs, PSOs, the need for long-term contracts and competition

- The Ukrainian government should establish a plan and a timetable to gradually remove PSO. This plan should also include the steady decrease of the share of nuclear energy in the PSO and replace it with traded electricity. The group of consumers entitled to PSO should be limited over time to vulnerable households.
- Apply regulatory scrutiny to intra-group sales: enforce unbundling of retail suppliers from DSOs.
- A pre-requisite for the introduction of electricity contracts based on hourly spot markets is the development of generalised smart metering infrastructure with at least hourly resolution. Finally, the regulator should establish a robust price comparison portal.
- Liquidity of the long-term market (in various timeframes) needs to be urgently improved.

Making day-ahead and intraday markets competitive

- Gradually remove price caps and replace them with a robust market monitoring system, supported by tools given by the REMIT legislation (Regulation on Wholesale Energy Market Integrity and Transparency).
- Authorities should invite more market players – in particular owners of price setting plants (TPPs) – to participate in the spot market. Regulatory measures would be conceivable to reach this goal, but also targeted incentives, like e.g. offering degressive trading fees (as used in the Nordic market) to bring more volume to the market.

Developing long-term markets

- The Ukrainian government could invite big international exchanges to establish a branch in Ukraine. This would bring know-how and credibility to Ukrainian power trading. International exchanges also dominate EU markets, only a few countries continue with a national independent power exchange.
- Volumes in the long-term market should be increased by various measures. Market makers are commonly used in other markets for this purpose. They are committed to make offers for products which are less liquid, in exchange for remuneration or other benefits.
- Also, increasing amounts of electricity from renewable, hydro and nuclear should appear in the long-term market, instead of being sold via the PSO.
- Moreover, it is important to ensure, that access to auctions of power generated by state-owned power producers is not restricted to specific consumers.

Improving balancing markets and ancillary services

There are many lessons to learn from the EU on how to improve balancing markets. Effective measures include:

- Careful sizing of reserves for meeting the daily needs, increasing the number of balance service providers among smaller players.
- Allow aggregators to connect more load to the balancing market.

- Incentivise industry to monetise their demand flexibility.
- Introduce smart metering as in many EU countries to open a completely new horizon for demand-side actions.
- Electricity contracts are more often based on hourly market prices which allow end customers to be active on the market with their flexible demand.
- An increasing number of consumers have also become electricity producers, from big industry to small households.

Furthermore, we recommend to:

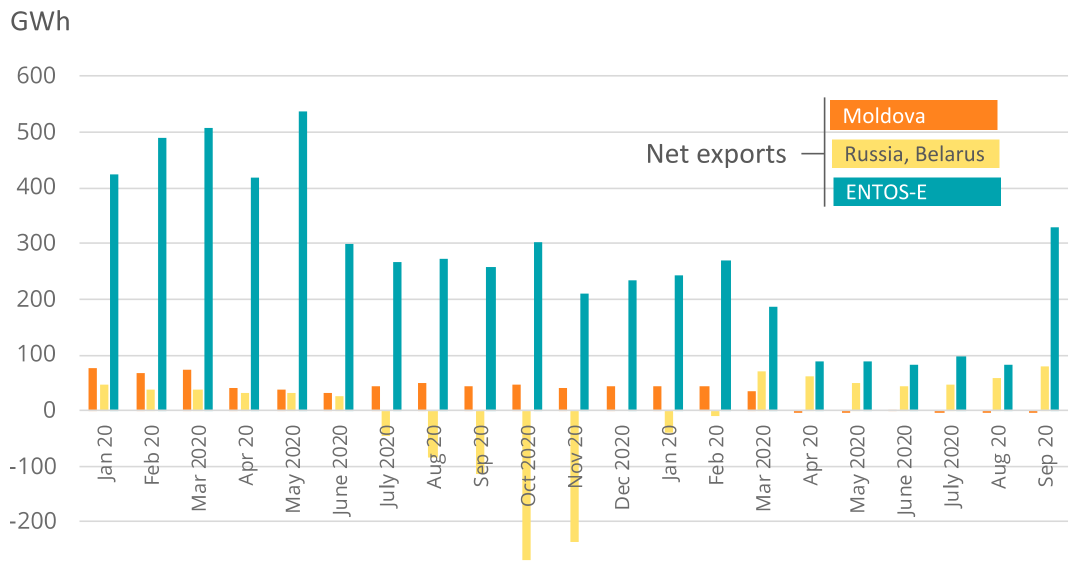
- Analyse and address any gaming opportunities the market might offer to balance-responsible parties and balance service providers;
- align the balancing markets as soon as possible with the EU rules;
- expand the group of balance service providers by removing obstacles for new players to participate, including the renewable producers and the demand side.

Re-structuring cross-border supply

Currently, flows from and to Russia only occur if necessary for system security.

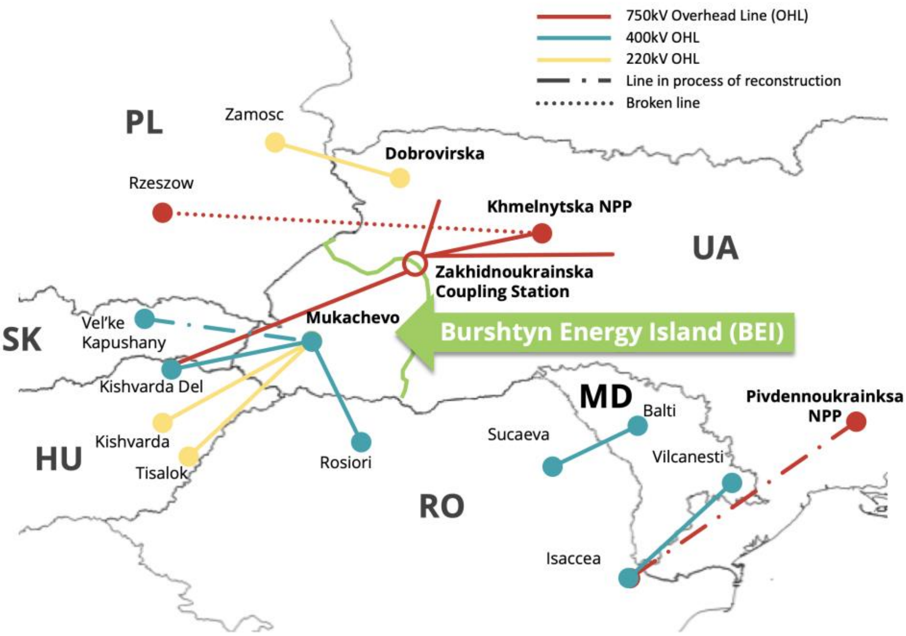
The Ukrainian power system was built as part of the electricity network of the Soviet Union. For this reason, the links to Russia are still technically strong even if for obvious reasons the trade has been reduced to a minimum. If allowed, the Russian imports will always be executed independently of the market price in Ukraine, according to a monopoly seller logic. The clear long-term objective for Ukraine is to make the power system independent from Russia. Thus, trade with Russia only takes place in a limited extent mainly for system security reasons under strict political control (see Figure 39).

Figure 39: Net exports from Ukraine to neighbouring markets in 2020



Source: Own calculation based on ENTSO-E (2020)

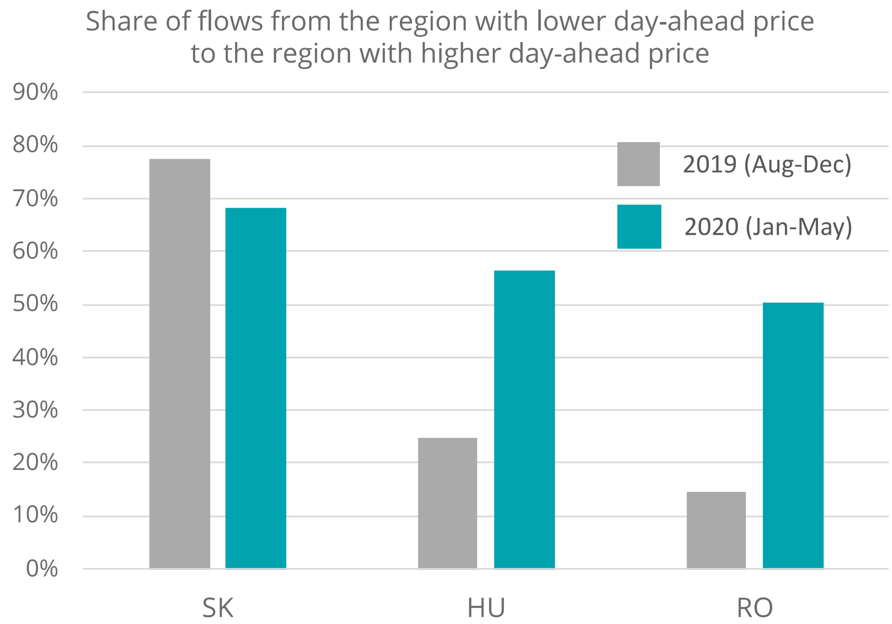
Figure 40: Electricity interconnections of Ukraine with the EU countries



Regarding Burshtyn Island, the cross-border trade with the neighbouring countries is important. Burshtyn Island was synchronised with the central European system already in 2002 and is an important node in the Central European power system (see Figure 40). As the cross-border capacity given to the market is limited, the influence on the market also remains limited. If the full technical cross-border capacity were used, trading would have a significant influence on the market price. Imports have increased considerably lately, as seen in Figure 39.

Ukraine's Burshtyn Energy Island is already synchro-nised with the European electricity system.

Figure 41: Inefficiency of cross border flows into the Burstyn island and the consequently lost welfare

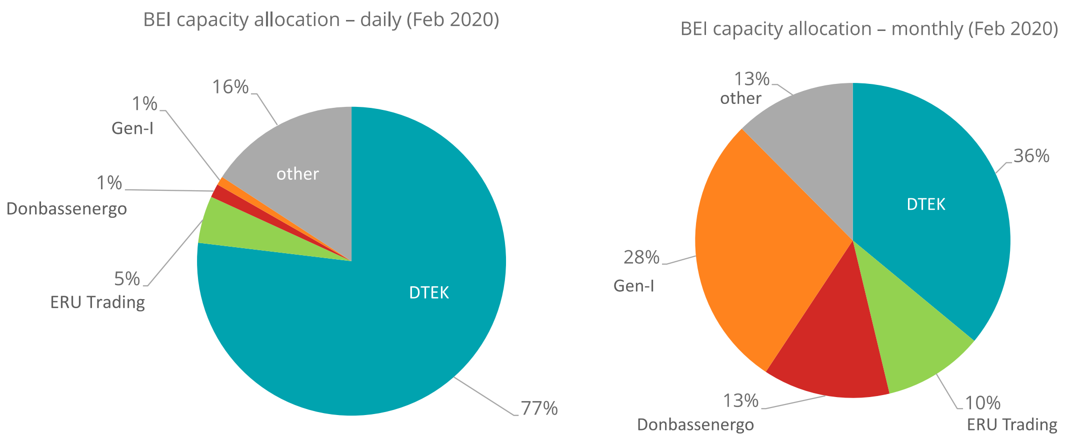


Source: Own calculation based on ENTSO-E (2020)

BEI controlled by monopoly: leading to cross-border flows flowing in opposite direction of prices.

From the observation of market prices at each side of the border and the flows, one can conclude that there is a discrepancy between the trades and prices. Roughly half of the time, electricity in the Burshtyn Electricity Island is flowing opposite to price signals, causing an estimated welfare loss of EUR70M during the first 10 months of market operation (see Figure 41). This could be explained by the monopolistic behaviour of the dominant power producer in the Burstyn Island. Figure 42 shows which companies control the capacity at the Burshtyn Electricity Island interconnectors.

Figure 42: Share of cross-border capacity allocated to different players at the Burshtyn Electricity Island interconnectors



Source: Mykhailenko, Vereshchynska, Mukha, Avetyan and Zachmann (2020)

Recommendations

Synchronisation with the central European system should be strongly pursued. This gives credibility for the future of the Ukrainian power market and for investments

In the meantime, the Ukrainian government should investigate the possibility to introduce a market coupling type of capacity allocation for the trade between the Burshtyn Electricity Island and the EU. In any case, one should limit the capacity which one company or group can have at the interconnectors. This improves competition and limits the possibility to exercise market power on the cross-border trade. Also, regulatory scrutiny should be applied to capacity auctions and electricity trades in the Burshtyn Electricity Island to reveal any market manipulation attempts.

To Do's: Politicians must strongly support synchronisation with the European grid. Meanwhile, market power in the BEI and over cross-border transmission capacity must be undercut.

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Annex: Construction of the merit order

The construction of Ukraine's merit order is based on several assumptions. For thermal power plants, the World Bank (2007) published a report on fuel consumption on plant level, from which plant efficiencies can be calculated. These plant efficiencies can be used to calculate the short-run marginal costs (SRMC) via:

$$SRMC = \frac{Fuel\ costs\ EUR/MWh\_th}{Eff\% * MWh\_el} + \frac{1\ MWh\_th}{Eff\% * MWh\_el} * Emf\frac{tCO2}{MWh_{th}} * tax\frac{EUR}{tCO2}$$

where Eff constitutes the efficiency and Emf the emission factor of tCO_2 per MWh.

While the marginal costs of thermal power plants can be approximated on plant level due to detailed data on fuel rates, this is not the case for the remaining electricity production types. For CHPs, an efficiency of 35% for all coal-based CHPs, and 40% for all gas-based CHPs is assumed. This assumption corresponds to technology assumptions in the EU POTEnCIA Central Scenario (European Commission, 2020). For the remaining production types, marginal costs of 0 EUR/MWh are assumed for RES, 22 EUR/MWh for hydro and 12 EUR/MWh for nuclear.

As only plant efficiencies of thermal power plants are available, this is only a very rough approximation of Ukraine's merit order. Moreover, it should be noted that the plant level data for thermal power plants is already 13 years old. Consequently, retrofitting measures that could have occurred in the meantime and hereby improved efficiencies, are not taken into account.

5. A Cost-efficient Deployment of Renewables

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Contributor: Dr. Matti Supponen

Executive summary

Thanks to generous feed-in tariffs (FITs) for renewable energy sources (RES), Ukraine has seen a remarkable surge in RES capacity addition in recent years. In 2020, 10% of electricity has been generated by RES (incl. hydro) in Ukraine. In order to rein in the spiralling costs of RES support, Ukraine has adopted an auctioning system for RES support. From 2021 on, this system will be used to determine support levels for utility-scale RES on a competitive basis.

In December 2020, the Ministry of Energy of Ukraine announced draft quotas for the first RES auctions in 2021 and indicative annual quotas for 2022 until 2025. According to the Ministry, 365 MW of RES capacity would be auctioned in 2021, and quotas would then slightly increase from 420 MW in 2022 to 570 MW in 2025.

In this Chapter, we show that at moderate electricity consumption growth, the current deployment path will increase Ukraine's RES share in electricity generation to around 21% in 2030. This path is insufficient to significantly move forward on decarbonising Ukraine's electricity sector. It moreover conflicts with the country's ambition to become a producer of green hydrogen. We estimate that doubling the currently planned auction volumes would allow Ukraine to achieve a 30% RES share in electricity generation in 2030, helping Ukraine to keep pace with global decarbonisation efforts.

A more ambitious deployment is feasible with policy measures that help to reduce the integration cost of renewables. To foster the integration of RES into the electricity market, we propose the introduction of a feed-in premium (FIP) scheme. For new RES plants, this FIP scheme would entail the obligation to sell the generated electricity on the wholesale market, rendering the intermediary step of selling electricity to the single offtaker Guaranteed Buyer (GB) unnecessary. Introduced together with balancing responsibilities for RES, a FIP scheme would incentivise RES to deliver better generation forecasts and allow them to sell or buy electricity on all short-term markets to react to forecast updates. These regulatory changes would reduce RES imbalances, ensure a more efficient dispatch of Ukraine's electricity system and hence reduce the need for costly balancing energy.

To incentivise the market entry of flexible generators that are needed to balance RES fluctuations, we argue that minimum and maximum price caps on Ukraine's electricity wholesale market should be phased out. We show that eliminating price caps is consistent with the objective to achieve low average prices and would help to address the high market concentration on Ukraine's electricty market.

The status quo of Ukraine's renewables support scheme

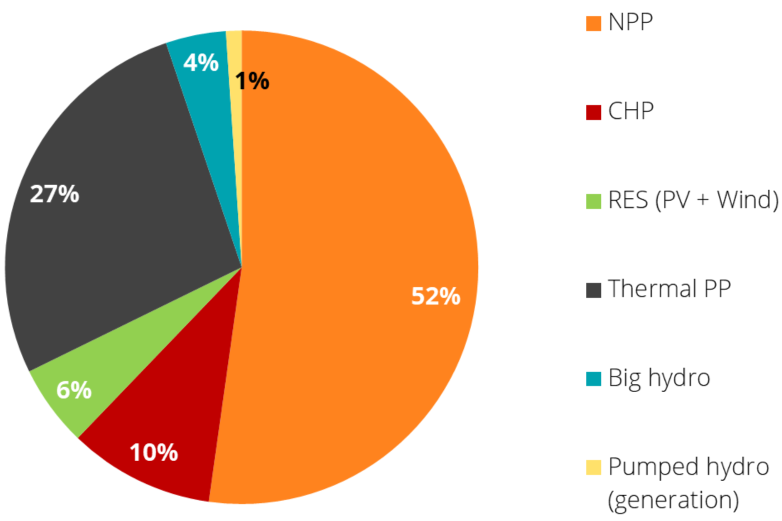
RES support has been effective in promoting deployment but has led to high costs

In 2009, the Ukrainian government implemented a feed-in tariff (FIT) scheme for certain types of renewable energy sources (RES). Under a FIT regime, the government legally guarantees investors to buy the electricity they produce and pay them a specified tariff over a certain period of time.

Ukraine's FIT scheme guaranteed eligible producers prices from 10 to 15 EURcts/kWh (IMEPOWER, 2019). It has proven to be effective in attracting investment: Since the scheme was introduced, RES capacities have increased rapidly from less than 100 MW in 2009 to 8.5 GW in December 2020. In 2020, wind and PV accounted for 6% of electricity generation (see Figure 43). RES producers in Ukraine that are eligible for FIT would sell their electricity to the single offtaker Guaranteed Buyer (GB), who then resells all RES electricity at the regular day-ahead market (DAM) or on the bilaterals segment. This means that the actual subsidy for the RES producer is the difference between the FIT and the DAM/bilaterals price, with lower (higher) wholesale prices implying higher (lower) total RES support cost. FIT subsidies are financed both through a tariff surcharge – which has a direct impact on final consumer prices – but also through proceeds from electricity sales from state-owned generating companies.

In recent years growing concern has been voiced that these subsidies for renewables may become too costly. Moreover, there are concerns that the high FIT expenditures could lead to increasing electricity prices for consumers. The government has reacted to these concerns by introducing a RES auction regime in which feed-in prices for new RES plants shall be determined via auctions from 2021 on. Existing installations, which have been granted FITs before the end of 2019, will nevertheless continue to receive FIT for the guaranteed period until 2030, when the FIT scheme for existing installations will be eventually phased out.

Figure 43: Electricity generation mix Ukraine, 2020



Source: Ukrenergo

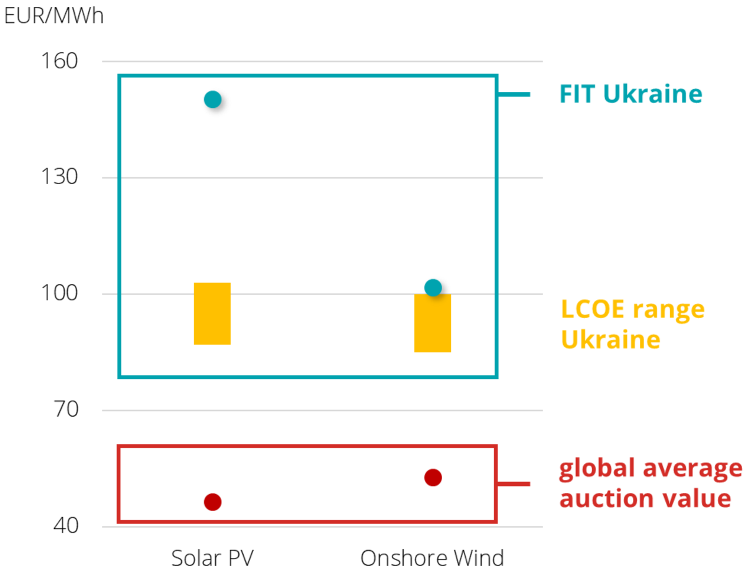
An auctioning system for RES should help to reduce support cost

The new scheme foresees that each year, auction volumes (in MW of installed capacity) will be put up for auctioning. There is a separate quota for wind, solar and for "other RES" installations, with the latter comprising of small hydropower, biomass/-gas and geothermal installations. While wind turbines larger than 5 MW and solar plants larger than 1 MW are obliged to participate in the auctions, smaller RES projects can participate on a voluntary basis. However, they can also opt for the fixed FIT tariff but would then have to accept a shorter support duration. Auction participants should submit closed bids containing the technical bids (the installed capacity of the project) and the price bid (the supported price in EUR/kWh). Starting with the lowest price bid, successful bidders are selected until the auction quota is exhausted. Auction volumes shall be set annually for five years. In December 2020, the Ministry of Energy of Ukraine announced draft quotas for the first RES auctions in 2021 and indicative annual quotas for 2022 until 2025. According to the Ministry, 365 MW of RES capacity would be auctioned in 2021, and quotas would then increase from 420 MW in 2022 to 570 MW in 2025.

As the FIT scheme for larger installations expired at the end of 2019, many investors tried to still benefit from the generous support levels. Figure 44 shows that the margin between guaranteed FIT and estimated Ukraine-specific levelised costs is significant especially for PV. Figure 44 also shows average global auction values for 2019 to give an indication of how Ukraine's high country risk inflates the costs of capital and therefore justifies above-average support levels to some extent. The 2019 FIT cut-off has led to an increase of installed RES capacities of 4 GW in 2019 – 3 GW of which were PV – alone. This has more than tripled the total installed capacity compared to 2018. With the adoption of the Law 810-IX "On Amendments to Certain Laws of Ukraine on Improving the Conditions for Promoting Electricity Generation from Renewable Energy Sources" on July 21, 2020, FITs will eventually be retroactively lowered and imbalance responsibilities will be phased in earlier than previously planned (Radchenko, 2020).

High country risk explains generous support levels to some extent – but PV FITs have clearly been excessive

Figure 44: Comparison of 2019 Ukrainian FIT[33], LCOE[34] and global average auction values



Source: Mantzos *et al.* 2019, IMEPOWER 2019, IRENA 2020, Own calculation

Policy proposal

Ukraine's auction scheme foresees two technology-specific auctions, one for wind and one for PV, as well as one technology-open auction for "other" RES generators that are neither wind nor PV. In this third auction, biomass/-gas, geothermal and small hydro plants would compete for feed-in prices. In addition to that, the Law 810-IX states that the Cabinet of Ministers of Ukraine can call technology-neutral and/or specific auctions for "other RES". We estimate RES shares in electricity generation implied by the Ministry of Energy's draft quotas until 2025 and show how much RES capacity should be auctioned if Ukraine were to reach a 30% RES share in electricity generation in 2030.

[33] FIT levels before retroactive changes. The Law 810-IX lowers FIT for PV >1 MW commissioned between 2015 and 2019 by 15% and for wind (turbine >2 MW) by 7.5% (Radchenko 2020).

[34] LCOE range calculated using POTEnCIA modelling tool (Mantzos *et al.* 2019) with discount factor range 13%-16%.

I. Extrapolating the current deployment path

Ukraine plans to gradually increase auction volumes from 365 MW in 2021 to 570 MW in 2025

In a first step, we show which RES shares could result from the currently discussed RES quotas. We use the planned quotas of 365 MW for 2021 and the indicative 5-year-quotas, which increase from 420 MW in 2022 by 50 MW a year to 570 MW in 2025, and extrapolate the increase of 50 MW per year from 2026 onwards (see Table 13). According to this heuristic, 820 MW would be put up for auctioning in 2030. We assumed an average time lag between being auctioning and commissioning of the RES capacity of one year, which means that only volumes auctioned until 2029 affect the 2030 electricity generation. In the third, technology-neutral auction category for "other RES", we expect one technology to dominate. This is in line with European experience on technology-neutral auctions (Pakalkaite, 2020). Given Ukraine's large agricultural sector and the entailing potential for utilising agricultural residuals as well as the geographical limitations to expand small hydro capacities, we assume a 90% share of successful biomass/-gas bids in this category. This, however, is conditional on biomass developers being able achieve levelised costs below EUR 120/MWh – the new ceiling price for this auction category recently set by the Law 810-IX (Radchenko 2020). Levelised costs for biomass plants tend to be close or above this threshold for two-digit discount rates (Mantzos *et al.* 2019). By applying average 2016-2018 Ukrainian capacity factors for wind, PV, biomass and small hydro plants we estimate a potential trajectory of total RES electricity generation until 2030 (Ukrenergo, 2020). We assume electricity generation from large hydro power plants, currently at 6 TWh/year, to remain constant.

Table 13: Planned 2021 RES quotas and indicative quotas for 2022-2025

Auction category	2021	2022	2023	2024	2025
Wind	150	170	190	210	230
Solar	155	170	180	190	200
Other RES	60	80	100	120	140
Total	365	420	470	520	570

Source: Teusch, Soshenko 2020

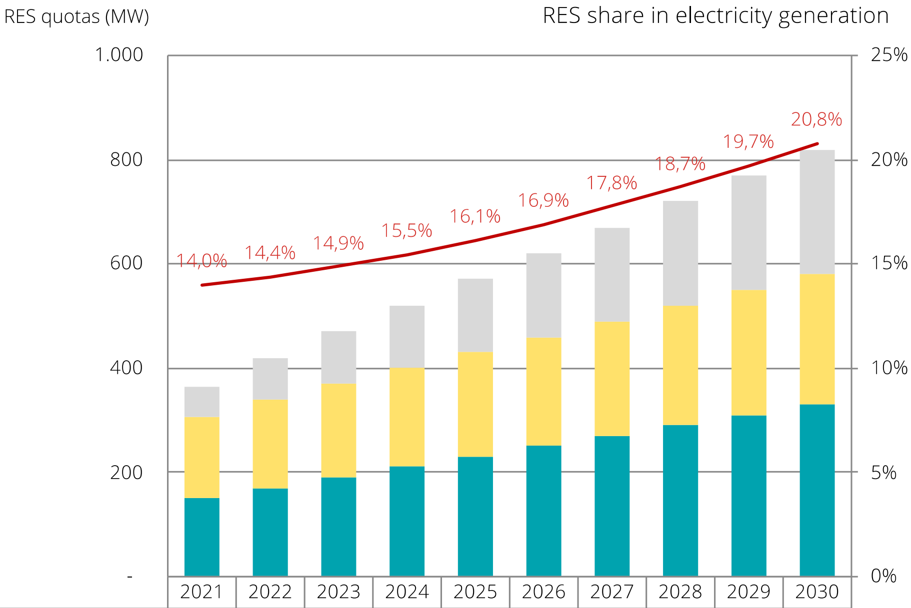
The estimated RES shares take 8.5 GW of installed RES capacities for end-2020, reported by Ukraine's State Agency for Energy Efficiency and Energy Saving of Ukraine, into acccount. After the retroactive changes to FITs, it remains unclear how many pre-PPA projects registered until December 2019 will be eventually realised. Due to this uncertainty, we did not include them in our estimations.

At moderate electricity consumption growth, the extrapolated current deployment path would result in a 21% RES share in electricity generation in 2030 (incl. hydro)

For translating annual RES generation into RES generation shares, one needs to make an assumption on the development of electricity consumption. The recent Covid-19 crisis has had a negative impact on electricity consumption in 2020, which declined by 4% compared to 2019. Assuming a moderate average annual consumption growth of 2% from 2021 onwards, total gross electricity consumption would reach 170 TWh by 2030. Assuming constant net exports and accounting for pump storage consumption, total electricity generation in 2030 would amount to 176 TWh.

As shown in Figure 45, the extrapolated current deployment path would hence imply that even though total RES generation (incl. large hydro) increases from 14 to 37 TWh (+75%), the RES share in electricity generation only increases by 50% from 14% in 2021 to 21% in 2030. This is due to the growth in electricity consumption, which offsets some of the effects of RES deployment.

Figure 45: RES shares according to extrapolated current deployment path



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total	365	420	470	520	570	620	670	720	770	820
Other RES	60	80	100	120	140	160	180	200	220	240
PV	155	170	180	190	200	210	220	230	240	250
Wind	150	170	190	210	230	250	270	290	310	330
RES generation share (incl. hydro)	14,0%	14,4%	14,9%	15,5%	16,1%	16,9%	17,8%	18,7%	19,7%	20,8%

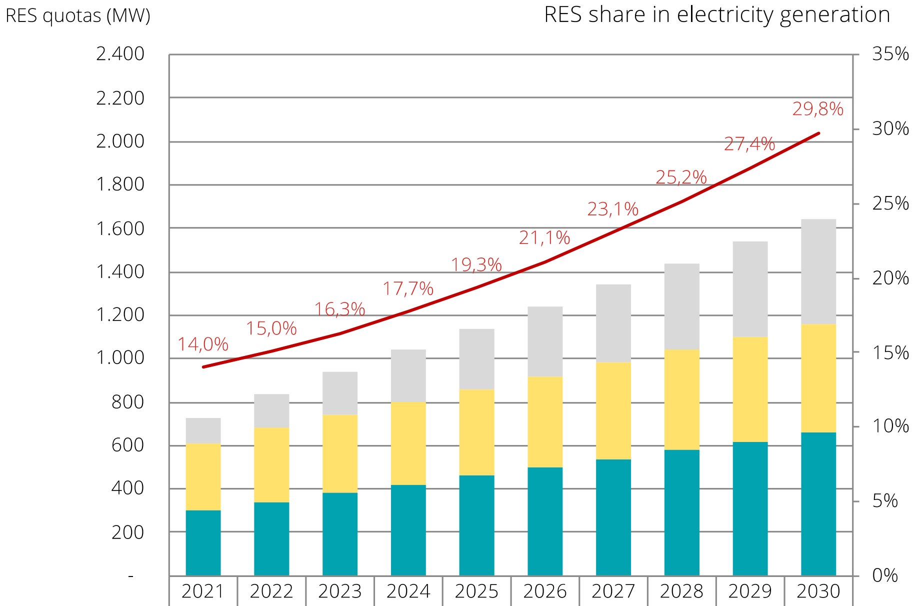
Source: Own calculation

II. Auction volumes to achieve a 30% RES share in 2030

To achieve a 30% RES share in 2030, current auction volumes would need to be doubled

In order to achieve a 30% RES share electricity generation in 2030, the currently planned annual quotas would have to be doubled (see Figure 46). As similar target shares are being discussed in the framework of Ukraine's updated Nationally Determined Contributions, our estimate serves as a guidance for the neccesary deployment to achieve those targets. Scaling up the currently planned quotas by the factor of 2 preserves the RES technology mix envisioned by the Ministry of Energy. The Ministry's decision to assign higher wind volumes is reasonable as it helps to balance to RES technology mix, which is currently heavily skewed: Since FITs have been especially favorable for PV developers, the recent surge in installations was largely due to PV additions. A higher share of wind electricity generation would lead to a more equal distribution of total RES generation throughout the day and mitigate the problematic decrease of residual load during noon, when PV infeed peaks. This would relieve pump hydro plants, which are now being dispatched to consume excess PV electricity during noon. This new dispatch routine constrains the usual rountine of pump hydro consuming excess electricity during low-demand hours at night. A simultaneous deployment of wind and PV also reduces the additional operational reserves needed to balance RES fluctuations (Ziegenhagen, 2013).

Figure 46: RES quotas to achieve a 30% RES share



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total	730	840	940	1.040	1.140	1.240	1.340	1.440	1.540	1.640
Other RES	120	160	200	240	280	320	360	400	440	480
PV	310	340	360	380	400	420	440	460	480	500
Wind	300	340	380	420	460	500	540	580	620	660
RES generation share (incl. hydro)	14,0%	15,0%	16,3%	17,7%	19,3%	21,1%	23,1%	25,2%	27,4%	29,8%

Source: Own calculation

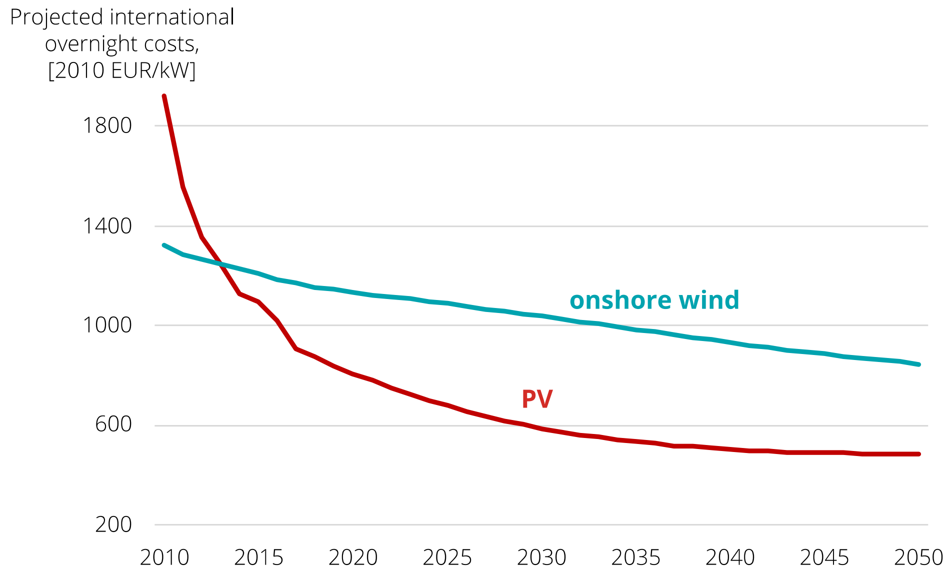
Translating decreasing technology costs into lower support cost

The investment costs for PV and wind have decreased significantly in recent years (Lazard 2019). In the next years, build costs are expected to further decline (see Figure 47).

With Ukraine's large available areas for building wind and PV plants and its considerable solar irradiation and wind resources, these two technologies are the prime candidates for producing electricity at low cost.

While the rapid deployment of PV and wind have driven cost reductions in recent years, a more mature market and thus reduced financing costs together with technology improvements are likely to further drive down costs. International experience shows that these cost reductions can translate into lower auction bids and hence less RES support (IRENA, 2020).

Figure 47: Projected international overnight capital costs for onshore wind and PV



Source: Mantzos *et al.* 2019

Ensuring competitive auctions is not trivial – authorities should review the auction design after the first auction rounds

While technology costs are falling globally, it is not trivial to also achieve lower auction results in Ukraine. Translating decreasing overnight cost into lower support levels depends on ensuring competitive auctions and lower risk premiums for RES investors. Ukraine should therefore closely monitor the auctions and adjust auction design and volumes if necessary.

Potential solutions to increase competition and mitigate risks include reviewing prequalification requirements to ensure all bidders have fair chances of participating. Providing transparent guidelines and the training of civil servants can help to mitigate administrative risks (Schenuit *et al.*, 2018). The fact that DTEK acts as the distribution company in many parts of Ukraine and is likely to be an auction participant as well illustrates that ensuring equal chances of grid connection and transparent connection procedures for all auction participants is another important factor to mitigate risks and increase competition. Moreover, authorities might prolong the available time for realising the project in case too strict deadlines or excessive fines deter bidders from participating. If the technology-specific auctions lack liquidity, mixed-technology auctions for PV and wind as included in the Law 810-IX may be an option to increase competition (Hanke, Tiedemann, 2020).

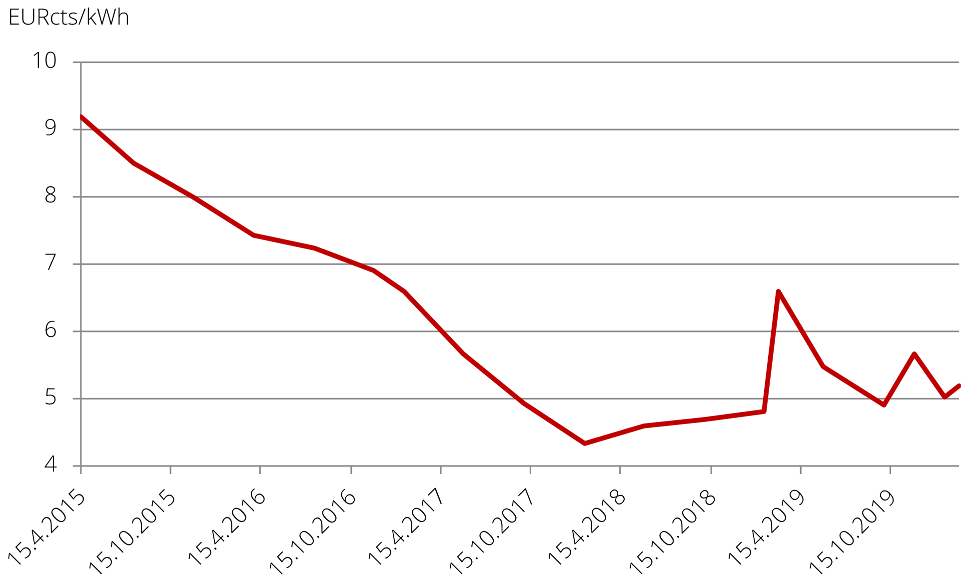
The investment risk faced by RES developers is a crucial factor to take into account. If investors perceive that the risks associated with a project are high, they are likely to look for a higher return on their investment as a compensation (Schenuit *et al.*, 2018). Higher risk premiums lead to higher bids – and eventually to higher electricity tariffs. It is therefore in the hand of the Ukrainian government to reduce the country-specific risk premium by pursuing a stable and consistent energy policy.

Background info

German PV auctions

In recent years, Germany has seen a decline in PV bid prices. Under the competitive bidding scheme in PV auctions, support payments decreased from 9 EURcts/kWh in 2015 to 5 EURcts/kWh in 2020. This significant decline is due both to high levels of competition and declining technology cost. This reduction in bid prices will only affect tariffs with a certain delay though as today's total RES support costs are heavily influenced by older, more expensive RES plants – which is why the tariff surcharge for renewables support that is borne by consumers is still rising. As older plants are increasingly falling out of the support scheme, the peak of RES support cost is in sight. As a result of decreasing technology cost, support levies and hence electricity prices are expected to fall in the 2020s (Fabian, H., Peter, F., Graichen, P., 2020).

Figure 48: Average awarded bid prices in German PV auctions, 2015-2020



Source: Bundesnetzagentur

Introduce a feed-in premium system

In Europe, feed-in premium (FIP) support schemes are increasingly complementing the traditional FIT schemes. FIP schemes require RES electricity to be sold directly to the organised segments of the electricity wholesale market, with RES operators then receiving a feed-in premium on top. The introduction of FIP schemes together with direct RES marketing is often accompanied by extending balancing responsibilities for RES producers (CEER, 2018). FIPs are often introduced as an option to existing FIT schemes, i.e. operators are allowed to switch between the two remuneration schemes on an annual or monthly basis. The Law 810-IX obliges Ukraine's Cabinet of Ministers to submit a draft law that allows RES to leave the GB balancing group, sell their electricity on the wholesale market and receive the difference between market price and auction price/FIT as a premium. We support this initiative:

When coupled with increased balance responsibilities, a FIP scheme could reduce system balancing costs and foster the integration of RES into the electricity market.

A feed-in premium system would expose RES to market signals and ensure a more efficient dispatch of power plants

A viable option would be to make the FIP scheme compulsory for RES investors participating in the auctions and allow existing RES to switch to the FIP scheme, as envisioned in the Law 810-IX. The law also foresees complete balance responsibilities for RES in the GB balancing group to be introduced from 2022 on. For RES in the proposed FIP scheme or existing RES that voluntarily switch to the FIP scheme– i.e. they leave the GB balancing group and hence need to join a regular balancing group – the same responsibilities should apply. It is important to note that the introduction of RES imbalance responsibilities, although necessary from a system perspective, might mean that RES operators include these costs in their auction bids, leading to higher auction prices (Anatolitis, Grundlach, 2020).

Imposing the same degree of accountability on all balancing groups and allowing RES operators to join those balancing groups together with conventional generators would prevent the current pooling of highly volatile generators into one balancing group and hence ensure a more decentralised scheduling of resources. These balancing groups would be able to adjust their positions on the spot market – e.g. after intraday generation forecast updates – and hence reduce the need for costly regulating power.

In case that a balancing group is unable to successfully adjust their positions and would deviate from its generation schedule, it would have to pay a significant imbalance price. Ideally, this imbalance price should represent the costs of activating the regulating power that is necessary to rein in the deviation of supply and demand caused by that balancing group (Hirth, Ziegenhagen, 2015).

Given the substantial delays in FIT payments from the GB to RES producers, the counterpart risk perceived by RES investors is especially high in Ukraine, which increases the risk premium and results in higher bids (Schenuit *et al.*, 2018). A more timely remuneration through direct marketing would serve as an incentive for existing RES to change to the FIP scheme.

FIPs moreover incentivise RES producers to respond to market price signals: When electricity supply is low or demand is high, RES operators can strike higher prices for providing electricity and hence balancing supply and demand.

In Germany, where the FIP scheme is compulsory for new RES plants commissioned since 2016, the premium is calculated as the difference between awarded auction bid price and average wholesale market revenues (EEG, 2017). RES producers therefore have a guarantee to always receive their awarded bid price. Yet, in situations of excess demand and high prices on the wholesale market, RES producers could sell for prices that even exceed the supported price. In that case, the GB would have to pay no premium at all. In cases of excess supply (e.g. on very windy and sunny days with low demand), wholesale market prices could turn negative – i.e. generators must pay to produce

We propose that no premiums are paid for hours of negative spot prices

To prevent that RES are paid the entire supported price plus the revenues for not producing in such situations, we suggest not to pay RES support during hours of negative spot prices in Ukraine. This would resemble the Danish RES support design, were no premiums are paid if spot prices for the respective hour are not positive (Garzón González, Kitzing, 2019). For negative prices to occur, the price caps currently in place would first need to be phased out.

Under such a "sliding" FIP scheme the GB would only have to pay RES producers the difference between awarded auction bid price and average wholesale market revenues for the respective RES technology. Average revenues could be calculated by the GB separately for every RES technology as in the German case: Multiply the average hourly contracts on Ukraine's electricity exchange (in UAH/MWh) with the RES infeed during that hour per technology (wind, PV and other). Summing up these products for every hour of the month and dividing it by the monthly sum of the respective hourly RES infeed (in MWh) would then give a proxy for the average revenue per MWh that a certain RES technology has achieved on the wholesale market during one month (EEG, 2017). The longer the averaging period, the higher the exposure of RES operators to market risks.

A special case of a two-sided or symmetrical "sliding" FIP is a Contract for Difference (CfD). Under a CfD scheme, applied e.g. in the UK, the awarded auction price also represents the maximum remuneration: If wholesale electricity prices are higher than the auction strike price, RES producers pay back their additional income to the contract counterparty (Woodman, Fitch-Roy, 2019).

The GB's high indebtedness, which is due to chronic delays in payments within the complex PSO mechanism, could be reduced with a FIP scheme – the payables to RES producers would only be a small share of today's figure. Further reducing the counterpark risk of the GB through the provision of long-term RES support strategies, as well as expansion targets and deployment forecasts, is crucial in this regard (Schenuit *et al.* 2018). The regulatory effort to introduce such a system is comparably small as the main instrument to determine premiums is already in place with the new auction system. In the medium term, DSOs or the TSO could take over the task of remunerating RES producers from the GB.

Background info

The Guaranteed Buyer's role in Ukraine's RES support system

Currently, all RES operators in Ukraine sell their electricity to the single offtaker GB and are being paid the guaranteed FIT per kWh produced. The GB then resells all RES electricity that it has bought from RES producers at the DAM or bilaterals segment. The difference between FITs (or future awarded auction prices) is the premium that is financed by TSO tariff surcharges and electricity sales from state-owned companies. At fixed support (i.e. FIT) levels, the level of wholesale prices therefore determines how much one kWh of green electricity is subsidised in Ukraine.

Since RES producers are selling only to the GB, they are pooled into one balancing group. This entails a responsibility for the GB to act as the balancing responsible party for all RES. If RES generation deviates from forecasts the GB would incur an imbalance and pay for it according to the prices on the balancing market. The financial responsibility of RES for their imbalances (i.e. the differences between expected and actual generation) was originally to be phased in slowly until 2030. The Law 810-IX now significantly speeds up the introduction of imbalance responsibilities for RES in the GB balancing group: RES plants above 1 MW will be fined for 50% of their imbalances from 2021 and for 100% from 2022 onwards (Radchenko, 2020). This regulatory change aims at increasing incentives for RES to deliver more accurate generation forecasts to the GB on the day ahead as well as more precise intraday forecast updates. The lack of financial responsibility has so far led to large aggregate forecast errors and imbalances. The resulting uncertainty regarding RES electricity generation in turn leads to a suboptimal and inefficient dispatch of power plants as well as a higher need to balance electricity demand and supply in very short time frames.

Phase out price caps to incentivise investment into flexible generation

To ensure that the electricity system can safely take up higher shares of intermittent RES electricity generation, the auctioning of RES capacities should be combined with measures that increase the electricity system's flexibility and hence allow for a better balancing of fluctuating RES generation. Options to increase system flexibility not only comprise of technical measures, such as building flexible generators or storage, but also include regulatory changes to better make use of the existing flexibility, e.g. via improved electricity market design.

An increased RES penetration means a higher share of non-dispatchable and intermittent generation in the electricity system. To ensure that demand is always met by supply, unforeseen fluctuations in RES electricity generation due to changing weather conditions need to be covered by demand- or supply-side flexibility providers. On the demand side, flexibility providers could be interruptible loads such as industrial consumers. On the supply side, flexibility can be provided by fast-ramping generators such as gas turbines, hydro plants, battery storage facilities or curtailment. When RES generation is higher or lower than expected, these flexibility providers are dispatched to rapidly ramp up/down their generation.

Ukraine's current electricity system relies on coal flexibility – to achieve a cost-efficient RES integration, more economical flexibility options are needed

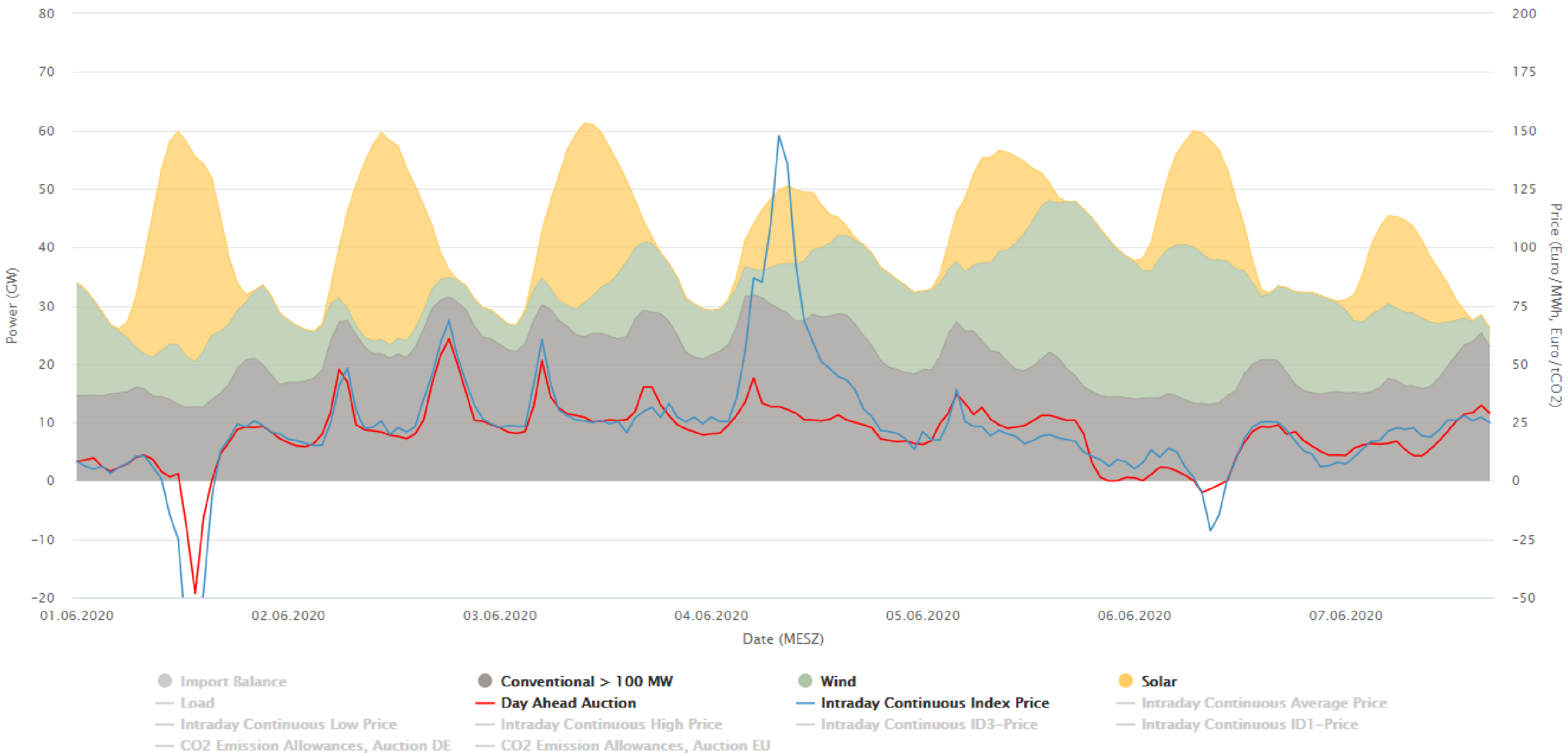
As of 2020, the only supply-side providers of flexibility in the Ukrainian electricity system are hydro, pump-storage and thermal power plants. Although the installed capacities of hydro (4.6 GW) and pump-storage (1.5G GW) can in theory provide significant flexibility at low cost, the irregular availability of water in the Dnieper and Dniester rivers limits the hydro balancing potential. This is true especially during summer, when PV generation and thus balancing needs are highest. From a technical point of view, Ukraine's 19.3 GW of thermal plants (of which 15.5 GW are coal- and 3.8 GW are gas-fired) offer sufficient flexibility to balance high RES shares. Their high average minimal load of 66%, however, means that many thermal units need to be kept spinning to provide sufficient up- and downwards flexibility, thus pushing inflexible nuclear units – which incur less variable cost and emissions – out of the system. Relying on Ukraine's current thermal fleet as the main provider of balancing services could therefore lead to both higher operational costs and higher emissions.

To keep the costs of a large-scale RES deployment in check, better balancing providers are needed. Electricity market design should incentivise the market entry of players providing those services. **Phasing out price caps should be the first step to attract investment into flexible generation capacity.**

The spot market should allow scarcity prices, which serve as an investment incentive for flexible generators or storage

Investment signals for flexible generators or storage depend on high, so-called scarcity prices that result from situations of excess demand – with higher RES shares, those situations are seen more often. During those scarcity events, prices are rising significantly for a short period of time. Flexible generators that only start up to meet this peak demand are therefore allowed to recover their fixed costs of capital (IRENA, 2017). Figure 49 shows a scarcity event on the German electricity market in the first week of June 2020: On Wednesday, wind generation was up to 4 GW below its forecast. High demand hence led to intraday prices rising up to 148 EUR/MWh.

Figure 49: Electricity production and spot prices in Germany in week 23, 2020



Source: B. Burger, Fraunhofer ISE, energy-charts.info

The German experience shows that it is possible to provide investment incentives through scarcity prices and achieve low average spot prices at the same time

In the same week, one could also observe the opposite situation of excess supply, when spot prices turned negative on Monday due to low demand and strong PV infeed (Next Kraftwerke, 2020). With prices being able to reach both very high and very low levels, it was possible to achieve low average prices of 19 EUR/MWh (day-ahead) and 25 EUR/MWh (intraday) during this week. Allowing for scarcity prices to materialise thus serves as a signal for new players to enter the market while being consistent with the objective to achieve low average prices.

In the context of Ukraine, this in turn means that attracting the desired investment and market entry of flexible generators will be very difficult with the current wholesale market price caps in place. The observable tendency to limit price fluctuations by setting maximum and minimum prices may be explained by the objective of keeping average prices at a low level. As shown in the German example, however, this objective can also be achieved without strict minimum and maximum prices. Eliminating price caps would moreover help to address the elephant in the room – the high market concentration on Ukraine's electricity market. When cost-recovery on short-term markets is likely, new, non-incumbent players will enter the market.

Still, due to the high regulatory and policital uncertainty in Ukraine, even a wholesale market that fully allows for scarcity prices might not be enough to incentivise the desired level of investment. Moreover, the overcapacity of Ukraine's current power plant park might water down investment signals: As higher RES shares drive down prices and load factors of conventional generators in a system with overcapacity, forecasting the frequency of scarcity events and hence potential revenue becomes difficult for investors (IRENA, 2017). Reinforcing investment signals by using sensible capacity mechanisms would therefore be a potential second step. Without allowing for scarcitiy prices to realise in the first place, however, providing flexibility via capacity mechanisms alone would potentially inflate network costs and hence electricity tariffs.

Effects of decarbonising Ukraine's electricity generation

I. Energy security

Ukraine's dependence on imported fuels, i.e. natural gas, coal and uranium has been perceived as a threat to the country's energy security for a long time. Especially net coal imports have increased significantly in recent years (IEA 2019). Higher RES shares in electricity generation would allow phasing out many of the old and depreciated coal-fired power plants and substantially reduce Ukraine's dependency on fuel imports.

II. Internal energy market

Higher RES shares could also prove beneficial for Ukraine's electricity market as less demand would need to be served by thermal power plants. With wind and PV bidding on the wholesale market at marginal costs close to zero – as no fuel cost is associated with their power generation – and nuclear providing cheap baseload generation, the remaining peak demand will primarily be served by hydro and thermal power plants, with the latter being the most expensive source in terms of marginal cost. The least efficient, i.e. most expensive thermal plants would therefore be pushed out of the merit order by increasing RES shares. As wholesale market prices are determined by the marginal costs of the most expensive power plant needed to serve demand, this means that wholesale electricity prices would eventually decrease.

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6. Synchronising Ukraine´s and Europe´s electricity grids

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Executive Summary

For Ukraine the cost of synchronisation with the Continental Europe power system will be significant. But the benefits in terms of energy security, market integration, energy efficiency, decarbonisation and competitiveness - i.e. the five dimensions of the Energy Union - would be even larger.

Ukraine and its TSO Ukrenergo intend to synchronise the Ukrainian with the Continental European electricity grid for political, economic, and technical reasons. Their aim is to finalise this integration already by 2023. This time plan is very ambitious as several key difficulties needs to be overcome before synchronisation:

1. A lack of balancing and frequency control capabilities. In a 2016 feasibility study, Ukrenergo's systems were not able to dampen its network's frequency in a hypothetical connection scenario with Europe. If modern systems are not installed and working, synchronisation will not be possible.
2. The need for cross-border transmission lines to Continental Europe. We estimate the cost for necessary lines to Ukraine's Western neighbours at more than EUR684 million.
3. Electricity market reforms. While not a strictly necessary criterion for synchronisation, technical synchronisation with Europe will be simpler if also the market structures are aligned.
4. To be allowed to export significant electricity volumes on the EU market, Ukraine will need some form of carbon pricing in its electricity sector.
5. Decoupling from the former Soviet electricity system (IPS) will have negative technical, economic and political implications for Belarus and Russia. To avoid a backlash, these effects need to be considered and managed.

Despite the difficulties, there are strong arguments for Ukraine to put political momentum behind the synchronisation initiative:

1. In the case of synchronisation, Eastern Europe's power sector emissions would fall by 18%, or by 14 Mt/year. However, only if Ukraine like the EU puts a price on carbon.
2. New balancing and frequency control technology would save Ukrenergo billions of EUR, estimates the World Bank.
3. Ukraine would no longer rely on the Russian Federation for balancing and frequency control.
4. Curtailment in Eastern Europe, including Ukraine, would fall by 3.6% in the case of synchronisation. These 3.6% represent a value of more than EUR850 million.
5. Lower prices for consumers due to integration benefit consumers more than they hurt producers, while more cross-border electricity flows mean more rents for TSOs.

While benefits outweigh the costs by far, considerable political will is necessary to achieve integration. It concerns many different layers of government, such as the ministries of energy, finance and foreign affairs, the transmission system operator Ukrenergo, private electricity generators, as well as international agencies such as the Energy Community, and ENTSO-E. Synchronisation can only happen if the entire Ukrainian government is committed to synchronisation, and vehemently pushes for it in its internal and international political dealings.

Challenges	Benefits
Lack of balancing and frequency control capabilities Need for new cross-border transmission lines to Continental Europe Electricity market reforms. Political relations with Russia might deteriorate, as Russia faces costs of decommissioning and loses influence	In the case of synchronisation, Eastern Europe's emissions would fall by 18%, or by 14.2 Mt/year New balancing and frequency control technology would save Ukrenergo billions of USD Curtailment in Eastern Europe, including Ukraine, would fall by 3.6% Ukraine would no longer rely on Russia for balancing and frequency control. Lower prices for consumers

Status Quo

Switching the Ukrainian grid from the Russian IPS to the European grid requires major efforts

Integrating the entire Ukrainian electricity system into the Continental European synchronous grid will be a major step. Currently, Ukraine is split in terms of its electricity system. A relatively small western area bordering Slovakia, Hungary, Romania and Poland is already synchronised with the Continental Europe power system [35]. This area is called the Burstyn Energy Island (BEI). In 2017, the BEI had 650MW of single-circuit transmission capacities to neighbouring ENTSO-E States. However, the largest part of Ukraine, including the temporarily occupied areas, is synchronised with the integrated power system (IPS) of the former Soviet republics, which also includes Belarus, Moldova, Russia, and the Baltic States. Synchronisation of Ukraine's main system with the Continental Europe power system in the next decade would inevitably imply de-synchronisation from the IPS (UCTE and TEN-E, 2008). In the long run it might be feasible to synchronise the Russian IPS and the European grid, but this option would require deep political shifts that are currently not conceivable. Given the context, costs and benefits of synchronisation need to not only be assessed on an economic and technical, but also on a political level.

Political will in Ukraine supports synchronisation with the European grid

Synchronisation has been discussed for a long time. In fact, Ukraine and Moldova already applied for it with ENTSO-E´s predecessor in 2006. But with the changes in geopolitical orientation after both the Euromaidan and Russian aggression, integration into the European grid has gained relevance. Meanwhile, the Ukrainian grid has also become more suitable for integration, due to the gradual implementation of the EU's Acquis Communitaire in Ukraine's energy sector (Energy Community Secretariat, 2020b), and Ukraine's electricity market reform of 2019[36].

2017: Ukrenergo signs Connection Agreement with ENTSO-E → needs to fulfil legal, regulatory, market and technical requirements

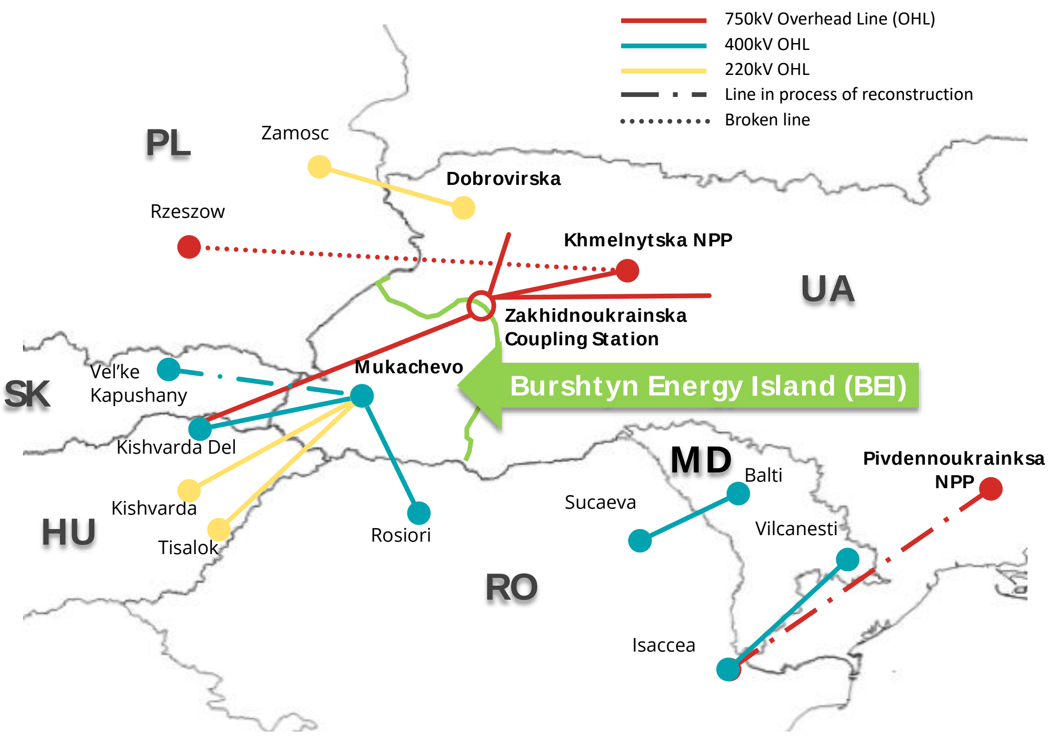
Thus, in 2017 the Ukrainian Transmission System Operator (TSO) Ukrenergo signed a Connection Agreement with the Moldovan TSO Moldelectrica and ENTSO-E, called "Agreement on the Conditions for Future Interconnection of Power System of Ukraine with Power System of Continental Europe with Ukraine's Ukrenergo and Moldova's Moldelectrica" (Energy Community Secretariat 2020). The agreement

[35] Burshtyn Thermal Power Plant (2,400 MW), belonging to DTEK Zakhidenergo (4,700 MW in total)

[36] E.g. as part of Ukrenergo's corporatization, its ownership was transferred from the Ministry of Energy and Environmental Protection (MoEEP) to the Ministry of Finance. In 2019, it became a private company. However, the MoF still holds all its shares.

contains, inter alia, a catalogue of legal, regulatory, market and technical requirements to enable accession to the synchronous European grid within a set timeframe of 6 years.

Figure 50: Transmission lines between Ukraine, Moldova and neighbouring European states (European Commission 2018, Ukrenergo 2019b)



Background info

How does synchronisation with the continental European grid work?

Ukraine and Moldova are not the first countries to seek synchronisation with the Continental European grid. Turkey did so in 2015, and the Baltic States Estonia, Latvia and Lithuania are currently also in the process of integration. All applicants go through a predefined series of integration steps:

Phase A

First, the applying TSOs (in this case Ukrenergo) seek the support from other European TSOs to apply at ENTSO-E for synchronisation with the Continental European grid. Most relevant is the support of neighbour states' TSOs. After the application, ENTSO-E prepares a feasibility study. In the case of Ukraine, such a feasibility study has been available since 2016. For more details, please see the next chapter.

With the feasibility study comes a "Connection Agreement", outlining the necessary steps the applicant needs to take in order to be able, and allowed, to synchronise its grid with Continental Europe´s. It is signed between the requesting party, ENTSO-E, and the majority of European TSOs.

Phase B

This is the phase Ukraine currently finds itself in. It consists of implementing and monitoring the technical and organizational measures in the applicants' systems, as stated in the Connection Agreement.

Phase C

Before the final synchronisation, the applicants' systems need to run an extensive set of tests, both in isolated and inter-connection modes, to see whether they are fit for integration. Key indicators are balancing capabilities, market functioning, sufficient power reserves and regulatory independency.

Synchronisation

The final step begins with an extensive interconnection trial operation, after which – if successful – the applicants sign a long-term agreement (LTA) with ENTSO-E. Upon signature of the LTA, the synchronous operation is permanent.

The LTA's main goal is to ensure that the TSOs maintain their compliance with the operational rules of the synchronous area (i.e. ENTSO-E's Operation Handbook) and with the grid connection codes, market guidelines and system operation code of the Third Energy Package (Network Codes, EU regulation (EC) 714/2009).

Challenges for synchronisation

De-synchronisation from the IPS and synchronisation with the Continental European power system requires thorough preparation. Especially, since in 2016 ENTSO-E's feasibility study indicated a number of shortcomings. It found problems relating to (1) the Ukrainian electricity sector's operational capabilities such as balancing, communication and ancillary services, (2) the way the sector is regulated and organized, as well as to (3) its cross-border transmission network (Bolborici, Zachia and Lazaroiu, 2016).

Main issues: Secure operations, efficient market regulation, and cross-border transmission

The original Connection Agreement, signed in 2017, planned complete synchronisation between Ukraine and the Continental Europe power system to be implemented already in 2023. In a recent study however, the World Bank found this objective to be optimistic (World Bank, 2020).

Full synchroni-sation by 2023 is extremely ambi-tious

While synchronisation faces challenges, the benefits of integration prevail. To understand the effects, we undertook a cost-benefit analysis of Ukrainian synchronisation with the European power grid, modeling the effects of interconnection on key indicators such as curtailing volumes, trans-border electricity flows, producer and consumer surplus, as well as greenhouse gas emissions. For this purpose, we assumed that the BEI will be connected to the Ukrainian IPS, either under a complete synchronisation of Ukraine with the Continental European power system, or just via a Back-to-back (B2B) connection between the BEI and the rest of Ukraine. Such a solution is already gaining support to bridge the time until complete synchronisation (World Bank, 2020). For existing connections, please see Table 14 and Figure 50.

A B2B connection with the BEI is already in discussion. We therefore disregard the possibility of the BEI not being connected to the IPS in the near future.

Table 14: Number of existing cross-border transmission lines to Ukraine's neighbours, by voltage class

Ukraine to…	750 kV	400 kV	330 kV	220 kV	110 kV	45 kV
Poland	1 (IPS, in need of refurbishment)	-	-	1 (IPS)	-	-
Slovakia	-	1 (BEI, getting re-established)	-	-	-	1 (IPS)
Hungary	1 (BEI)	1 (BEI)	-	2 (BEI)	-	-
Romania	1 (IPS, getting re-established)	1 (BEI) 1 (MLD)	-	-	-	-
Moldova	-	-	7 (IPS)	-	11 (IPS)	-

BEI = connecting the Burstyn Energy Island to other States
IPS = connecting the Ukrainian IPS to other States
MLD = connecting Moldova to other States

Source: (European Commission 2018, Ukrenergo 2019b)

The process of integration is coupled with numerous difficulties and large needs for investment. Yet, Ukrenergo, the main responsible for bringing Ukraine's electricity grid up to European speed is determined to synchronise. It expects great benefits from being part of a network promising a *"single legislation base, unified tech standards, market pricing, free interstate trade, and distributed contribution to the system´s stability"* (Ukrenergo, 2018). Overall, Ukrenergo estimates benefits of EUR1.2/1.3 billion per year, compared with costs of EUR352 million (Ukrenergo, 2020a). This might however be a too low estimate, as we analyse in chapter IV.

Ukrenergo is optimistic, sees benefits in market structure, in supply security & stability, and in cost-saving

Due to the large benefits of integration and the high political stakes at play, synchronisation would profit strongly from political support in the highest ranks of the Ukrainian government. An important first step was the adoption of Ukrenergo's "Synchronisation Plan" by the Ukrainian Cabinet of Ministers, which outlines the key steps to take until synchronisation. This plan, however, is not public (Ukrenergo, 2019a)

I. Improving operations: Balancing, ancillary services, and communications[37]

To ensure that a country´s system can contribute to the security of the European system, it needs to (1) prove its ability to independently balance its own electricity system, as well as (2) ensure being able to absorb potential fluctuations entering from other parts of the integrated system. If the joining system would return such fluctuations or even amplify them, this could cause systemwide problems.

Most crucial for synchronisation: To overcome Ukrenergo's frequency damping problems

As a 2016 feasibility study by ENTSO-E explains, low Ukrainian frequency control capabilities could potentially lead to rolling blackouts across Europe, if not addressed before an integration (Bolborici, Zachia and Lazaroiu, 2016). Due to a lack of power stabilisation capabilities at Ukrainian thermal power plants, a sudden loss of 1GW generation in Spain could lead to escalating frequencies all across the European grid (see Figure 51). However, the exact severity of shortcomings and investment needs is difficult to establish, as none of the highly technical studies is public.

Overcome frequency problems with damping technology, and sufficient reserves

In general, investments in both hardware and software could help overcome the network challenges. For instance, more reserves would improve both (1) and (2). Currently, Ukraine´s reserves are not sufficient. However, as Ukrenergo has certified several hydro power plants for the provision of balancing reserves, USAID and Tetra Tech estimate that enough reserves will soon be available (Tetra Tech, 2020).

To Do: install balancing and demand-forecasting technology

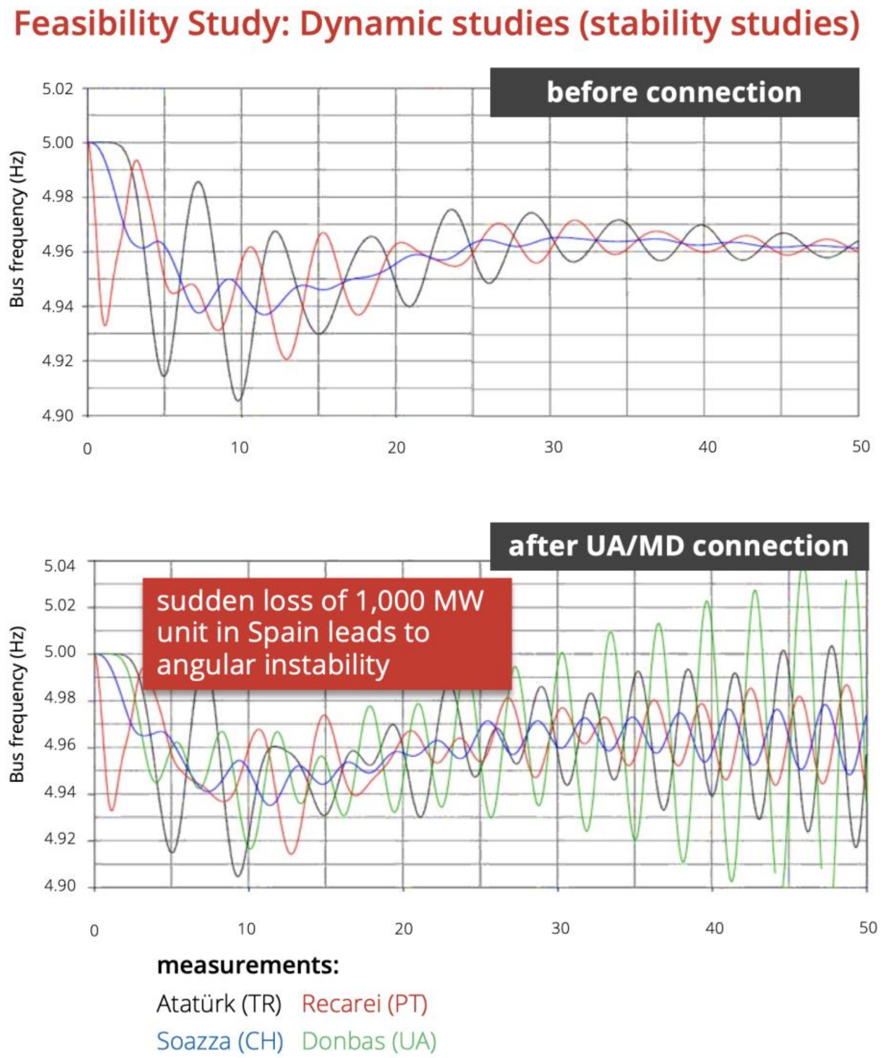
A better demand-forecasting system would similarly benefit Ukraine on both fronts. Additionally, such a system would save Ukraine USUSD11.5 billion of future investment needs (World Bank, 2020). Ukrenergo could apply the DAKAR software, which is already being used in the BEI (Kovalchuk, 2019).

To Do: Data collection and sharing: e.g. on network security, voltage, congestion, and reactive power management

Another important issue is the collection and sharing of data on electricity demand and supply forecasts, as well as of actual generation and consumption. Exchanging data with neighbouring countries would strengthen Ukraine's ability to absorb the EU network's fluctuations (2). Besides the establishment of data centres, the 2016 feasibility study also recommends Ukraine to establish a reliable communication network between the TSO and generators, to control the dispatch of electricity in a timely manner (Bolborici, Zachia and Lazaroiu, 2016).

[37] For a more extensive version of this chapter, please refer to chapter 0 in the Appendix.

Figure 51: Balancing Problems (Transelectrica, 2019)



A successful implementation of up-to-date damping technology is not unlikely. Ukrenergo is already participating in an EU awareness system for data-sharing (ENTSO-E, 2020b), and is adopting EU regulation on congestion management methodologies (Nitsovych, Serebrennikov and Mykhailenko, 2020). This assessment is underscored by an ongoing feasibility study of Ukraine's frequency control capabilities, using new balancing and frequency data from 2019, by USAID and UHE (World Bank, 2020).

Success not unlikely, due to ongoing efforts in Ukraine and international support

II. Basic regulations mandating TSO operation[38]

The role of ENTSO-E: connecting European TSOs, creating and implementing network codes

ENTSO-E's Network Codes are mandatory for EU Member States: (1) market codes, (2) operation codes, and (3) grid connection codes (so far, only (3) mandatory for Ukraine)

ENTSO-E, the "European Network for Transmission System Operators for Electricity", was established in 2009 by the EU's Third Legislative Package for the Internal Energy Market (Regulation (EC) 713/2009). It is an association of 42 TSOs from 35 countries across Europe, extending beyond the EU. ENTSO-E drafted eight Network Codes, which are legally binding for all EU member States, as well as for members of the Energy Community, of which Ukraine is a contracting party (Energy Community Permanent High Level Group, 2012; Energy Community Secretariat, 2018). However, the EnC has so far only adopted the three grid connection codes (please compare Table 15).

Table 15: EU Electricity Network Codes and Guidelines

Market Codes	System Operation Codes	Grid Connection Codes
Capacity Allocation and Congestion Management Guideline (CACM GL)	Electricity Transmission System Operation Guideline (SO GL)	Network Code on Requirements for Grid Connection of Generators (RfG NC)
Forward Capacity Allocation Guidelines (FCA GL)	Emergency and Restoration (ER NC)	Demand Connection Network Code (DC NC)
Electricity Balancing Guideline (EB GL)		Requirements for Grid Connection of High Voltage Direct Current systems and direct current-connected Power Park Modules Network Code (HVDC NC)

Most crucial for synchronisation: compliance with operational rules

TSOs can reject Ukraine's bid for synchronisation in case of balancing and frequency issues – as in 2016 feasibility study.

As ENTSO-E´s member TSOs have the final say over whether Ukraine is allowed to synchronise with the European grid, they may reject Ukraine´s bid for integration despite political will in the EU to pursue it. They will definitely not allow synchronisation if Ukraine does not comply with operational rules. Further, the TSOs will carefully assess any deviations from other Network Codes (please compare chapter I).

Looking beyond operational security, Ukraine has further room for improvement. The Energy Community regularly criticises Ukraine for not fulfilling its market regulations and for political circles to rule into the electricity markets. Recently, it refused to certify the independence of Ukraine´s regulator NEURC (Kopač, 2020). Any step closer to the Energy Community would be a step closer to European regulations, and thus one step closer to synchronization.

Compare also LCU´s policy paper on electricity markets by Alex Mykhailenko

For further analysis of Ukraine's electricity markets, and thus its implementation of the Network Codes not relating to operational security, please have a look at LCU's **4. Reforming Ukraine's electricity market**.

[38] For a more extensive version of this chapter, please refer to Annex.

III. Transmission lines

The European Union and ENTSO-E demand from their parties to have cross-border transmission capacities with neighbouring ENTSO-E States equaling 10% (2020) or 15% (2030) of their total installed generation capacity (ENTSO-E, 2016; European Council, 2020). Ukraine went one step further and in its *Energy Strategy 2035* plans to achieve 15% interconnection by 2025 already (Szabó, Mezősi and Kácsor, 2020). (For an overview over all currently existing connections between Ukraine and ENTSO-E, please compare Table 14 and Figure 50).

The EU demands from its parties to have interconnect-tions of 10% by 2020 and 15% by 2030

Since in April 2020, Ukraine's total installed generation capacity reached 53.6 GW (Nitsovych, Serebrennikov and Mykhailenko, 2020), 10% interconnection would entail transmission lines to Hungary, Moldova, Poland, Romania and/or Slovakia of around 5.4 GW, while 15% would require 8 GW of transmission capacity. Ukraine is still far from achieving these levels. Currently, it has a 0.7 GW connection to Moldova, while the Burstyn Energy Island possesses additional 0.7 GW of single-circuit capacity, and there is one small interconnection between the Ukrainian IPS and Poland (0.2 GW). Larger lines connect the Ukrainian market with Russia and Belarus, but are in low use due to political turmoil (NEURC, 2018). Total electricity flows in and out of the country hardly ever exceed 1.5 GW. This level was reached last in March 2020 (Ukrenergo, 2020b).

Ukraine needs ca. 4 GW of additional transmission capacity to fulfill the 10% goal

While Ukrenergo still emphasises the need to synchronise with the Continental European grid by 2023, it is realising that time is running short. It thus proposes to build a Back-to-back connection via an AC-DC-AC converter station with the Burstyn Energy Island by 2023, to quickly enable the benefits of integration. Currently, Ukrenergo intends to build a 600MW connection. It aspires to build the interconnection in just two and a half years, at costs of USUSD150 million. It expects gains of USUSD150 million already in the first year of operation (Kosatka Media, 2019). A World Bank study from 2019 finds the project to entail great benefits for Ukrainian load-balancing capabilities and power quality, and therefore proposes to fund it via the International Bank for Reconstruction and Development. However, the World Bank expects a cost of USUSD224 million (World Bank, 2020) (please also compare chapter IV on the costs of synchronisation).

To quickly benefit from interconnect-tion without sync, a B2B station between BEI and Ukraine could be helpful and quickly recover costs

A further project is the rehabilitation of a 750 kV line connecting Ukraine with Poland, the so-called "Rzeszow – Khmelnytska" line with a capacity of 1.3 GW (*Poland's international power connections*, 2012). It was decommissioned in 1995, when Poland synchronised with the Continental European grid and thus was not synchronised with the Ukrainian network any longer. Energoatom would like to refurbish the line, in order to export electricity from the Ukrainian Khmelnitsky Nuclear Power Plant to Poland. The line would thus run in synchronisation with the Polish, and therefore the European grid. This project, called "Energy Bridge", was also assessed as beneficial for damping and demand balancing by 2016´s feasibility study. However, in a letter to the then-acting Ukrainian Minister of Energy and Environmental Protection Vitalii Shubin in April 2020, the Polish government saw "no compelling value in this undertaking", especially not for Polish electricity consumers (Naimski, 2020). Ukrenergo is equally opposed to the new connection, since it doesn't see any value of only exporting electricity from one power plant (Ukrainian Energy, 2019).

The "Energy Bridge" from Ukraine to Poland – rejected by the Polish government

Ukrenergo is pushing two other projects of transmission, both of which are considered 'Projects of Mutual Interest' (PMI) (European Commission, 2018), in line with the 'Trans-European Networks for Energy Regulation' (European Parliament and European Council, 2013), aiming to foster the construction of cross-border transmission capacity in Europe. First, it endeavours to rehabilitate a 400kV line between Mukacheve in Ukraine and Kapusany in Slovakia and second, to revive and modernize a 750 kV line between the Pivdennoukrainska Nuclear Power Plant in Ukraine and Isaccea in Romania. Being accepted as a PMI by the Energy Community does not necessarily bring financial benefits but fosters cooperation by the States crossed by the transmission line. Judging by the capacity of similar lines, these two projects might add around 1.5-2 GW of cross-border transmission capacity to the Ukrainian grid.

Projects of Mutual Interest: The EU supports new Ukrainian cross-border trans-mission lines

4.3 GW of lines between Ukraine and Russia, and Belarus would need to be dismantled

It must further be taken into account that in the case of synchronisation with the Continental Europe power system the 17 transmission lines to Belarus and Russia, representing 4.3 GW of connection capacity might need to be decommissioned or combined with Back-to-back converters, a potentially time-consuming and expensive process (Energy Community Secretariat, 2019). The costs in this case would not only be borne by Ukraine, but also by Belarus and Russia.

Ukrainian regulators have understood the need to improve and extend transmission capacities. In this regard, NEURC approved Ukrenergo's Transmission System Development Plan for 2020-2029 in March 2020, aiming to enhance cross-border connections. The total cost projection sums up to EUR2.3 billion, of which around EUR300 million are supposed to go to cross-border projects, and which is supposed to be funded mainly by international financial institutions like the EBRD, the EIB, the KfW, etc. (Ukrenergo, 2019b; Nitsovych, Serebrennikov and Mykhailenko, 2020).

Additional regulatory changes necessary to make use of interconnections and participate in EU markets

However, this transmission capacity will be of most value to Ukraine if the country manages to take part in international markets. To achieve this, Ukraine would need to implement the regulations mentioned in chapter II. Using international markets as emergency suppliers in moments of high demand will, for example, only be possible if the SAFA standards[39] for cross-border capacity allocation are respected and implemented (Kovalchuk, 2019). Ukraine gained first experiences with such capacity allocation procedures in 2017, when cheap electricity imports from Belarus and Russia were made possible, however only under one-year contracts (Szabó, Mezősi and Kácsor, 2020).

IV. Costs

Ukrenergo's cost assumptions are lower than in international comparison. Nonetheless, synchronisation would benefit Ukraine financially.

Beyond the precise effects for consumers and producers, Ukrenergo estimates that the monetisable benefits alone from synchronisation are worth more than EUR1 billion annually, while it estimates costs at around EUR352 million (Ukrenergo, 2017). In total, Ukrenergo sees costs for grid development at around EUR130 million, additional generation, as well as new balancing and damping technology similarly at EUR130 million, communication infrastructure for quick dispatch orders at EUR92 million, and additional feasibility studies to be in the range of another EUR5 million.

So far, it hopes to receive funds of EUR138 million from international financial institutions, and to pay EUR222 million itself (Kovalchuk, 2019). These numbers might be estimated too low, though. The World Bank, in a recent project assessment for the International Bank for Reconstruction and Development (IBRD) estimates alone the B2B interconnection between Ukraine and the BEI to cost at least USUSD224 million (ca. EUR191 million) (World Bank, 2020).

Transmission lines alone would likely cost more than EUR1 billion.
For one B2B station, Ukrenergo could build around 200km of 600 MW AC overhead lines.

Overall, Ukrenergo's estimates seem to be quite optimistic. Necessary transmission projects alone would cost Ukraine and its TSO more than EUR600 million. These costs arise when simply adding up the cost for two B2B stations (one already planned in the BEI and one additional station Ukraine might need to increase its transmission capacities, at EUR191 million each), Ukrenergo's own estimate for the cost of transmission lines to Romania and Slovakia of EUR226 million and EUR17 million respectively (REKK, 2016; Ukrenergo, 2019b), and the costs of re-establishing the 750kV line to Poland (which we use as a proxy for the costs of a similar line which Ukraine would need to build/rehabilitate) of EUR4 million according to Ukrenergo. The latter are however a stark underestimate according to the Energy Community's experts (REKK, 2018). They instead foresee costs of around EUR240 million for the line to Poland. Summed up, one arrives at costs for

[39] Refers to the ´Synchronous Area Framework Agreement´, to which Ukraine submitted in the Connection Agreement of 2017. SAFA is mandated by ENTSO-E's Network Code on System Operation, article 118. It is a contract between all its member TSOs and regulates cross-border load-frequency control and reserves (European Commission, 2017).

transmission infrastructure alone of EUR629 million, even when disregarding the Energy Community´s higher estimate for the Polish connection.

According to Ukrenergo, not all of these projects are necessary for the possibility of synchronisation. Yet they are, if Ukraine would like to follow through on its own commitments of 15% interconnection by 2025, or EU regulations demanding 15% interconnection by 2030 (please compare previous chapter III).

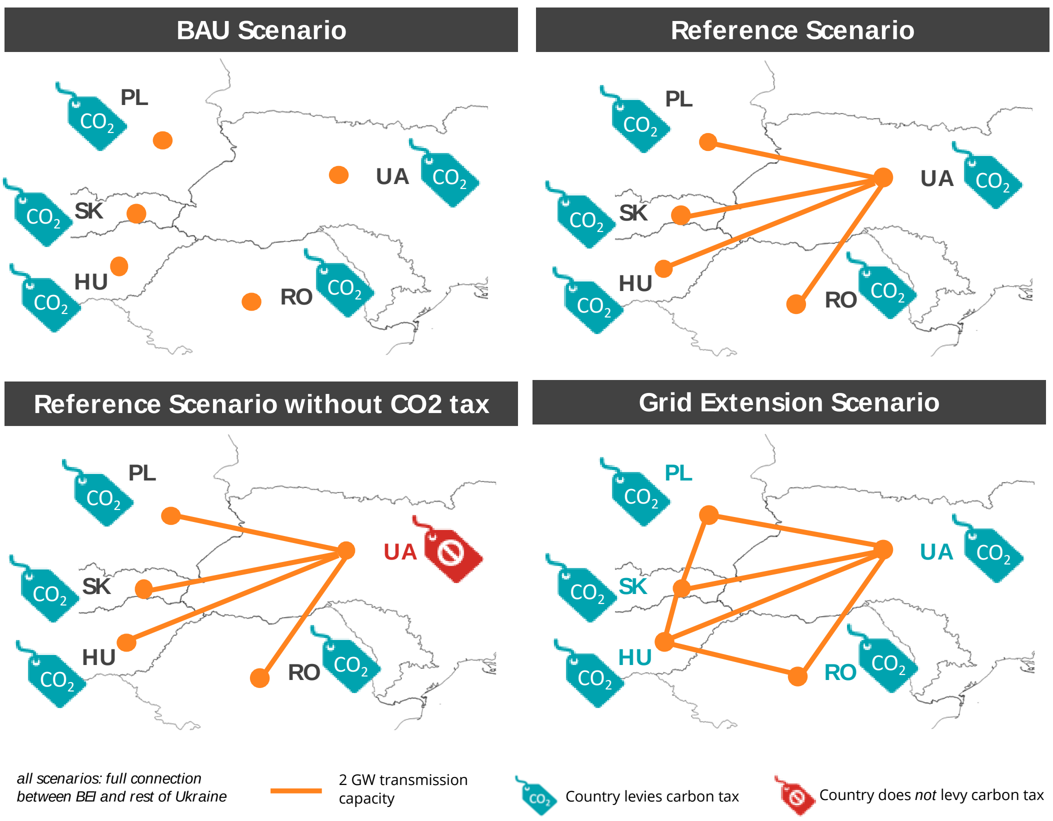
B2B stations furthermore are expensive. For the envisaged EUR191 million, Ukrenergo could build around 180 km of a 400 kV, AC, double-circuit overhead line (REKK, 2016).

Assessment: Effects of Network Synchronisation

This paper assesses 4 different scenarios comparing the effect of different levels of interconnection between Ukraine and its neighbours

In order to compare the integration of the Ukrainian electricity grid with Continental Europe, we modelled four scenarios of possible future developments of cross-border transmission capacities. In all scenarios, the BEI and the rest of Ukraine are well-connected and can be counted as one network node. In the business as usual (BAU) scenario, Ukraine´s grid is separated from its European neighbours. We then modelled one reference scenario, with 2GW of transmission capacities between Ukraine and each of its neighbouring countries ("Reference scenario"). In an additional scenario, we hold everything equal to the Reference scenario, but assess the effects of what happens if Ukraine does not introduce a price on carbon. Fourth and lastly, we modelled a "Grid Extension scenario" with 2GW of transmission capacities between all countries. More details can be found in the Annex and in Figure 52. According to already existing cross-border transmission capacities between Ukraine´s neighbouring States, the 2GW are a reasonable assumption (ENTSO-E, 2020c). For the development of fuel prices, GDP and demographics, we chose assumptions also taken in Ukraine´s draft NDC scenario 2.

Figure 52: Transmission Capacities of the four scenarios



We will present the resulting effects of a synchronisation along the five pillars of the European Energy Community, to which Ukraine is a party: (I) Energy security, solidarity and trust, (II) a Fully integrated internal energy market, (III) Energy efficiency, (IV) Climate action – decarbonising the economy, and (V) Research, innovation and competitiveness.

I. Energy security, solidarity, and trust

Synchronisation with the Continental Europe power system would lower Ukrainian dependence on Russian balancing services

Security of electricity includes both political, and technical elements. Currently, Ukraine's electricity system is synchronised with the Russian and Belarussian grid. In this context, Ukraine relies on Russian balancing and frequency damping capabilities, as well as on Russian coal for Ukrainian thermal power plants (World Bank, 2020). In light of current geopolitical tensions, Ukraine is in a weak spot should the Russian Federation choose to make use of this dependency. Energy independence thus is part of Ukraine´s sustainable development strategy "Ukraine – 2020", as well as of Ukrenergo's reform strategy 2017-2026 (Ukrenergo, 2018). Additionally, Ukrenergo perceives integration with the European Union's grid to offer the advantage of a single legislation base, grid balancing support and access to additional energy emergency reserves. However, de-coupling from the Russian PIS will in the short-term worsen balancing services in Ukraine, and the risk remains that Russia will politically retaliate against this further integration of Ukraine into the European realm[40]. Even beyond political concerns, Russia also has reason to protest against the de-synchronisation due to the unsolicited costs for the Russian system. Russia would have to either decommission the lines on its side, reconnect them internally to close the lines´ electric circuits, or build B2B stations.

After synchronisation lower need for primary reserves in Ukraine, due to higher security of supply

On the technical side, Ukrenergo estimates that integration with the European grid, and the ensuing modernisation, will enhance reliability and security of its electric supply, lowering the need for primary reserves by approximately 140-160 MW compared to business as usual (Ukrenergo, 2018). It further expects improved grid resilience and options for mutual assistance with Europe due to non-simultaneous peak hours for electricity demand.

II. A fully integrated internal energy market

Cross-border trade in electricity would grow from USUSD250 million to USUSD1.5 billion a year

While integrating Ukraine's transmission lines would be beneficial for the European grid, as Ukrainian transmission lines would improve the connection between northern and southern Europe, Ukrenergo expects cross-border trade in electricity to increase almost fourfold from currently 4-5 billion kWh/year (representing approximately EUR213 million) to 18 billion kWh/year (EUR1.28 billion) (Ukrenergo, 2017). LCU's 'Grid Extension' scenario even projects cross-border flows of more than 30 billion kWh/year (compare Figure 55).

III. Energy efficiency

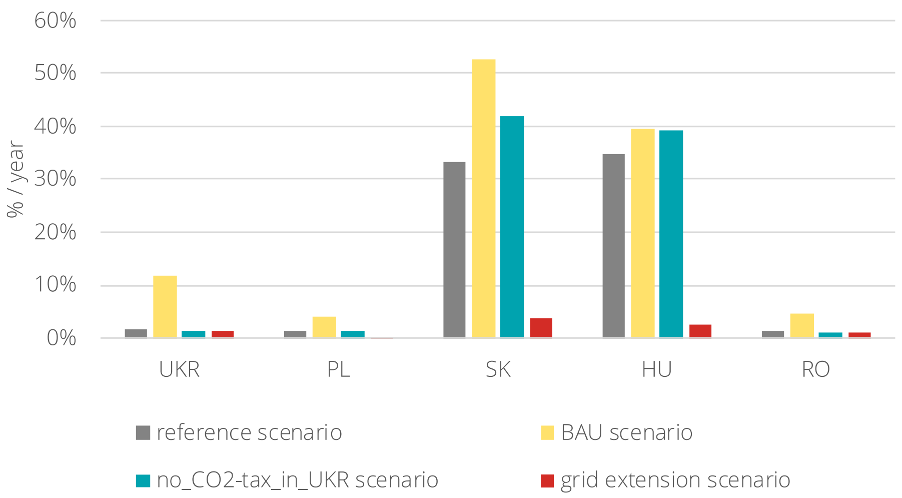
Ukraine and its neighbours would face far lower curtailment rates in the case of synchronisation

Adopting the Energy Community's market standards would also mean the end of subsidized electricity prices for consumers, thus improving investment incentives for the right times and the right locations, as prices would rise in times of real scarcity. As Ukrenergo expects trade to increase by four times, rapid and frequent cross-border flows would also allow to use generation capacities more efficiently, especially since Ukrainian and European peak demand hours do not coincide (Ukrenergo, 2018). As our model shows in Figure 53, necessary curtailment of electricity sources due to grid congestion or imbalances would therefore

[40] Not being connected to the Russian IPS might reduce costs for Russia to launch cyberattacks on Ukraine's electricity system. Meanwhile, higher standards and grid modernization stemming from the synchronisation can offset this risk for Ukraine.

shrink in an integrated scenario, compared with business as usual. In our grid extension scenario, this would benefit all States, but especially so Slovakia and Hungary, who suffer high curtailment needs. In absolute terms, Ukraine would benefit even more, since 10% curtailment in Ukraine correspond to more TWh (3.6 TWh, worth ca. EUR230 million) than 52% in Slovakia (1.7 TWh) or in Hungary (2.5 TWh), since Ukraine´s total electricity consumption is so much larger.

Figure 53: Electricity curtailment rarely required under grid extension scenario

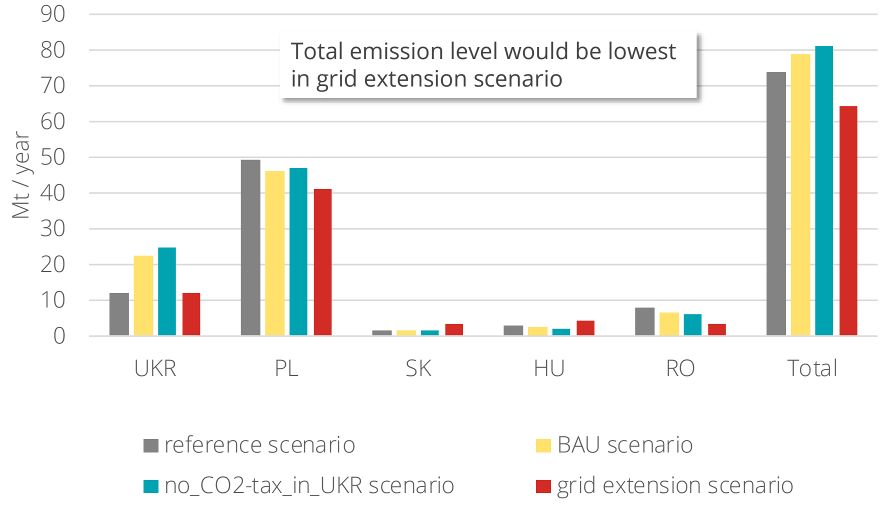


IV. Climate action – decarbonising the economy

Synchronisation would lower emissions substantially, but only if Ukraine also implements a carbon tax

As curtailment reaches its lowest levels, so would Ukrainian greenhouse gas emissions. However, only if Ukraine couples its integration into the European electricity markets with a price on carbon. In the politically hardly realistic case that Ukraine would be allowed to trade electricity with EU countries without being forced to implement a substantial price on carbon, electricity production from neighbouring countries would be replaced by Ukraine's old coal power plants, which is reflected in our scenario without a carbon tax. This would result in even higher emissions than in the case of a continuation of business-as-usual policies. Nonetheless, if Ukraine does introduce a carbon tax of around EUR35 per tonne of CO_2 equivalents, both Ukraine and its neighbouring countries would be more likely to fulfil their international commitments in the fight against climate change. Integration into the Continental Europe power grid would also be beneficial for all countries' emission balances, as the higher flexibility stemming from cross-border balancing transfers lowers the need for base-load coal and gas plants. Compared to the reference scenario, overall emissions from thermal power plants would be down by 12.9% relative to the reference scenario in the case of the grid extension scenario. On the other hand, if the grid is extended, but Ukraine does not introduce a carbon tax, emissions will rise by 9.4%. Please find absolute results in Figure 54.

Figure 54: Emission in Mt/y (from TPPs)



V. Research, innovation and, competitiveness

Ukrenergo projects that integration with Continental Europe would increase liquidity and competition in Ukraine's wholesale market (Ukrenergo, 2018). In our most ambitious scenario 'Grid Extension', imports would make up 15.4% of total electricity consumption in Ukraine by 2030 (please compare Figure 55).

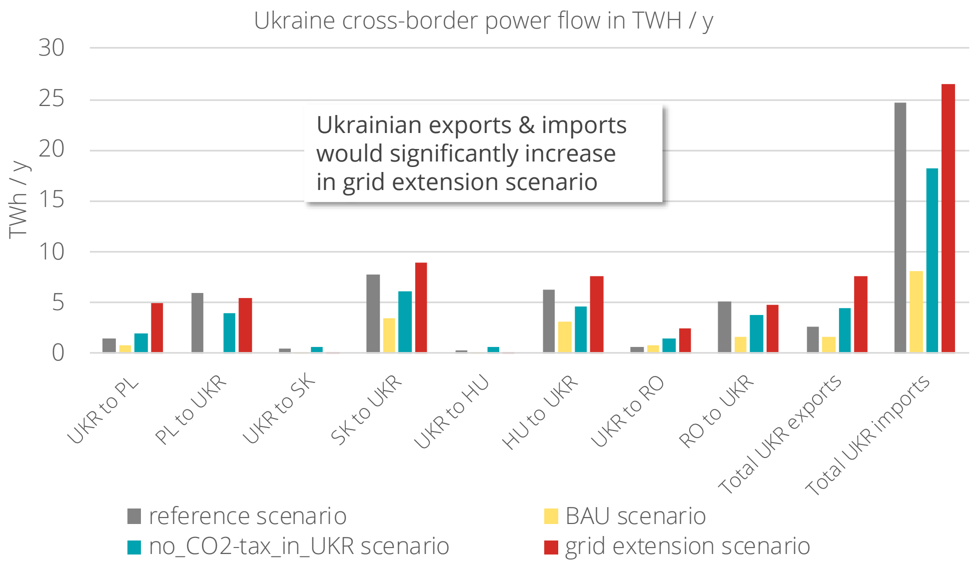
Synchronisation would benefit mainly Ukrainian consumers, and Ukrenergo but not Ukrainian producers. The latter would lose profits to foreign competitors, explaining incumbents' opposition to synchronisation.

In our "reference" scenario opening up cross-border transmission would thus **increase consumer surplus by EUR0.9 billion, and the transmission system operator's congestion rent by EUR0.3 billion,** compared to a "business as usual" development with no connections. However, producer surplus would shrink, as competition from neighbouring countries would eat away profits. In their analysis of cross-border transmission lines between Ukraine and its neighbours, the Energy Community's experts expect even higher benefits for transmission operators and consumers when assessing the lines' benefits (REKK, 2020).

Cancelling the CO_2 tax would have an even larger effect on producer surplus. It would lower producer surplus by more than USUSD3.9 billion in comparison to the connected reference scenario with a price for carbon, as generators lose their windfall profits. However, overall Ukrainian welfare does not decrease, as gains in consumer surplus and congestion rents would more than offset the producer's losses. Consumers would benefit from lower prices, but due to the international competition also from better service quality and higher energy security, as generators compete for customers. In effect, Ukraine would become a net importer of electricity (please compare Figure 55).

Besides fostering competition, Ukrenergo also forecasts higher investment attractiveness for the Ukrainian electricity sector, due to less curtailment and a both well-known and stable regulatory environment. According to the TSO, the additional investments would benefit especially renewable energy sources, leading to a diversification of the national energy mix (Ukrenergo, 2018).

Figure 55: Ukrainian exports and imports under different scenarios



Conclusion: Benefits of synchronisation surmount

Ukraine would benefit from an integration into the Continental European grid. While for a successful synchronisation, it still faces challenges such as the need to install frequency-damping technology, implement data-gathering and dispatch control mechanisms, and establish new transmission lines to neighbouring countries, the costs are more than offset by the potential gains.

These gains would materialise first and foremost for consumers, benefitting from cheaper electricity and better services, due to international competition, but also by the environment, which would see significantly lower total emission levels in Eastern Europe. Also, the transmission system operators would gain from higher congestion rents, and generators would face less curtailment. Additionally, Ukraine would be connected to the EU's internal energy market, benefitting the EU via better north-South connections, and Ukraine via clearer regulations and access to new and secure emergency electricity supply.

As benefits thus outweigh the costs by far, considerable political will is necessary to advance the project of integration. It concerns many different layers of government, such as the ministries of energy and finance, the transmission system operator Ukrenergo, private electricity generators, as well as international agencies such as the Energy Community, and ENTSO-E. Synchronisation can only happen if the entire government is committed to overcoming the challenges this report has presented and vehemently pushes for synchronisation in its internal and international political dealings.

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Annex

I. Model assumptions

Table 16: Different scenarios and their respective assumptions

	BAU scenario	Reference scenario	Reference Scenario without CO_2 tax	Grid Extension scenario
JRC-data for Electricity demand in 2030 used	✓	✓	✓	✓
Burshtyn Electricity Island connected with the Ukrainian grid	✓	✓	✓	✓
2 GW transmission capacity between Ukraine and each of its neighbours		✓	✓	✓
Ukraine puts a price on carbon	✓	✓		✓
2 GW transmission capacity between all countries				✓

Transmission capacities

The model calculates optimal dispatch levels in 2030, comparing four scenarios: first, a business as usual scenario (BAU) with hardly any interconnection between Ukraine and its neighboring countries Hungary, Poland, Romania, and Slovakia. Second, we analyze optimal dispatch level in a reference scenario with 2GW transmission capacity between Ukraine and each of its neighbors. Third, we modeled the same scenario again, but without Ukraine levying a price on carbon, as it does in all other scenarios. We assumed this price to be EUR35 per ton of CO_2 equivalent emission, as it would be under the projected EU ETS price by 2030. Fourth and lastly, we modeled a "Grid Extension" scenario with 2 GW interconnections between all named countries (again with Ukraine putting a EUR35 price tag on emissions).

We found 2 GW interconnections to be plausible, as Ukraine has the goal to establish 15% transmission capacity relative to its installed generation capacity already by 2025 (15% interconnection are also the goal for all EU member States by 2030). In Ukraine's case, 15% correspond to overall levels of 8.04 GW transmission capacity. For a more in-depth analysis of International transmission lines, please refer to chapter 3.3.

Meanwhile, the Burshtyn Energy Island is assumed to be entirely connected with the Ukrainian main grid under both scenarios, also in line with Ukrainian plans and existing interconnectors. Moldova, another neighbor of Ukraine is however excluded from the model, as data from the country was scarce and not reliable.

Installed capacities, incl. reserve capacities

We acquired data on projected generation capacities for 2030 for Hungary, Poland, Romania, and Slovakia from the JRC Open Power Plants Database (Kanellopoulos K. *et al.*, 2019). This data base uses ENTSO-E data and cross-checks it with several other publicly available data bases. For Ukraine, we assumed the capacities projected by Scenario 2 of the NDC process ("Nationally Determined Contributions" under the Paris Agreement framework), which are currently still under discussion in the Ukrainian Ministry of Energy. The NDC scenario 2 projects a moderate but ambitious increase in RES from around 6GW (2020) to 15 GW (2030), as well as a feasible coal phase-out from 17 GW to 10 GW during the same time period. Total assumed generation capacities can be seen in Table 17.

We further assumed all countries to have sufficient reserve capacities in order to balance out their own electricity grids.

Table 17: Assumed generation capacity in 2030

Capacity in GW	Ukraine	Hungary	Poland	Romania	Slovakia
Total Generation	51	11	55	24	10
Thereof RES	15	4	22	11	3
Thereof Thermal	15	3	29	5	3

Demand structure and fuel prices/generation costs, incl. carbon taxes

We furthermore assumed relative fuel prices to stay constant, meaning that the relation between coal, uranium and gas prices would stay as they were in 2018/2019.

Meanwhile, we took demand projections for the year 2030 for Hungary, Poland, Romania, and Slovakia from the JRC Open Power Plants Database (Kanellopoulos K. *et al.*, 2019), just as the generation capacity projections.

The price on carbon levied on tonnes of greenhouse gas emissions in scenarios 3 and 4 we assumed to be at EUR35/tonne of CO_2 equivalent, in line with the EU´s Emission Permit System´s projections for 2030.

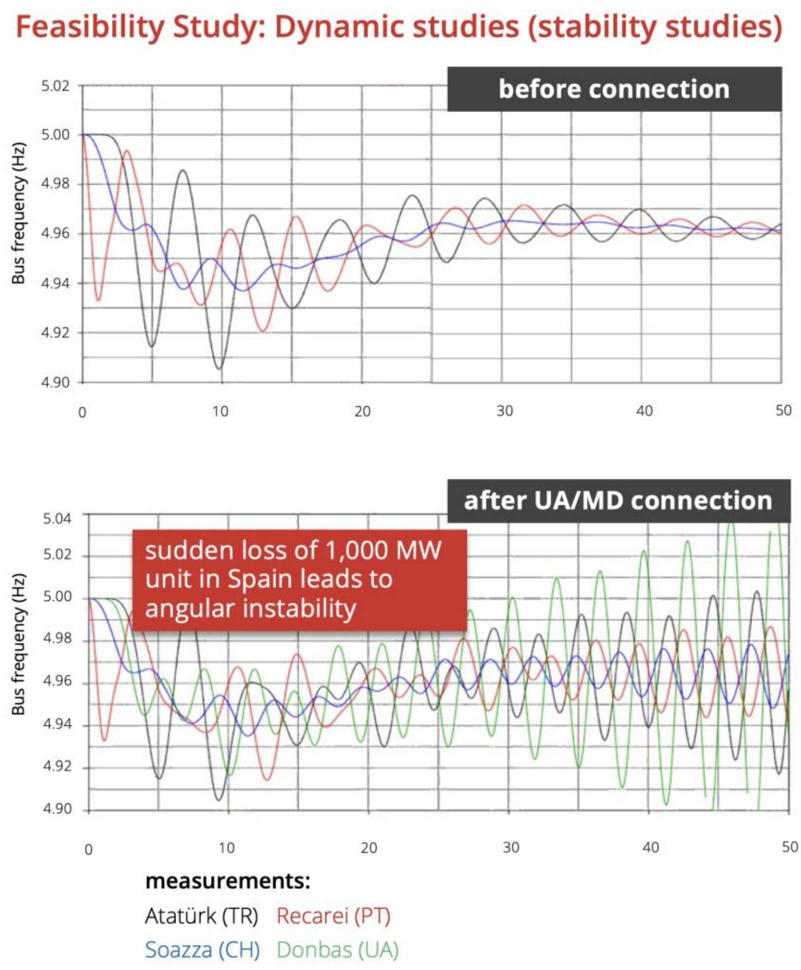
II. "Improving operations: Balancing, ancillary services, and communications", in detail

Most crucial for synchronisation: To overcome Ukrenergo's frequency damping problems

Arguably most crucial for the viability of Ukraine's bid to join the European power system, are the frequency balancing problems found by 2016's feasibility study. As the study explains, they could potentially lead to rolling blackouts across Europe, if not addressed before an integration (Bolborici, Zachia and Lazaroiu, 2016).

Especially Ukrainian electricity flowing into the EU posed a severe problem for the system's frequency in the simulations. Damping of the newly detected inter-area oscillation modes was very poor for winter peak and for summer off-peak scenarios. In the feasibility study´s model, oscillations strongly escalated after a sudden 1GW loss in Spain. The effects, including black-outs, and damaged machinery and power plants, would be felt across Portugal, Switzerland, Turkey, and Ukraine (Bolborici, 2019). For a graphic depiction of the escalating frequencies, please see Figure 56.

Figure 56: Balancing Problems (Transelectrica, 2019)



Overcome frequency problems with damping technology, and sufficient reserves

To ensure that a country´s system can contribute to the security of the European system, it needs to prove the availability of sufficient reserves, as well as of modern damping equipment at its power plants, and a well-administered dispatch steering and control system.

We assess the current level of Ukraine's balancing and ancillary reserves from the situation of its balancing and ancillary services markets. The immediate situation shows room for improvement, but recent developments promise beneficial changes in the near future. So far, only the balancing market has been implemented, as Ukrenergo's frequent price changes for ancillary services delayed the ancillary services market (Tetra Tech, 2020). Meanwhile, the balancing market has been off to an only partially successful start, since low supply often only provided 55% of the needed capacity for short-term load-increase or -decrease, granting the few suppliers large market power. (Szabó, Mezősi and Kácsor, 2020).

Balancing Market does not yet offer enough reserves for down- and upwards regulation

However, Ukrenergo has by now certified ten hydro power plants to offer their services on a future ancillary services market (Tetra Tech, 2020). USAID and Tetra Tech estimate that reserves will soon outpace demand for ancillary services. According to Ukrenergo, they even already do (Tetra Tech, 2020):

Ancillary services market not yet running, but certification of reserve capacities is ongoing and promising

- Frequency Containment Reserves (Primary): +-115 MW certified vs +-119 MW demand,
- Automatic Frequency Restoration Reserves (Secondary): +-724.5 MW vs. +-372 MW
- Manual Frequency Restoration Reserves (Secondary): 3,483 MW vs. 628 MW
- Restoration Reserves (Tertiary): 3,900MW vs. 1,000 MW

Additionally, the World Bank intends to finance up to five battery storage projects, in each case connected to renewable energy projects, that could contribute to a more liquid ancillary services market.

However, for balancing and ancillary services to become available, and thus help control frequency and load levels, TSOs first need to install and use balancing technology and a precision demand-forecasting system. According to the World Bank, in the case of Ukraine these systems would save the country USUSD13 billion and USUSD11.5 billion respectively, in terms of future investment needs for new power sources and other infrastructure (World Bank, 2020).

To Do: install balancing and demand-forecasting technology

Another important issue is the collection and sharing of data on electricity demand and supply forecasts, as well as of actual generation and consumption. Since March 2020, an EU energy support project for Eastern European States, EU4Energy, is helping Ukrenergo to implement systems to monitor and share congestion management data, and disaggregated generation data, translated into English (Bolborici, Zachia and Lazaroiu, 2016; Mykhailenko, Vereshchynska and Mukha, 2020). ENTSO-E also generally recommends all TSOs to share real-time calculations of network security, including data for voltage and reactive power management.

To Do: Data collection and sharing: e.g. on network security, voltage, congestion, and reactive power management

In order to profit from the damping equipment, as well as from the ancillary and balancing markets, TSOs also need a strong communication infrastructure. Only then can a TSO order (or prevent) the dispatch of electricity in a timely manner. 2016's feasibility study recommends Ukrenergo to install special protection systems, such as duplicate communication links (Bolborici, Zachia and Lazaroiu, 2016).

To Do: install communication infrastructure

Further, Ukrenergo deems it necessary to implement automatic 24-hour demand forecasting (Kovalchuk, 2019). For this, Ukrenergo could use the DAKAR software, which is already being used in the Burstyn island. 2017's Connection Agreement additionally requires Ukrenergo to conduct its operational planning on a yearly, monthly, weekly and daily basis in XML format, in order to be able to share it with neighbouring TSOs. Transelectrica, Romania's TSO, also found in 2019 that Ukrenergo yet has to implement the usage of real-time "n-1" calculations in its control rooms (Bolborici, 2019).

To Do: use demand forecasting software, conduct operational planning on a yearly, monthly, weekly and daily basis in XML format

A successful implementation of up-to-date balancing technology is not unlikely. Ukrenergo is already participating in an EU awareness system for data-sharing (ENTSO-E, 2020b), and is adopting EU regulation on congestion management methodologies (Nitsovych, Serebrennikov and Mykhailenko, 2020). 18/05/2021 09:25:00(World Bank, 2020)The World Bank also estimates that Ukrainian power plants have enough capacities to provide for a functioning and liquid balancing market (World Bank, 2020). This

Success not unlikely, due to ongoing efforts in Ukraine and international support assessment is underscored by an ongoing feasibility study of Ukraine's frequency control capabilities, using new balancing and frequency data from 2019, by USAID and UHE (European Parliament and European Council, 2009). Such feasibility studies will have to indicate which substations need to be strengthened to accommodate changing flow patterns from synchronisation.

III. "Basic regulations mandating TSO operation", in detail

The role of ENTSO-E: connecting European TSOs, creating and implementing network codes

ENTSO-E, the "European Network for Transmission System Operators for electricity", was established in 2009 by the EU's Third Legislative Package for the Internal Energy Market (Energy Community Permanent High Level Group, 2012; Energy Community Secretariat, 2018). It is an association of 42 TSOs from 35 countries across Europe, extending beyond the EU. Ukrenergo is not a member of ENTSO-E, which would be a separate step from synchronisation with the European grid. The EU's third energy package, aimed at further liberalization and integration of the bloc's energy markets, gave ENTSO-E the mandate to create and implement so-called Network Codes. ENTSO-E drafted eight such codes, which after a process stretching over several years became EU regulations in 2017. They are therefore legally binding for all EU member States, as well as for some additional States who subjected themselves to following the codes deliberately, such as the members of the Energy Community, of which Ukraine is a contracting party (Energy Community Permanent High Level Group, 2012; Energy Community Secretariat, 2018). The Energy Community is an EU organization with the goal to unify the European energy market. However, while the Energy Community has set itself the goal to adopt all network codes, it has so far only adopted the three grid connection codes (compare Table 18) (Energy Community Secretariat, 2020a).

ENTSO-E's Network Codes are mandatory for EU Member States: (1) market codes, (2) operation codes, and (3) grid connection codes (so far, only (3) mandatory for Ukraine)

The codes are usually presented in three groups: (1) market codes organizing the integration of power markets across ENTSO-E member States, (2) system operation codes organizing the seamless operation of integrated power systems, and (3) grid connection rules organizing how and which generators can be interconnected with one-another, with consumers, and across borders (please compare Table 18). Both 'codes' and 'guidelines' are legally binding for EU States.

Table 18: EU Electricity Network Codes and Guidelines

Market Codes	System Operation Codes	Grid Connection Codes
Capacity Allocation and Congestion Management Guideline (CACM GL)	Electricity Transmission System Operation Guideline (SO GL)	Network Code on Requirements for Grid Connection of Generators (RfG NC)
Forward Capacity Allocation Guidelines (FCA GL)	Emergency and Restoration (ER NC)	Demand Connection Network Code (DC NC)
Electricity Balancing Guideline (EB GL)		Requirements for Grid Connection of High Voltage Direct Current systems and direct current-connected Power Park Modules Network Code (HVDC NC)

While Ukraine is bound by its obligations to the Energy Community to implement the codes, the key question remains as to which level of compliance with the Network Codes Ukraine needs to achieve in order to be able to synchronise its grid with the Continental Europe power system. The threshold for integration is difficult to make out, as the currently already synchronised parties within the network have not implemented all codes themselves (ENTSO-E, 2020a). And despite the political will from Brussels supporting Ukrainian integration into the Continental Europe power system, the ENTSO-E's member TSOs might reject synchronisation if the Ukrainian grid fails balancing and frequency control tests, such as in 2016's feasibility study. Arguably, the most important codes Ukraine needs to implement are thus the operational codes (please compare chapter I).

TSOs can reject Ukraine's bid for synchronisation in case of balancing and frequency issues – as in 2016 feasibility study. Most crucial for synchronisation: compliance with operational rules

Looking beyond operation codes to assess Ukraine´s readiness for integration with Europe, a comparison can be drawn between Ukraine's potential future, and Turkey's 2015 synchronisation with the Continental Europe power system. In 2015, the Energy Community (EC) hailed Turkey to be "legally synchronised" with the Energy Community (Energy Community Secretariat, 2015). The EC especially praised Turkey's balancing markets and its power exchange. The EC perceived Turkish markets as about to fulfill the Third Energy Package, which had been adopted by the EU five years before, and fully compliant with the Second Energy Package from twelve years earlier.

When Turkey synchronised its grid with continental Europe in 2015, its regulations were better aligned with the Energy Community's than Ukraine's are today.

Ukraine is in a similar position now as Turkey was in 2015. However, in Ukraine's case, the Third Energy Package was adopted eleven years ago, and the Network Codes four years ago. Judging by the Energy Community's assessment of the current state of Ukrainian regulations and laws, Ukraine still has room for improvement in terms of implementation of the Network Codes and Guidelines. For any party, a step closer to the Energy Community's regulations would be a step closer to synchronization with the European grid. In general, Ukraine could further unbundle its electricity generators, as well as increase the political independence of Ukrenergo and the regulator NEURC(Kopač, 2020)(Kopač, 2020).

Market codes also not implemented in Ukraine: missing liberalization

In its latest analysis of Ukrenergo, the Energy Community for example refused to certify the **independence of the TSO Ukrenergo** (European Parliament, 2009; Energy Community Secreteriat, 2020). Its experts stated that *"Ukrenergo does not own the electricity transmission assets as required by Article 9(1) of the Electricity Directive 2009/72/EC, and does not enjoy and exercise rights over them equivalent to an owner."* (European Parliament, 2009; Energy Community Secreteriat, 2020).

Ukrenergo's missing certification by the Energy Community: Lacking independence

For further analysis of Ukraine's electricity market, and thus its implementation of the Network Codes not relating to operational security, please have a look Chapter **4. Reforming Ukraine's electricity market.**

7. A socially sustainable coal phase-out in Ukraine

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Executive Summary

Despite its continuously decline in the past 30 years, Ukrainian hard coal production still plays a salient role in Ukraine's economy. On the demand side, thermal power plants which are fueled with coal, still generate 31% of Ukrainian electricity. However, to comply with its climate obligations, a coal phase-out is an inevitable step for Ukraine on its decarbonization path. Economic reasons will also push coal out of the market as an energy source. This is due to the decreasing profitability of coal mines in Ukraine, which will be further reduced by the implementation of the National Emission Reduction Plan, a potential move away from coal subsidies and a presumed increase of the carbon tax.

This paper proposes accompanying measures for the coal phase-out, aimed at dampening its negative impact on the development of affected regions and their labour market. The measures proposed include direct measures addressing former miners, such as retraining programs, but also broader instruments like the set-up of a just transition fund and the creation of new regional development agencies. If successfully implemented, a politically accompanied structural change offers the opportunity to bring about an economic shift towards a more future-oriented industrial landscape and to overcome the socio-economic challenges that coal mining areas are facing today. A phase-out of subsidies can accelerate the process and carry some costs of this change.

Overview of the coal sector

I. Coal mining

Ukraine has abundant deposits of hard coal in the Lviv-Volyn and the Donetsk basins.

Ukraine has large coal reserves with hard coal accounting for the largest share at 32 Gt making it the 6th largest reserves in the world (BGR, 2020). Hard coal deposits are concentrated mainly in the Lviv-Volyn and the Donetsk basins (Figure 57). In the latter, up to 90% of the country's hard coal deposits are located comprising the oblasts Donetsk, Lugansk and Dnipropetrovsk (larger area of the Donbas) (ILO, 2018). Hard coal mining operations take place at 500 to 1,000 metres by thin seams of 0.8 to 1.0 metre. In fact, Ukraine also has abundant lignite deposits (2.3 Gt) which are located in the Dnieper basin. However, Ukrainian lignite production is negligibly small.

Figure 57: Ukraine's coal deposits

Source: Ogarenko (2010)

The country suffers from an unproductive coal mining sector with state mines in particular generating losses.

After the collapse of the Soviet Union, Ukraine inherited an unproductive coal sector with low-quality coal that had a high sulphur content (Amosha *et al.*, 2017). In 1991, there were around 280 coal mines in Ukraine. Following the economic liberalisation path in the 1990s, production of Ukrainian mines dropped sharply (Dudău *et al.*, 2019). Between 2000 and 2005, a bulk of state-owned coal mines were closed while the most prospective mines were privatised. Due to the conflict in Donbas that started in 2014, the government lost effective control over many mines, including all anthracite producing mines. Today, only 27 state-owned mines are still controlled by the government and most of them are not profitable. This compares with 17 private mines that are economically viable and outperformed state mines with 90 % higher utilization of production capacity. The Ukrainian government plans to continue to close unprofitable mines, and an in-depth plan to do so is to be developed by September 2022.

Coal production has been declining year by year. Total coal production (including steam coal and coking coal) decreased from 164 m tons in 1990 to 31 m tons in 2019. With 89%, most of the coal was extracted by private mines, with 72% of total extraction coming from DTEK, a vertically integrated company dominating the coal mining as well as heat and power market (Table 19).

Since the early 1990s, coal production has been declining.

Table 19: Coal extraction in Mt in Ukraine

The sharp decline of coal production in 2014-15 can be attributed to the conflict in Donbas, which added to the already declining trend of the sector.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
State-owned coal mines	37.5	24.9	24.1	17.7	8.0	5.8	4.8	4.1	3.1
State share in total	46%	29%	29%	27%	20%	14%	15%	12%	11%
Private coal mines	43.6	61.1	59.6	47.3	31.8	35.1	28.2	29.1	27.7
... of which DTEK	38.4	39.4	40.0	35.0	26.7	25.7	22.9	24.1	22.4
Private share in total	54%	71%	71%	73%	80%	86%	85%	88%	89%
Total	81.1	86.0	83.7	65.0	39.7	40.9	33.0	33.3	31.2
DTEK share in total	47%	46%	48%	54%	67%	63%	69%	73%	72%

Source: MEEP (2016-2019), Razumkov Centre (2015), Kazanskyi *et al.* (2017)[41]

The main consumers of coal are the energy and the iron and steel sectors. In 2018, the energy sector consumed 27 m tonnes of steam coal while the iron and steel sector used 2.5 m tonnes of coke and 1.8 m tonnes of steam coal (Ukrstat, 2020).

The energy and iron/steel sectors are the main consumers of coal.

Due to a constant deterioration in the quality of coal since 1991, particularly in terms of sulphur content, Ukraine, formerly a net exporting country, became a net importer of coal (Oprisan, 2011). The conflict in Donbas has even increased the dependency on coal imports with Ukraine importing 22 Mt and exporting 0.09 Mt of coal in 2018 with the Russian Federation accounting for around 70% of coal imports (Ukrstat 2020).

Due to the low quality of domestic coal, Ukraine became a net importer.

Ukraine's state-owned coal mines are old, highly unprofitable and receive large subsidies to prevent their bankruptcy. Additionally, Ukrainian coal mines are among the most dangerous in the world. 1 Mt of extracted coal were paid off by 2.5 of miners' lives (ILO 2018).[42] However, it still plays a salient role as an employer in some regions. Especially in the regions Donetsk and Lugansk, a substantial share of the local working force is employed in the coal sector (Table 20). In 2019, 86,000 workers were employed in Ukrainian coal mines, equivalent to 0.5% of the total workforce in the country, 38,000 of them in state-owned and 48,000 in private mines. These figures, however, represent a loss of more than 91% of mining jobs from 1991 to 2019 (Dudău *et al.*, 2019).

Despite a lack of work safety, Ukrainian coal mines are important employers in some regions.

[41] The large drops in state production in 2012 and 2015 occurred due to the privatization of many mines in the respective year as well as the conflict in Donbas.

[42] By comparison, an average of 0.01 miners per million tonnes of coal lost their lives in US mines between 2015 and 2017 (US Department of Labor 2020; US EIA 2020).

The share of coal mining (incl. quarrying) in the economy and the share of coal workers are in particularly high in Donetsk and Dnipropetrovsk.

Table 20: The economic role of the coal sector in different regions

	Year	Ukraine overall	Donetsk region	Lugansk region	Lviv region	Volyn region	Dnipro-petrovsk
GDP per person in USD	2018	3,097	1,661	588	2,571	2,133	4,189
Share of coal sector in regional gross value added	2017	1.0%	21.8%	2.5%	6.4%	0.2%	21.6%
Total labour force working in coal sector	2019	85,529	37,659	8,018	8,438	1,414	30,000
Share of total labour force working in coal sector	2019	0.5%	5.1%	2.7%	0.8%	0.4%	2.1%
Unemployment rate	2019	8.2%	13.6%	13.7%	6.5%	10.6%	7,7%

Source: Ukrstat (2020)[43]

In international comparison, labour efficiency is very low in Ukrainian coal mines.

Labour efficiency in the Ukrainian coal sector is far behind international standards. Average labour efficiency in Poland is twice as high, in Western Europe five times as high and in the USA 20 times as high (Savitsky, 2015). While labour efficiency at private mines has increased substantially since 1991, at state-owned mines it has remained relatively low. Today, labour efficiency as tonnes of coal extracted on average by one miner is more than five times as high at private mines than at state-owned mines.

II. Coal in the electricity sector

Most thermal power plants have already exceeded their design lifetime and are far behind technical standards of the EU.

In 2019, coal has provided around 31% of Ukraine's electricity supply (IEA 2020). Electricity from coal is generated by three companies: the private companies Donbasenergo and DTEK with one and nine thermal power plants respectively, and the mostly state-owned Centroenergo, which owns three plants (Energy Community Secretariat, 2019). In Ukraine, thermal power plants are mainly fuelled with coal and only to a small extent with natural gas. Meanwhile, they are old and inefficient, with efficiency factors ranging between 0.29 and 0.34, and averaging at just 0.31. The efficiency of comparable hard coal-fuelled German plants is significantly higher at 0.39 (Agora 2019). With an average age of around 49 years most Ukrainian plants have already exceeded their technical lifetime of 40-45 years. The average load factor of Ukrainian thermal power plants is 35%, way below the EU average of 50%. A lower load factor tends to make it more difficult to achieve profitability. This is even more difficult for the operators of thermal power plants, because although prices on the Ukrainian wholesale electricity market are formed by marginal cost pricing, they are also regulated with minimum and maximum price caps.

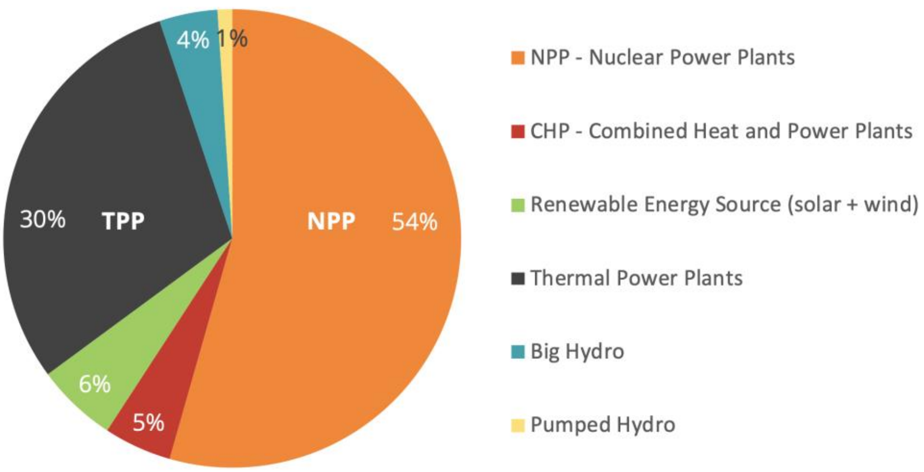
After nuclear power, coal is the second largest source of electricity generation, accounting for 55% of Ukrainian emissions.

Figure 58 shows the technology shares in electricity generation. After nuclear power, coal is the second largest source of electricity generation in Ukraine. However, the poor environmental performance and unreliability of Ukraine's depreciated coal power plants could make them unfit for competition in the EU power market after full synchronisation with ENTSO-E (OECD 2020). The electricity sector is responsible

[43] Official oblast statistics aggregate value-added numbers at mining and quarrying level and, up to our knowledge, it is not possible to get the figures only for coal mining. Therefore, for Dnipropetrovsk, for example, the high share of iron ore extraction is included.

for about 50% of Ukraine's CO2 emissions (88 of the total 183 Mt CO2). Coal is responsible for 75% of CO2 emissions in the sector, making it the main driver of greenhouse gas emissions in Ukraine (IEA 2020).

Figure 58: Technology shares in electricity generation in Q1, 2020



Source: Ukrenergo (2020)[44]

III. Expected development of coal in the electricity sector

The economic disadvantage of coal as an energy source is even enhanced through recent political developments.

The large Combustion Plants Directive requires Ukraine to lower their NOX, SO2 and dust emissions.

When Ukraine signed the Paris Agreement as one of the first countries, it committed itself to achieve net zero emissions in the second half of this century. An early coal phase-out is not only necessary for Ukraine to achieve its climate goals but will also be unavoidable for economic reasons. Coal as an energy source is losing its competitiveness against renewable energy (Lazard 2018). This economic disadvantage will soon be enhanced through recent political developments becoming effective.

When Ukraine joined the Energy Community in 2011, it committed itself to implement the Directive 2001/80/EC (Large Combustion Plants Directive). The commitment contained the regulation of emissions of large combustion plants, incl. thermal power plants and combined heat and power plants. In 2013, when it became clear that the conditions could not be fulfilled until 2018, since no progress was made, the government agreed with the Energy Community to omit compliance with these regulations and directly move to the directive with more stringent requirements – Directive 2010/75/EU (Industrial Emissions Directive). Notably, Ukraine received new, more ambitious emission standards for sulphur dioxide (SO2), nitrogen oxide (NOx) and dust under the Industrial Emissions Directive without even complying with the standards under the Large Combustion Plants Directive. Based on both directives, Ukraine adopted the National Emission Reduction Plan in November 2017. The plant contained ambitious goal, namely (1) SOX emissions reduction by factor 20 until 2028, (2) dust emissions reduction by factor 40 until 2028, and (3) NOx emissions reduction by factor 3.5 until 2033. NASU (2020) estimates that the total amount of capital investment to implement the requirements of the NERP may reach EUR 4.1 bn for the entire period until 2033.

[44] All thermal power plants in Ukraine use hard coal as a fuel, only some use additionally gas. About 32% of Ukrainian combined heat and power units use coal while the remaining units use mostly gas.

The implementation of the National Emission Reduction Plan is constantly being postponed.

In 2018, the government approved an action plan to implement National Emission Reduction Plan, but since then, no progress has been made. Due to lack of action, the Cabinet of Ministers approved amendments to the National Emission Reduction Plan already in July 2019. Currently, a postponement to the year 2038 is being discussed. Without such a law, Ukraine is currently in breach with its international obligations as a member of the European energy community, since the Industrial Emissions Directive is one of the key documents defining the acquis.

The carbon tax is likely to increase.

Secondly, the carbon tax in Ukraine is likely to increase within the next years. On the one hand this is fostered by the country's climate obligations, because a revision of the country's carbon pricing system offers great potential for its decarbonization. On the other hand, Ukraine might need to adapt its carbon price to EU levels in order to avoid negative border tax adjustment effects from the EU. We therefore propose an increase of the carbon tax from 0.33 EUR/tCO_2 to 39 EUR/tCO_2 (see Chapter "**2. A Revision of Ukraine's Carbon Tax"**). This development will make it even less economical to operate coal-fired power plants.

This makes the phase out of the coal production from state and private mines economically rational.

Hence, a coal-phase out in Ukraine is necessary and economically rational. This includes not only the state-owned coal mines but also private ones as the whole sector is affected by the factors mentioned above. But with the shut-down of a whole economic sector come severe potential problems that need to be accounted for. Past mine closures in Ukraine were riddled by missing government engagement with local authorities and miners, a profound loss of social institutions connected to mining facilities, and a generally missing political will to implement recommendations by international institutions for a promising change to new economic structures (Dudău *et al.*, 2019). The think-tank ´Open Democracy´ even links the desperation of former mining communities in Eastern Ukraine to the escalation of the still ongoing conflict (Open Democracy 2016).

It would be cheaper for the country to phase out coal.

In light of these past shortcomings, and aware of the dire need to close unprofitable coal mines, we therefore propose policy measures necessary to flank a successful coal phase-out in Ukraine. All in all, a just transition - with all its expenditures - would be cheaper for Ukraine than continuing its subsidies to ill-performing coal mines.

Policy measures for the coal phase-out

The next chapter will propose policy measures for a socially and economically sustainable development path for Ukraine. A phase-out of coal subsidies could be made in order to not just reveal the unprofitability of Ukrainian coal mines, but to tap into crucial sources for financing the coal phase-out. Furthermore, we discuss policy measures aimed at miners and measures aimed at potential structural changes in coal regions.

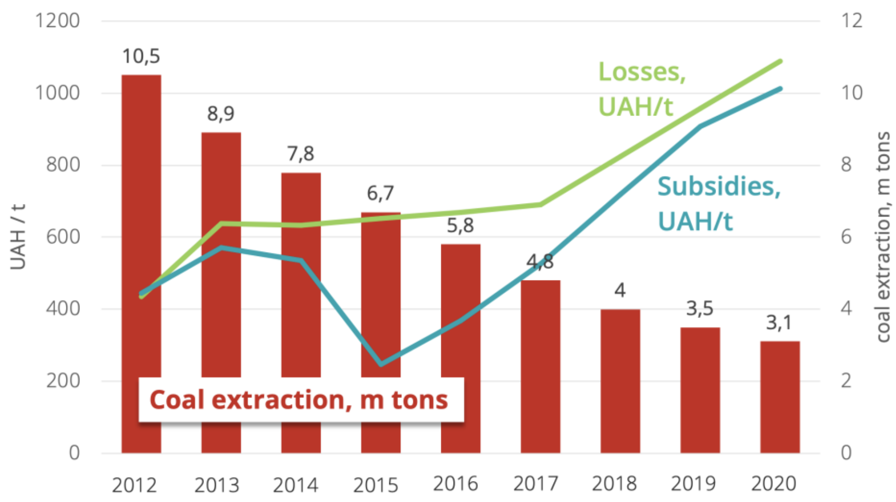
We, therefore, propose accompanying measures for a successful coal phase-out.

I. Phasing-out of subsidies

Despite stable decrease in coal production, state support per t of coal produced is increasing as illustrated in Figure 3. From 2013 to 2015 budget transfers to partially cover production costs of unprofitable state-owned coal mines decreased from UAH 536 /t to UAH 246 /t. Afterwards, however, there is a steep increase in subsidies again, exceeding pre-crisis levels. The increase in the ratio of subsidies paid per ton of coal extracted even outperforms the decrease in coal extraction, so that the total amount of fiscal support-type subsidies increased from UAH 2.0 bn (EUR 75.9 m) in 2015 to UAH 4.2 bn (EUR 145.9 m)[45] in 2019 (see Table 21 in the Annex).

Fiscal support-type subsidies per t of coal increased in recent years.

Figure 59: Coal extraction and fiscal support-type subsidies, 2012-2020



Source: MinEconEnergy (2020)

To estimate the revenue the Ukrainian government could save by phasing out producer subsidies in the coal sector, the approach from Miljevic, Mumovic and Kopac (2019) is adopted to deliver estimates for 2019. Next to fiscal support-type subsidies, as presented in Figure 3, their approach refers to the World Trade Organization definition of subsidies, i.e., it also considers public finances support subsidies and state-owned enterprise (SOE) investment support subsidies. Fiscal support-type subsidies cover direct budget transfers by the government as well as forgone government revenue. These types of subsidies directly impact the government budget. Public finance support subsidies, on the other hand, cover support (loans, grants, guarantees or equity) granted by institutions under government control or by international financial institutions. The last category, SOE investment support subsidies covers transfers of funds made by SOEs (at least 50% government owned), that cannot be justified from a pure economic or market point of view.

We add subsidies to support public finances and subsidies to encourage investment by state-owned companies to create a more complete picture of coal subsidies.

[45] Conversions are based on average exchange rate of the respective year.

In 2019, the government spent EUR 407 m on state coal mines.

Not only fiscal support-type subsidies, but also investment support subsidies increased substantially, while public finance support subsidies remained relatively constant (see Table 21 in the Annex). In 2019, the Ukrainian government spent in total EUR 407.1 m on state coal mines.

Rotterdam+ was a form of implicit subsidies.

In addition to direct subsidies, there was another form of implicit subsidies present in the sector – “Rotterdam+”. “Rotterdam+” was introduced in 2016, after the loss of control over the coal-producing area in Donbas. To decrease the dependency on occupied regions and the Russian Federation, a coal-pricing formula was introduced that should allow building coal reserves from international sources and, thus, increase energy security.

Through the Rotterdam+ scheme, power producers, such as DTEK, gained profits.

Under “Rotterdam+”, the price for coal was determined by the coal price index of the European coal transhipment centre in Rotterdam, taking into account the transit costs for transporting coal to Ukraine. The National Energy and Utilities Regulatory Commission (NEURC) then based the wholesale market price for electricity on this coal price. Instead of buying coal from abroad, it was still mainly sourced from Ukraine or the Russian Federation at cheaper rates. As the amount of money paid by the centralized wholesale buyer Energorynok to heat and power producers was independent of the actual coal price and solely depended on “Rotterdam+”, power producers gained profits. Andrii Herus, former member of NEURC, documented that heat and power producers had a coverage of UAH 2,200/t but sourced coal for UAH 1,330/t from Ukrainian mines. The biggest beneficiary of the pricing scheme was DTEK.

The loss Induced by Rotterdam+ is estimated at around EUR 1,2 bn.

According to the anti-corruption bureau, the loss induced by “Rotterdam+” is estimated at around UAH 39.9 bn (EUR 1.2 bn) between May 2016 and June 2019 (AntAC, 2020). However, most of the costs were carried by electricity consumers due to higher wholesale prices and actual costs for the taxpayer are hard to quantify. Therefore, these implicit subsidies will be disregarded here. Additionally, with the opening of the wholesale electricity market in June 2019, “Rotterdam+” is no longer in place.

II. Labour policies

We assume a loss of 46,000 jobs in the period 2020-2030.

Ecoaction (2020) proposes to reduce the electricity share from coal to 5% until 2030. We estimate that this would imply a reduction of coal demand from the electricity sector by 80% and a reduction in the overall coal demand by 54% of the 2019 level. Assuming a proportional decrease in the number of workers in coal mining, we expect a loss of 46,000 jobs in the period 2020-2030 (see ‘Estimation Method’ in the Annex).

Measures aimed at coal workers are needed to accompany the reduction of coal production.

In the course of reducing coal production, accompanying measures taking care of these workers need to be an essential part of the transition strategy. Note that coal mine workers in all five oblasts are paid above average wages in the industry compared to similar jobs outside the industry. Thus, replacing the jobs without backlash from the miners is challenging.

There are three possibilities for former miners: they could be (1) occupied in the maintenance of the closed underground mines to leave it in a socially and environmentally responsible way[46], (2) retrained for another kind of job, or (3) enter early retirement.

[46] In Ukraine, most mines are underground mines which have a smaller footprint than surface mining. It is crucial to adopt sound management practices during the closure periods due to uncertainties associated with the post-closure phase and the end of economic activity (Krzemien *et al.* 2016).

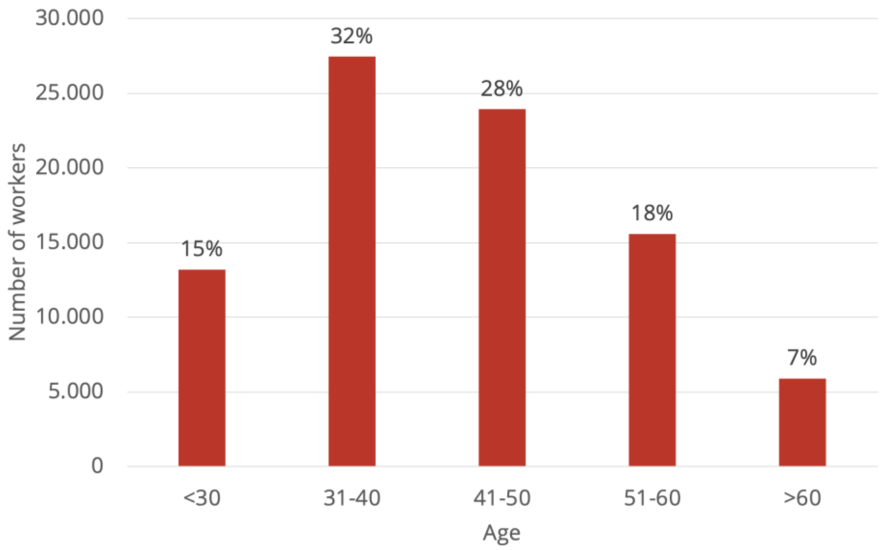
(1) The closure of the mines will require continuous support from miners. Especially the more senior miners are suitable for this job.

(2) Miners at different ages are suitable for different options. Especially younger workers should be offered attractive training programs, so they can enter jobs in renewable generation, gas power facilities or other industries.

(3) Workers with an age of up to 5 years before they would normally retire, should be incentivized to retire early by specially targeted early-retirement schemes. 22% of workers in Ukrainian coal mines are already at the age of retirement. But because the pensions are very low, they are forced to keep working. They should receive a fair pension top-up, so they do not need to work anymore (for more information on the pensions, see Table 22 in the Annex).

Options: (1) maintenance of closed mines9, (2) retraining or (3) early retirement.

Figure 60: Age structure of state mine workers



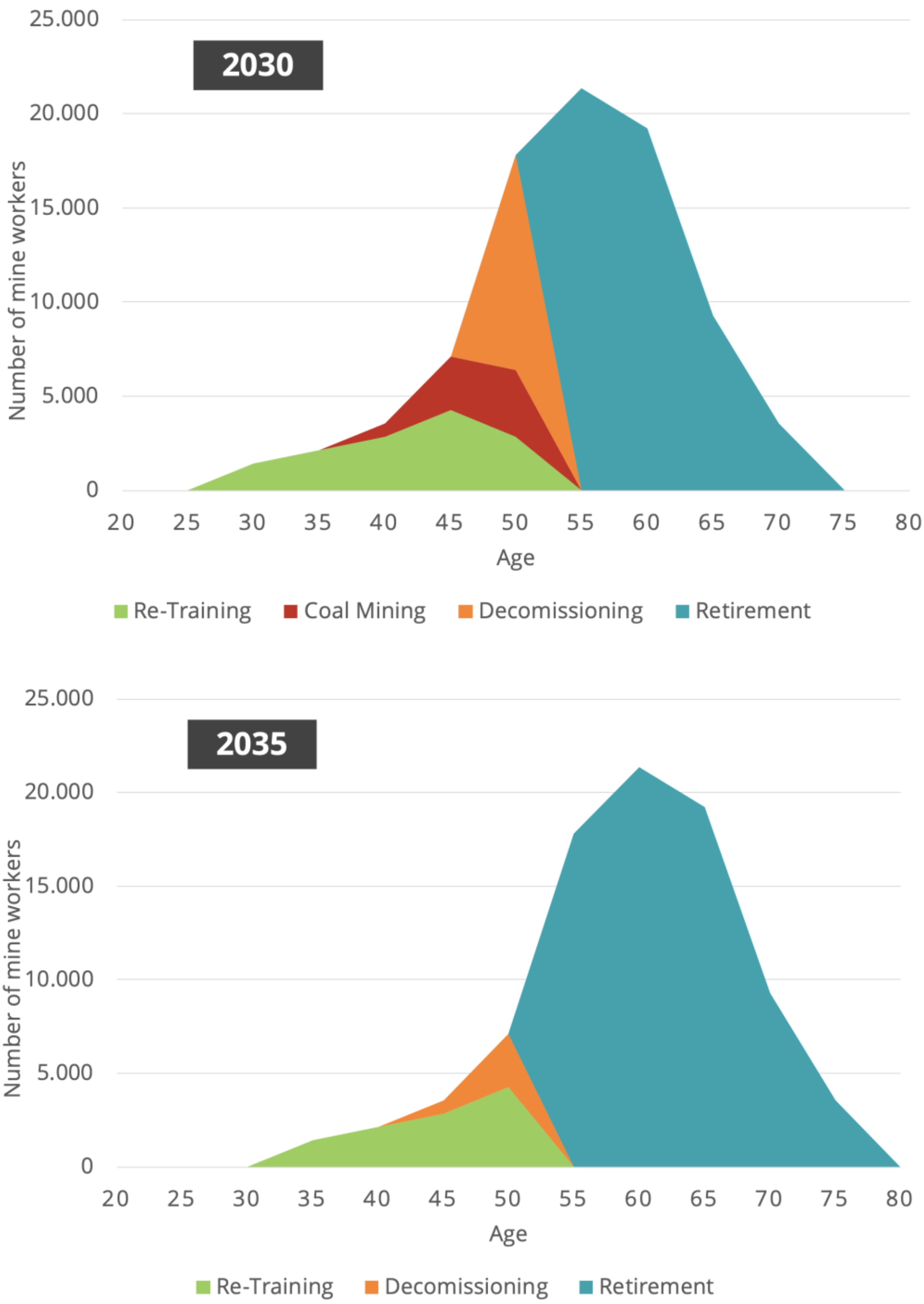
Source: Ministry of Energy and Coal Industry, as of May-2019

Figure 61 shows the exemplary distribution of the occupational activity of all 85,000 miners in the years 2030 and 2035 based on the age structure shown in Figure 60. Assuming a gradual exit from mining, only 8% of workers will be employed in mining activities in 2030, while 63% will have already reached retirement age. Young workers, about 16%, will take advantage of retraining and re-employment programs to cushion potential mass layoffs from mine closures. By 2035, most miners will have reached retirement age while the others will either be employed in the maintenance of closed mines or retrained.

Until 2030, most miners will have reached retirement age.

Figure 61: Slow phase-out of coal mining in Ukraine

Most of today's state mine workers will be on retirement in 2030, none left in mining by 2035



Source: Own estimates based on data provided by Ministry of Energy and Coal Industry, as of May-2019

Estimated costs for retraining programs sum up to around EUR 225 m until 2030.

For estimating the cost of retraining programs, we used expenditure per pupil at vocational schools in Ukraine, which amounted to EUR 1,333 in 2014 (CEDOS 2015). For the time period 2020-2030 our estimated costs sum up to around EUR 225 m. We assume that all miners that continue to work need retraining. Retraining programs should, if possible, start already before the closure of the coal mines to enable a more seamless career switch. Additionally, regional employment agencies will support the miners in finding and preparing for a new career in other economic sectors (Dudău *et al.* 2019). Due to problems in data availability, costs of early retirement programs could not be estimated.

For comparison, a study by Szabó *et al.* (2020) estimated the cost of a just transition including measures such as retraining, job matching, business start-up aid and early pensions for the countries Bulgaria, Greece and Romania. For Romania, they estimated that a just transition of around 9,100 directly affected workers in the coal sector, i.e. miners or workers in power plants, would cost around EUR 112 m. In Greece EUR 227 m would be needed due to 5,600 direct job losses. For Bulgaria EUR 220 m would be required to compensate for 14,000 direct job losses.

The costs for affected workers in a just transition ranged from EUR 112 m to EUR 227 m in GR, BG and RO.

As large shares of the miners affected by the closures are not employed by state-owned mines but private companies, it is important to create a strategy that takes both worker groups into account. Therefore, the schemes will be accessible to all miners.

All labour market policies should also be aimed at workers from private mines.

III. Structural measures

The regions that were formerly reliant and strongly influenced by the mining sector, now need support for a successful structural change and economic reorientation to build up new industries and thus, new job opportunities for the local population. These issues need to be accounted for, to avoid severe socio-economic instability in the regions. The just and comprehensive transition process needs to be organized by a set of new institutions.

New institutions need to be established to avoid socio-economic instability.

To begin with, a commission with a clear mandate representing the most important stakeholders should be established. In Ukraine, already some progress could be observed in this regard. In May 2019, a Coordination Centre for sustainable development was founded by six coal-mining cities in the Donetsk area to develop a transformation strategy for the region.[47] Today, it includes eight municipalities, three NGOs from the affected towns and the Donetsk Regional Chamber of Commerce. Furthermore, in May 2020, a national Coordination Centre for the transformation of coal regions was created under the Cabinet of Ministers including national bodies. To make this initiative more likely to succeed, it could be strengthened by making sure that all stakeholders, i.e. trade unions, local authorities, civil society and scientific institutes that could derail the process, become part of the solution and hence do not obstruct its implementation in the future. Furthermore, the Coordination Centre is lacking a clear mandate for developing a national coal transformation strategy. A permanent coal strategy working group could be mandated to develop different scenarios with international expert support to achieve this strategic goal.

A commission should be established with a clear mandate and all stakeholders in order to develop a long-term strategy.

By using the recommendations of the commission, a thorough transition strategy should be established including dates when coal shall be phased-out in energy use and how the region shall be restructured. Hereby, a bottom-up approach that takes into account the needs of the local population is essential. This strategy can be supported by regional development plans that are tailor-made to the conditions, needs and potentials of the region. As job losses and negative economic impacts are highly spatially clustered, there is a need for regional agencies in addition to the national commission. These can facilitate the participation of stakeholders, and measures can be better targeted at groups in the region.

A bottom-up approach with local stakeholders (regional agencies) is crucial for a successful just transition.

Szabó *et al.* (2020) provides cost estimates for regional development as government investment into sectors other than the coal sector to compensate for economic losses caused by a coal phase-out. For Romania, Greece and Bulgaria EUR 478 m, EUR 1,619 m and EUR 532 m respectively were estimated.

In GR, BG and RO, costs for economic development ranged from 470 m to EUR 530 m.

[47] https://www.kmu.gov.ua/en/news/minenergo-obstoyuye-kompleksnij-pidhid-do-transformaciyi-vugilnih-regioniv

For the development of the regions, Ukraine should build upon existing human capital and infrastructure.

In August 2020, Germany and Ukraine agreed to establish a German-Ukrainian energy partnership. Its aim is to intensify the collaboration between both countries in the fields of energy policy, such as the transformation of Ukrainian coal regions. During this process, a decarbonization partnership between the European Union and Ukraine could be established that would provide long-term support for financing and development of transition strategies and programmes, i.e. promoting the building of new business clusters (Heinrich Böll Foundation, 2019). They can build upon existing human capital and infrastructures aimed at new low carbon energy generation systems and other clusters of industrial development. Former coal mining sites could be reused for cultural sites to underline the regional coal-based identities, for renewable energy generation, e.g. for wind or solar parks, or they could be re-used for geothermal energy and hydropower generations (Egenhofer *et al.* 2020).

Promoting economic diversification and improving the local education system will be crucial.

An integral part of the transformation process should be the development of the local education system so that the adaption to the new labour market conditions is facilitated and the development of clusters between R&D and the industry is supported. Building modern infrastructure to connect mining regions with neighbouring cities could lead to an increase of the regions' attractivity for new emerging industries. The overall aim is to increase economic diversification in the region in order to cushion the rise in unemployment and be less vulnerable to economic shocks or sectoral downturns.

A fund for environmental damages is needed.

Lastly, a fund needs to be established that takes into account the restoration of environmental damages that occurred due to the coal mining activities (Dudău *et al.* 2019). For example, for the closure of three coal mining sites in Romania, EU state aid funds of EUR 83 m were used to finance underground safety works, surface re-cultivation and rehabilitation of the sites for the period 2016-2024.

Background info

German experience

Many former coal-mining areas in the EU have gone through transitional processes because of a coal phase-out. These coal phase-outs were accompanied by strategies designed for these regions to prevent negative effects and to enable the transition towards a successful future.

The German Ruhr region was the largest hard coal mining area in Germany which in combination with the down-stream steel industry made it an important pillar for the country's economic development in post-WWII West Germany. The highest coal output was achieved in 1957 with around 150 m tonnes of total German hard coal production in 173 mines. At the same time, the number of employees in hard coal mining peaked at around 607,000 workers from which around 500,000 were employed in the Ruhr region. From the end of the 50s, the liberalisation of coal prices made coal too costly, broke its competitiveness on the world market and put a stop on the rising German hard coal output. However, subsidies for the coal sector delayed the closure of mines so that the last two hard coal mines in the Ruhr region were closed only in 2018 when the subsidies ended. Based on the recommendations of the German Coal Commission established in 2018, Germany has committed itself to a nationwide phase-out, including lignite, in the whole country by 2035 to 2038.

During the last six decades, the Ruhr area underwent different stages of transition. In the 1950s and 60s, the strategy focused on the restoration of the industry and its workforce while also building up new alternative economic sectors. With the industry losing its competitiveness, the latter element became more dominant over time. In the advanced process, several agencies and funds were established to take account for different needs of the transitional process: the economic development, cultural and social challenges, the environmental restoration of former industrial sites.

On top of finding solutions for the direct effects, additional projects enhanced education, innovation, infrastructure and living conditions of the region. Throughout the whole process, the integration of several stakeholders such as administrations, politicians, representatives of the civil society as well as larger and small businesses played an important role.

The strategy resulting from this bottom-up approach was therefore tailor-made to the individual needs and potentials of the region. Due to the promotion of universities and the attraction of new industries, the region's economic diversification could be increased in order to cushion the rise in unemployment. However, strong incumbent players obstructed the transformation, formed strong connections with political decision-makers and thus preserved the hard coal sector beyond economic and ecological reasons. Notably, the Ruhr hard coal phase-out took a full 60 years and Oei *et al.* (2020) argue that a faster and more pro-active hard coal mining phase-out in Germany would have been much less expensive and paved the way for new industries. (Dudău *et al.* 2019; Botta 2019)

Financing sources

A potential financing source is a gradual phase-out of state mine subsidies - EUR 1.8 bn until 2030.

To finance the measures for a just transition, there are a couple of potential financing sources. First of all, there is a potential of cross financing the measures, as a gradual phase-out of coal subsidies would save about EUR 1.8 bn over the period 2020-2030. This, for instance, could completely cover the retraining program that is estimated to cost EUR 225 m for the same period. Secondly, parts of the revenues from an increased carbon tax could serve as additional funding.

Money from the state budget for mine liquidation is mostly used to pay miners' wages.

As part of its mine closure program the Ukrainian government has earmarked money for the maintenance of closed coal mines, but this money is unlikely to be sufficient to maintain all the mines to be closed in the coming decade (Oprisan 2011). Furthermore, although the Ukrainian budget plan provided for UAH 660 m (EUR 23 m) in 2019 for the liquidation of coal mines, based on the analysis of budget transfers it can be concluded that for this reason only UAH 159 m (EUR 6 m) were used, while the majority of these funds are often spent on miners' salaries (Kornlyuk *et al.* 2020). In the first half of 2020, the government allocated UAH 3 bn (EUR 100 m) from the state budget to pay coal miners' wages.

A just transition fund is suitable to use scarce public money in a transformative way and attract private capital.

Ukraine could use its scarce financing sources in a transformative way in order to unlock potential private investment. A transition fund scheme could be established to finance the accompanying measures. To begin with, a front-loading of the fund's resources using grants will be necessary to kick-start investments. Apart from that, the fund should provide loans (incl. micro loans) and bank guarantees. The choice of instrument depends on the type of project and its development phase. E.g., a loan requires periodic servicing of interest and repayment which means that it may be more suitable for low-risk projects that generate periodic cash inflows. A competitive awarding of funding could be explored, where projects can apply by stating the amount of co-financing they need. The use of grants for the projects should always be accompanied by other financial contributions co-financing should strictly remain below 100% to ensure that the investments make sense commercially. Miners could, in parts, finance their training themselves or coal companies could carry some of the costs for retraining to employ the workers in another occupation within the company. All financing going through the Ukrainian transition fund should then reach employment-related/social projects run by public or private organisations.

Conclusion

Ukraine is facing the necessity to pursue a coal phase-out, because it is essential for the country to achieve its climate goals but also because coal loses its competitiveness as an energy source and will soon be pushed out of business. The economic disadvantage, which is reflected in a steady decline in domestic coal production and unprofitable mines, is being exacerbated by legislation such as the implementation of the National Emission Reduction Plan and a likely increase in the carbon tax.

Ukraine has to actively design a long-term strategy for the affected coal mining regions and introduce a transition plan that is accompanied and controlled by efficient policy measures. Only with a comprehensive strategy at hand mass unemployment and economic crises in the regions can be prevented.

In this paper, we propose a policy package that shall provide a basis of this strategy, offer guidelines and - where possible - some quantitative orientation of the potential costs as well as potential financing sources for the measures. This policy package consists of five different elements:

1. Phase-out coal subsidies
2. Take care of the former coal miners
3. Design comprehensive bottom-up strategies for the economic development of the regions taking into account all stakeholder
4. Create institutions guiding the transition process on both the national and local level
5. Create funds to provide grants and unlock private capital

With these measures successfully put in place, a coal phase-out will be a chance to take big steps towards decarbonization and the building of new industries for Ukraine.

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Annex

I. Additional Tables

Table 21: Subsidies for state coal mines (for all categories)

EUR m	2015	2016	2017	2018	2019
(1) FISCAL SUPPORT-TYPE SUBSIDIES	76	80	93	107	146
Restructuring of coal and peat industry (2015-17)/ Liquidation of non-profitable coal enterprises (after 2018)	8	4	8	9	4
Rescue measures at coal mining enterprises	9	9	10	9	10
State support for coal mining enterprises on partial compensation of production costs of finished marketable coal	46	48	70	33	-
Measures to improve safety measures at mining enterprises	-	-	3	-	-
Replenishment of current capital or increase the statutory funds of coal mines to settle the arrears of wages to employees as of 01-01-2015	8	18	-	-	-
State support for construction of mine №10 "Novovolynska"	6	2	2	1	2
Implementation of measures to ensure domestic coal production and further reform of the state sector of the coal industry	-	-	-	52	114
Prevention of the emergency situation due to flooding of the mines of Pervomaysko-Stakhaniv coal mining region	-	-	0	3	16
(2) PUBLIC FINANCE SUPPORT SUBSIDIES					
Loan guarantee payment from budget for Loan between Lisichanskvugillya PJSC and the State Development Bank of the PRC	16	16	15	14	14
(3) SOE INVESTMENT SUPPORT SUBSIDIES					
Taxes and contributions in arrears - state coal mines	127	147	174	239	248
Total subsidies to state coal enterprises	219	244	282	370	407

Note that one matter of expense is excluded from Table 21). Miljevic et al. (2019) add "Electricity arrears of state-owned mines to SOE 'Regional Electricity Networks'" to their list characterizing it as an indirect subsidy (see below). It is not an official subsidy like tax-related arrears but debt between the state coal mines and state electricity market operator. The characterisation as an indirect subsidy results from the fact that almost 100% would be written off after the liquidation of state coal mines. In 2018, only around 25% paid for consumed electricity since the remaining state mines suffer from a negative cash balance. However, including it to the total subsidies amount would require further analysis.

Source: Miljevic *et al.* (2017), Ministry of Finance Ukraine (2020)

Electricity arrears of state-owned mines to SOE "Regional Electricity Networks"	135	186	239	283	364

Table 22: Pensions to miners compared with other pensions in 2019

UAH m	01/2019	04/2019	07/2019	12/2019
Minimum pension (by age)	1,497	-	1,564	1,638
Average pension (by age)	2,648	2 943	-	-
Maximum pension limit	14,970	-	15,640	16,380
Minimum pension (miners)	4,491	-	4,692	4,914
Average pension (miners)	8,418	-	-	-

Source: State Pension Fund of Ukraine, Ministry of Social Policy, State Statistic Service

According to the Law "On Raising the Prestige of Miners' Work" the miners' pensions are calculated equal to 80% of earned wages (incomes) but not less than three subsistence minimums. In addition, the Ministry of Social Policy of Ukraine implemented in three consecutive rounds an increase of miners' pensions in 2014, 2015 and 2017 at the expense of the additional incomes of the Pension Fund. As of January 2017, the average miners' pension was UAH 3,926 and more than doubled to UAH 8,418 as of January 2019. Additional surcharges for occupational diseases (so called regress payments) may increase the average pension of miners up to UAH 13,000. Nevertheless, the average pension for miners can cover only average monthly living expenditures per 1 household in Donetsk region (~UAH 6,000.00 in 2018) and pose insufficient motivation for early retired miners to leave their jobs at coal mines.

Note that the reform of the pension system has to be conducted before pension schemes can be expanded. So far, Ukraine only has an ineffective and highly subsidised obligatory state-run solidarity pension system in place. The pension reform law was adopted in 2017 but the reform introducing the obligatory state-run cumulative pension system is not enacted yet as preconditions are not in place.

II. Estimation Method

Table 23: Input data of the estimation method

	2019	2030	Source
efficiency of TPPs MWh_el./MWh_therm.	0.35	0.35	Own assumption
calorific value of UA coal (MWh_therm./t)	6.92	6.92	IPCC
coal input factor, t/MWh_el	0.41	0.41	
total coal production, Mt	31.22		MEEP
emission factors, tCO_2/MWh_el	0.97	0.97	Own assumption
total electricity generation, TWh	146	198	NDC
electricity generation from coal, TWh	50.5	9.9	NDC, own assumption
Number of employees in coal mining	85,529		State Statistical Service

Calculations

1. Estimate total coal input from electricity generation
   coal (t) = 1/efficiency (MWh_el./MWh_therm.) * electricity generation (MWh_el.)/calorific value (MWh_therm/t)
2. Reduce coal share in electricity generation to 5%
3. Estimate coal input necessary for reduced electricity generation
4. Estimate reductions in coal production and employees in the coal sector

Table 24: Results of the estimation method

EUR m	2019	2030
coal share of total generation, %	34.6	5
coal consumption, Mt	20.9	4.09
coal consumption reduction 2030 vs. 2019, Mt		16,77
reduction share of total coal production in 2019, %		-53.72
Reduction of employees 2030 vs. 2019, absolute		45,945
Remaining employees in 2030		39,584

8. Towards a decarbonisation of Ukraine's steel sector

Author: David Saha

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Executive summary

This paper considers the potential for decarbonizing Ukraine's steel sector, at present one of the main sources of Ukrainian CO_2 emissions. The aim is to propose policy measures that lead to a decarbonisation of Ukrainian steelmaking whilst taking into account the importance not to undermine the viability of this key industrial sector and the existence of a challenging international environment for the Ukrainian steel industry.

We analyse the status quo of the steel sector in Ukraine, its CO_2 emissions and economic challenges before reviewing the potential of different avenues (changing production processes, retrofitting or replacing technologies and plants) to reduce CO_2 emissions. Finally, we recommend a set of policy measures and set out a scenario to decarbonize the Ukrainian steel sector by 2050.

The steel sector in Ukraine

Steelmaking in Ukraine remains an important industrial sector. Together with the impact on other sectors, steelmaking contributed around 12% to GDP and accounted for 23% of Ukrainian goods exports in 2018. Steelmaking in Ukraine is based on three main technological routes: The blast furnace and basic oxygen furnace (BF-BOF) integrated route, open-hearth steelmaking (BF-OHF), and recycling mainly scrap steel in Electronic Arc Furnaces (scrap-EAF). The BF-BOF route is dominant in Ukraine, accounting for 70% of crude steel production in 2019, in line with its share in the world market. The outdated OHF technology still accounted for 24% of crude steel with scrap-EAF only accounting for 6%.

CO_2 emissions of the Ukrainian steel sector are substantial. Using world average emission intensities of steelmaking technologies, Ukraine's steel industry emitted 47.4 Mt CO_2 in 2019. This estimate is probably a lower bound as due to the old asset base, the Ukrainian steel industry is probably more emissions-intensive than the international average.

The steel sector is currently facing substantial challenges: Low world market prices combined with a high cost base lead to thinner profit margins. Trade protectionism around the globe threatens export markets. And high interest rates on credit in Ukraine coupled with political and economic uncertainty make investment difficult.

However, modernisation and decarbonisation are necessary in tandem: Production costs must be reduced using more modern equipment and methods. And producing low- or zero-carbon steel may soon become very important for selling steel on important markets. The EU is already discussing implementing a "Carbon Border Adjustment Mechanism", a tax on CO_2-content of steel. Other markets may follow, and carbon-intensive steel may be at a crucial competitive disadvantage on the world market.

Possible routes towards reducing steel industry CO_2 emissions

In general, there are three ways to reduce CO_2 emissions: optimising production processes (without hardware changes), retrofitting existing production infrastructure, replacing plants with newer technology. Each of them has specific limitations for Ukrainian producers.

Optimising production processes may involve using coal with a lower sulphur content, pig iron inputs with lower silicon content and an optimal share of scrap metal in the steel production. The quality of domestic coal is also not optimal. In general, some adjustments to production processes are likely to be the least-cost method to reduce emissions intensity, however total potential to reduce emissions is limited by the technical potential and other factors such as limited scrap steel availability and costs of imports.

Retrofitting existing production infrastructure refers to the modernisation of existing equipment without rebuilding entire plants. This includes, for example, the installation of Pulverised Coal Injection (PCI) or Carbon Capture and Storage (CCS) facilities. In past, Ukrainian companies have already invested in retrofits that increase the commercial efficiency of steel making and also reducing emissions intensity, such as PCI. This avenue also has potential, but it should be considered that, eventually, the present plants need to be replaced with completely new technology and lock-ins into old technologies because of having undertaken costly refits should be avoided.

Replacing plants with newer technology is the most expensive avenue but has the potential to substantially reduce or cut emissions and create efficiency gains. Eventually, the present park of BF-BOF and BF-OHF plants could for example be replaced by hydrogen-DRI-EAF plants. The direct-reduced iron (DRI) technology linked up with EAF is a complete alternative to other steelmaking technologies, also producing primary steel from iron ore. Hydrogen-based DRI-EAF is particularly attractive as it could produce steel without CO_2 emissions if hydrogen is generated using zero-carbon electricity. This and other technologies to fully decarbonise steelmaking are currently operated in pilot stages but are likely to reach commercial maturity in the next decade. The main difficulty for Ukraine's steel sector will be shouldering the massive required investments in a competitive market environment with low and uncertain margins.

Proposed policy measures

We propose to combine several, related policy measures, consisting of a "stick" (an increasing CO_2 tax) and "carrots" (support for investment into less emissions-intensive steelmaking, access to discounted credit). We propose a linear phase-in of a carbon tax on the steel sector, reaching a level of EUR 39/t in 2050. This long phase-in is justified by the fact that the technologies for producing carbon-free steel are not yet commercially available. Furthermore, as the carbon tax will be used for pricing carbon emissions of the steel sector, it should be exempt from the ETS for MRV-sectors.

Revenues from the CO_2 tax should actually be fed back to the steel sector in the form of investment support through a "modernisation fund", modelled on the EU modernisation fund. This fund should provide co-financing of investments that lead to reduced CO_2 emissions and be set up in cooperation with an international bank, ideally the European Investment Bank. Awarding of co-financing grants should be competitive to reward the highest emission abating investments and a frontloading of resources through borrowing on future carbon tax revenues is possible. This tax and its phase-in should be cast into binding law as early as possible to fix expectations, unlock investments into clean technology, and discourage investments and lock-ins into dirty technology.

Next, international development banks should be approached to make credit available at improved conditions for investments that lead to reducing CO_2 emissions in steelmaking as high borrowing costs for domestic steelmakers are probably a constraint on investment. Also, to ensure the feasibility and carbon neutrality of electricity-based steelmaking methods (such as EAF and hydrogen generation for DRI), steelmakers should have the possibility to procure a significant part of their power demand through public renewables auctions for 20 years in advance. This would give them planning security, lower electricity costs and the possibility to prove that their steel is carbon neutral.

Finally, an integrated strategy for a low-carbon steel sector should be created to anchor expectations and ensure consistency of private investments and public policy. It would serve to guide the setting up and calibration of the modernisation fund, address challenges in related sectors such as ensuring that sufficient zero-carbon electricity for electricity/hydrogen-based steelmaking is available and provide transparency and visibility of the entire set of policy measures.

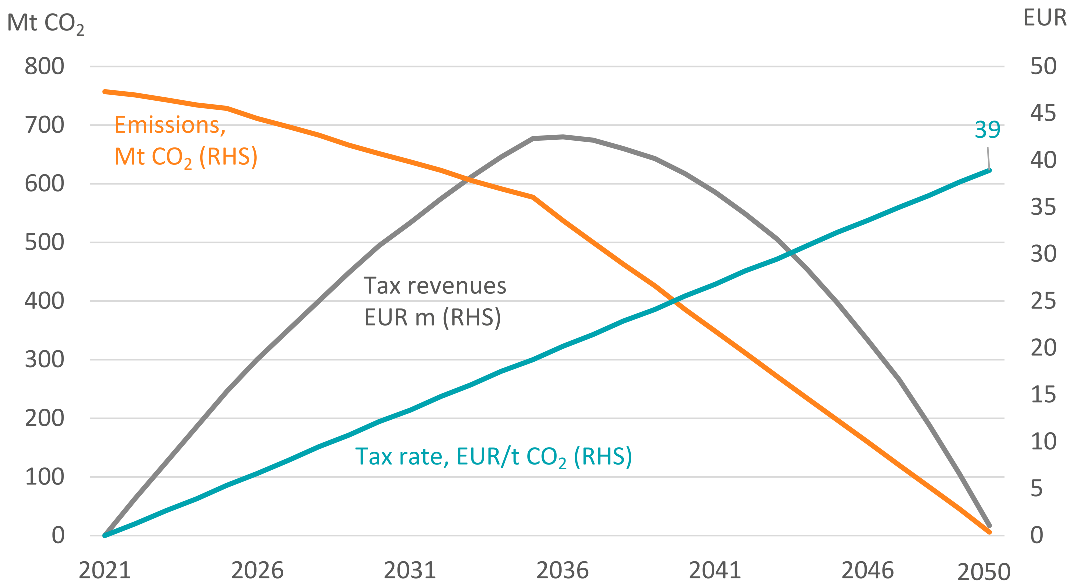
A scenario to decarbonise Ukrainian steelmaking by 2050

Full decarbonisation of the Ukrainian steelmaking sector should be achieved by 2050, in line with the intended decarbonisation of the EU steel sector. This will ensure that Ukraine does not fall behind in this essential technological development – and possibly be locked out of markets because it does not meet environmental/emissions standards or is subjected to high carbon border adjustment taxes.

Our illustrative scenario shows that this is possible using the set of policy measures proposed above. The combination of the phase-in of the carbon tax with the modernization fund should be sufficient to unlock the necessary investments whilst ensuring that the tax burden on the steel sector does not become excessive at any moment in time. We assume the potential to first cut 1% of present emissions per year until 2025, 2% until 2035 and then 5% per year, reflecting increasing availability and maturity of low- or zero-carbon steelmaking technologies.

Until 2050, this would lead to a complete decarbonization of the steel sector. At the same time, a total of EUR 12.4 bn in tax revenues will have been raised, that can be used as cofinancing grants through the modernisation fund. In order to fully replace capacity to produce 20Mt of steel (present production levels) per year, investments totalling around USD 25 bn will be required. Hence, cofinancing through the modernisation fund could reach levels of 50%. In our view, this shows that the combination of revenue and expenditure instruments, solely dedicated to the carbon-free modernisation of the Ukrainian steelmaking sector (indeed, CO_2 tax revenues after 2050 will be zero) can achieve the decarbonisation of Ukrainian steelmaking by 2050. By 2050, Ukraine can have not only a carbon-free, but also a modern, efficient and competivie steel sector. Decarbonisation and efficiency-enhancing modernisation can go hand in hand.

Figure 62: Decarbonisation scenario. Projected CO_2 emissions, CO_2 tax rate and tax revenues



Note: Dual use RHS scale for MtCO2 (CO_2 emissions) and EUR (tax rate)

Source: Own calculation

Motivation

This paper considers policy measures aimed at maintaining/re-establishing the competitiveness of Ukraine's steel industry in the context of stricter climate policy. As the second largest industrial sector and huge user of coal/coke and other forms of energy, CO_2 emissions from the steel sector contribute a large share to Ukraine's total CO_2 emissions. Furthermore, the steel sector appears to be a promising candidate for achieving emissions reductions. The old and often depreciated assets are likely to be more emissions intensive than modern plants. Technology options for shifting steel production from using coal and natural gas towards (low carbon) electricity a exist.

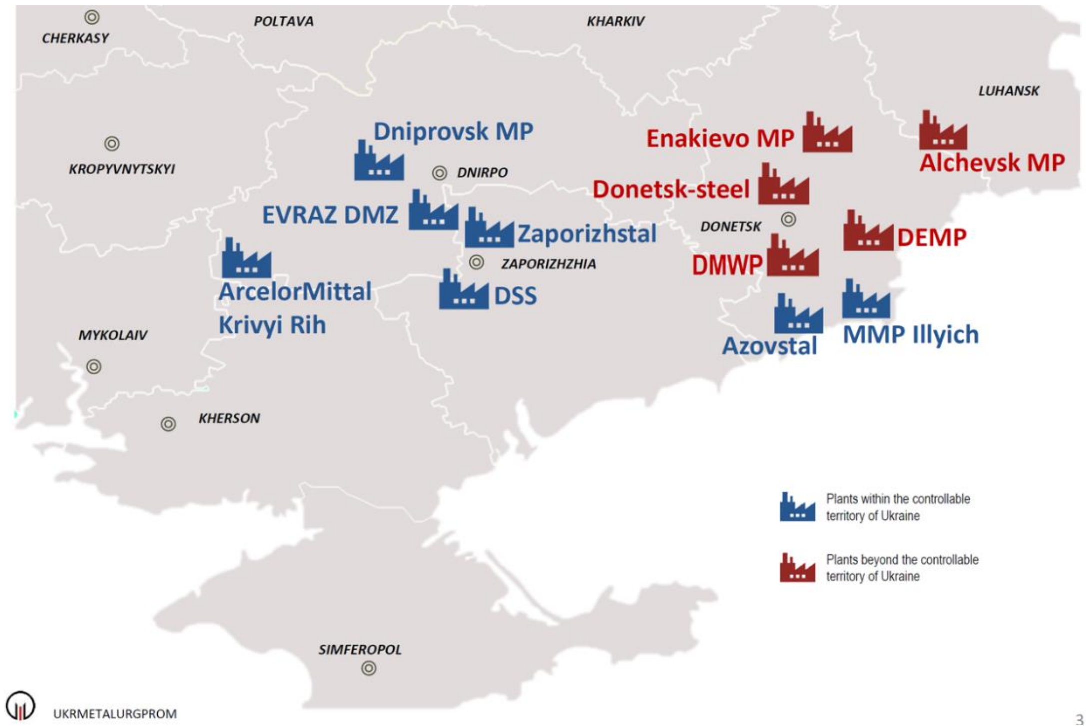
It is the aim of this paper to propose financially and economically viable policy measures towards reducing the CO_2 emissions of the steel sector. Towards this end, we first analyse the situation of the steel sector in Ukraine with regards to its economic role and situation, its technical setup and its present CO_2 emissions. We then analyse options for reducing the CO_2 emissions from the sector before proposing a set of policy measures that, given the availability of sufficient zero-carbon electricity, would permit a full decarbonisation of Ukrainian steel production by 2050.

The steel sector in Ukraine

I. Economic role and situation

Steel production is one of the main economic activities of Ukraine. The metallurgy sector is the second largest industrial sector of Ukraine and heavily export-focused, with 18 Mt of steel exports out of 20 Mt total crude steel production in 2019. Steel exports accounted for 23% of Ukraine's total outputs in 2018 (German Advisory Group, 2019). The entire value chain of the steel sector, which includes parts of the manufacturing and mining sectors contributed USD 15 bn to Ukraine's GDP, 12% of total GDP and employed ca. 603,000 people in 2018 (GMK Center, 2020).

Figure 63: Steel-making plants in Ukraine

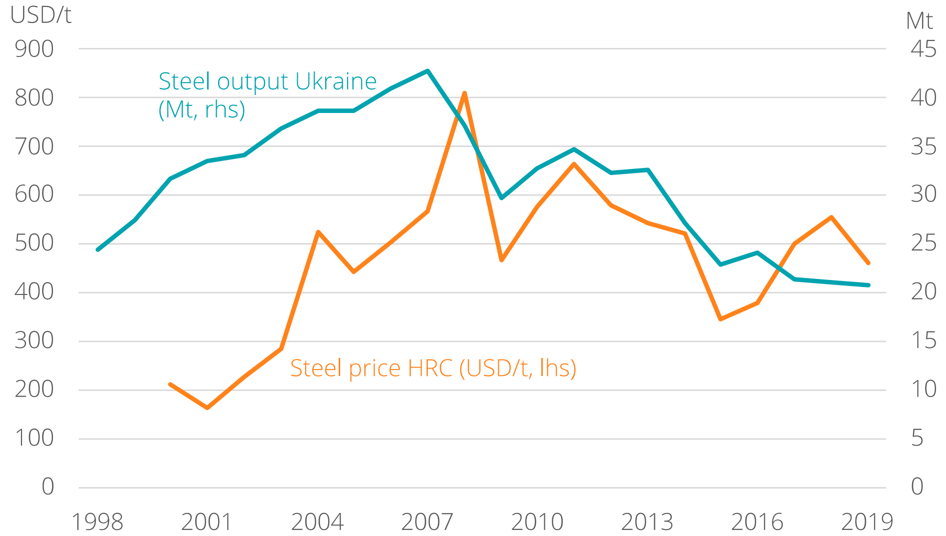


Source: Ukrmetalurgprom (2017)[3]

Ukraine's steel industry is concentrated in the East and South of the country. The large steel plants are situated in the oblasts of Dnipropetrovsk, Zaporizhia, Donetsk and Luhansk, near the iron ore mines of Kriyvy Rih and the Donetsk basin coal mines. The steel industry hence is an important downstream industry for Ukrainian coal and iron ore mining and coke production and is the backbone of the economy of many areas in the South and East of Ukraine. When considering policy measures on the steel industry, the impact on the domestic supply chain and regional economy must be taken into account.

Ukraine's steel sector is under pressure from multiple developments. The Black Sea hot rolled coil (HRC) reference price for Ukrainian steel stopped increasing in 2008 and decreased to around USD 500/t during the past years. Production costs in Ukraine are comparatively high due to the old facilities used, closer to costs of Western and Central European than Russian, Turkish or Chinese producers (CEPS, 2015). Expert estimates of costs in Ukraine range between USD 415 (for crude steel) to USD 460 per t (average of all steel output) while in 2019 steel prices were USD 464/t on average (Dragon Capital, 2019). This implies that profit margin were very thin already before the global pandemic hit in 2020.

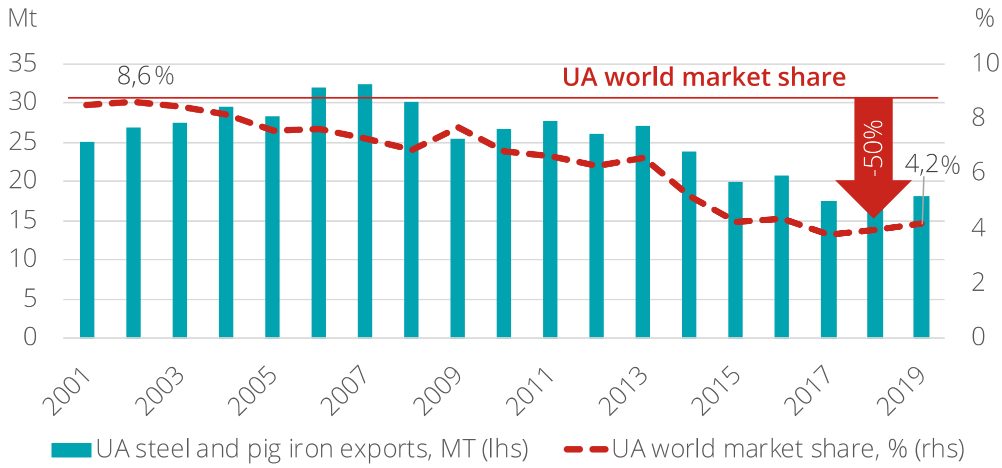
Figure 64: Crude steel production in Ukraine, Mt and steel price, USD/t



Source: Ukrmetalurgprom, Dragon Capital, Own calculation

Global trade protectionism also has harmed Ukrainian steel exports (German Advisory Group, 2019b) and may increase in the wake of the pandemic. The conflict in the Donbas also hit the output of the steel sector hard. Many steel mills are located in the non-government-controlled areas of Donetsk and Luhansk oblasts and were seized by the de-facto authorities in 2017 (German Advisory Group, 2017). Consequently, crude steel production dropped after 2013 from an average of around 33 Mt per year between 2010 and 2013 to an average of 22 Mt (2015-2019). Finally, emissions-related international regulation, such as the proposed EU Carbon Border Adjustment Mechanism, may make market access harder for Ukrainian steel with a high emissions content (see 2.3), or could at least reduce its competitiveness due to an extra duty (German Economic Team, 2020).

Figure 65: World steel and pig iron exports and Ukraine's share, 2001-2019



Note: Pig iron exports included

Source: World Steel Association, Trademap.

Over the past two decades, Ukraine has constantly lost market share on the world market for steel, dropping from a market share above 8% to around 4%. Some part of this is due to the increase in supply and exports from China, but the total quantity of steel exports has also decreased since 2007. Some of the decrease is of course attributable to the loss of steel mills in Donbas after 2014. But the decline of output and export volumes had started before, correlated with falling steel prices after 2007 and is more related to the competitiveness problems and large cost base of the Ukrainian steel industry.

Chronically low investment in the steel industry in Ukraine appears to be an important factor for the high cost base, as operational costs of older, less efficient plants are higher. Since 2008, capital investment in the steel industry was around 20 USD/t of steel on average (Ukrmetalurgprom, 2017). This is not much compared to steel prices around 500 USD/t, with most value added being domestic and often almost wholly within vertically integrated companies. More investment would have increased capital costs, but decreased operational costs.

II. Installed capacity and technologies

Steel production in Ukraine is based on three main technological routes:

1. Integrated route (BF-BOF): Iron ore is converted into pig iron in a blast furnace (BF) and then, usually in molten form (as "hot metal") further converted to crude steel in a basic oxygen furnace (BOF). This route mainly uses coke as fuel for the BF, whereas in the BOF, pure oxygen is blown into the still liquid hot metal.
2. Open-hearth steelmaking (BF-OHF): In this technologically outdated route, only in use in some ex-Soviet countries, solid pig iron inglets are converted to steel in an open-hearth furnace (OHF), heated by gas.
3. Scrap-EAF: In this route, recycling steel is made from scrap steel in an electric arc furnace (EAF). Scrap steel is also used alongside "primary steel" in the other two routes, but in lower ratios up to around 30%.

The total annual capacity of the Ukrainian steel making industry is now around 30 Mt, without the plants in the non-government-controlled areas. In the last few years, roughly 70% of this capacity was utilised, reflecting a combination of outages/repair and upgrading works as well as economic considerations due to the steel glut on global markets and low market prices. Overall, the integrated BF-BOF route for steelmaking is the dominant route of steelmaking in Ukraine, accounting for 70% of crude steel production in 2019, in line with its share in the world market. The outdated OHF technology, however, still accounted for 24% of crude steel produced in Ukraine in 2019. Even after the Kryvyi Rih OHF plant will be closed in 2020, the Zaporizhstal OHF facility will produce a significant share of Ukrainian crude steel. The scrap-EAF route only accounted for 5.5% of steel output in 2019 and 7.2% in 2017 and 2018, well below the international average of 28.8% (World Steel Association, 2019).

In general, the Ukrainian steel sector remains characterised by the presence of relatively unmodernised, Soviet vintage plants. In 2014, 90% of rolling mills, 89% of blast furnaces, 87% of OHFs and 54% of coke ovens were fully depreciated (Shatoka, 2014), although investments in initial production stages (blast furnaces, coke batteries, sinter shops etc.) will have somewhat reduced this figure by now. Continuous casting, directly casting the hot steel from BOFs into the desired shapes, only accounted for 54% of steel production in 2019 (Worldsteel, 2020). As mentioned in 2.1, this old and at least partially outdated asset base leads to relatively high production costs and low profit margins for Ukrainian steel producers. Investment projects concerned the replacement of some OHFs with BOFs, the installation of Pulverised Coal Injection (PCI) units in blast furnaces and the building of some new EAF units.

Table 25: Capacity, technology and crude steel output of steel plants in Ukraine, Mt

	Type	Capacity, kt/a	2013	2015	2017	2019
ArcelorMittal Kryvyi Rih	BOF	6.5	3.8	4.7	4.9	4.6
ArcelorMittal Kryvyi Rih	OHF	1.5	2.7	1.6	1.2	1.7
Azovstal	BOF	6.6	4.5	3.6	3.2	3.7
Zaporizhstal	OHF	4.7	3.8	4.0	4.0	3.9
Ilyich Iron and Steel Works	BOF	3.9	5.0	3.5	2.6	2.7
Dniprovskyi Iron and Steel Works	BOF	3.5	2.9	2.5	2.3	2.0
Interpipe Steel	EAF	1.3	1.0	0.9	0.6	0.6
Dnipro Metallurgical Plant	BOF	1.5	1.0	1.0	1.0	1.1
Dniprospetsstal	EAF	n/a	0.3	0.3	0.2	0.2
Elektrostal	EAF	0.6	0.4	0.4	0.3	0.3
Other		0.0	0.3	0.1	0.1	0.1
Alchevsk Iron and Steel Works*	BOF	5.5	4.2	2.5	0.7	1.4
Yenakieve Iron and Steel Works*	BOF	3.3	2.9	2.1	1.8	2.0
TOTAL			32.8	27.2	23.0	24.3

** plants located on non-government-controlled areas of Ukraine, their data was counted in total production volume till march 2017, when the assets were seized*

Source: GMK Center

III. CO_2 Emissions of the steel sector

In Ukraine's "emissions inventory", a total 37 Mt of CO_2 emissions of the iron and steel sector are reported for 2017, amounting to 17% of total CO_2 emissions of Ukraine and corresponding to 1.7 t of CO_2 per t of steel (tCO_2/t) (Ministry of Ecology and Natural Resources of Ukraine, 2019). Despite this already large number, there are reasons to believe that actual CO_2 emissions of the steel industry may be yet higher. Current legislation on reporting emissions in Ukraine is not in line with EU-MRV (Monitoring, reporting and verification). A compatible system is slated to be introduced in January 2021.

Using emissions factors based on expert estimates and international average values, we calculate a lower bound for the CO_2 emissions of Ukraine's steel industry in Table 26. The following average emission intensities were employed that reflect the entire CO_2 emissions generated by steel production (starting with coke and iron ore production for primary steel): BF-BOF – 2.3 tCO_2/t; scrap-EAF – 0.6 tCO_2/t; BF-OHF – 2.6 tCO_2/t. The emissions intensities for OHF steel are subject to uncertainty. We proceed on the assumption, backed up by industry experts, that the OHF stage itself generates twice more (0.6 tCO_2/t) emissions than a BOF, with the upstream technology (BF) being the same as in the integrated route.

Table 26: CO_2 emissions of the Ukrainian steel industry by technological route

	2017	2018	2019
Steel production, Mt			
BF-BOF	15.2	14.7	14.6
BF-OHF	4.6	4.8	5.0
Scrap-EAF	1.6	1.5	1.2
Total	*21.4*	*21.1*	*20.8*
CO_2 emissions, Mt			
BF-BOF	35.0	33.8	33.7
BF-OHF	11.9	12.5	13.0
Scrap-EAF	0.9	0.9	0.7
Total	*47.9*	*47.3*	*47.4*
Emissions intensity, tCO_2/t			
Average	*2.2*	*2.2*	*2.3*

Source: Own calculation

In sum, we arrive at 47.4 Mt CO_2 emissions of the steel industry in 2019. Although already substantially higher than the emissions inventory figure, this number is in our view still a lower bound. The old asset base in the steel and upstream industry is probably more emissions intensive than the international average. Overall, the large output share (>90%) of the emissions-intensive BF-BOF and BF-OHF steel will cause higher emissions than in other countries with an average 30% share of scrap-EAF steel.

IV. Assessment of the status quo

CO_2 emissions of the Ukrainian steel sector are substantial. With an old asset base and a high share of the emissions-intensive BF-BOF and BF-OHF routes, at first glance there appears to be a large potential for reducing CO_2 emissions of this sector. However, the economic side already indicates that this will not necessarily be easy: The steel sector is under economic pressure. Low world market prices combined with a high cost base lead to thinner profit margins. Trade protectionism around the globe threatens export markets. And high interest rates on credit in Ukraine coupled with political and economic uncertainty make investment difficult.

On the other hand, modernisation and emissions reduction are required to ensure the future of the sector. The dwindling world market share of Ukraine related to underinvestment. The high operational costs of old, inefficient plants lead to thin margins whilst world market prices are decreasing below USD 500 per t. Investment into more modern and efficient plants will be required to stay cost competitive.

Furthermore, the world market may start discriminating between “clean” and “dirty” steel. The EU is discussing introducing a Carbon Border Adjustment Mechanism which would drive a drastic price wedge between “clean” and “dirty” steel. Other large markets may follow. Being able to offer “clean” steel produced with no or minimal CO_2 emissions may become crucial to retain share in such important markets.

Possible routes towards reducing steel industry CO_2 emissions

The CO_2 emission intensity of the steel industry can be reduced in three broad dimensions: Optimising production processes for lower emissions without hardware changes, retrofitting existing production infrastructure and replacing equipment with newer and different technologies.

I. Adjusting production processes

Adjusting the input mix, especially in the BF-BOF and BF-OHF routes, can help reducing emissions intensity. This can involve using coal with a lower sulphur content, pig iron inputs with lower silicon content and an optimal share of scrap metal in the production of steel. However, if sub-optimal mixes from an emissions perspective are financially cheaper, companies may require further incentives or regulation.

For Ukrainian steel production, experts state that a higher share of scrap metal in the BOF and OHF routes has limited potential to reduce emissions intensity. According to GMK Center estimates, CO_2 emissions from BOF-shop accounts for 5-10% total carbon emissions in BF-BOF route. Increasing the scrap share of BOF charges from 10% to a maximum of 20-30% would reduce total carbon emissions by 0.5-2.0%. Increasing scrap usage is restricted by a limited domestic supply of scrap steel. Whether and under what circumstances scrap imports would be economical is disputed among industry experts.

The quality of domestic coal is also not optimal. Importing coal would however be more expensive, create transport-related carbon emissions of its own and would lead to repercussions in the coal mining industry of Ukraine. Similar reasoning applies to domestic iron ore/pig iron, although Ferrexpo demonstrated with a successful USD 1.5 bn investment that purification to a higher quality is feasible (Khoroshun, 2019).

II. Retrofitting existing technology

Due to the large capital costs of the heavy equipment required to produce steel, modernisation and retrofitting of existing equipment appears attractive as it allows reducing CO_2 emissions without rebuilding entire plants. Several options for retrofits are discussed in the literature, with different degrees of technological maturity. We focus on the two most frequently mentioned retrofit possibilities.

Pulverised Coal Injection (PCI)

This technology injects pulverised coal into blast furnaces, eliminating the need for natural gas and significantly reducing coke consumption, hence significantly reducing CO_2 intensity. The UNFCC project fiche for the installation of PCI in Donetsksteel after 2008[48] indicates a reduction of emissions intensity from 2.56 tCO_2/t to 2.37 tCO_2/t. Amortisation of PCI is quick when natural gas prices are high. Most BF in Ukraine have had PCI installed in the past, but due to lower gas prices at present, PCI retrofitting to the remaining BFs has been deprioritised by steel makers (Khoroshun, 2019).

[48] https://ji.unfccc.int/JI_Projects/DB/1ZL7OZE8KMZYH7QOB0Q0FPFXN06YVH/Monitoring/9O7SIO5YU7FTPSAZ69EYQQ2DNB5EZU/viewVerificationReport?visible

Carbon Capture and Storage (CCS)

Carbon capture and storage can be retrofitted to BF-BOF steelmaking without significant changes to the installations (ETC, 2018). CCS is the most economic option to reduce emissions intensity if prices for zero-carbon electricity are too high for other technologies, such as those based on green hydrogen (McKinsey, 2019). No CCS devices have been retrofitted to blast furnaces as of today and the first operational steelmaking unit using CCS in Abu Dhabi was fitted to a Direct Reduced Iron (DRI) plant.

Other retrofits

Furthermore, other retrofitting options focus on improving carbon efficiency by using by-products - heat for electricity/heat cogeneration, slag for road surfacing, furnace gases for preheating the charges. Automatic combustion control systems can also be retrofitted where not yet installed to improve efficiency. The orders of magnitudes of cost and efficiency gains from these upgrades are not well documented and may vary according to the specificities of each installation.

III. Replacing plants with newer technology

Given the relatively high age and high depreciation rate of Ukraine's steel making plants, replacing plants with more modern technology should be contemplated as an option. Of course, rebuilding entire plants will be very costly, but efficiency gains from newer technologies will not only reduce emissions but also operating costs.

Replacing BF-BOF and BF-OHF plants with EAF plants

Increasing the share of secondary steel, produced mainly from scrap rather than new iron ore could substantially reduce the emission intensity of Ukrainian steelmaking. The scrap-EAF route is based on electrical energy and can hence be almost carbon neutral if zero-carbon electricity is available. Investment costs to build EAFs are however substantial, around USD 600 m to 1 bn per 1 MT annual steelmaking capacity[49]. Scrap steel is in limited supply globally and building more scrap-EAF production in one place may only shift the emissions to another country, especially as recycled steel is of lower value than primary steel and can only be used for simpler purposes (ETC, 2018).

For Ukraine, focusing more on scrap-EAF steel production could make sense given the already substantial low-carbon electricity production (current emission factor is 360 g/MWh) with the potential for yet cleaner electricity in coming years of around 200 g/MWh by 2030 (EBRD, 2020). However, this will require decreases in the production costs for renewables generation (also the feed-in tariffs for renewable electricity) and substantial modernization of the grid. The downsides would be a reduction of demand for domestic coal and iron ore and the necessity of scrap imports if scrap utilisation increases by more than the present annual scrap exports of 300-500 kt. On the other hand, replacing the remaining OHF plants more modern technology will eventually become necessary for the respective companies to remain competitive (Khoroshun, 2017).

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[49] The 1.3 Mt/a interpipe plant apparently required a USD 700 m investment, http://www.interpipesteel.biz/en/news/kyiv-post-pinchuk-launches-new-steel-mill-700-million-investment,

DRI-EAF

The direct-reduced iron (DRI) technology is usually linked up with EAF furnaces is a complete alternative to the integrated route. It also produces primary steel from mainly iron ore (avoiding the scrap scarcity problems of the scrap-EAF route) and is a highly promising alternative to the emissions-intensive BF technology altogether. Currently, DRI usually uses natural gas, with its hydrogen content being used as a reduction agent to remove the oxides from the iron input and produce sponge iron. Even using natural gas, the emissions intensity, at around 0.6 tCO_2/t, is much lower than that of BF technology (~1.5 tCO_2/t) (ETSAP, 2010). Natural gas can later be replaced through limited retrofits with (emissions-neutral) biogas and hydrogen, produced by electrolysis using clean electricity [50].

According to McKinsey (2018), for zero-carbon electricity prices below USD 25/MWh, hydrogen DRI-EAF will be more cost-efficient than retrofitting CCS on existing BF technology. Our Own calculation indicate that the operational costs of a hydrogen DRI-EAF plant could be at around USD 400/t at USD 30/MWh The total investment costs for hydrogen-based DRI-EAF production lines remain subject to uncertaint as the technology has not yet commercially matured, but are estimated to be at around USD 1 bn per Mt of annual crude steelmaking capacity (Vogl, Ahman and Nilsson, 2018)

Other options and pilot technologies

Further technological changes are possible with regard to the downstream processing of crude steel by building combination rolling mills, especially at smaller facilities, and by investing into more continuous casting machines. In addition, extensive research on innovative steel-making technologies that will drastically reduce emissions is ongoing but in pilot stages. This includes technologies such as ULCOS, HIsarna or ULCORED (Climate Action Tracker, 2017, Energy Transitions Commissions, 2018, EU Strategic energy technologies information system, 2009). These technologies may also reach maturity and commercial viability during the second half of the 2020s.

IV. Assessment of suitability for Ukraine

It is generally acknowledged that decarbonising steel is one of the harder challenges of greening the economy. A key challenge is of course that CO_2 emissions in the predominant BF process are not due to energy usage, but to the chemical process of reducing iron oxides with carbons (McKinsey, 2018). Nevertheless, options to reduce emissions intensity in the steel industry already exist and further, promising technological innovations are under development.

Optimising production processes

This avenue that does not require any capital investment and technological changes is likely to only have limited potential for emissions abatement but is deemed by experts to be the least-cost option. It is currently not fully utilised due to the lower cost of lower-quality ingredients (domestic coal, impurified iron ore, larger pig iron rather than scrap shares in integrated production), whilst CO_2 emissions are not internalised at the current, negligible level of CO_2 prices. The potential especially of measures to replace domestic inputs by higher-quality imported coal or ore may be limited by detrimental effects of shipping on the quality of imported coal, shipping costs, CO_2 emissions of transport as well as considerations related to the remaining economic importance of mining for Ukraine. With the right set of policy measures (e.g. a higher CO_2 tax), this avenue would certainly be exploited by Ukrainian producers. It could also cause side-effects as some domestic inputs, especially coal, could be replaced by higher-quality imports.

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[50] http://www.hybritdevelopment.com/steel-making-today-and-tomorrow

Retrofits

In past, companies have already invested in retrofits that increase the commercial efficiency of steel making and also reducing emissions intensity at the same time, such as PCI. With the right set of incentives, such retrofits could probably be incentivised relatively easily, as they also have commercial advantages. Policy measures would have to help bridge the cost-benefit gap created by low cost of some polluting factors and high capital costs. Technologies such as CCS however, that have no commercial benefit, would be harder to incentivise and appear useful only if other methods to achieve a further decarbonisation of the sector prove too expensive (McKinsey, 2018).

Investing in new plants

Considering the age and depreciation rate of the steel industry's plants, replacing plants by modern technology could lead to major efficiency gains. As Ukraine also has good potential for low-cost, low-carbon electricity, more EAF-based steel production, both scrap- and iron-ore-based, would appear an ideal way forward for the Ukrainian steel industry. DRI technology could be used, switching to Hydrogen-based DRI once the technology and infrastructure are readily available, to almost fully decarbonise the steel industry and enhance its competitiveness, benefiting from low energy costs.

Especially DRI-EAF technology appears suitable to give Ukraine's steel industry a long-run perspective, whilst continuing to exploit comparative advantages such as the availability of iron ore. It should also lead to reduced operational costs. Nevertheless, companies will require strengthened incentives and indeed support to shoulder the necessary investments due to their magnitude and difficulties in the access to finance.

Proposed policy measures

We propose a set of policy measures combining a "stick" – an increasing CO_2 tax – with a "carrot" – support for investment into less emissions-intensive steelmaking – to assist the reduction of CO_2 emissions from the steel sector without overburdening it.

I. A gradual phase-in of a CO_2 tax until 2050

Under the present CO_2 tax of UAH 10 per tCO2, CO_2 emissions are essentially unpriced (accounting for roughly USD 1 in the production of 1 t of steel worth at least USD 450). Carbon prices need to rise to incentivise companies to abate unnecessary emissions, invest in further efficiency-enhancing equipment and develop a strategy to deeply decarbonise in the long run, but must not excessively burden companies at given emissions levels in the short run. Low Carbon Ukraine (2020) recommends an economy-wide implementation of a linearly increasing upstream tax on CO_2 emissions, reaching a level of EUR 39/t by the end of the NECP planning period in 2030, comparable to expected carbon prices in the EU. Moreover, it is suggested that in 2025 an ETS is introduced for large emitters with fixed priced allowances, which will evolve to an auction-based scheme from 2030 onwards.

We recommended to exempt the steel sector from the ETS and instead cover it by a carbon tax with a much extended phase-in phase to provide clear guidance on future carbon prices for investors. A rebate system should refund steel makers 60% of the CO_2 tax (paid by the coal mining companies) until 2030 upon proving the purchase of CO_2-taxed coal and the consequent production of steel from it. The rebates would then be linearly phased out until 2050. Effectively, for the steel sector, the implementation path of the CO_2 tax would hence be stretched to reach EUR 39/t by 2050 instead of 2030 for the rest of the economy. This is justified by the particular situation of the steel industry (heavy exposure to world market prices, technology for clean steel still in earlier technological stages).

Effective cost of CO_2 emissions per t of BF-BOF steel with current emissions intensities of 2.3 tCO_2/t would reach 12.5 EUR/t by 2025 and 28 EUR/t by 2030, with the perspective to increase to 90 EUR/t by 2050. This would set strong incentives to invest into clean technologies before the full magnitude of the tax hits, while not excessively burden producers in the short run. It is of crucial important that the phase-in of this tax is both transparent and robust (i.e. the entire phase-in should be legally fixed, not just as a political announcement) to ensure that industry participants are certain of the phase-in and consequently take future tax rates into account in their business decisions.

II. Modernisation fund for the steel industry

Steel making companies should be supported when investing in new technologies and upgrades of existing installations that lead to reduced emissions. CO_2-tax revenues from the steel sector should be used to fund a modernisation fund for the steel industry that, similar to the EU Modernisation fund[51], supports investments contributing to lower CO_2 emissions intensities through grants. As in the EU, this fund should set up in close cooperation with an international bank, ideally the European Investment Bank (EIB) that also manages the EU's modernisation fund's assets, evaluates and monitors projects and disburses resources to the implementing member states.

Front-loading of the fund's resources could be attempted enable companies to invest into reducing CO_2 emissions before facing the final CO_2 tax rate in 2050. This could be achieved by financing fund expenditures from a EUR or USD credit (as national debt), to be repaid from future CO_2 tax revenues. Although a legal "earmarking" of taxes for specific expenditure purposes is undesirable (German Advisory Group, 2019b), revenues from the CO_2 tax could be politically tied to repaying the credit.

Disbursement volumes should be phased in gradually to reach a maximum level when new CO_2-free technologies for steel production have reached commercial maturity and large investments are required to replace old by new technology. In the beginning (e.g. 2021-2025), projects would probably focus on smaller-scale measures such as PCI retrofits. Fund allocation should maximise the emissions reductions effected by the fund's resources. A competitive awarding of funding could be explored, where those projects with the highest emissions reductions per Dollar receive prioty access to the fund's resources in each application period. Grants should be strictly limited to co-funding investments. Requiring a significant financial commitment of the owner companies ensures that investments make commercial sense and do not go into technological dead ends.

III. Improved credit conditions for emissions-reducing investments

Furthermore, international development banks should be approached to make credit available at improved conditions for investments that lead to reducing CO_2 emissions in steelmaking. At present, capital costs are relatively high, especially for Ukrainian steelmakers not linked to a multinational corporation. As an example, a Metinvest USD bond due to mature in 2029 currently is traded at a yield of 9.1% whereas an ArcelorMittal bond with similar maturity trades at 4.2%. Also, difficult financial market access tends to imply the need for short amortisation periods for investments in Ukraine – 5 to 10 years in the steel industry according to industry sources, whilst the normal depreciation term for steel plants is at least 20 years. Hence, credit lines, conditioned on improving emissions intensities, with long maturities and/or at cheaper rate

[51] https://ec.europa.eu/clima/policies/budget/modernisation-fund_en

than normally available for Ukrainian steel companies could unlock further and perhaps substantial investments.

IV. Long-term electricity contracts

Making long-term contracts for zero carbon electricity available for steel producers could unlock further investments in electricity-dependent production methods. Already today, some shift towards a higher share of scrap-EAF production could be incentivised if producers had more certainty about electricity prices over the time horizon of their investment. Potential low-carbon steel production technologies such as hydrogen-based DRI-EAF are likely to almost entirely depend on electricity as their energy input, further increasing the role of predictable power prices for making the necessary investments. Furthermore, to ensure that steel is really low-carbon, the electricity must be low-carbon as well. The electricity used for low-carbon steelmaking should preferably be *additional* low-carbon electricity. Channelling existing low-carbon electricity to steelmakers would merely induce other consumers to use more high-carbon generation[52].

To ensure this, and keep cost of power low for Ukrainian steelmakers, we suggest that new low-carbon steel mills could procure a significant part of their power demand through public renewables auctions for 20 years in advance. That is, the renewables plants will send their electricity to the guaranteed buyer that passes this on to the steel mills; while the steel mills pay the agreed price to the guaranteed buyer that passes the money on to the renewables plants. This has three advantages for the steel plants:

1. They can prove to the market that their steel is really low-carbon – hence potentially selling it at higher prices for clean steel in corresponding future markets (e.g., in the EU)
2. They get renewable electricity for lower cost than if they procure the electricity themselves, as their counterparty risk (i.e., the risk that the steel-mill is not taking off the electricity in the future at the agreed price) will be borne by the guaranteed buyer. Moreover, the auctions might increase significantly in liquidity and hence attract larger players that might even more fiercely bring down prices.
3. They benefit from the falling cost of renewables. The prices in 2030 auctions might be as low as 20 EUR/MWh.[53]

To prevent gambling, we would suggest that steelmakers can only bid for less than 90% of their expected electricity demand and that there are sensible penalties for failing to take off the electricity. Moreover, the electricity from the procured renewables plants will not be a flat baseload-band, but a weather-dependent volatile stream. The steel mill will be responsible to procure the necessary complementary power on the market (or sell excess to the market). This will increase the overall electricity cost for the steel mill. If electrolysers get cheap enough, however, steel mills could adjust (at least intra-day or in other short time horizons) hydrogen production levels (along with storage) in order to ensure more efficient usage of "their" renewables stream.

V. An integrated strategy for a low carbon steel sector

An integrated strategy towards creating a commercially sustainable low-carbon steel sector will be required to anchor expectations and ensure consistency of private investments and public policy. The strategy should be developed in collaboration with stakeholders from the steel industry, science and research organisations as well as players from related sectors. However, some key objectives and measures, in particular the phase-

[52] In technical terms: the marginal power plant is often a coal plant.

[53] https://www.mckinsey.com/industries/oil-and-gas/our-insights/what-if-the-latest-wind-and-solar-auction-results-were-the-new-reality-of-electricity-prices#

in of the CO_2 tax and the target year for decarbonisation of the steel sector should be set and, in the case of the carbon tax, cast into law independently and probably before the strategy is elaborated. The strategy's role is to enable the most consistent and efficient path towards decarbonisation, given a target for decarbonisation and a phase-in timing of the carbon tax, which is the key policy instrument.

Firstly, the strategy should inform and guide steelmakers and public policy alike to ensure that investments into emissions reduction are maximally efficient, investments into technological dead-ends and lock-ins to old and dirty technology are prevented. One important contribution will be to elaborate design criteria for the modernisation fund, which must be calibrated with regard to timing of the financing, allocation mechanisms and cofinancing shares. Also, a perspective should be formed, which technologies and investment are suitable and mutually compatible for the Ukrainian context and by what time new technologies will likely reach commercial maturity. Whilst micromanagement of the modernisation fund should be prevented and it should remain as neutral as possible towards candidate technologies, inconsistencies, dead-ends and inefficient lock-ins should be prevented.

Secondly, adequate linkage of policies on other sectors, especially in the field of energy provision, should be ensured. If the decarbonisation of the steel sector should mainly be achieved by gradually replacing existing steel mills with hydrogen-based DRI-EAF plants, zero-carbon electricity will be required in significant magnitude (see section "**A scenario to decarbonise Ukrainian steelmaking by 2050**"), requiring coordination with the requisite sector policy. Also, if natural gas or biogas should be employed as an intermediate/bridging technology for DRIs, this should be linked with energy policy. And finally, the phasing out of coal as an input to steel production should lead to adequate strategies for the economic transition of coal mining regions.

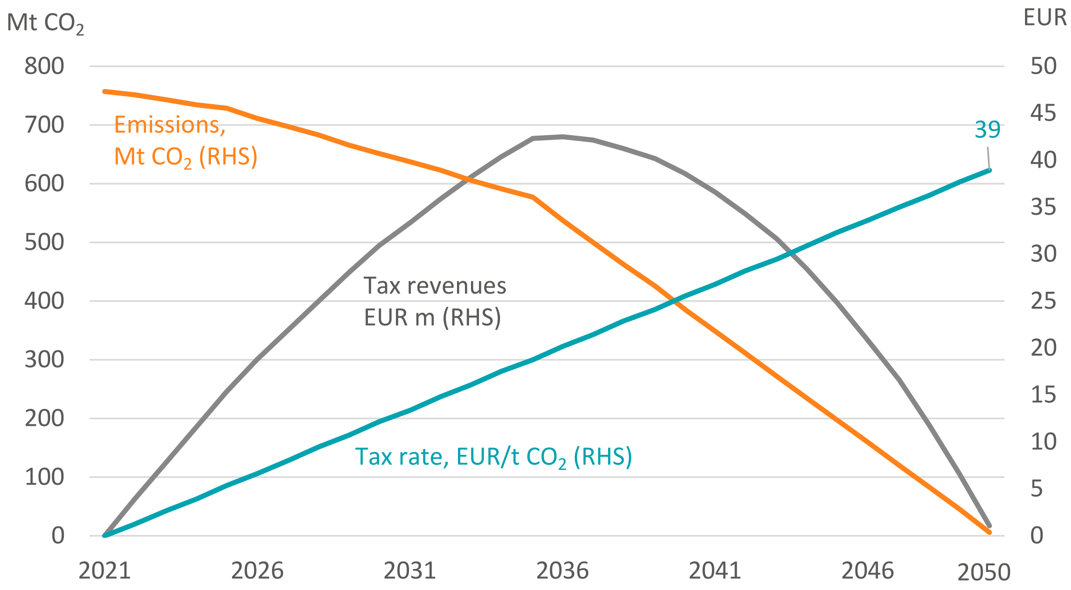
Finally, an important role of the strategy will be to contribute to the transparency of the entire process. By emphasising the phase-in path of the carbon tax for the steel sector and elaborating its relation to the other policy instrument (modernisation fund, credit conditions, electricity contracts, policies on related sectors), it will help anchoring the expectations of market participants on which their actual investments are based. Again, what is important is to fix expectations of steelmakers now to prevent lock-ins through long-lasting investments into dirty technologies (e.g. replacing an OHF plant by BF-BOF instead of DRI-EAF) that will become uneconomical with a rising CO_2 tax.

A scenario to decarbonise Ukrainian steelmaking by 2050

In the following, we attempt building a scenario the policy measures proposed in the previous chapter could effect a decarbonisation of the Ukrainian steel sector by 2050 – a date also announced by EU steelmakers as a target for decarbonisation (and, consequently, very relevant for Ukrainian producers in order not to get out of step with the EU producers and risk losing market access due to measures such as a Carbon Border Adjustment Mechanism). The numbers presented here are to be understood as a rough quantification under several assumptions and remaining uncertainty. They are intended to show that a gradual decarbonisation of the sector with our proposed measures is feasible and economically sustainable.

Aim of the scenario is to show, how the combination of CO_2 tax burden and the use of CO_2 tax revenues through the modernisation fund (to incentivise investment into CO_2-neutral steel production) could jointly play out. We hence take the proposed path of the tax on the CO_2 emissions for the steel sector (linear increase between 2021 and 2050 to reach 39 EUR/tCO_2 in 2050) as a given. We next make assumptions on a technologically feasible path for reducing CO_2 emissions (see next section). From these assumptions result the main parameters for the scenario detailed in Figure 66 and Figure 67, achieving a carbon neutral and commercially viable steel sector by 2050.

Figure 66: Projected CO_2 emissions, CO_2 tax rate and tax revenues



Note: Dual use RHS scale for MtCO2 (CO_2 emissions) and EUR (tax rate)

Source: Own calculation

Decarbonisation of the steel sector until 2050 is possible

Although steelmaking is responsible for a large share of emissions (roughly 17% of Ukrainian CO_2 emissions according to current methodology and probably at least 47 MtCO_2/year according to our calculations), decarbonisation potential in the short run is limited. Mainly smaller reductions of CO_2 emissions due to adjusted production processes and limited retrofits in plants are possible in the next few years.

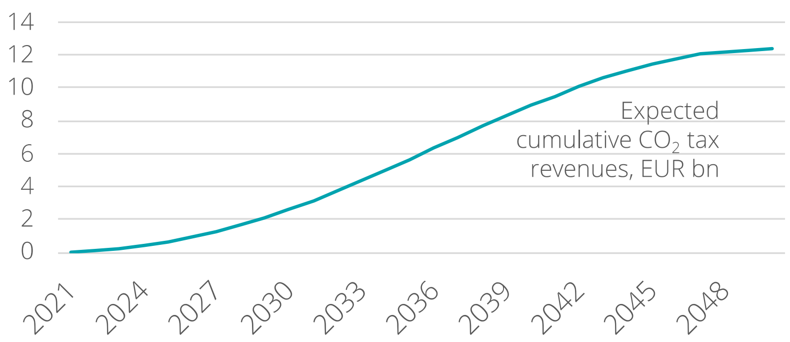
In our scenario, we assume that between 2021 and 2025, CO_2 emissions could decline by 1% of present levels per year. During this time, relatively few options (limited optimisation of production processes, some retrofits of emission-abating technologies to plants) with limited emissions-abating potential exist and will be used. Between 2026 and 2035, we assume an increase in pace of emissions reductions to 2% of present emissions per year as more technologies become commercially suitable and first larger-scale investments into replacing technology may commence – perhaps first DRI-EAF plants, running first on natural gas, to eventually convert to hydrogen (as e.g. the investment into Galati steel works in Romania by GFG Alliance). After that time, we expect technologies to produce carbon-neutral steel to have reached commercial maturity, permitting an annual reduction of CO_2 by 5% of present emissions levels (corresponding to 1 Mt of steel converted to zero-carbon production methods). This results in the steel sector finally reaching carbon neutrality in 2050.

I. Economic effect of the proposed measures on the steel sector

Investment into new technologies is indispensable to ensure the competitiveness of the Ukrainian steel sector, which is now in a situation of underinvestment. Due to that, it has low capital costs, but high costs for energy inputs (GMK Center, Khoroshun, 2019). Our calculations on the cost of h-based DRI-EAF in Table 27 show that the operational costs of DRI-EAF steelmaking could be lower than that of the current mix of plants if sufficiently cheap (zero-carbon) electricity is available. Furthermore, if main destination markets such as the EU introduce punitive tariffs for high-carbon steel imports (German Advisory Group Ukraine, 2019b), Ukraine would even more be at risk of becoming uncompetitive unless investment takes place. Hence, a successful incentivisation of investment into efficient, carbon-neutral steelmaking by the combination of CO_2 tax and investment support would strengthen rather than weaken the Ukrainian steel sector.

As proposed, the CO_2 tax would only rise very gradually, reaching its final magnitude of EUR 39/tCO_2 by 2050 only. In our scenario, by 2030, the tax would reach EUR 12.1/tCO2, but total steel sector emissions would have already been reduced by 14%. By 2040, when the tax would reach EUR 25/tCO2, emissions would have roughly halved to 25 MtCO2. When the final tax rate of 39 EUR hits in 2050, the steel sector could be fully decarbonised and no-one would actually need to pay this tax, which has then fulfilled its role as an incentive to decarbonise and not as a government revenue instrument, as most of its revenues should be channelled back to the steel sector to support decarbonisation investments!

Figure 67: Expected cumulative CO_2 tax revenues, EUR bn



Source: Own calculation

Tax revenues from the CO_2 tax would be substantial and could equip a large modernisation fund. Until 2050, CO_2 taxes from the steel sector up to EUR 12.4 bn would be received (thereafter being zero, as no more emissions occur in our scenario). Even by the standards of the steel sector with its heavy capital investments, this is a large sum of money. As co-financing for investments in the form of grants from the modernisation fund, it should easily unlock still larger investment volumes.

Investment costs for replacing current steel mills with new technology

Full capacity replacement would require USD 25 bn investment

Based on the figures in section **"Retrofitting existing technology"**, we calculate that a full replacement of a primary steel production line by h-based DRI-EAF[54] would cost approximately USD 1 bn per Mt of annual capacity once the technology has matured[55]. To maintain roughly the present annual steel output of 20Mt steel, a capacity of 25 Mt is required, as ongoing maintenance, repair and upgrade work enables an average capacity utilisation of 80% in the sector according to industry experts. Hence, replacing sufficient capacity to produce the present output would require USD 25 bn investment costs. This would allow basically a 50% co-financing through the modernisation fund if all CO_2 tax revenues from the steel sector were used.

Table 27: Cost, emissions consequences and energy requirements for replacing steel mills by hydrogen-based DRI-EAF technology.

	Maintaining current steel plants	Full replacement of existing assets by DRI-EAF
Annual Production	20 Mt	20 Mt
Investment needs		USD 20 bn
Annual CO_2 emissions	47 Mt	0 t
Annual coal consumption	20 Mt	0 t
Annual electricity consumption (excl. H_2)	-11 TWh/y	12 TWh/y
Annual H_2 consumption	0 t	1 Mt (40 TWh electricity)
Annual operation cost	420-460 USD/t	400 USD/t [@30USD/MWh] 480 USD/t [@60USD/MWh]

Source: Own calculation

Even with less expected CO_2 tax revenues (if quicker emission reduction occurs as companies invest early to avoid higher CO_2 taxes in future), financial resources for co-financing will still be substantial and probably sufficient, especially combined with the availability of long-term credits at attractive rates. Front-loading the modernisation fund's resources as proposed in section "**Proposed policy measures**" will permit earlier investment by steelmaking companies. The right degree of front-loading is crucial, and care should be taken to calibrate the policy measure correctly to ensure that investments can take place once technologies have matured (i.e. investment and operations cost of the new plants have sufficiently decreased along the learning curve).

[54] We do not have an explicit position on the future technology for carbon-neutral steel production. Whichever technology is most suitable and commercially viable for Ukrainian steelmaking should be adopted. We simply calculate our example on hydrogen based DRI-EAF as the most promising technology from our present perspective. Policy measures should be designed as neutral as possible towards technologies to ensure that other technological innovations could also be used, depending on their merits.

[55] Including electrolysers for hydrogen generation.

II. Impact on energy policy and energy security

As discussed previously, the decarbonisation of the steel sector will most likely require zero-carbon electricity at low prices to work. If all current steel plants were replaced by electrically powered hydrogen-based DRI-EAF production facilities Ukraine would need an additional 52 TWh/y of electricity; out of which 40 TWh/y would be required to generate the 1 Mt of hydrogen necessary to reduce the iron ore. While this is an ambitious target, such a build-up of renewables is possible (Low Carbon Ukraine, 2020a).

In the medium term, natural gas and biogas could be used for DRI plants before switching to hydrogen generated from zero-carbon electricity. This could temporarily increase gas imports and also, permanently, be a market for biogas from waste products of the large agricultural sector.

Furthermore, steel decarbonisation will eventually require moving away from coal as the primary energy source, taking away one of two main client sectors of the coal industry – with a similar process being underway in the second main client sector, electricity. Currently, ca. 20 Mt of mainly domestically mined coal are used annually for steel production. Adequate compensation and transition strategies for regions focused on coal mining should therefore be developed and deployed in a timely manner.

III. Assessment: Ambitious, but absolutely possible

This scenario is of course a very rough one. It makes many assumptions in a context of large uncertainty about important issues such as technological readiness, investment and operational costs of new, zero-carbon steelmaking technologies. Nevertheless, the scenario shows that a full decarbonisation of the Ukrainian steelmaking sector is possible. In order to succeed, this ambitious plan requires careful design of policy measures, especially the modernisation fund, and coordination with the build-up of large renewable energy production. But our calculations show that with a measured CO_2 tax, sufficient revenues can plausibly be generated to support substantial investment into new, efficient, and carbon-neutral steel mills through a modernisation fund to entirely replace current plants in a 30-year horizon.

As a result, Ukraine’s steelmaking would be transformed from a very aged asset base with high production costs for very emissions-intensive steel to all new steel mills, efficiently producing carbon-neutral steel. Especially as market entry barriers for CO_2 intensive steel are likely to emerge in many developed markets through the coming years, these investments are likely to be necessary to secure a future for Ukraine’s steel sector.

In our view, this shows that the combination of revenue and expenditure instruments, solely dedicated to the carbon-free modernisation of the Ukrainian steelmaking sector (indeed, CO_2 tax revenues after 2050 will be zero) can achieve the decarbonisation of Ukrainian steelmaking by 2050. By 2050, Ukraine can have not only a carbon-free, but also a modern, efficient and competitive steel sector. Decarbonisation and efficiency-enhancing modernisation can go hand in hand.

Conclusion

We presented policy measures aimed at maintaining/re-establishing the competitiveness of Ukraine's steel industry in the context of stricter climate policy. As the second largest industrial sector and huge user of coal/coke and other forms of energy, CO_2 emissions from the steel sector contribute a large share to Ukraine's total CO_2 emissions. Furthermore, the steel sector appears to be a promising candidate for achieving emissions reductions. The old and often depreciated assets are likely to be more emissions intensive than modern plants. Technology options for shifting steel production from using coal and natural gas towards (low carbon) electricity a exist.

This paper aimed to propose financially and economically viable policy measures towards reducing the CO_2 emissions of the steel sector. We first analysed the situation of the steel sector in Ukraine with regards to its economic role and situation, its technical setup and its present CO_2 emissions. We then analysed options for reducing the CO_2 emissions from the sector before proposing a set of policy measures that, given the availability of sufficient zero-carbon electricity, would permit a full decarbonisation of Ukrainian steel production by 2050.

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9. Low-Carbon Transport Policies for Ukraine

Author: Alexander Roth

Executive summary

Ukraine's greenhouse gas (GHG) emission from transport saw a strong decline in the 1990 and have been slightly increasing since the year 2000. While the economic contraction was largely responsible for past emission decreases, Ukraine needs a set of policies to actively steer the transport sector towards a low-carbon future. Despite economic challenges, we argue that Ukraine is in a good position to further decrease transport emissions and to reach its long-term climate goals. Ukrainian policymakers should focus on developing an integrated strategy that connects road, rail, and aviation. Especially the transport sector deserves holistic thinking: while different levels of governance and governments have to coordinate vertically, the decarbonization of the transport sector must be thought together horizontally with the decarbonisation of other sectors. Without a low-carbon electricity sector, many policies for the transport sector will fail.

Although Ukraine can build on an already good efficiency level of new cars and trucks, it should think about introducing its own CO_2 emission targets for vehicles. Crucially, policies aiming to upgrade the old and inefficient stock of cars and trucks should be introduced. In the context of a sustainable development, Ukraine's low rate of motorisation should be seen as an asset rather than a deficiency, helping to avoid building a car-centred mobility system. Importantly, Ukrainian policymakers should push for alternative modes of transportation, especially in the cities. Local public transport must be improved, active modes of transportation, such as walking and cycling, strengthened, and cars more efficiently used. Although emissions from domestic aviation are still small, they have been increasing in recent years. Instead of investing into new air-related infrastructure, investment should be primarily targeted to railway. Railway has a key part to play when it comes to decrease emissions from domestic flights, long-haul car travels, and freight transportation.

Crucially, transport policies for Ukraine need to be designed to provide new modes of transportation for citizens and to improve their quality of life. Policies need to be socially just, so they are attainable for citizens and politically feasible. Transport policies must be designed in an integrative way: for instance, pricing of traffic will only successful when adequate transport alternatives exist for citizens. If done correctly, various transport policies offer possibilities for economic development and will generate several co-benefits, such as lower levels of pollution, traffic, and noise. With the right policies, Ukraine can achieve to further decrease transport emissions and reach its mid- and long-term climate goals. Ukrainian policymakers will in due time need to take decisions towards this direction so that harmful trends, such as an over-reliance on cars, can be avoided from their beginning.

Introduction

Transport sectors are difficult to decarbonize due to lock-in effects and a fragmented governance.

Many researchers regard the transport sector as rather difficult to decarbonise. The reliance on fossil fuels, the persistence of demand (thus the ineffectiveness of taxes) (Pietzcker *et al.*, 2014) as well as lock-in effects and a fragmented governance (Banister *et al.*, 2011) are often given as reasons. Viable solutions are being complicated by the multitude of actors as well as interactions with other sectors and fields. To reach a low-carbon transport future, Ukrainian policymakers will have to take the right political and economic decisions now. Ukraine must avoid getting locked in a carbon-intensive transport infrastructure, which will be costly to change in the future. Instead of suggesting isolated measures, we argue in favour of a comprehensive strategy. As described by Banister *et al.* (2011), the transport sector is multifaceted, making it necessary to coordinate small and targeted measures for individual measures under a wider strategy.

A carbon-intensive transport infrastructure can be avoided with a comprehensive strategy.

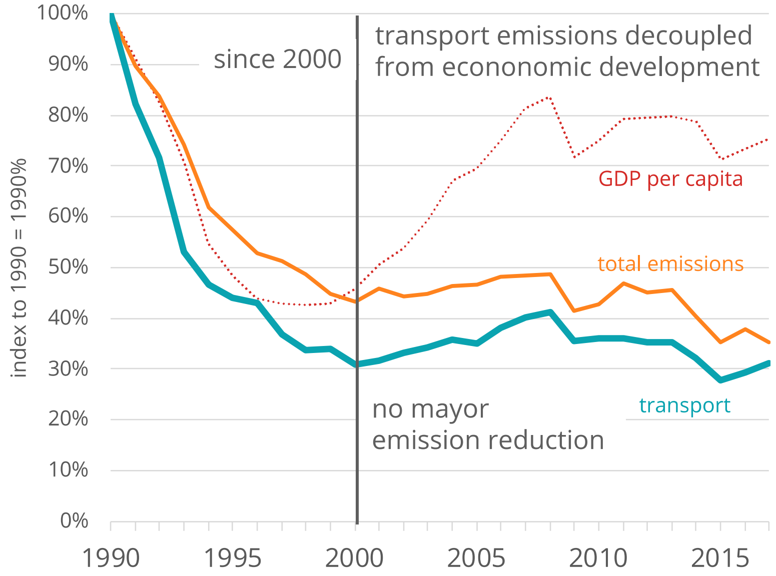
This policy report serves several goals: First, it aims to inform the reader about the latest state of GHG emission of the Ukrainian transport sector as well as its main transportation trends. Second, it sheds light on some of the most important policy developments in the European Union that could serve as inspiration to Ukraine. Finally, it discusses different transport policies that could be developed in Ukraine.

Overview emissions

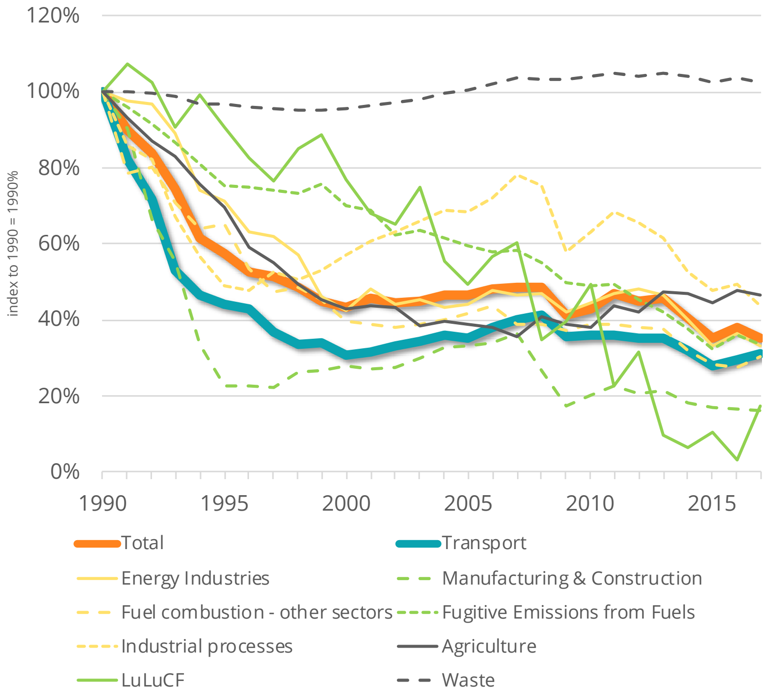
Ukraine's transport sector reduced its yearly GHG emission by 70% between 1990 and 2017.

Ukraine's transport sector and its emissions are still shaped by the drastic changes the country underwent during the last 30 years. The collapse of the economy in the 1990s resulted in a strong decrease of demand for transport and thus emissions. Ukraine's transport sector reduced its yearly GHG emission by 70% between 1990 and 2017. Figure 68 provides an overview of past emissions per sector (relative to 1990) and highlights the similarity of reductions between the sectors (except for "waste"). Like most sectors of the Ukrainian economy, reductions occurred during the contraction of the Ukrainian economy in the 1990s (see the drawn line "GDP per capita"). Emissions from transport stabilized around the year 2000 and have been decoupling from the further economic development since then, yet no mayor emission reduction has been achieved since 2000.

Figure 68: GHG emissions per sector (relative to 1990)



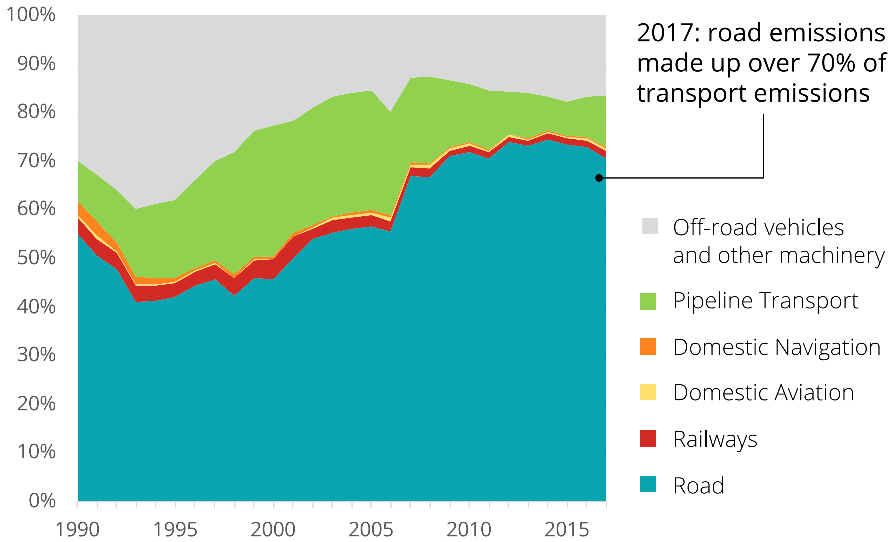
Notes: GDP per capita in purchasing power parity (PPP) (constant 2017 international USD)



Source: UNFCCC (2020); World Bank (2020)

While transport emissions fell from 112 Megatons CO_2 equivalent (Mt CO_2-eq) in 1990 to 35 Mt CO_2-eq in 2017[56], their share in overall emissions remained about constant. Currently, Ukrainian transport sector emits about 10% of all GHG emission, but accounts for 71% of total Ukrainian oil consumption in 2018[1] (Ukrstat, 2020a). The composition of emissions changed markedly over the past three decades. The most pronounced change is the increasing share of road vehicle emissions (Figure 69). In 2017, road emissions were responsible for over 70% of all transport emissions, making it the most important issue to tackle for future transport policies.

Figure 69: GHG emissions of the transport sector (in shares)



Source: UNFCCC (2020)

[56] Latest numbers available.

Overall, transport emissions are still a minor issue in Ukraine as compared to other countries. However, if the trends from the EU are of any guidance – increasing car ownership for example – there is a risk that wrong strategic choices today could make transport emission a problematic issue in the future.

Road emission

With a share of over 70%, road emissions are the largest contributor to Ukrainian transport emissions.

With a share of over 70%, road emissions are the largest contributor to Ukrainian transport emissions. According to latest numbers (2015) by the International Organization of Motor Vehicle Manufacturers (OICA, 2020), Ukraine's vehicle fleet consists of around 9.1 million vehicles, of which 7.4 million are passenger cars and 1.7 million commercial vehicles (light and heavy duty trucks and buses)[57]. However, two reports (Hill & Klimenko, 2016; The State Enterprise 'State Road Transport Research Institute' & Institute of Engineering Ecology, Ltd, 2017) point out that those fleet numbers are most likely too high because official numbers do not properly account for scrapping of old cars. For 2014, Hill & Klimenko (2016) report an entire vehicle fleet of 4.6 million vehicles consisting of 3.7 million passenger cars, 766,000 trucks, and 105,000 buses[58]. The large discrepancy of fleet sizes between different sources also calls for an improvement of data management and publication so that independent researchers can work with reliable data.

The level of motorization is low compared to other countries.

Ukraine's level of motorization is low compared to other countries. In 2015, Ukraine had 164 passenger cars per 1000 inhabitants, which is less then direct neighbours such as Russia with 308 and Hungary with 325 and more prosperous countries such as Germany with 552 and Italy with 614 (Figure 70). As for commercial vehicles, Ukraine has a rate of 38 per 1000 inhabitants which makes it also the lowest in the abovementioned group of countries, however, the differences are much smaller. Overall, we see that between 2005 and 2015 (almost) all countries had growing rates of motorisation, especially with regard to passenger cars. The growth was particularly strong in Russia (79%) and Ukraine (39%). These motorization rates are based on OICA (2020) numbers to allow for cross-country comparison. As mentioned above, these figures are called into question and when using data by e.g. Hill & Klimenko (2016), motorization rates would be lower for Ukraine. These varying data, however, do not alter our subsequent policy recommendations.

Vehicle fleet has a high average age.

A prominent issue is the age of Ukraine's vehicle fleet. Reliable and good data are hard to obtain. Yet, the report by Global Fuel Economy Initiative in Ukraine (2018) lists an average age of the Ukrainian vehicle fleet of around 19 years (in 2015). Unfortunately, we were not able to obtain disaggregated age data for CARS and trucks separately. The age of the fleet is an indicator for its low efficiency with respect to CO_2 emissions and other pollutants. For the entire fleet (2014 data), Hill & Klimenko (2016) reports that over 65% of vehicles cycling in Ukraine are of Euro-3 standard or older, while around 30% of the fleet have Euro-4. Less than 5% of the fleet are Euro-5 vehicles. We expect that these numbers have improved since 2014, however they show the age and efficiency problem of the Ukrainian fleet.

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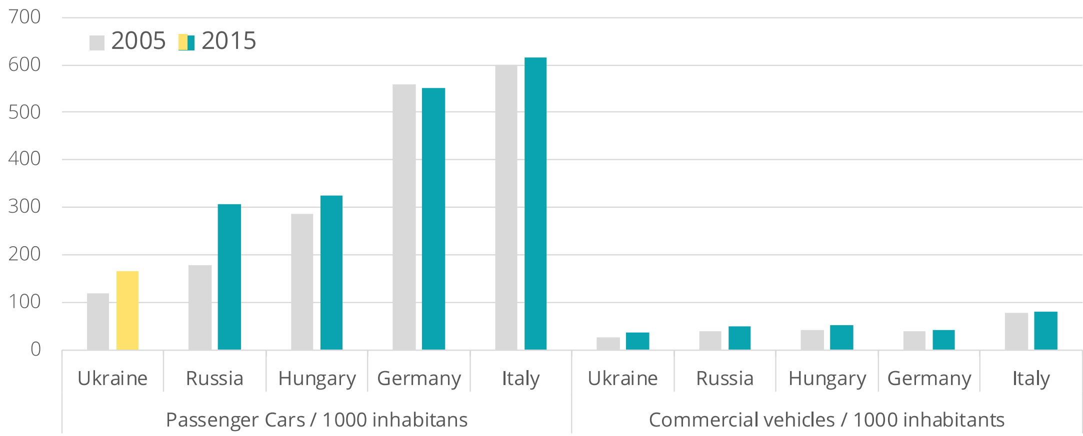
[57]The numbers by OICA (2020) are roughly equal to the ones stated by the Ukrainian Ministry of Infrastructure (without date) (Ministry of Infrastructure of Ukraine, n.d.). Global Fuel Economy Initiative in Ukraine (2018) cites the same numbers: 9.2 million vehicles in total, out of which 6.9 million passenger cars, 1.3 million trucks, 840,000 motorcycles and 250,000 buses. In contrast, numbers by the European Automobile Manufacturers Association (ACEA, 2018) are consistently higher (for Ukraine as well as other countries): for 2015, they report 12.7 million vehicles in total, out of which 9.6 million vehicles are passenger cars, 3 million are trucks (light and heavy), and 150,000 are buses.

[58] These numbers coincide broadly with those of the report by The State Enterprise 'State Road Transport Research Institute' & Institute of Engineering Ecology, Ltd, (2017)

Figure 70: Motorisation in selected countries (units per 1000 inhabitants)

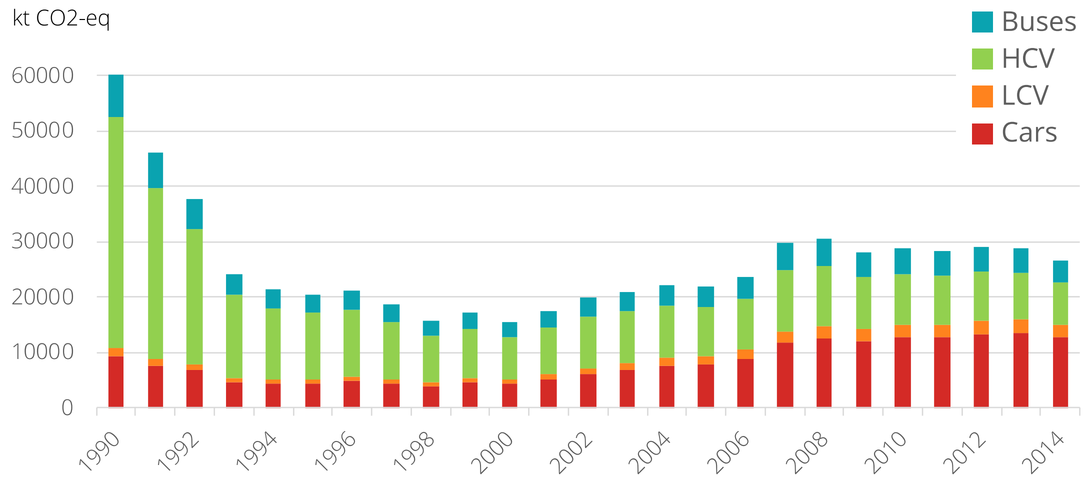


Source: OICA (2020); World Bank (2020)

Passengers cars emit half of all road emissions, increasing their share strongly since 1990.

The assessment of road emissions is complicated due to the lack of detailed data. Ukraine only reports partially disaggregated road emission data to the UNFCCC. Using those data, we are not in a position to analyse separately the importance of subgroups on road emissions: passenger cars, light-duty commercial vehicles[59] (LCV), heavy-duty commercial vehicles[60] (HCV), and buses. Fortunately, other sources (Hill & Klimenko, 2016) report disaggregated shares for at least certain years. According to that report, passenger cars emitted half of all road emission (48%) in 2014 (latest data available), while HCVs emitted 29%, buses 14%, and LCVs 10%. Since 1990, passenger cars strongly increased their emission share, while the share of LCVs only increased slightly. Emissions of HCVs have lost some of its importance, yet they still hold the second-largest share of road emissions in 2014 (Figure 71).

Figure 71: Road emissions



Notes: Absolute emissions are based on total road emissions and emission shares; share values for the years 1990, 2000, 2010, 2014 are taken from Hill & Klimenko (2016), remaining share values are interpolated.

Source: Hill & Klimenko (2016); UNFCCC (2020)

[59] Commercial vehicles (trucks) with a weight of less than 3.5 tonnes

[60] Commercial vehicles (trucks) with a weight of more than 3.5 tonnes

Looking at the more recent period, we see that road emissions rose by 70% between 2000 and 2014. In the same period, car emissions increased by 190%, LCV emissions by 234%, buses emissions by 39%, while HCV emissions dropped by 1%. Despite the fall of emissions in 1990s, these short-term trends call for action to limit the further increase of road emissions and to provide solutions for their long-term.

Policy Fields

This chapter discusses four different "policy fields" we identified as especially relevant. For each field, we start with a brief analytical part by highlighting the most important facts. Subsequently, we propose and discuss different policy options for that field. Because of the overarching importance, we discuss "passenger cars" separately (section I), as urban and non-urban emissions are both affected. The remaining policy fields "urban traffic", "freight", and "long-haul transportation" are structured around their functions and not around specific modes of transportation to emphasise the holistic approach of transport policy we put forward.

I. Passenger Cars

a. Analysis

Car fleet

Currently, Ukraine's passenger car fleet contains around 7.4 million vehicles (OICA, 2020). However, due to missing mandatory technical inspection, numbers have to be interpreted with caution as the official registration system fails to properly account for scrapped or obsolete vehicles (Global Fuel Economy Initiative in Ukraine, 2018). As said before, figures for the entire fleet (not only passenger cars) may indicate that Ukraine has a problem with an old and inefficient car fleet.

Used cars play a significant role and still account for 40% of new car registrations.

Used cars play a significant role in Ukraine. While the share of used cars among the newly registered vehicles has been decreasing recently, those still account for 40% of new car registrations. Around two thirds of newly registered used cars are less than 4 years old, yet a third is still older than 5 years (Global Fuel Economy Initiative in Ukraine, 2018). In addition to used cars, Ukraine's car fleet also has a large share of foreign registered cars. As of January 2018, more than 400,000 foreign registered cars (Global Fuel Economy Initiative in Ukraine, 2018) were driven in Ukraine, accounting for a substantial share of the entire car passenger fleet. Other sources even report total numbers of up 1 to 2 million (Holubeva, 2020). Due to their age (often 15 years and older) they are a major problem when it comes to reducing emissions in the Ukrainian car fleet.

Sales of electric cars have seen a recent increase.

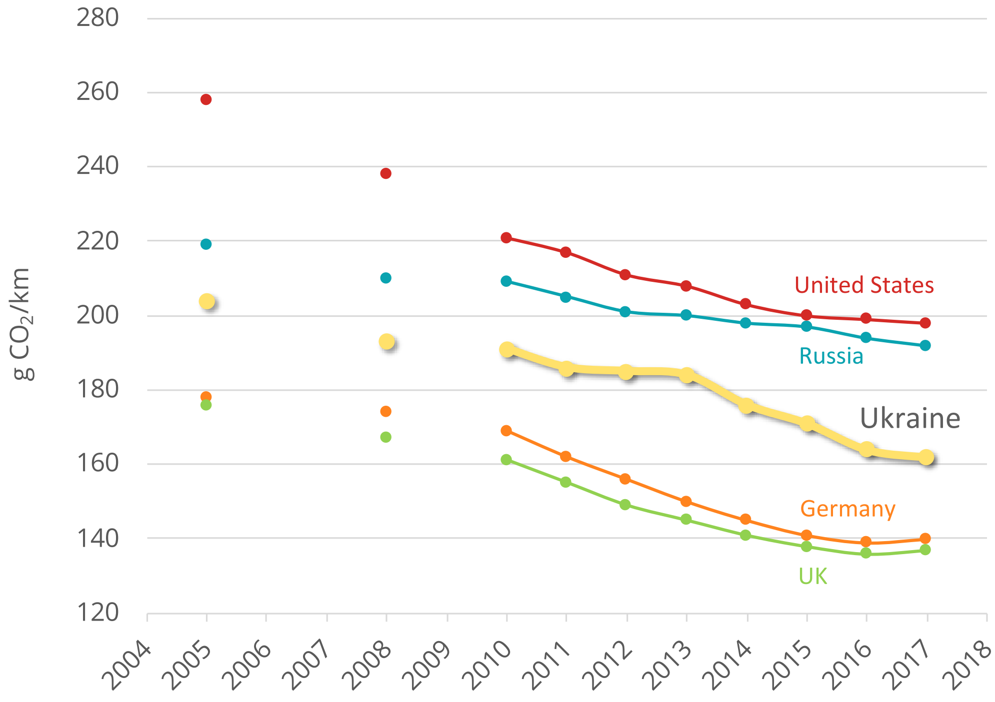
Regarding electrification of the fleet, electric car sales have seen an uptake in recent years in Ukraine. In 2014, only 62 electric cars were sold (share of 0.07%), yet this number has increased to 1,148 cars (share of 1.5%) in 2016 (Global Fuel Economy Initiative in Ukraine, 2018) and further to 7,012 vehicles in 2019 (112 Ukraine, 2020). Thus, Ukraine is in the top 12 of European countries by total amount of electric vehicles and shows one of the highest growth rates (IRS Group, 2019).

CO_2 efficiency

CO_2 efficiency of new firstly registered cars has improved in recent years.

CO_2 efficiency of new firstly registered cars has improved in recent years in Ukraine. CO_2 emissions of per kilometre of new cars were around 160 g/km in 2017, which makes Ukraine ranking above countries like Germany and the UK, but below neighbours such as Russia and other advanced economies such as the US (Figure 72) (IEA, 2019a, 2019b).

Figure 72: Emissions of newly registered passenger cars



Source: IEA (2019a; 2019b)

Regarding the emissions of the existing fleet, a recent report (The State Enterprise 'State Road Transport Research Institute' & Institute of Engineering Ecology, Ltd, 2017) shows that the average fuel consumption of the passenger car fleet has also been decreasing, thus CO_2 efficiency has been increasing (yet with differences between gasoline and diesel cars).[61]

b. Policy recommendations

The role of cars should be limited for the future Ukranian transport model.

Instead of opting for a car-centred mobility model followed by many European countries, Ukraine should aim to progress to a sustainable transport sector in which cars are only one means of transportation besides many others. The still low level of motorization offers Ukraine the opportunity to directly move to a sustainable mobility model. Public transport (chapter II) has to play a strong role, which is complimented by an efficient fleet of passenger cars. Even an overreliance on a fleet of electric cars only would go hand in hand with problems such as high energy usage, loss of public space, and ultimately congestion. A more effective car taxation, mainly guided by actual emissions, could steer car sales towards more efficiency. Ukraine policymakers have to consider implementing policies that foster the upgrade of the existing car passenger fleet. Crucially, all policies have to be pursued in a socially acceptable way. Only if effective and affordable alternatives such as a strong public transport system exist, the proposed policies will turn out to be successful.

[61] For gasoline cars, fuel consumption decreased from 11.18 l/100km (2000) to 8.74 l/100km (2015), for diesel cars it increased from 6.98 l/100km (2000) to 7.38 l/100km. Assuming 2,392 grams of CO_2/litre of gasoline and 2,640 grams of CO_2/litre diesel, we come up with the following average CO_2 efficiency of the Ukrainian car fleet: for gasoline cars, efficiency increased from 267 g CO_2/km (2000) to 209 g CO_2/km (2015), while for diesel cars efficiency decreased from 184 g CO_2/km (2000) to 195 g CO_2/km (2015).

Emission standards

Emission stan-dards, especially for used cars, should be discussed to increase passen-ger car efficiency.

Ukraine has relatively strict pollution standards for new vehicles. As of January 2016, only vehicles that comply with the Euro-5 standard are permitted to be registered (Hill & Klimenko, 2016). However, the introduction of the Euro-6 standard, initially planned for 2018, was rescheduled first to 2020 and recently even pushed to 2025 (Ukrainian Journal, 2019). For used cars, Ukraine lowered its standard to Euro-2 in 2018 (Verkhovna Rada of Ukraine, 2019), detrimental to increasing its fleet efficiency. The Euro standard is primarily a pollution standard that limits the emissions of different pollutants but foresees no limit on GHG emissions (European Union, 2007). Ukraine has no own standard that restricts the amount of GHG emissions emitted by newly registered cars.

We propose the introduction of a CO_2 emission standard for new cars which would make sure that the needed fleet renewable would be sustainable. In addition, Ukraine might be negatively affected by tightened regulatory standards in the EU (Box 1). There is the possible danger that manufacturers will try to sell CO_2-inefficient cars in Ukraine instead in the EU. Ukraine should use the opportunity to introduce a legislation similar to EU that would be (1) effective in reducing CO_2 emissions from new cars and (2) be simple for manufacturers to comply with, given a possible similarity with EU regulation. In any case, tighter emission standards could effectively lower future CO_2 emissions and are possibly politically easier to adopt than other measures.

Background info

CO_2 emission performance standards for passenger cars and light commercial vehicles in the EU

In 2019, the EU saw a mayor update of its CO_2 emission performance standards for standards for passenger cars and light commercial vehicles (LCV). Until 2019, Regulation (EC) 443/2009 defined CO_2 emission targets for cars, while Regulation (EU) 510/2011 set targets for LCVs. For cars, a target of an average 130 grams of CO_2 per kilometre (g CO_2/km) was set. Car manufacturers had to ensure that average CO_2 emissions of their sold cars in the EU ("EU fleet-wide target") were not above that target in the years 2015 to 2019. This target was tightened to 95 g CO_2/km for the year 2021. For LCVs (Regulation (EU) 510/2011), EU fleet-wide targets were at 175 g CO_2/km for the period 2017 to 2019 and then decreased to 147 g CO_2/km as of 2020.

In 2019, Regulation (EU) 2019/631 was adopted that replaced the preceding regulations. This new regulation aims to reduce CO_2 emissions for passenger cars LCVs setting EU fleet-wide CO_2 emissions targets for the years 2025 and 2030, applying to newly registered vehicles. Targets are defined as relative changes in comparison to the year 2021. For cars, a 15% reduction target as of 2025 on and 37.5% reduction target as of 2030 is foreseen. For LCVs, the reductions are 15% as of 2025 and 31% as of 2030.

To incentivise the sale of electric and hybrid vehicles, car manufacturers can exceed the benchmark if a certain minimum number of zero- or low-emission vehicles are sold. If targets are not met, car manufacturers have to pay fines according to the number of cars sold in the EU and to the excess of the target.

Since many car manufacturers are supplying the EU car market as well as the Ukrainian car market, Ukraine could indirectly profit from the EU legislation as improved cars will also be sold in Ukraine. However, since the legislation only defines fleet standards, there is a risk that car manufacturers will try to sell inefficient cars to non-EU markets, including Ukraine, to increase fleet efficiencies in the EU.

Source: European Union (2019);
EU Commission (n.d.-a, n.d.-c)

Taxation

A recently published report (Ecoaction, 2020) points out that Ukrainian legislation has moved in recent years towards favouring car ownership. Taxes on vehicle registration and emission of cars were abolished in the beginning of 2015 and the newly introduced tax on car ownership has no real environmental component: while expensive cars are taxed, old and inefficient cars remain untaxed. Although politically sensitive, an effective taxation scheme has to be introduced that favours the uptake of small, efficient cars over inefficient cars.

The current taxation system does not properly incentize the uptake of efficent cars. A reform should be discussed.

Ecoaction (2020) points also out that there is a tax privilege for owners of old European cars who do not have to perform customs clearing when importing their car. That policy is detrimental for upgrading the Ukrainian passenger car fleet and for reducing emissions from GHG gases and pollutants.

Stimulating measures have helped to increase sales of electric vehicles. In 2016, custom duties on electric vehicles were abolished, and as of 2018, excise tax and VAT for the import of electric vehicles have been dropped as well (Global Fuel Economy Initiative in Ukraine, 2018). Due to increasing sales of electric vehicles, we believe that further measures (including subsidies) should be viewed with caution as they tend to be very costly and often highly regressive, favouring consumers with higher incomes. Crucially, Ukraine has to decarbonise its electricity sector. Without increasing the share of renewable energy on Ukrainian electricity production, electric cars will not be of help to decrease GHG emissions of passenger cars.

Used cars

Although politically sensitive, Ukraine needs to tackle the age and efficiency of its passenger car fleet. Its car fleet is old and inefficient, and without upgrading car emissions are unlikely to decrease eventually. Hence, the used car market will have to be limited and the number of foreign registered cars driving in Ukraine to be reduced. Stricter regulations on the registration of cars, the circulation of non-registered cars, higher customs for imported cars, and emission standards for already registered cars could be used to slowly reduce the number of old cars in the Ukrainian vehicle fleet. In July 2020, the Ukrainian government discussed changing the rules of importing cars to limit the number of foreign registered cars driving in Ukraine (Holubeva, 2020). In addition, appropriate and reliable governance structures to (technically) check cars on a regular basis should be introduced. These checks could be used to certify cars regarding their safety as well as emissions.

Measures need to be Introduced that limit the importance of used cars.

II. Urban transportation: cars, local public transport, and active modes

Due to the growing relevance of cities at different socio-economic levels, urban transport policies are increasingly important. However, due to the complexity of urban transportation system, the multitude of stakeholders involved, as well as strong "lock-in" effects, we observe that changes in mobility patterns in cities will be difficult to achieve.

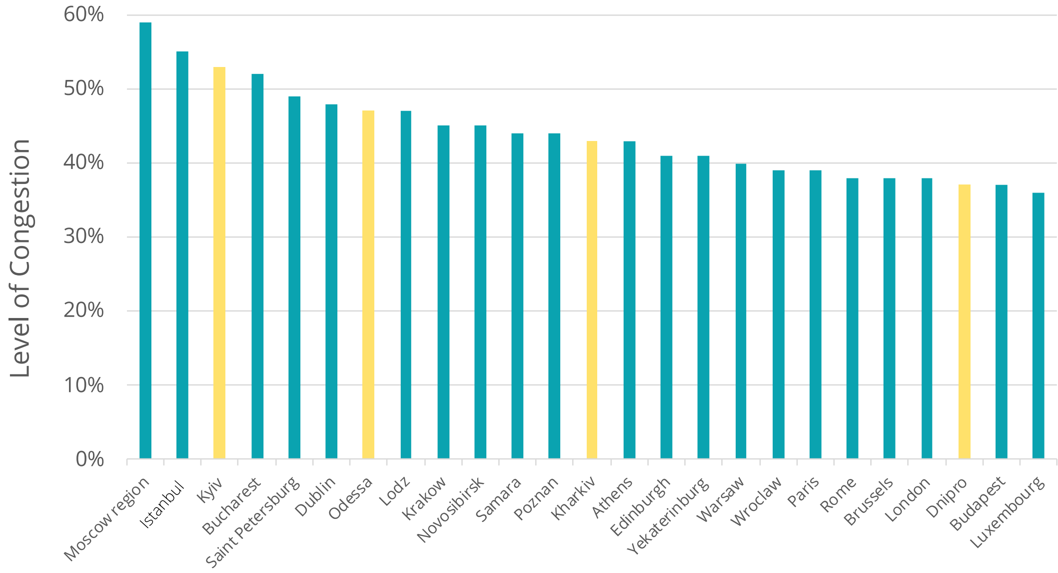
a. Analysis

Despite the relative low levels of motorisation, recent evidence by the TomTom Traffic index 2019 (TomTom, 2020) and Stepanchuk *et al.* (2017) suggests that Ukrainian cities are strongly congested, actually among the most congested cities in Europe. The index places four Ukrainian cities in the list of the 25 most congested cities in Europe: Kiev ranks 3rd in Europe and 12th worldwide. The increase of congestion has been especially strong in Kiev between 2017 and 2019. The city of Odessa ranks 7th Europe-wide (18th

Ukrainian cities are among the strongest congested in Europe.

worldwide), Kharkiv 13th (29th), and Dnipro 23rd (47th). Interestingly, Dnipro, a city of around 1 million inhabitants, is just one place behind London, the largest city in the UK (Figure 73).

Figure 73: Top-25 congested cities in Europe



Notes: The TomTom Traffic index (TomTom, 2020) measures the average congestion time of a city. For example, a congestion level of 53% in Kiev means that a 30-minute ride with a car will take 53% longer in congested times than in uncongested times.

Source: TomTom (2020)

Within Ukrainian cities, cars are however only one mode of transport. A recent study (Rudakevych *et al.*, 2019) provides a comprehensive overview over the state and development of urban (electric) transportation in Ukraine. In competition with local public transport, there are numerous private bus operators (mainly marshrutkas) that drive mostly small buses (Rudakevych *et al.*, 2019). These private companies, a result of the privatisation of the bus system, are mainly operating on highly demanded lines and are not a perfect substitute for public transport, which is supposed to run in less frequented areas as well.

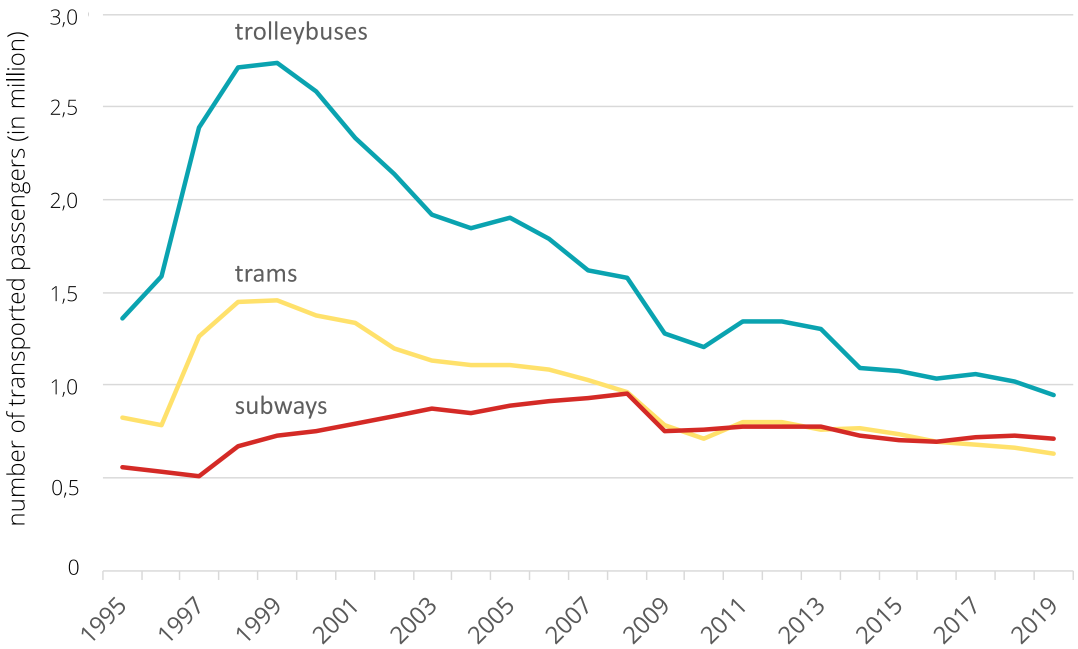
Ukraine has a strong network of local public transport, which has been witnessing a decline since 1990.

Overall, Ukraine has still a strong network of local public transport, which, however, has been witnessing a decline since 1990s. At the end of 2018, Ukraine had 19 active tram networks (down from 32 in 1991). Most trolleybus networks remained in operation as their number decreased only slightly from 45 to 41. Three metro networks (Kyiv, Kharkiv, Dnipro) are currently in operation. Yet, the current state of local public transport infrastructure in Ukraine tells us only a partial story about its performance. As Rudakevych *et al.* (2019) reports, the rolling stock (of trams and trolley buses) is renewed too slowly and about 90% of the fleet has already exceeded its foreseen maximum life. In parallel, the number of trams and trolleybuses decreased since the 1990s by 54% and 49%, the number of metro coaches by 50%.

As shown in Figure 74, also the number of passengers of (electrified) public transport decreased strongly in the last 25 years, especially for trolley buses and trams. Only subways were able to gain passengers. While data[62] on car and bus rides are sparse (or not disaggregated), we assume that people have partly switched to cars given that both car ownership and emissions have been rising in the last years.

[62] Available data do not differentiate between local and long-haul buses rides; hence we cannot attribute the number of passengers transported by buses purely to urban bus transportation. Moreover, the number of passengers carried by

Figure 74: Number of passengers transported by type of carrier



Notes: After 2013, excluding Crimea, the city of Sevastopol and the territories in the Donetsk and Luhansk regions.

Source: Ukrstat (2020b)

b. Policy Recommendations

As said, cities are gaining importance throughout the world, and urban transportation is becoming more and more relevant. Especially in urban contexts, transport policies have to be thought holistically. That means that it is crucial for policymakers of different levels (e.g. national and local) to work together. Their goals can align when for example federal CO_2 reductions targets and local traffic reductions targets can be reached in the same way, e.g. fostering public transport. However, a push of electric cars by the federal levels to decrease CO_2 emissions would counteract local ambitions to decrease traffic.

Transport policies have to be thought holistically so that different governance work together.

The promotion of alternatives to cars is important at several levels. Without viable alternatives, citizens have no chance to change their mobility choices, and potential traffic measures will only lead to higher costs. Alternative modes of transportation to cars can also contribute to an economic development and to increases in citizens' quality of life. An improved local public transportation service can enable more citizens to reach areas for work or consumption, which would not be accessible otherwise. Local authorities should also be willing to cooperate with private actors (e.g. via private public partnerships) to reach effective and cheap solutions to reduce traffic and emissions.

Alternatives to cars are important and can contribute to an economic development and an increases in citizens' quality of life.

To reduce traffic and thus emissions in Ukrainian cities, a combination of "push" and "pull" policies is needed. A potential "push" policy is a congestion charge that is discussed below. Possible "pull" policies encompass the extension of local public transport and the promotion of alternatives modes of transportation.

buses has decreased in the last 25 years. Unfortunately, no data exist that show the development of passengers carried by (private) cars (in urban and/or rural areas).

Pricing and restriction policies

Pricing urban traffic could be one tool to lower GHG emissions.

A possible "push" policy is a congestion charge scheme (Box 2) which could decrease traffic in major Ukrainian cities and generate funds to expand and upgrade public transportation services. Pricing urban traffic via a congestion charge scheme would not only lower GHG emissions, but also decrease local pollution, noise, commuting times, and the need for infrastructure repair. Another policy of that kind would for example be the introduction and increase of effective parking fees in public spaces.

Car restriction policies (for example on the basis of the number (even/odd) on the license plate) are seemingly effective at first sight but can often lead to unintended consequences in the long run, as citizens tend to adapt their behavior. Car ownership increases because citizens buy a second car which is often old and inefficient. Thus, emissions and pollution can even increase because of wrongly designed car restriction policies (Berg *et al.*, 2017).

Public transport

Local and federal governments need to work together to extend and improve the quality of public transport.

As Ukraine has already an existing and far-spread system of local public transport, we see most potential to reduce traffic and emissions by extending and improving its quality. We believe that the trend of shrinking passenger numbers has to be reversed. Obviously, an extension of service will come along with substantial costs that have to be borne by local authorities. Every municipality has to find its own solution as no "common solution" unfortunately exists. Yet, it is important that local and federal governments work together to reach the common goal of traffic and emissions reductions, as well as a better transport service for inhabitants.

Tram lines as well as (electric trolley) buses with separate lanes are a rather cheap and effective way for local governments to extend its service. There are many promising projects (such as Bus Rapid Transit) that could be applied in Ukraine would not be as costly as other local public transport means (IFT, 2019). Metro lines should only be considered for very congested areas and only if no other practical solution is available. Due to the long planning and construction time, metro services cannot decrease traffic and emissions in the short term and their high investment costs are a major obstacle for local governments.

Background info

A congestion charge for Ukraine?

Given the high share of road emissions and the level of congestion in Ukrainian cities, could a congestion charge system by a sensible policy in Ukraine? A possible system could include all mayor Ukrainian cities with more than 500,000 inhabitants (Kiev, Kharkiv, Odessa, Dnipro, Donetsk, Zaporizhia, Lviv, Kryvyj, Rih). Together, these 8 cities have 9.4 million inhabitants corresponding to almost a quarter of Ukraine's population (Ukrstat, 2020c).

Distinct models of congestion charging exist: (1) the London model charges a daily fare independent of the time of entry in the zone (certain times excluded) (Transport for London, 2020), while (2) the Stockholm model has varying fares during the day (Transportstyrelsen, 2020). It is important to think about which types of vehicles (low emission, residents, buses etc.) can enter for free or are eligible for reduced fares as this affects strongly results and revenues of the scheme. A congestion charge that excludes certain low emission vehicles (e.g. hybrid and electric vehicles) could help to renew the Ukrainian car fleet and thus increase overall energy efficiency (Beck *et al.*, 2011; Morton *et al.*, 2017). That could be effective in combination with stricter CO_2 emission standards for new cars. In order to build a socially just system, fees could be coupled to income or other indicators.

Most existing empirical studies show a long-run reduction in traffic, yet reductions vary a lot depending on city, design, prices, and exemptions (Anas & Lindsey, 2011; Eliasson, 2009; Lehe, 2019; Transport for London, 2007). Overall, reductions in traffic (mostly measured in entries to the priced zone) are between 10% and 40%, the associated CO_2 reductions are between 14% and 19%. To make congestion charging effective and avoid a simple tax increase, alternatives modes of transportation that citizens can use have to be available.

Implementation costs vary strongly between different cities (Anas & Lindsey, 2011) and are therefore hard to predict. However, experience has shown that these schemes are usually quite profitable for cities. Thus, we expect that participating cities would recover first investments within a few years. Therefore, effective congestion charging could contribute to the reduction of traffic and at the same time raise necessary funds for the extension and improvement of local public transport.

Carsharing/-pooling and priority lanes

Carsharing and -pooling is another efficient way of reducing the number of cars in cities and thereby reducing traffic and emissions. Thanks to digital solutions, local authorities could relatively easily create databases that connect drivers with potential co-passengers, so that existing car rides are used more efficiently. Priority car lanes which can only be used by vehicles with 2 or more passengers can support carpooling and are a quick and not a costly way for local authorities to steer transport.

Active modes of transportation

Active modes of transportation can be a cheap way to reduce traffic and emissions.

Alongside cars and public transport, local governments should promote active modes of transportation, such as cycling and walking. Citizens will only decide to walk or to take the bike if safety is guaranteed. Hence, local governments have to enable a safe infrastructure first. In contrast to most public transport measures, the promotion of active modes of transportation is cheap and an important complement for urban transportation.

III. Freight: Trucks and railway

a. Analysis

Rail is dominating domestic freight transportion.

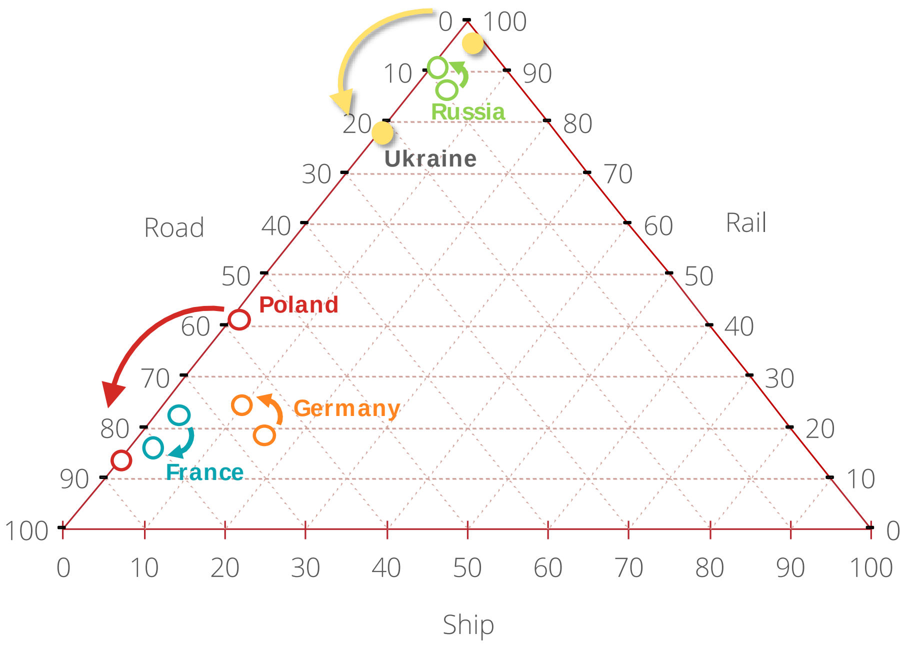
Like other economic sectors, inland freight transport[63] has seen a steep fall after 1990 and then stabilised in the late 1990s. Since then, it has kept constant with a slight upward trend. Since 1990, the dominance of rail in inland freight transport has not changed fundamentally. Yet its share has fallen over the years from 95% in 1990 to around 78% in 2019. Especially transportation on roads has gained importance and is now at 21% while water remains at 1% (OECD, 2020). In terms of transported tonne-kilometres, Ukraine's rail

[63] In the entire subsequent analysis, we have excluded inland freight transport by pipelines because of the distinctively different nature. All freight figures shown below do not contain any pipeline transport.

system dominates domestic freight transportation. Heavy products such as steel, coal, as well as grain, are the backbone of the Ukrainian economy, and rail handles their transportation. However, this might change in the future if the Ukrainian economy moves away from heavy industry towards a more services-based industry model.

As said, the dominance of rail for freight has not been changing much in recent years. Comparing to other countries (Figure 75), we see that Ukraine has a very high share of railway yet is slowly moving towards the "Western" model (Germany and France in the figure) of freight transportation with higher road shares and lower railway shares. A similar, but stronger trend has been visible in Poland that has even "overshot" and has now even a higher share of road transport than France and Germany.

Figure 75: Change in share of freight transport type (in tonne-km), 2000-2018



Source: OECD (2020)

Regarding trucks, Ukraine has seen a shift of commercial transport emissions from heavy-duty commercial vehicles (HCV) to a more even spread between these and light-duty commercial vehicles (LCV). The share of HCVs on all road emissions has been 68% in 1990 and decreased to 29% in 2014, while the share of LCVs increased from 2% (1990) to 9% (2014).[64] Similar to cars, the age of Ukraine's truck fleet is high, and an upgrade is urgently needed.

[64] Given the remaining importance of emissions from HCV, one major obstacle in the analytical process is data availability and quality. Data on fleet composition, registration, efficiency, and related topics is extremely spare for Ukraine.

b. Policy Recommendations

Trucks

To decrease emission, CO_2 emission for trucks should be introduced.

Ukrainian legislation requires also older trucks to follow more recent European emission standards (Euro 5). However, there are doubts about the accuracy on recent upgrade numbers (Kyiv Post, 2018). Similar to cars, Ukraine does not have any regulation on CO_2 emissions for trucks. Thus, we believe that it should discuss the introduction of a CO_2 emission target for trucks like the legislation introduced in the EU (Box 3). Certain best practises could be adopted from the EU and manufacturers would have to follow a similar set of regulations. Like in the case of cars, stricter CO_2 emission standards would limit the risk that Ukraine becomes a place where CO_2-inefficient trucks would be sold to as they cannot be sold in the EU.

A gradual fade-out of used trucks could increase fleet efficiency.

Although a recent increase in sales of more modern trucks has been seen, the Ukrainian truck fleet is still dominated by many old and inefficient vehicles (Kyiv Post, 2018). Ukraine should consider to gradually fade out old CO_2-inefficient trucks from its truck fleet. This step would require a scheme to regularly check trucks and their conformity with efficiency standards. Policy makers will have to discuss whether old, inefficient trucks should be allowed to continue operating in Ukraine.

The truck sector in Ukraine is shaped by small companies and individual drivers. Forcing out old vehicles through stricter legislation and preventing the registration of inefficient ones through tighter emission standards could have a strong impact on their business as they might not be able to afford to upgrade their rolling stock. However, the Ukrainian government could accelerate the turnover of the truck fleet by a corresponding support scheme for small enterprises.

Background info

EU's CO_2 emission standards for heavy-duty commercial vehicles

Regulation (EU) 2019/1242 is the first EU-wide legislation that sets CO_2 emission standards for HCVs and came into force in 2019. It requires that newly registered heavy-duty commercial vehicles (HCV) emit on average 15% less CO_2 by 2025, and 30% less by 2030 compared to the reference period 2019-2020. Like Regulation (EU) 2019/631 (which applies to cars and vans), truck manufacturers must decrease emissions based on their EU fleet-wide average. The regulation incentivises truck manufacturers to sell zero- or low-emission vehicles as these allow manufacturers to exceed the efficiency limit. A similar legislation in Ukraine could help to modernise the HCV fleet, increase CO_2 efficiency, and foster uptake of modern (electric) trucks.

Source: European Union (2019a); EU Commission (n.d.-b)

Railway

Infrastructure spending should primarily be directed to railway to make it competitive enough to attract more freight in the future.

As only 47% of Ukraine's rail tracks are electrified (Ukraine, 2018b), an increased electrification and an expansion of renewable energy production could even further decrease emissions. Although, we have no explicit data on rail track usage and in most countries electrified tracks see a higher numbers of trips per days. Thus, the share of percentage of electrified tracks is a too conservative measure for the degree of electrification of the Ukrainian railway. Due to the already low emissions, emission saving within the rail systems should not be the main policy focus. Instead, the rail system has to be upgraded in a way that it can enable emission reduction by replacing other forms of transportations. Regarding modern forms of efficient freight transport, Ukraine has to make sure that its train service can be competitive against truck services and can be integrated in multi-modal freight transport chains. Overall, future infrastructure spending should primarily be directed to the rail system. Investments are needed to improve the efficiency and to make rail competitive enough to attract a substantial share of freight.

IV. Long-haul passenger transport: railway and aviation

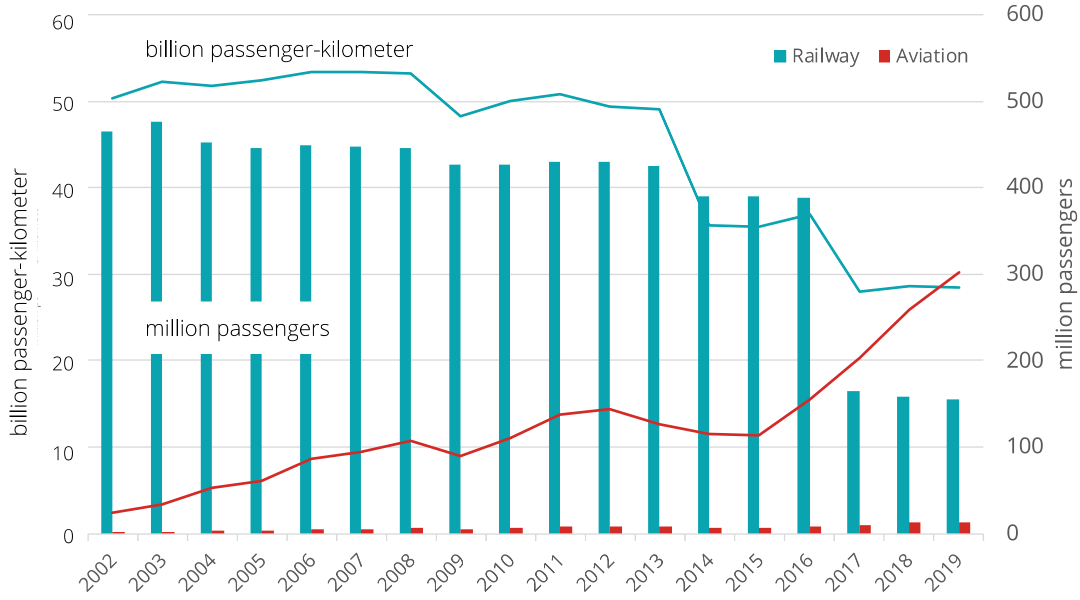
a. Analysis

In recent years, the number of passengers transported by rail decreased, while domestic aviation gained passengers.

Our analysis of rural and long-haul passenger transport is comparatively short. As data are limited (footnote 62), we restrict our analysis to rail and domestic aviation passenger transport. As shown in Figure 76, unsurprisingly, passengers carried by railway are significantly more than passengers of air planes (bars referring to right axis). Despite changes in methodology in 2017, we see however a long-term trend of reduction of passengers of railway and a long-term term trend of passenger increase in aviation (yet on a low level, see small green bars). Passengers by rail dropped from 465 million in 2002 to 155 million in 2019. In the same time, aviation increased its passengers from 2 million to 14 million.

When analyzing long-haul passenger transport in terms of passenger-kilometers (lines, left axis), we see how domestic aviation has caught up and even overtook passenger transport by rail in 2019. Between 2002 and 2019, aviation increased its passenger-kilometers from 2,400 to 30,200, while railway decreased from 50,400 to 28,400. The discrepancy seems to suggest that passenger transport by aviation becomes increasingly important for domestic long-distance travel, which explains the rather low passenger numbers but high passenger-kilometer numbers.

Figure 76: Passengers of railway and domestic aviation (lines - left axis, bars - right axis)

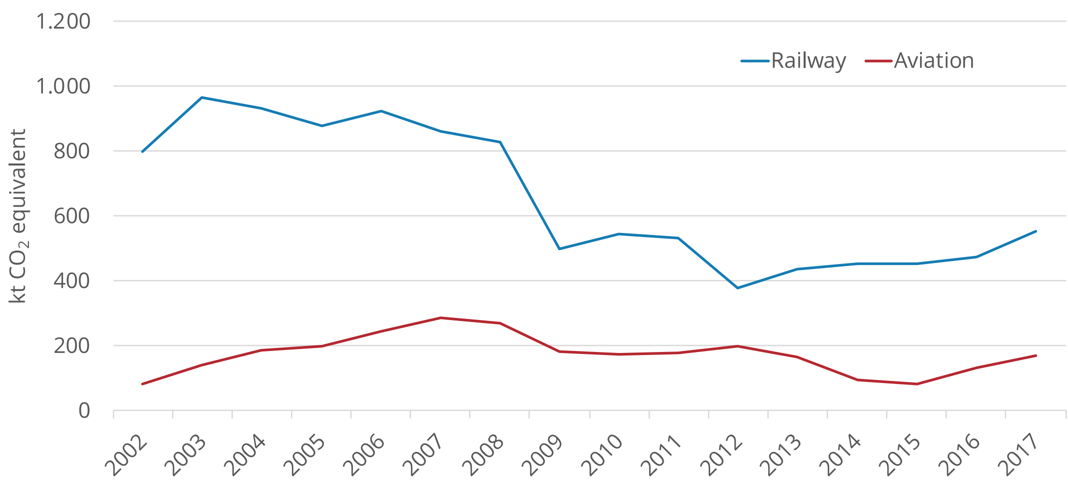


Notes: For railway, the number of passNengers carried according to data from the joint-stock partnership "Ukrzaliznytsia"; since 2017, including passengers transported by city rail; since 2017, the procedure for accounting passengers carried by rail who enjoy the benefits of free travel has been changed; since 2010, data excluding the territories of Crimea, the city of Sevastopol and parts of the eastern part of the country.

Source: Ukrstat (2020b)

Emissions from domestic aviation decreased strongly in the 1990s and then increased again in the 2000s. The recent crisis of 2014 lowered emissions again but since then we see a steady increase in domestic aviation emissions (Figure 77). Overall, domestic aviation contributes only marginally to Ukraine's transport GHG emissions. The same holds true for railway which saw declining emissions since the 1990s and only most recently an uptake.

Figure 77: GHG emissions from railway and domestic aviation



Source: UNFCCC (2020)

b. Policy Recommendations

The railway system needs to be set up as potent competitor against domestic flying and inter-city car passenger rides. As international evidence suggests that there is a competition between freight and passenger transport within rail and proper coordination among these two segments is not easy to achieve, a good railway management and coordinated policies are needed.

When it comes to future investment spending, rail should be favoured over domestic aviation to decrease emissions.

Ukraine's transport strategy for 2030 (Ukraine, 2018a, 2018b) plans the upgrade of domestic airports and the increased integration of Ukraine in international air connections. While these goals and measures can have positive regional effects, domestic aviation should be viewed with scepticism. As argued before, an increased effort to upgrade the Ukrainian rail system should be undertaken. As already seen in many countries, an efficient high-speed train system could compete with domestic flights and take over its function. However, efficient, and high-speed train systems require substantial investments, especially in countries that do not yet have such infrastructure.

Conclusion

While most countries worldwide have seen increasing GHG emissions, especially in the transport sector, Ukraine experienced strong emission reductions in the 1990s. Thus, we believe Ukraine is in a good position to comply with future international climate targets.

Policymakers in Ukraine should use this situation to steer the transport sector in the right direction, in order to make future emission reductions attainable. Therefore, Ukraine should focus its future mobility sector on the needs and possibilities of the 21st century and should not replicate the dead-end mobility strategies of many EU countries. Instead of solely focusing on individual mobility provided by car transportation, these should just be seen as an additional option and only be used when other forms of transportation are difficult to be provided. While many countries face the challenge to reduce emissions from cars, Ukraine could more easily reach a low-carbon transport future because it has still a relatively low level of motorisation. Instead of increasing that level by all means, viable alternatives could lead citizens directly to use public transport or long-distance trains, instead of increasingly switching to cars.

The future mobility sector should focus on the needs and possibilities of the 21st century and not replicate the dead-end mobility strategies of many EU countries.

The goal of fewer cars, especially in cities, would also go hand in hand with several co-benefits, such as less local pollution, less congestion, less noise and an improved quality of life and health in cities. A limited number of cars and an increased efficiency of the remaining car and truck fleet would also decrease dependence on oil imports. As the coming decades could witness changes in Ukraine's industry, rail could increasingly shift to passenger transport instead of freight, due to a shrinking demand for heavy duty transport and to an increase use of maritime transport.

In cities, fewer cars would go hand in hand with less pollution, less congestion, less noise and an improved quality of life and health.

Ukraine has published two policy documents that aim to guide the transport sector towards a low-carbon future: the "Ukraine 2050 Low Emission Development Strategy" (Ukraine, 2017) and the "Transport Strategy 2030" (Ukraine, 2018b). While the Low Emissions Strategy discusses broad goals, the Transport Strategy lists numerous details measures. However, it remains unclear how these measures fit in a broader cross-sectoral strategy. There is no value in tackling issues individually as the different measures are highly interdependent. Therefore, Ukraine should consider integrating individual transport policy measures into a comprehensive strategic framework that comprises all sectors of the economy.

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10. Energy efficiency in public buildings – 50% retrofitting target until 2030

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Executive summary

Deferred maintenance and repair investments reduce the value of the Ukrainian building stock and annihilate private and public property. Moreover, the poor condition of the Ukrainian building stock accounts for high energy consumption and is a large contributor to GHG emissions. Both is economic inefficient in short and long-term and directly impact living conditions of the population negatively. A long-term retrofitting strategy in line with the Energy Efficiency Directive (2012/27/EU) is required for residential as well as public buildings.

We evaluate an ambitious annual retrofitting of approx. 5,500 public buildings representing approx. 16 m m^2. This will require energy saving related investments of EUR 1 bn annually until 2030. The primary energy savings sum up to 700 TWh until 2059 and save 140 Mt CO_2. We propose to finance the energy retrofitting through emitting green bonds worth EUR 8 bn. Assuming a constant bond issue in EUR in the period 2021-2030 with an interest rate of 7% and a run time of 15 years – trough reinvestment of bonds with a maturity of approx. 5 years – the CAPEX sums up to approx. EUR -19.6 bn, including a budget funded own contribution of building owners of approx. EUR 1.6 bn (see Table 28). Energy savings reduce payoffs amounting to approx. EUR 24 bn until 2059 while the resulting CO_2 abatement costs are approx. -5 EUR/t CO_2 discounted which indicates a gain. We expect additional non-energy related investment needs of about EUR 640 m that are required for an overall modernisation of these public buildings. A funding has to be provided by the state and/or municipal budgets for securing long-term usability of the building stock. This funding is not considered in the following analysis.

We are aware of the administrative difficulties resulting from the implementation of green bonds at state level to finance investments at local and/or municipal levels. We recommend that this issue be addressed in a newly established working group for exchange between the Ministry of Finance and the Ministry of Regional Development of Ukraine.

Table 28: Results of retrofitting public buildings 2020-2059

	m UAH	m EUR
Bond issue	260,000	8,000
Governmental extra payment	53,000	1,600
Total investment	313,000	9,600
Interest payments	-330,000	-10,000
Bond payback	-333,000	-8,000
Governmental extra payment	-53,000	-1,600
CAPEX	-716,000	-19,600
Monetary energy Savings	980,000	24,000
Total 2021- 2059	264,000	4,400

Required policy measures, more precise regulatory economic planning as well as information instruments need to be anchored in national legislation and provide framework enforcing and supporting retrofitting activities. Therefore, we recommend the following measures:

i. Define quantitative retrofitting targets following a long-term retrofitting plan.

ii. Define what type of construction activity to what extent in or at a public building counts as an energy efficiency retrofitting measure in the sense of this proposal.

iii. Define energy efficiency levels that must be achieved by a retrofitting measure.

iv. Define funding instruments that consist of national and regional contributions and include national and international financial intermediaries.

Apart from primary energy savings of up to 2,300 ktoe annually and related emission reductions of up to 5 Mt CO_2 annually from 2030 onwards, further socio-economic co-benefits arise. Investing in public buildings represents an economic governmental demand-side stimulus that increases aggregated demand and, therewith, GDP. Such investments will create about 50,000 jobs. In the course of job creation, new business models arise and employees' skills increase. The latter will lead to improvements in economic efficiency in case large-scale retrofitting measures are taken on the residential building stock. The retrofitting of schools, hospitals and offices further improve basic building services, which has positive effects for the users of these buildings.

Ukrainian public building stock

The share of public buildings in the total building stock accounts to max. 15%.[65] In total, the building sector consumed 42% of total final energy in 2017 with commercial and public services consuming 9% (IEA, 2019).

Ukraine suffers from an outdated building stock that often does not comply with modern EE requirements.

In Ukraine, like in other former communist countries, outdated Soviet style buildings are a common problem. Most public buildings were built before 1990. Their architectural and building systems include mostly large-panel, large-block and frame made systems with precast concrete and do not comply with modern energy efficiency requirements. Their poor physical conditions are amplified by the absence of metering and heat consumption measurement as well as lack of regulators/thermostats which leads to a high use of heat and water consumption. 22% of non-residential buildings are not equipped with heat meters, 5% with cold water meters and 46% with hot water meters, which shows that Ukraine still does not meet the obligations on commercial heat metering standards (SAEE, 2019a). The outdated codes regulating the construction of buildings do not allow for exploiting economic and environmental benefits of district heating, which is quite inefficient in Ukraine. The lack of consumption-based billing has meant that there are often no incentives to implement energy-efficiency measures.

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[65] Up to our knowledge, official statistics only provide limited statistical information on the structural breakdown by types of public buildings. Thus, we cannot accurately determine the generalized value of estimated energy consumption of the entire stock of public buildings, since it is impossible to precisely determine (as %) the number of typical objects relative to the total number of buildings. According to the Energy Community (2019), Minregion has developed a form of data collection to create a Ukrainian national database of non-residential buildings. The aim is to provide information about energy efficiency on the municipal and national level for public buildings. Data collection for this project is still ongoing.

In recent years, individual heating units have been massively installed at multi-apartment and public buildings in Ukraine to regulate heat demand and perform localised hot water preparation for the clients (KeepWarm, 2019). Projects supported by the EU, GIZ, UN, NEFCO and EBRD triggered improvement of energy efficiency in Ukrainian public buildings[66]. Nevertheless, while these projects are implemented on a small scale, annual energy saving potential of public buildings still amounts to 800 million m^3 in gas equivalent (SAEE, 2018). Therefore, we propose broad-based energy efficiency retrofitting for Ukrainian public buildings.

On a small scale, projects supported by International organisations triggered EE improvements.

Currently, significant bottlenecks hinder broad-based energy efficiency retrofitting activities:

There are still crucial obstacles to EE retrofitting In Ukraine: limited capacities, limited ability and Institutional barriers.

- limited capacities and know-how in the building sector to set up complex and nationwide retrofitting programs; most contractors are located in Kyiv, meaning huge deficits in other regions,
- limited ability on the municipal level to plan, procure and control implementation of the projects,
- high risk of poor-quality implementation on regional level,

current decentralization reforms (transfer of ownership of many public buildings from the central to the local level).

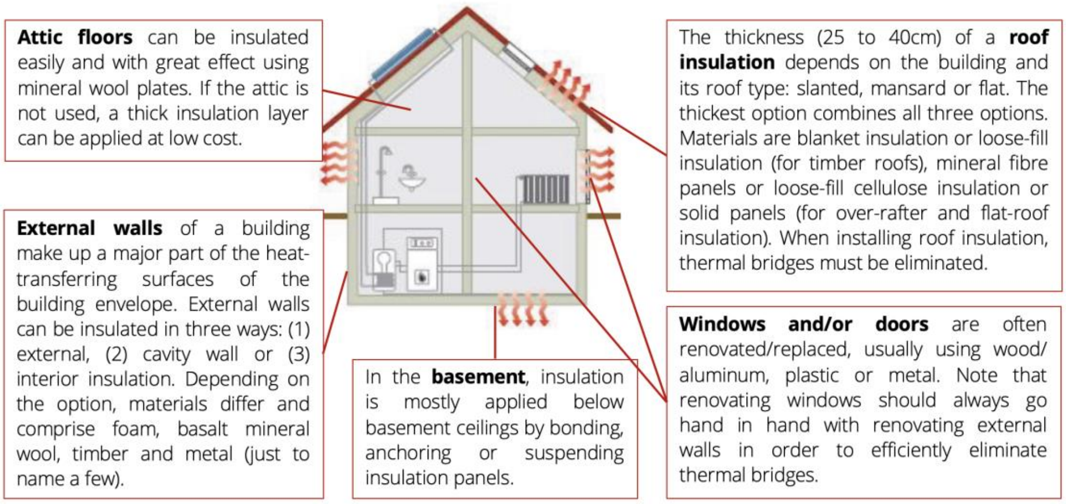
Proposed measures

I. Technical measures

For any thermal insulation, the physics of the building needs to be considered. Figure 78 presents building components which can be renovated.

Retrofitting measures can be aimed at the building components and the engineering systems.

Figure 78: Retrofitting measures for different parts of a building



Source: SAEE (2019b) and Schulze Darup *et al.* (2015) (adapted)

[66] Covenant of Mayors (funded by EU), Removing Barriers to Increase Investment in Energy Efficiency in Public Buildings in Ukraine through the ESCO Modality in Small and Medium Sized Cities (funded by UNDP), Public Sector Energy Efficiency Financing Framework (PSEEF) (funded by EBRD), Energy Efficiency financing program for public buildings (funded by NEFCO) and Implementation of the Municipal Energy Management System in 20 Small Cities (funded by GIZ)

Retrofitting measures are also applied to the building engineering systems. Table 29 presents its different components and typical retrofitting measures. Note that in most public buildings, the heating systems consume the bulk of energy while the ventilation, hot water, and lightning system only account for minor parts of total energy consumption of the building.

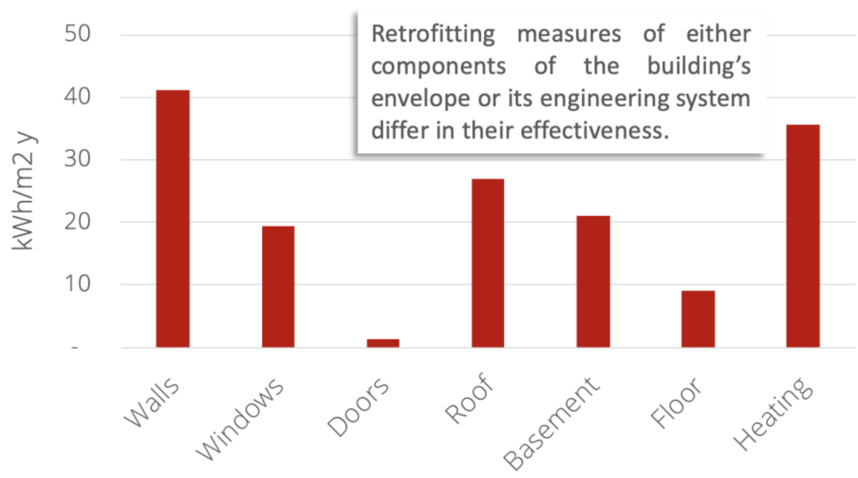
Table 29: Building engineering systems

	Heating system	Cooling system	Hot water system	Lighting system
Retrofitting measure	• Regulators to automatically adjust amount of heat consumed • Insulation of main pipelines • Installation of balancing valves	• Modernization of ventilation system	• Installation of electrical storage boiler	• Replacement of old lamps with LED lamps

Source: SAEE (2019b)

Figure 79 shows the average energy saving potential per retrofitting measure based on our sample. According to this, thermal renovation of walls has a big effect on energy saving while renovating doors only has a minor contribution.

Figure 79: Average energy saving potential per retrofitting measure



The range of investments, energy savings and profitability of the measures differ due to the type of building, size and the initial energy efficiency class.

Our analysis of SAEE data indicates that for the technical measures the range of investments, energy savings and, thus, profitability of retrofitting measures in public buildings is large. We identified three main reasons for that:

1. The **type of public building** (schools, universities, hospitals, offices etc.) determine the usage patterns of the building, such as
    a. required room temperature
    b. ventilation needs
    c. illumination needs

   d. daily use time
2. The **building size** – co-determined by the type of building – defines the relation of building envelope to basement and roof.
3. The initial energy efficiency class and to some extent the age of the building obviously define **energy consumption per square meter**.

SAEE data further indicates that some measures are much more cost-effective (e.g. replacement of heating equipment) than others (e.g. roof insulation). Hence, we will assume that all proposed measures are conducted by a retrofitting activity because of two reasons:

The analysis focuses on educational buildings, healthcare facilities and administrative buildings based on 64 buildings of the SAEE database.

1. It remains unclear whether only single measures enable an efficient energy consumption reduction as they could, e.g., leave thermal bridges behind.
2. Furthermore, some measures discussed in the SAEE database are necessary to ensure the continuity of the building. Even if the energy retrofitting share in such measures (e.g. wall insulation or roof replacement) remains limited, it increases the lifetime of the building and is therefore considered in our analysis.

Our assessment is based on three types of public buildings: Educational buildings, healthcare facilities and administrative buildings, such as offices. We use a sample of 64 buildings in energy efficiency classes D, E, F and G. For the further analysis of aggregated effects, we only use the average investment and energy saving deducted from this sample.

We evaluate an ambitious scenario assuming that 16 million square meters can be retrofitted annually, which leads to an aggregated energy retrofitting of 160 million square meters of public buildings until 2030 – about 50% of the total stock, respectively.

II. Policy measures

Planning instruments

We recommend defining an ambitious quantitative retrofitting target of around 50% of the public building stock by 2030 following a long-term retrofitting plan for public buildings, whereby annual retrofitting should not undershoot 10 million square meters.

A long-term plan needs to be developed.

Regulatory instruments

A retrofitting measure should result in an energy efficiency level of at least class C. To guarantee the energy efficiency outcome, we propose defining required skills for executing energy audits and energy retrofitting in various types of public buildings to support specialisation of energy auditors on particular types of buildings. Therefore, training programs to qualify the workforce on all levels to conduct efficient and high-quality retrofitting measures are needed. Regions beyond Kyiv should be in the focus of such qualification programs.

The regulatory instruments include a minimum target for retrofitting (EE class C), the qualification of auditors and a transparent procedure for retrofitting measures.

The issuer of green bonds must establish a transparent procedure for project evaluation and selection of eligible retrofitting projects, taking into account the environmental objectives of the projects, as well as a system for managing the proceeds of the bonds issued in order to comply with international green bond principles.

Financing instruments

The financing structure foresees a financial contribution by the owner of the building and up to 80% financing through green bonds.

We recommend a funding structure consisting of a 15-20% contribution by the owner of the buildings at lowest administrational – e.g. within regions – level and up to 80% financing through green bonds issued by the state. The issuance of green bonds by the state needs to be coordinated with the overall borrowing policy of the Ministry of Finance taking into account any restrictions/limits on the size of the external debt of Ukraine (see section "Financing via green bonds").

Information instruments

Database on retrofitting options by 2025

A comprehensive database on energy consumption and retrofitting options for at least 80% of the public building stock in Ukraine should be established until 2025. In parallel, a reporting system to report the allocation of proceeds from issued bonds must be established.

Reporting system on proceeds from issued bonds

The issuer of green bonds must establish a reporting system to report on the allocation of proceeds from issued bonds to eligible retrofitting projects in order to comply with the international principles for green bonds.

Background info

Public Buildings in EU Member States

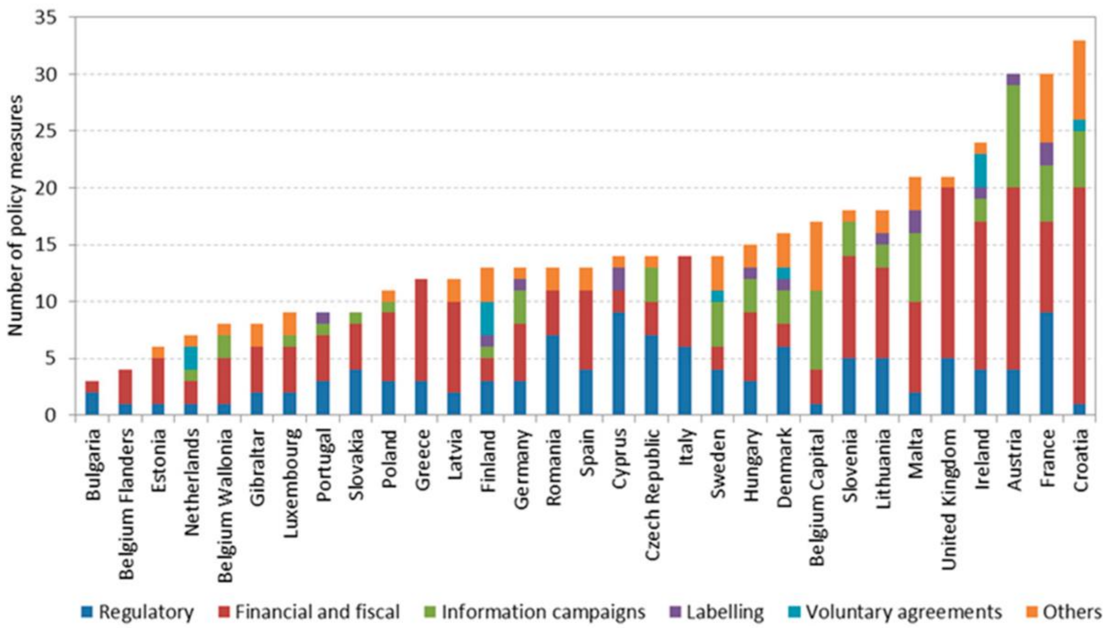
Approx. 12% of the total building stock in the EU is either owned or occupied by public authorities (EUROSAI 2018). The average energy consumption in the non-residential sector is 280 kWh/m2 (D'Agostino *et al.* 2017). Between 2000 and 2008, energy consumption in the non-residential sector increased by 2.5% per year and since then by 1.1%. Member states are required to establish a long-term building renovation strategy (Buildings Directive, EPBD, Directive 2002/91/EC & Directive 2010/31/EC). The Energy Efficiency Directive requires that EU countries conduct energy efficient renovations of at least 3% per year of buildings owned and occupied by central governments. The renovation rates for non-residential buildings, including public buildings in the EU between 2012 and 2016, amounted to approx. 10% (EUC 2019, pg. 18) whereby only 2% followed a at least 'medium' retrofitting below 1% a 'deep'. (see Figure 81). Deep renovation allows for energy savings of up to 66%.

Table 30 lists the different types of measures and indicates which EU member states have implemented supporting energy retrofitting in public buildings. D'Agostino *et al.* (2016) indicate a heterogeneity of national policy packages in the EU member states in terms of the number of measures and policies. Regulatory, financial & fiscal policies represent the most extensive types of interventions in all member states, while labelling is underrepresented.

Table 30: Examples of measures targeting central government buildings

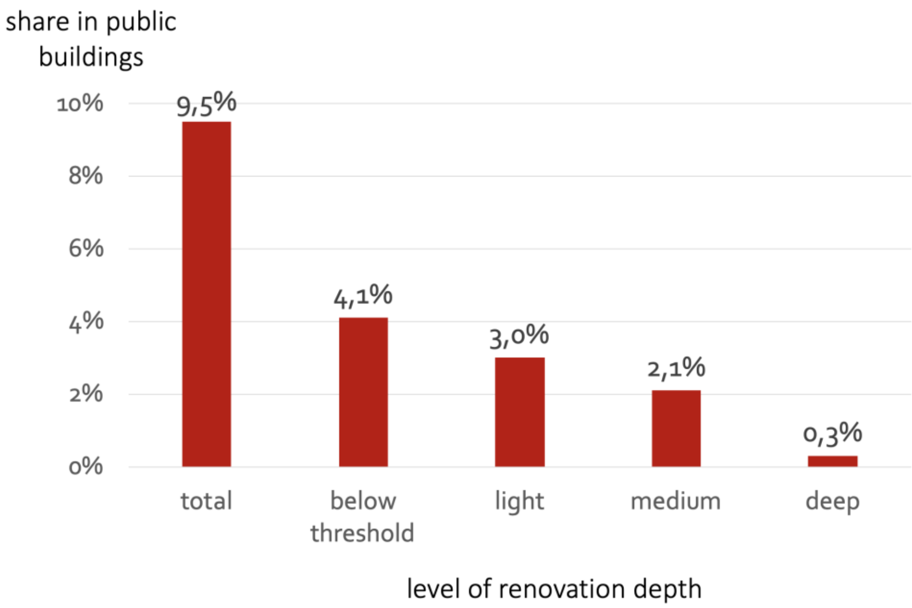
Type of measures	Examples from EU Countries
Financing	• Energy performance contracting and ESCOs (Austria, Portugal, Croatia)
Renewable energy	• PV installations for own consumption (Malta, Poland)
Energy management	• Appointing energy officers in each building (Ireland, Portugal) • Operations optimisation (Denmark, Austria) • Metering for energy and water (Croatia) • Smart meter installation (Malta) • Control of air conditioning (Malta)
Inspections	• Inspections of down-time electricity use (Finland) • Analysis of energy consumption during off-times (nights, weekends etc.)
Property management	• Penalties and bonuses for energy efficiency in contracts with property management companies (Finland)
Public procurement/ sustainable procurement	• Switching to energy-saving devices (Denmark) • Rental contracts being renewed become green lease contracts (Finland)
Behavioural change	• Raising awareness among building users (France, Denmark) • Large-scale behavioural change campaign (Ireland) • Behaviour change programme for employees (Netherlands)

Figure 80: Number of measures in the building sector (implemented and planned) in the EU by country and type



Source: D'Agostino *et al.* (2016)

Figure 81: Share of non-residential buildings that underwent energy-related renovation per level of renovation depth in EU28 countries (average 2012 – 2016)



Source: EUC (2019, pg 18)

Assessment of effects through energy retrofitting of public buildings

At this stage, we discuss the overall effects induced by successfully implemented retrofitting measures in public buildings taking into account the five dimensions: energy security, internal energy market, energy efficiency, decarbonisation of the economy and research, innovation and competitiveness. In addition, we will present a quantitative assessment of additional socio-economic co-benefits.

Energy security

A reduction of energy consumption in the public building stock of Ukraine reduces the need for energy imports as well as for domestic extraction of natural gas and coal. The implementation leads to savings of up to 500 TWh of final energy and up to 700 TWh of primary energy until 2059. By avoiding imports of up to 70 bcm this reduces dependency on international energy markets and secures for negative macroeconomic effects due to price fluctuations and/or supply shortages.

The implementation of retrofitting leads to a reduction of energy consumption and, thus, reduces the need for energy imports.

The aggregated direct effect remains limited due to the relatively low share of public buildings in the cumulated energy consumption. However, spill over into other retrofitting activities leads to indirect effects and supports the long-term reduction of energy imports.

Internal energy markets

The modernization of buildings, such as the improvement of metering systems, increases price sensitivities. Consumption-based billing affects purchasing behaviours and, thus, leads to more economical behaviour of consumers. We, therefore, expect a better functioning internal energy market.

Metering systems for the buildings increases price sensitivities.

Energy efficiency

Improving energy efficiency is a key target of energy retrofitting of public buildings. The building specific efficiency improvements range – depending on type of building, initial energy consumption and size – between 20% and 70%. Average improvements of approx. 40% for all types of buildings with an initial energy efficiency class of D-G becomes possible. Energy consumption per square meter can be reduced to 100 – 200 kWh/m^2 with an average of 120 kWh/m^2. Annual final energy savings – following an annual retrofitting trajectory of 16 million m^2 – amount to 19,000 GWh in 2030 (approx. 1,600 ktoe).

Energy efficiency improvements range between 20% to 70%. The annual primary energy savings of 300 ktoe lead an emission reduction of 0.6 mton per year.

Decarbonisation of the economy

Assuming a reduction in natural gas consumption through the energy retrofitting – either for decentralised heat generation within the buildings or for heat generation in district heating facilities – the annual primary energy savings of up to 300 ktoe (of mainly natural gas) per retrofitted 16 million m^2 lead to an emission reduction of 0.6 Mt per year. CO_2 savings increase to approx. 5 Mt CO_2 in 2030 or 2% of current national emission, respectively.

Research, innovation and competitiveness

The Ukrainian building stock requires deep energy and comfort related retrofitting measures. Given approx. 14.9 million households, nearly 10 million apartments and single-family houses need to be retrofitted within the next 20 years. With increasing incomes, the demand for such retrofitting will increase. For this process and for meeting the increasing demand, the construction sector requires the acquisition of new skills. Typically, this acquisition is time- and cost-consuming and follows long-term learning curves. Especially at the beginning of such a process, learning rates are very high and marginal learning costs are low.

Retrofitting of public buildings can be seen as a training ground for energy efficiency improvements of residential buildings.

Furthermore, with increasing skills and increasing experiences in retrofitting, aggregated retrofitting costs will decrease.

Investments allow for developing new green business models alongside the entire value chain.

Green-business models are business models that generate – in addition to the underlying profit related reasoning – an environmental related co-benefit. In general, investments allow for developing such new business models alongside the entire value chain (respectively within value networks). New business models lead to the development of new interactions within value networks, increase competition and induce therewith innovation processes. Ideally, such effects spill over onto other sectors.

Public buildings provide an appropriate training ground for these learning and cost reduction processes. The following points support this assessment:

- Public buildings are typically more complex than residential buildings, which increases the learning effect (broader learning due to more types of craft work in action)
- In contrast to residential buildings, only one owner is responsible for the commissioning which reduces coordination
- Learning includes the learning about the final costs of a retrofitting measure. Handling an overshoot of costs is less complicated in public buildings than it would be within homeowner associations.

Socio-economic co-benefits

Even if the present analysis focuses mainly on the effects that energy retrofitting measures have on energy consumption and GHG-emissions, we want to present a rationale for focussing on public buildings that finds its reasoning in additional co-benefits.

a. Governmental demand-side economic stimulus

A governmental demand-side stimulus is expected to incur increasing GDP and employment directly and indirectly.

Investments in energy retrofitting of public buildings – EUR 10 bn are connected to state expenditures and increase aggregate demand. Therewith, such expenditures have a positive economic stimulus which increases the GDP as well as employment directly and indirectly. Even if the limited number of public buildings restricts the overall economic effects, they might stabilise the expectations within the construction sector. Positive expectations on the other hand lead to new market entries, an increase in competition and investments in the sector alongside the value chain.

b. Employment effects

Employment effects from energy retrofitting sums up to approx. 50,000 new jobs generated in the construction sector and alongside the value chain.

Following international experiences, the direct and indirect employment effects from energy retrofitting activities account for 30 – 60 working years per invested EUR 1 m.

Given this figure and following an assumed constant investment flow of approx. EUR 1 bn until 2030, the employment effect from energy retrofitting sums up to approx. 50,000 new jobs generated in the construction sector and alongside the value chain. Additional effects of about 20,000 new jobs can be expected if non-energy related modernisation is also taken under consideration.

c. Improvement of basic building specific services

Non-energy related measures that accompany energy efficiency retrofitting will increase the quality of the building's specific service.

While technological measures of energy retrofitting only focus on reducing energy consumption, comfort related measures increase the conditions of the specific type of building. Like each type of building, public buildings provide a specific service to their specific users. Retrofitting measures that exceed pure energy retrofitting will increase the quality of the building's specific service:

- Hospitals with higher comfort increase the well-being of patients and therewith the recovery,

- Retrofitted schools and universities have a positive influence on the teaching and learning atmosphere and
- Retrofitted offices increase the well-being of employees which typically increases productivity.

Financing via green bonds

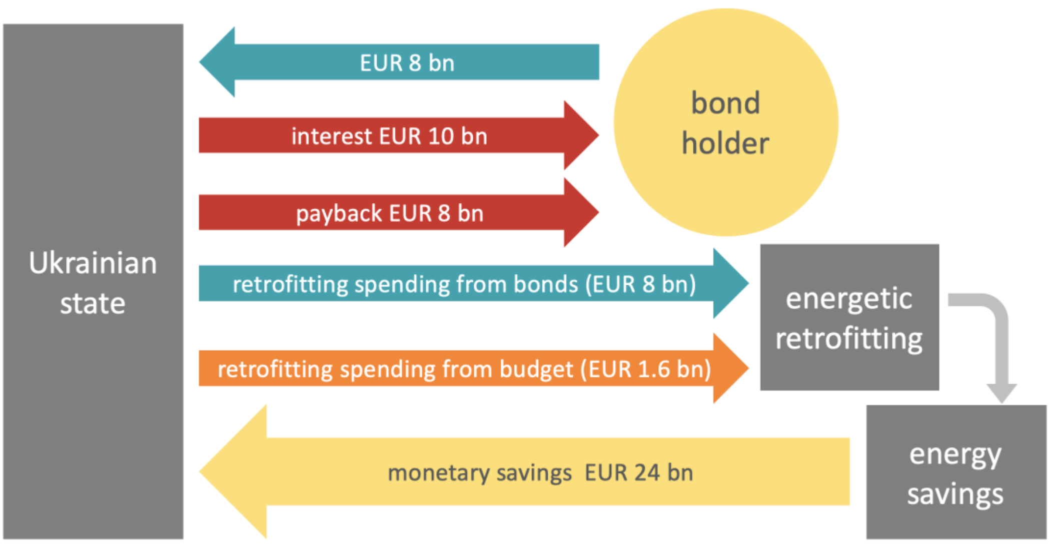
We propose the use of green bonds for covering the retrofitting activities in the sector of public buildings. Due to increasing demand for this type of investment, green bonds provide the ability to raise high volumes of funding for specific investment targets. They address investors focussing on environmentally friendly projects and can provide relatively cheap capital (compared to loans) if well-structured. Institutional as well as private investors are searching for new types of investment options to diversify their portfolios. They are increasingly focusing on integrating environmental, social and governance factors which led to a significant increase in green bond issuance worldwide from USD 41.8 bn in 2015 to USD 257.7 bn in 2019. For such investors, green bonds offer relatively secure options in large-scaled projects. Climate Bond Initiative (2020) assesses that in the long-term 40% of the green bond market will relate to energy efficiency retrofitting and zero emission building constructions. Note that in 2019 the share of the buildings sector already accounted for around 30% of all green proceeds allocation.

Green bonds can raise high volumes of funding and should be used for financing the retrofitting measures.

Required funding for the proposed retrofitting sums up to approx. EUR 8 bn within 10 years. Assuming a lending period of 15 years, an automatic reinvestment of bonds with lower maturities up to 15 years respectively, the bond holders receive total interest payments of approx. EUR 10 bn and at the end of the lending period the provided funding. The bonds issuer – the Ukrainian state – receives approx. EUR 24 bn energy savings until 2059, if bonds' term to maturity ends.

Required funding sums up to around EUR 8 bn within 10 years.

Figure 82: Structure of green bond funded retrofitting



Source: own depiction

Issuance of green bonds by the Government of Ukraine for the purpose of retrofitting public buildings which belong to local governments (municipalities, consolidated territorial communities) will require changes in the budgetary legislation (the Budget Code, in particular). Current interbudgetary relations do not provide for loans to be extended from the State budget to the local budgets for the purpose of retrofitting of buildings. Such financing can only be done in a form of the non-refundable subventions. At the same time, the administrators of the public buildings (so called "managers of budget funds") are to be financed on non-

The Ukrainian Budget Code needs to be changed so that loans can be extended from the State budget to local budgets.

refundable basis from the local budgets and are not allowed to borrow. In addition, the current mechanism of defining the basis for calculation of expenses to support a public building from public funds does not provide for accumulation of monetary savings (as compared to the baseline spending level prior to a retrofitting project) to be channelled to repay investment into such building – as soon as a lower level of expenses for energy is reached for a particular building, this level should be used as the basis to calculate the local budget expenses for this building for the next budget year. In order to implement the proposed green bond issuance program, it will be required to make changes in the budgetary legislation – e.g. allowing loans from the State budget to the local budgets and/or to administrators of public buildings by the means of establishing a communal enterprise that is allowed to borrow.

Coordination with decentralisation reform requried that envisages a transfer of the ownership of many buildings from the central to the local level.

Notably, the logic of the current decentralization reform envisages transfer of the ownership of many public buildings from the central to the local level with the expectation that the decisions will be made by the local governments which buildings to maintain and which to dispose of. The proposed green bond issuance program will require coordination with the directions of the decentralization reform in order not to discourage the local governments in fully assuming the responsibility for maintenance and renovation of the public buildings in the most effective way. Such coordination may include clear definition of the scope of the program in the long-term.

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Annex: Methodology

The calculation is based on a three-step approach:

1. Determination of energy retrofitting costs and energy saving potentials for respective building types
2. Determination of retrofitting costs and energy savings for an average generic public building, based on an aggregation of three building types – educational buildings, hospitals and administrative buildings including offices
3. Determination of a cash flow trajectory, based on annual pay-outs and monetary energy savings

The methodology follows the assumption that funding will be based on issuance of bonds, emitted in Euro. We consider an exchange rate increase from 30 UAH/EUR to 41 UAH/EUR until 2032.

Retrofitting costs and energy savings

The calculation is based on energy efficiency analyses of a sample of 64 public buildings, provided and collected by SAEE. All buildings are in energy efficiency classes D-G. Based on that sample, retrofitting costs and energy savings per square meter are determined.

Average retrofitting costs and energy savings

We follow EU4Energy *et al.* (2020) that indicates the shares of building types in the public building stock of Ukraine and defines average energy consumption, savings and costs:

Table 31: Weighted averages for calculations

parameter	weighted average
energy consumption, kWh/m^2 y	260
energy savings, kWh/m^2 y	120
energy saving related investment, EUR/m^2	60

Source: Own calculation based on SAEE

We assume constant energy retrofitting costs in Euro of 60 EUR/m^2. Given the assumed depreciation of the Hryvnia, retrofitting costs in UAH will increase from 1,600 to 2,300 UAH/m^2 in 2030.

Determination of cash flow trajectory

The determination of a cash flow trajectory, including all pay offs and monetary energy savings, takes place in the following steps:

a. Energy saving trajectory

We assume that the retrofitting activities will take place between 2020 and 2030. The energy savings for each building will be achieved within a time span that depends on the typical lifetime of the various building components, such as walls, heating equipment, windows, etc. The lifetime of these components varies and so do future energy savings.

Table 32: Average lifetime of building components

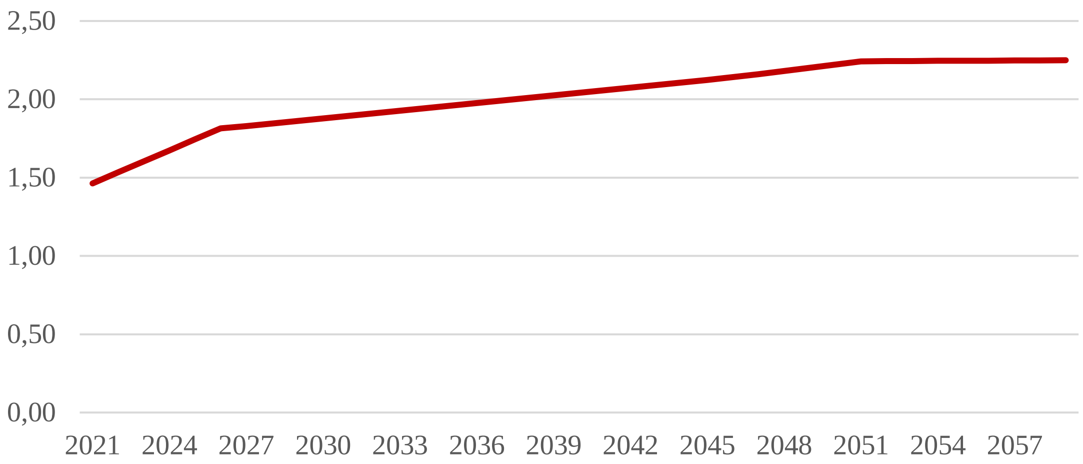
Building component	Energy consumption kWh/m2 y
Walls	44
Window, balcony	41
Doors	41
Roof + attic floor	40
Basement	50
Floor	50
Heating system	18
Cooling system	18
Hot water system	16
Lighting system	10

Source: Bund Technischer Experten e.V.
(Association of Technical Experts) (2008)

b. Assumed price development

Monetary energy savings depend on the assumptions of price changes. Due to the long perspective of the effects of retrofitting, all assumptions are quite uncertain. We assume that **all buildings consume heat from district heating companies**. Further, the district heating price is linked to the natural gas price projections, depicted in the National Determined Contribution (NDC) report of Ukraine (EBRD, 2020, draft).

Figure 83: Heat price assumptions (UAH/kWh)



Source: Own assumptions based on EBRD (2020)

c. Definition of a retrofitting target

We assume a retrofitting target of 50% until 2030. According to EU4 Energy (2020), the total stock of public buildings in Ukraine sums up to approx. 322 million m² from which approx. 160 million m² would be retrofitted within 10 years. We split these on a constant annual target of approx. 16 million m² and further assume that the structure of annually retrofitted buildings represents the respective shares in the total stock. We also assume that buildings of energy classes E-G will be retrofitted according to the respective shares of each class in the total stock. The reasoning is that it is not obvious to start retrofitting with so called "low hanging fruits", meaning buildings that have very high energy consumptions. Learning effects and the resulting reduction in retrofitting costs could cancel out any higher monetary savings that might have been achieved earlier.

d. Structuring project funding

We propose funding energy retrofitting of the public building stock through the issuance of (green) bonds. We assume that required bonds are Euro denominated from external markets.

We assume a bond interest of 7%, based on current 10y governmental bonds in Ukraine.

We do not consider changes of the interest rates over the funding period.

Bond payback takes place in Euro. Due to the depreciation of Hryvnia, bond payback is 28% higher than the issued volume in Hryvnia.

We further assume a duration of 15 years for the bonds (total run-time through reinvestment of bonds with maturity of ca. 5 years).

We assume a 17% governmental spending as the share of the total investment value each year until 2030. We do not consider any additional costs (interest payments) from the budget spending.

Figure 84: Energy-retrofitting results, trajectory 2021-2059

Source: Own calculation

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All results of the project are available online on www.LowCarbonUkraine.com.

We are grateful for your feedback on this Policy Proposal. Please get in touch via info@LowCarbonUkraine.com.

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