SELECTED HIGH-IMPACT MEASURES

Towards a decarbonisation of Ukraine’s steel sector

by David Saha

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

Motivation and project background

This policy proposal is part of a series which 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.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to the experts of GMK Center, Kyiv, for providing extremely valuable deep sectoral insight and figures for the Ukrainian steel sector, to Dennis Sakva of Dragon Capital, Åsa Ekdahl of the World Steel Federation, Vladyslav Antypov; Tamara Burenko of the State agency on Energy efficiency and Energy saving of Ukraine, Andrii Hunko of the GIZ; Alexander Martynenkov of Investment Capital Ukraine and Alexandra Kolmogortseva, ecology expert for valuable conversations, insights and comments. We thank Frank Meissner, Anna Temel and Dmytro Naumenko for extremely helpful analysis and quantitative contributions and the team of Low Carbon Ukraine for excellent discussion.

Contents

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.

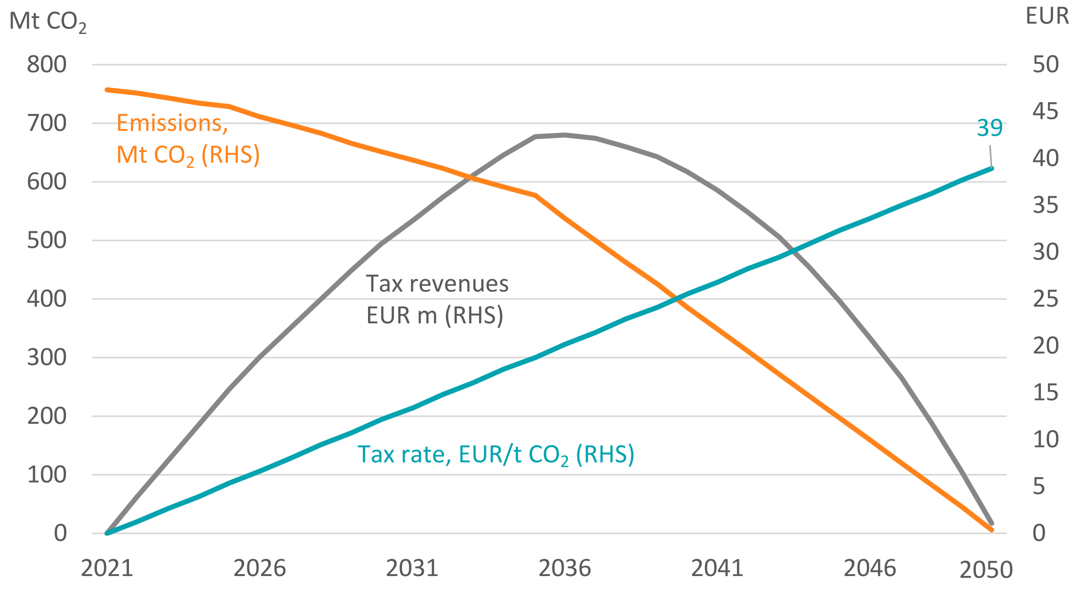
A scenario to decarbonise Ukrainian steelmaking by 2050

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 1: 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).

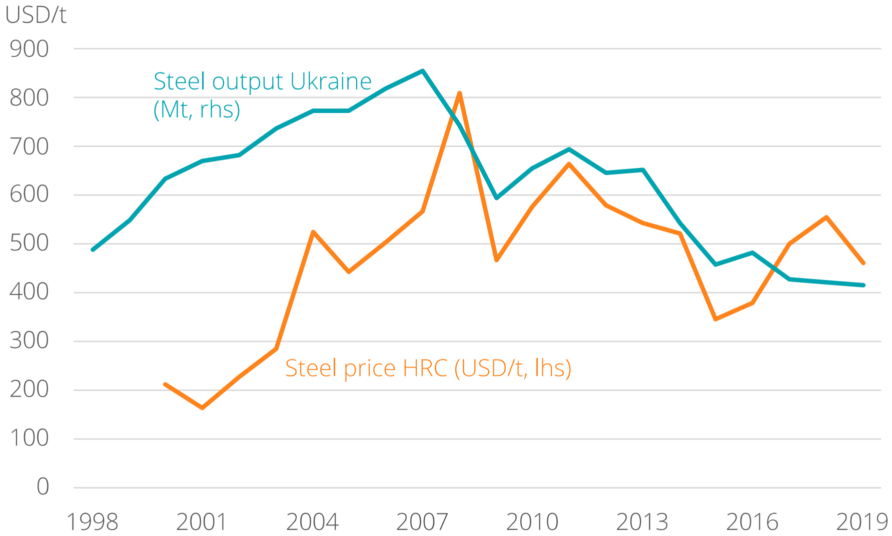
Figure 2: Steel-making plants in Ukraine

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.

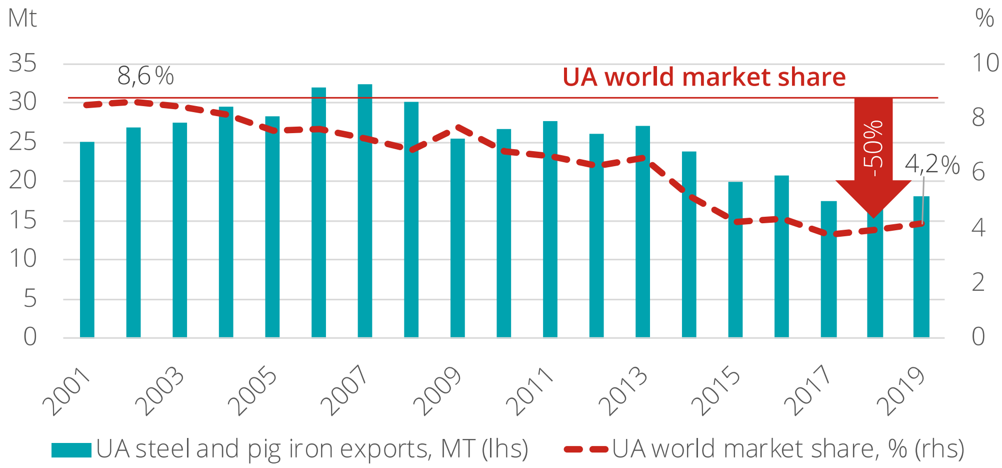
Figure 3: Crude steel production in Ukraine, Mt and steel price, USD/t



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 4: 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 1: 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 2. 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 2: 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[1] 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).

[1] 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[2]. 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).

---

[2] 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 [3].

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.

---

[3] 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[4], 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

[4] 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[5].

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.[6]

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-

---

[5] In technical terms: the marginal power plant is often a coal plant.

[6] 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.

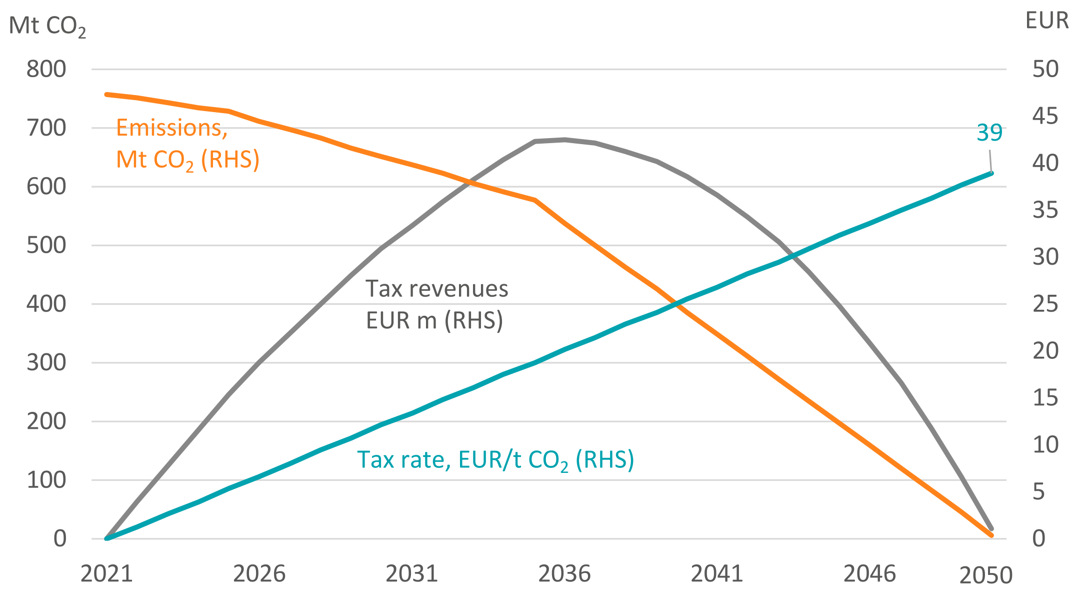
Finally, an important role of the strategy will be to contribute to the transparency of the entire process. By emphasising the phase-in path of the carbon tax for the steel sector and elaborating its relation to the other policy instrument (modernisation fund, credit conditions, electricity contracts, 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 5 and Figure 6, achieving a carbon neutral and commercially viable steel sector by 2050.

Figure 5: 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.

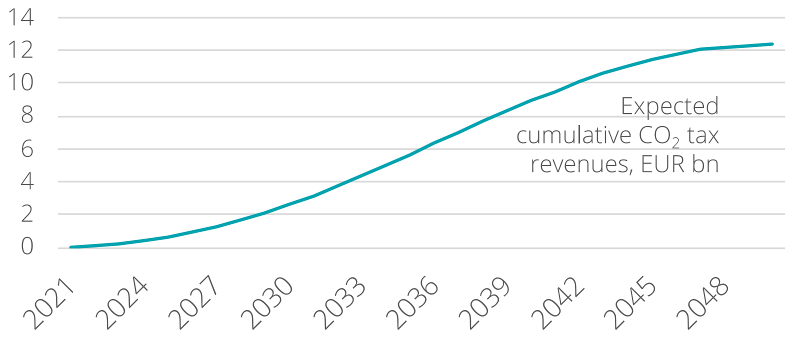
In our scenario, we assume that between 2021 and 2025, CO_2 emissions could decline by 1% of present levels per year. During this time, relatively few options (limited optimisation of production processes, some retrofits of emission-abating technologies to plants) with limited emissions-abating potential 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 3 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 6: 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[7] would cost approximately USD 1 bn per Mt of annual capacity once the technology has matured[8]. 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 3: 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).

[7] 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.

[8] 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.

References

Arcelor Mittal (2019). 'Climate Action Report 1'. May 2019

Climate Action Tracker (2017). 'Manufacturing a low-carbon society: How can we reduce emissions from cement and steel?'. CAT Decarbonisation series, www.climateactiontracker.org

CEPS (2013). 'Assessment of Cumulative Cost Impact for the Steel Industry – Final Report'. Brussels Available at: https://www.ceps.eu/wp-content/uploads/2015/04/steel-cum-cost-imp_en.pdf

European Bank for Reconstruction and Development (2020). 'Support to the government of Ukraine on updating its nationally determined contribution (NDC), Report 3/Modelling Report'.

Energy Transitions Commission (2018). 'Reaching zero carbon emissions from steel'. Consultation paper

EU Strategic energy technologies information system (2009). ‚Energy Efficiency and CO_2 Reduction in the Iron and Steel Industry'. European Commission. Available at: https://setis.ec.europa.eu/system/files/Iron_and_Steel.pdf

German Advisory Group Ukraine (2017). 'Trade suspension and company seizures in non-controlled area: Economic impact on government-controlled area'. Policy Briefing PB/06/2017.

German Advisory Group Ukraine (2019). 'New trade barriers on the global steel market: Impact on Ukraine's steel exports'. Policy Briefing PB/04/2019.

German Advisory Group Ukraine (2019a). 'Economic implications of transport restrictions in the Sea of Azov'. Policy Study PS/01/2019.

German Advisory Group Ukraine (2019b). 'Earmarking of carbon tax revenues: Implementation in OECD/EU countries and recommendations for Ukraine'. Policy Briefing PB/08/2019.

German Economic Team (2020). 'What would be the impact of a possible EU Carbon Border Adjustment Mechanism on Ukraine?'. Policy Briefing PB/05/2020.

GMK Center (2020). 'Economic Impact of Iron & Steel Industry of Ukraine in 2019'. Available at: https://gmk.center/wp-content/uploads/2020/03/Economic_Impact_of_IronSteel_Industry_of_Ukraine_in_2019_compressed.pdf.

Khoroshun, K. (2019). 'A 10-year overview: is efficiency of Ukraine`s mining & metals sector rising?'. GMK Center. Available at: https://gmk.center/en/opinion/a-10-year-overview-is-efficiency-of-ukraine-s-mining-metals-sector-rising/

McKinsey & Company (2018). 'Decarbonisation of industrial sectors: the next frontier'. June 2018

Ministry of Ecology and Natural Resources of Ukraine (2019). 'Ukraine's greenhouse gas inventory 1990-2017 (draft)'. Available at: https://menr.gov.ua/files/docs/Zmina_klimaty/kadastr2017/Ukraine_NIR_2019_draft.pdf

Shatoka, V. (2014). 'Iron and steel industry in Ukraine: current state, challenges and future perspective'. Conference paper. Available at https://www.researchgate.net/publication/264197433_Iron_and_steel_industry_in_Ukraine_current_state_challenges_and_future_perspective

Ukrmetalurgprom (2017). ‘The Steel Sector in Ukraine: Challenges and Opportunities’

Vogl, V., Åhman, M., Nilsson, J. (2018). ‘Assessment of hydrogen direct reduction for fossil-free steelmaking’. Journal of Cleaner Production (203), pp 736-745. Available at: https://gmk.center/en/opinion/a-10-year-overview-is-efficiency-of-ukraine-s-mining-metals-sector-rising/

World Steel Association (2020), World Steel in Figures 2019

Implemented by

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

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.

This project 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.

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.

BE Berlin Economics GmbH

Schillerstraße 59, 10627 Berlin, Germany | +49 30 / 20 61 34 64 - 0 |

info@berlin-economics.com | Imprint