Emission Reduction and Slovak Industry

*
MARTIN
VLACHYNSKÝ

The European Union (EU) produces around 8%[1] of global greenhouse gas emissions. As a consequence, it has set itself a binding target of achieving carbon neutrality by 2050[2]. As a step toward this goal, the EU has also raised its 2030 climate ambition considerably, by committing to cut emissions by at least 55% by 2030 relative to the 1990 levels (compared to a previous target of 40%)[3].

These ambitions will inevitably have a serious impact on European economies – especially on industry. Therefore, let us inspect the current 'emission environment' in Slovakia, describe the proposed path towards reaching the carbon goals, and provide some critique.

EMISSIONS IN SLOVAKIA

Slovakia is one of the most industrialized countries in Europe, with industry (excluding construction) composing 22% of the gross domestic product[4] [See: Figure 1].

Similar to many post-socialistic economies in Europe, GHG emissions have significantly dropped in Slovakia since 1990[5]. Slovak GHG emissions decreased by almost 40% between 1990-2000, and the decrease in emissions continued until 2015[6]. This was caused by several factors: a decline of heavy industry during the transformation period, introduction of modern (cleaner) technologies, construction of two additional nuclear reactors (but with two older decommissioned in 2006 and 2008), power production decline in thermal powerplants, fuel switch in heating, and housing reconstruction with focus on energy efficiency.

> SLOVAKIA IS ONE OF THE MOST INDUSTRIALIZED COUNTRIES IN EUROPE

Industry, power/heat, and residential/commercial sectors recorded the key GHG emission declines. Meanwhile, the transport sector observed slight gains, mainly due to a rapidly growing vehicle fleet in the country during the past thirty years[7] [See: Figure 2]. The decline is more pronounced when compared to GDP[8] [See: Figure 3]. When it comes to carbon intensity measured by emissions weighted by production (GDP), Slovakia falls into the average in Europe[9].

---

[1] European Environmental Agency (2020) *EU Greenhouse Gas Emissions Kept Decreasing in 2018, Largest Reductions in Energy Sector*. Available [online]: https://www.eea.europa.eu/highlights/eu-greenhouse-gas-emissions-kept

[2] https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2050-long-term-strategy_en

[3] Ibid.

[4] Eurostat (2022) Gross value added and income by A*10 industry breakdowns [nama_10_a10].

[5] https://www.mfsr.sk/files/archiv/35/Decarbonization-of-the-Slovak-economy-by-2030_study-062022.pdf

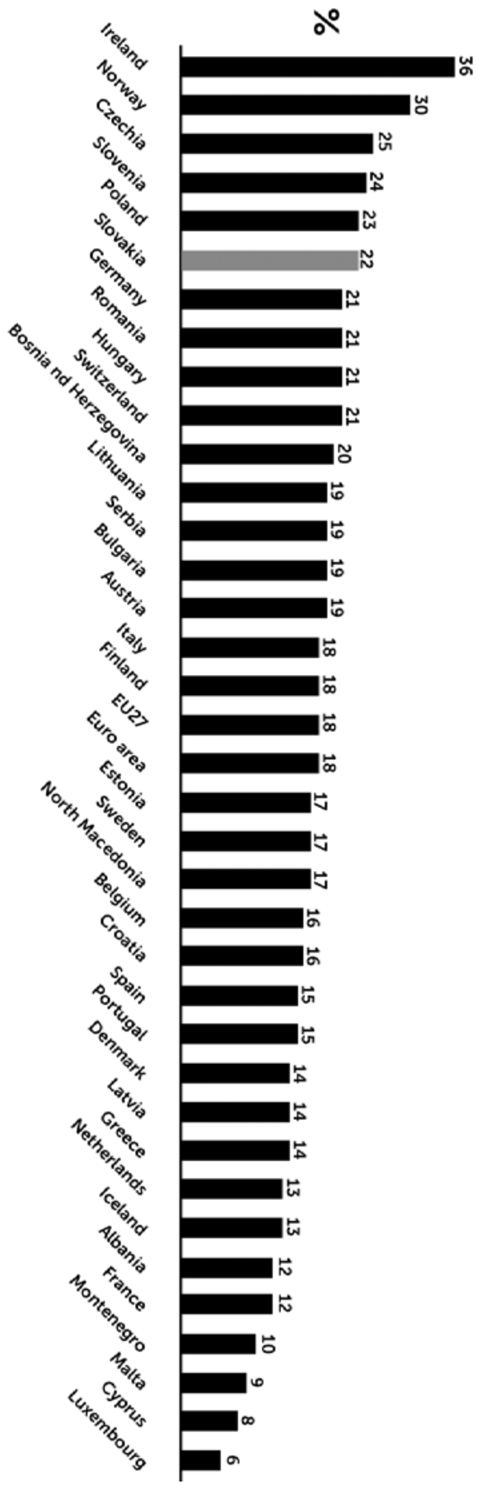
[6] Ibid.

[7] Ibid.

[8] World Bank (2022) CO2 Emissions (kg per PPP $ of GDP) – Slovak Republic, European Union. Available [online]: https://data.worldbank.org/indicator/EN.ATM.CO2E.PP.GD?locations=SK-EU

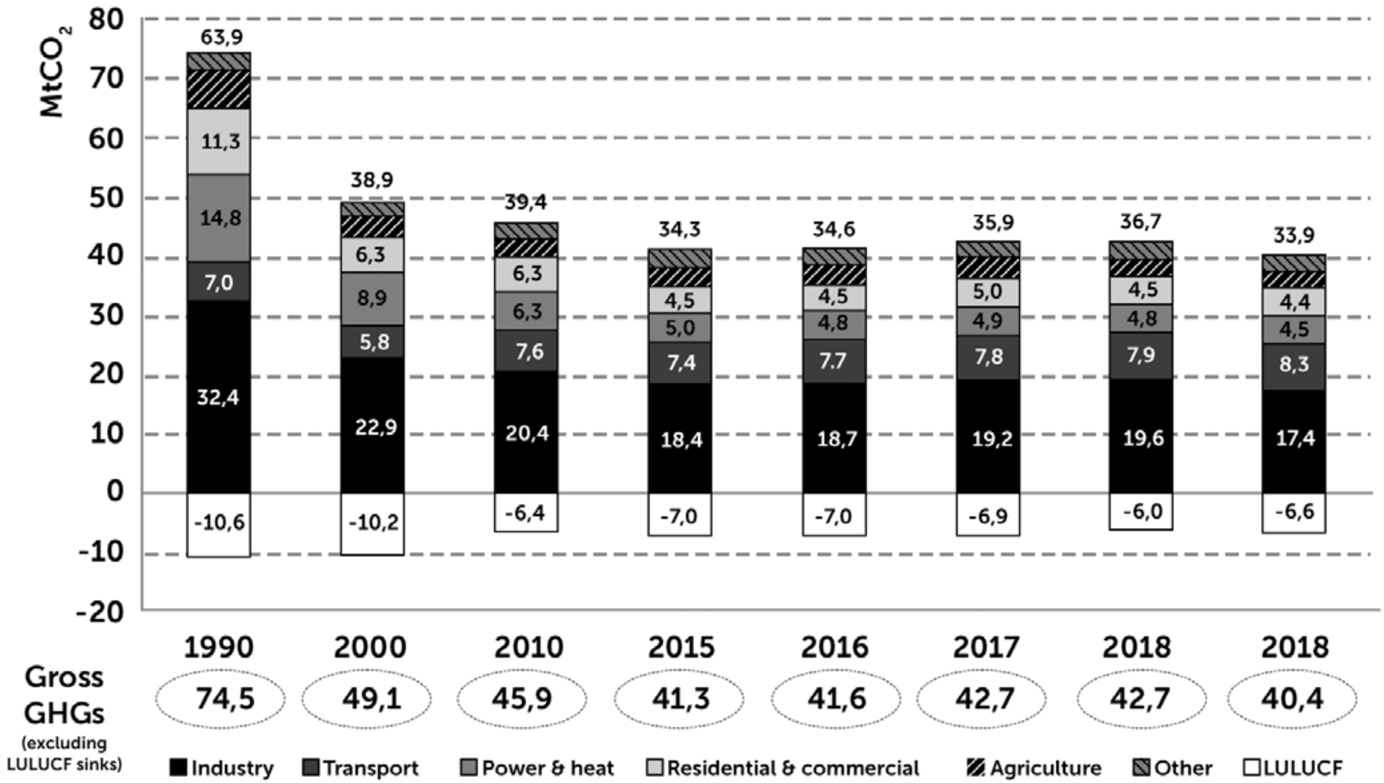
[9] Our World in Data (2018) *CO_2 Emissions Per Capita vs GDP Per Capita*. Available [online]: https://ourworldindata.org/grapher/co2-emissions-vs-gdp?zoomToSelection=true&time=2020..latest&country=ALB~AUT~BLR~BEL~BIH~BGR~HRV~CYP~CZE~DNK~EST~FIN~FRA~DEU~GRC~HUN~ISL~IRL~ITA~LVA~LTU~LUX~MLT~MDA~MNE~NLD~MKD~NOR~POL~PRT~ROU~RUS~SRB~SVK~SVN~ESP~SWE~CHE~UKR~GBR

Figure 1: Industrial production (excluding construction) share on GDP (2021)



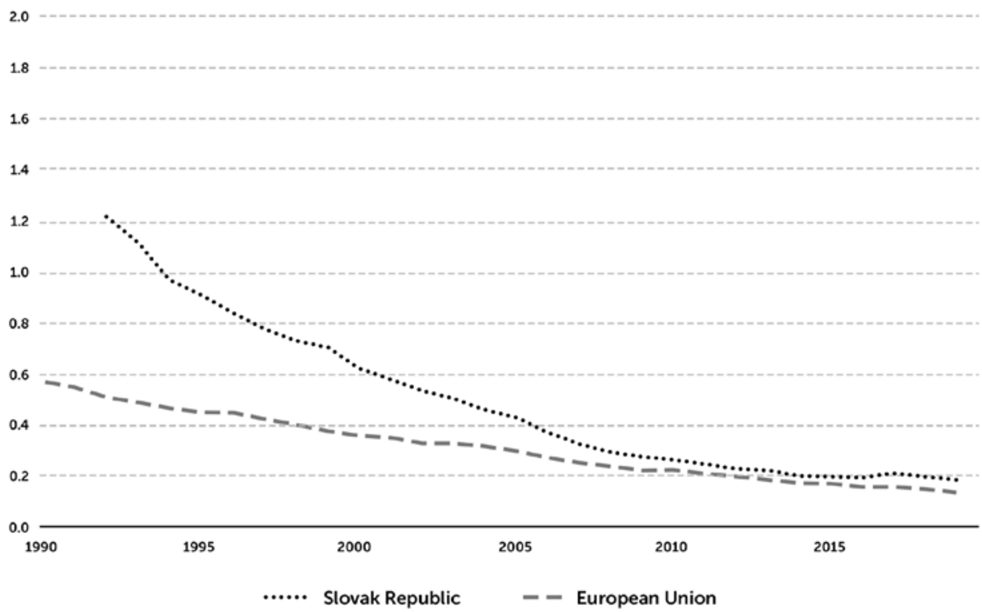
Source: Eurostat

Figure 2: The development of Slovak GHG emissions



Source: EEA

Figure 3: CO2 emissions (kg per PPP USD of GDP)



Source: Eurostat

> SIMILAR TO MANY POST-SOCIALISTIC ECONOMIES IN EUROPE, GHG EMISSIONS HAVE SIGNIFICANTLY DROPPED IN SLOVAKIA SINCE 1990

Talking in numbers, Slovak gross GHG emissions dropped from 74.5 MtCO2 in 1990 to 40.4 MtCO2 in 2019[10]. However, due to lower sequestration (attributed to the reduction in land use, land-use change, and forestry), the net effect was a bit smaller, with net emissions falling from 63.9 MtCO2 to 33.9 MtCO2[11]. To reach a 55% GHG reduction in Slovakia from the 1990 levels by 2030, a further 5-7 MtCO2 will have to be eliminated, compared to the current years. Looking at the sectoral structure, it is obvious that the industry (currently emitting 17-19 MtCO2 annually, depending on the current economic activity) will have to bear a substantial part of this reduction.

[10] https://www.mfsr.sk/files/archiv/35/Decarbonization-of-the-Slovak-economy-by-2030_study-062022.pdf

[11] Ibid.

[12] MH Teplárenský holding, which is a holding of several smaller state-owned heating companies, was excluded.

Table 1: 10 biggest emitters in Slovakia[12]

Company	Primary sector	2021 GHG emissions MtCO2	Share on total national GHG
US Steel	Metallurgy	8.97	21.9%
Slovnaft	Rafinery	2.24	5.5%
Slovenské elektrárne	Power	1.41	3.5%
Danucem	Cement	1.38	3.4%
Duslo	Chemicals	1.07	2.6%
ZSE elektrárne	Power	0.85	2.1%
Carmeuse	Cement	0.51	1.2%
Považská cementáreň	Cement	0.50	1.2%
SMZ	Raw materials	0.33	0.8%
Slovalco	Metallurgy	0.29	0.7%

Source: ICZ Slovakia a. s. and author's own elaboration

Table 2: Sectoral share on national GHG

Industry	2021 Share on national GHG (author's own estimation)
Metallurgy	23%
Rafinery/Chemicals	8%
Cement	6%
Power	6%
Materials	1%

Source:: ICZ Slovakia a. s. and author's own elaboration

"

SLOVAKIA IS A SMALL COUNTRY, AND THE INDUSTRY IS STANDING ON THE PILLARS REPRESENTED BY SEVERAL BIG COMPANIES. A SINGLE COMPANY (US STEEL) IS RESPONSIBLE FOR MORE THAN HALF OF THESE TOP TEN EMISSIONS

Slovakia is a small country, and the industry is standing on the pillars represented by several big companies. Therefore, the key carbon emitters can be easily counted[13] [See: Table 1]. The ten biggest industrial emitters contribute more than 40% of the total national GHG emissions. A single company (US Steel) is responsible for more than half of these top ten emissions, the top five generate more than one third of Slovakia's total GHG emissions.

It is obvious that to reach the 55% reduction goal, the Slovak strategy will have to be specifically oriented on several companies – most notably US Steel. Let us have one more look at the statistics via sectoral division. [See: Table 2]. Any GHG reduction strategy will have to focus on three specific industries – metallurgy, chemicals, and cement. Power generation has a special role since electrification is a key to decarbonization in all other sectors.

THE PLANS...

There are two official documents related to strategies for reaching the 55% GHG reduction goal in Slovakia. One (we may call it the 'prelude') was published by the World Bank in early 2019[14]. Due to its age, it works with older data but offers a more theoretical approach towards GHG emission reduction. There are four decarbonization scenarios analyzed for Slovakia in the document, which have been designed as contrasting combinations of energy efficiency and renewable targets, representing the trade-offs between targets. All four decarbonization scenarios involve the construction of new nuclear generation capacity for Slovakia, continuing the importance of nuclear energy in the generation mix, but they differ in the extent to which renewables enter the generation mix. The study focuses on macroeconomic modelling the scenarios (GDP changes, consumption changes, emissions changes)

[13] ICZ Slovakia a. s. (2022) *Stav plnenia podmienok pre prevádzky v Slovenskej republike za rok 2021*. Available [online]: http://emisie.icz.sk/files/Stav_plnenia_podmienok_2021.pdf [in Slovak]

[14] http://documents.worldbank.org/curated/en/772561553850127627/pdf/A-Low-Carbon-Growth-Study-for-Slovakia-Implementing-the-EU-2030-Climate-and-Energy-Policy-Framework.pdf

– the economic impacts of a low carbon growth path. It does not go into detail how exactly the reduction will happen, instead focusing on modelling electricity demand and generation.

A much more specific decarbonization strategy was published[15] by the Value for Money Department under Ministry of Finance of the Slovak Republic in cooperation with Institute of Environmental Policy (analytical unit under the Ministry of Environment) and the Boston Consulting Group in May 2022. To model the most cost-effective path of decarbonization, the strategy utilizes a marginal abatement cost curve (MACC). The curve is marginal in the sense that it estimates the cost of abatement for the next (cheapest) unit of GHGs.

The strategy contains 58 specific actions (or 'levers', as the authors call it), each with GHG reduction size estimation and with cost (both capital cost and net present value of operational cost) estimation per ton of GHG saved. These levers are ordered according to their cost from the 'cheapest' ton saved to the most expensive tons. 18 levers have negative cost, since these often represent expected savings (closure of subsidized lignite powerplant, gradual switch from gas heaters towards more efficient heat pumps etc.). On the other hand, the most expensive levers are mostly represented by carbon capture and storage options [See: Table 4].

The complete list provides options to save around 20 $MtCO_2$ – way above what is needed to reach the 55% reduction goal in Slovakia (around 5-7 $MtCO_2$). Implementing all the levers would bring a 76% reduction in emissions compared to the 1990 levels (but not carbon neutrality!) and would cost over EUR 13.5 billion according to the authors, representing around 13% of current Slovak GDP.

> ALL FOUR DECARBONIZATION SCENARIOS INVOLVE THE CONSTRUCTION OF NEW NUCLEAR GENERATION CAPACITY FOR SLOVAKIA, CONTINUING THE IMPORTANCE OF NUCLEAR ENERGY IN THE GENERATION MIX, BUT THEY DIFFER IN THE EXTENT TO WHICH RENEWABLES ENTER THE GENERATION MIX

[15] https://www.mfsr.sk/files/archiv/35/Decarbonization-of-the-Slovak-economy-by-2030_study-062022.pdf

> IMPLEMENTING ALL THE LEVERS WOULD BRING A 76% REDUCTION IN EMISSIONS COMPARED TO THE 1990 LEVELS

This 'maximalist' option is for now a more hypothetical one. Many suggested technologies (especially carbon capture and storage) are far from industrial-scale availability[16].

For the 'minimalist' 55% reduction target, the societal costs exceed EUR 2.7 billion – the majority of which is on the shoulders of decentralized emitters. This scenario employs 33 out of the 58 levers, reducing thus 6.3 MtCO2. Most importantly, it does not include two levers implementing construction of two electric arc furnaces in US Steel (with the potential to reduce further 4.6 MtCO2) nor the interconnected direct cast-and-roll technology (another 1.5 MtCO2). These two levers fall into middle scenario, which comes with 67% reduction since 1990 and the price tag of EUR 5 billion.

The most important levers in the minimalist (55 % GHG reduction) scenario are the closures of Nováky and Vojany coal powerplants, bringing alone 2.2 MtCO2 savings out of the total 6.3 MtCO2. These levers are almost costless, since before the Russian attack on Ukraine, these powerplants were struggling to operate profitably. Counting the closure of Nováky coal mine (another 0.2 MtCO2 saving), which is heavily subsidized, these three levers (two powerplants and a mine) should bring substantial financial savings.

Overall, the minimalist scenario looks encouragingly optimistic – the GHG reduction is reaching the set goal for a very modest financial price and the levers listed do not employ any underdeveloped technological solution. However, the model works with numerous simplifications and dubious assumptions. These influence the minimalist model, but become even more pronounced when we look at the levers added in the medium and maximalist reduction scenario. One shall remember that the long-term EU goal is carbon neutrality – so even the most complete list for the maximalist scenario (76% reduction in emissions compared to the 1990 levels) will not be enough.

... AND THE PROBLEMS

Every analysis has to work with assumptions, simplifications, and limitations. If we start to analyze every lever (and every assumption preceding the implementation of these levers) in the analysis, we will discover many discussion points. However, to ensure we keep within the space and topic limitations of this text, let us focus on several key issues.

SUPPLY CAPACITY

There are numerous levers which foresee spreading of a specific kind of technology or fuel: electric vehicles, heat pumps,

[16] Ma, J. et. al. (2022) "Carbon Capture and Storage: History and the Road Ahead", [in]: *Engineering*, Vol. 14, pp. 33-43. Available [online]: https://www.sciencedirect.com/science/article/pii/S2095809922001357

waste fuel, biomass, and biofuel... These inputs have their price, which is duly noted by the analysis, but their sufficient supply might be a problem (e.g., biomass). In numerous cases, these levers even have negative costs due to the assumption that the new technology will have lower operating cost, thus not only covering the capital expenditure, but also providing lifetime cost savings. These assumptions are based on existing comparative models and lifetime cost calculators (for example EV vs ICE vehicle)[17].

However, the levers often expect mass adoption of the new technology, happening in a relatively brief timeframe (the year 2030 being the latest). Moreover, almost identical actions (adoption of EVs, heat pumps, and fuel switch) will be happening all across Europe at the same time. Therefore, supply constraints may arise, which will either prohibit the spread in sufficient numbers, or will substantially rise the expected cost beyond modelled expectations.

One shall not underestimate markets, which are able to react on demand pressure and rise supply with often surprising speed and quantity (as proven during the pandemics). However, the supply constraint factor cannot be completely disregarded, especially counting in the massive rise in global uncertainty, stemming from the war in Ukraine. Also, some of these constraints may be rooted in regulation and thus difficult for the markets to overcome (for example, alternative fuel for cement industry is based on waste, but waste collection and sorting is fully dependent on regulations).

> THE LONG-TERM EU GOAL IS CARBON NEUTRALITY

POPULAR BACKLASH

At the moment of writing, farmers in the Netherlands have been staging massive protests for weeks. The core reason is the proposed reduction of livestock numbers due to emissions[18]. Clearly, some of the levers will require direct contribution from citizens and some costs could be easily traced to the green policies even by laymen, which may generate popular backlash against such a policy. Further reduction of livestock is proposed among the levers of the decarbonization study, despite the fact that the number of cattle in Slovakia already fell below 45% of the 1993 number.

TECHNOLOGY READINESS

While the 55% GHG reduction limit is theoretically reachable without the need to implement immature technology, carbon neutrality is not – it will require carbon capture and storage and a new array of hydrogen technologies. Some industries (especially the cement industry) rely on chemical processes, which emit CO2 by its chemical nature.

---

[17] Such a calculator was, for example, constructed by the co-author of the study, the Institute of Environmental Policies, in 2019. Available [online]: https://minzp-iep.shinyapps.io/auta/ [in Slovak]

[18] BBC (2022) *Why Dutch Farmers Are Protesting over Emissions Cuts*. Available [online]: https://www.bbc.com/news/world-europe-62335287

> WHILE THE 55% GHG REDUCTION LIMIT IS THEORETICALLY REACHABLE WITHOUT THE NEED TO IMPLEMENT IMMATURE TECHNOLOGY, CARBON NEUTRALITY IS NOT – IT WILL REQUIRE CARBON CAPTURE AND STORAGE AND A NEW ARRAY OF HYDROGEN TECHNOLOGIES

BEHAVIORAL CHANGES

Few levers expect behavioral changes from the citizens and company managers, albeit nudged by prices and infrastructural improvements. A best representative lever is the mode shift for passenger transport. Increased fuel prices and denser public transport will motivate citizens to switch transport modes. Nevertheless, status effect, sunken cost fallacy ("*I will drive a car there, because I already paid for the car*") and some other effects are difficult to quantify.

MANAGERIAL AND PUBLIC ADMINISTRATION CHALLENGE

Reaching the minimalist 55% GHG reduction goal will require implementation of around thirty levers. When analyzing the lever on a one-by-one basis, they seem more or less challenging, but reasonably feasible. Yet, every single one of these levers will require intensive efforts – both on the private side (preparation and implementation of investments, workforce adjustment, negotiation of new supply networks, among others) and on the public administration side (regulatory changes, grant schemes, and coordination, to name but a few).

Some of the levers require complex reforms on their own – in agriculture, power markets, waste management etc. These need to be implemented relatively quickly, since by 2030, all levers should be up and running. Multiplied by thirty, it will require extreme efforts, especially on the public administration side, which is a partner in every single one of the thirty levers. In reality, public administration is riddled with staff shortfalls, slow processes, political instability and internal conflicts, limited knowledge of the very broad spectrum of issues, and with many other obstacles which may limit the ability to implement the levers in time.

CETERIS PARIBUS IN CONSUMPTION

The 2019 World Bank analysis estimated consumption pattern shifts between industries[19]. The 2022 ministerial analysis does not reflect this – it focuses only

[19] http://documents.worldbank.org/curated/en/772561553850127627/pdf/A-Low-Carbon-Growth-Study-for-Slovakia-Implementing-the-EU-2030-Climate-and-Energy-Policy-Framework.pdf

> SLOVAKIA HAS A LOW CARBON ELECTRICITY MIX, WITH AROUND 70-80% OF ELECTRICITY GENERATED BY NUCLEAR POWER, HYDRO, AND RENEWABLES

on the potential sources of GHG reduction, not the potential sources of new GHG emissions. Patterns of consumption gradually change, and it may be possible that by 2030, some sources of GHG emissions will become more important (new power consumers like A/C in households, increased travelling etc.). Mechanisms outside the scope of the study will probably reduce the rise of new emission sources (ETS, carbon tax, energy standards, and other), but it may cause different arrangement of priorities and costs in the levers list.

NET COST CALCULATION

The strategy balances negative and positive costs to receive the final cost of the levers' implementation (EUR 2.7–13.5 billion). However, reduction of a cost on one side does not automatically create capital on the other side. The authors of the strategy call it 'societal net cost'. However, mechanisms will have to be created to transfer the savings to finance the new investment.

The most notable example is the closure of the Novaky mine. It is supposed to save around EUR 120 million annually. However, its closure is already a done deal, and the savings will go towards utility bills of consumers (who directly pay these subsidies). These resources will have to be extracted from the population in some way, and only then can they be spent on levers with positive cost. Constructing these mechanisms will not be an easy feat.

POWER AVAILABILITY

The previous six problems mentioned in relation with the plan to cut emissions in Slovakia were just a warm-up before the final, most important problem – electric power generation and distribution.

First, we need to note that this is less of a problem when focused on the technical side and Slovakia solely. Slovakia has a low carbon electricity mix, with around 70-80% of electricity generated by nuclear power, hydro, and renewables. With two more nuclear reactors hopefully nearing commissioning after numerous delays (bringing the total up to six), the low carbon power generation ability will be further strengthened.

Looking from the European perspective, the problem is substantially bigger – electrification of the steel and chemical industry in Europe will bring massive requirements for new clean power generation. For example, just the complete electrification of the German chemical industry will require more than 600 terawatt-hours (TWh) of green electricity per year, more than Germany's entire current electricity

> WHILE THE SHEER AMOUNT OF ELECTRICITY MAY NOT BE A BIG PROBLEM IN SLOVAKIA, THE PROBLEM IS ITS PRICE

consumption of around 500 TWh, according to its Roadmap 2050[20].

While the sheer amount of electricity may not be a big problem in Slovakia, the problem is its price. With interconnected power networks and commodity exchanges, massive uptake in electricity demand will spread higher prices across Europe. That this is not just a theory can be witnessed right now, in the summer of 2022, when the electricity prices are skyrocketing to the EUR 700 /MWh level (way above the long-term price around EUR 50/MWh) due to the war in Ukraine. The main problem is created by the peak electricity demand, satisfied mainly by thermal power plants. With two major Slovak thermal power plants destined to be closed (and numerous others facing the same fate around Europe), the problem will grow deeper.

The ministerial analysis does not reflect a need for new power generation, storage, and power transmission. With the key levers relying on electricity prices (especially the electric arc furnaces, but also electric vehicles, heat pumps, and railway utilization), the economic feasibility of the plan lays in question.

CASE STUDY: US STEEL

When it comes to US Steel and its possible routes towards lower carbon intensity, this steelmaker (employing 9,000 people and with revenues around EUR 3.5 billion) is the largest employer in the eastern part of the country. It is also by far the biggest CO2 emitter in Slovakia – with around 9 MtCO2 emissions per year. It produces steel in three blast furnaces, using coke as the reducing agent.

There are two major steps for the company to make. One is a combination of electric arc furnaces (EAF) and direct cast and roll technology (DCR). The second major step is the use of hydrogen as a reducing agent in production instead of coke.

According to the company representatives interviewed by authors, installation of the two EAFs will enable the company to produce around 70-75% of the current portfolio of products, the rest of the portfolio products will be produced by the remaining third blast furnace. The installation of EAFs will require additional power supply and scrap metal supply, since EAF input is around 80% of scrap metal, instead of the current 20%. Installation of EAFs should reduce around 4.6 MtCO2 of annual emissions.

Power requisite can be technically met (although we do not know the power needs of hydrogen production yet), due to expected commissioning of a new reactor in the Mochovce nuclear power

[20] VCI (2019) *Roadmap Chemie 2050*. Available [online]: https://www.vci.de/services/publikationen/broschueren-faltblaetter/vci-dechema-futurecamp-studie-roadmap-2050-treibhausgasneutralitaet-chemieindustrie-deutschland-langfassung.jsp [in German]

plant and ongoing negotiations with the Slovak transmission operator[21]. It is important to note that, currently, the company is able to produce some power using waste heat from blast furnaces. Therefore, the need for an external power source is higher than the EAF requirement alone.

The need for scrap metal will be met by expanding the network of suppliers. Currently, the European Union is exporting about 20 million tons of scrap metal per year and obtaining additional supplies of scrap metal should not represent a substantial obstacle. EAFs are interconnected with the DCR technology, which has the potential to reduce further 1.5 MtCO2 per year[22]. Projected cost of the two EAFs and the DCR unit is around EUR 1.3 billion[23], with expected substantial support from the state. However, according to the interviewed representatives of US Steel, the investment will rise competitiveness of the company thanks to a wider range of products, which is currently limited by the too narrow old casting and rolling unit.

The combination of EAFs and the DCR has the potential to reduce around 68% of existing emissions – given the electricity is supplied from a low carbon (most probably nuclear) source. This will leave around 3 MtCO2 of emissions in the company. To further cut these emissions, the remaining blast furnace would have to be converted as well. To keep the ability to produce primary steel (and not just recycle scrap metal), the coke reduction process would have to be replaced by hydrogen via direct reduction process[24]. While the technology is sixty years old (albeit using natural gas, not hydrogen), there is only one DRI plant in Europe, owned by ArcelorMittal and located in Hamburg, producing meagre 0.6 Mt of steel per year[25]. However, another 10-14 plants are planned to be in the state of market production by the end of the decade in Europe (not all utilizing hydrogen).

THERE IS ONLY ONE DRI PLANT IN EUROPE, OWNED BY ARCELORMITTAL AND LOCATED IN HAMBURG, PRODUCING MEAGRE 0.6 MT OF STEEL PER YEAR

The main culprit in this case is not the technology itself, but the electricity needed to produce green hydrogen. The electricity need for electrolysis is around 3.3 TWh per

[21] Based on own interviews with company managers.

[22] https://www.eurofer.eu/press-releases/stop-waste-and-scrap-export-to-countries-not-meeting-eu-environmental-and-social-standards-asks-eurofer/

[23] https://spectator.sme.sk/c/22851363/kosice-steel-works-to-invest-more-than-1-billion-into-modernisation.html

[24] https://bellona.org/news/industrial-pollution/2021-05-hydrogen-in-steel-production-what-is-happening-in-europe-part-two

[25] Ibid.

"
THE MORE WE AIM BEYOND THE 55% LIMIT AND TOWARDS CARBON NEUTRALITY, THE MORE DEPENDENT WE BECOME ON THESE LEVERS ON THE AVAILABLE GREEN ELECTRICITY, COMBINED WITH INSUFFICIENT TECHNOLOGY READINESS

Mt of iron[26]. Therefore, 1 Mt of *green* iron requires steady power supply equivalent of a 400 MW nuclear reactor. Theoretically, the power may be available in Slovakia thanks to the second reactor coming online in 2024, and with the potential closure of the aluminum smelter, which consumes around 3 TWh of power annually and already interrupted production due to high electricity prices in the summer of 2022. Still, besides additional capital expenditures on the electrolyzer and other technology, such a move greatly increases dependence on electricity markets.

CONCLUSIONS

To reach GHG reduction targets, Slovakia needs to implement dozens of actions. However, the main bulk of reductions will happen in metallurgy, chemical, cement, and transport industries. While transport industry is decentralized, the majority of GHG emissions generated in the three remaining industries are centered on a single-digit number of companies. The most important is a single steelmaker, emitting over one fifth of total carbon in Slovakia.

Reaching the level of 55% is technically possible, coming with a large, but not unimaginable price tag. The main obstacles are in implementation – managerial unpreparedness, political instability, or supply capacity. The more we aim beyond the 55% limit and towards carbon neutrality, the more dependent we become on these levers on the available green electricity, combined with insufficient technology readiness (in some cases).

Slovakia is part of the European power market, and the abundance of national low-carbon power sources does not provide any advantage when it comes to the question of economic availability of power in Europe. There will be demand for any additional megawatt hour from industries all over Europe, increasing the costs of decarbonization in Slovakia. The European Union as a whole still lacks the required abundance of low carbon or zero-emissions sources of electric power in Europe.

[26] Ibid.

[27] Residential and commercial sector.

Therefore, the emission reduction plan is an example of the *chicken or egg* question: will green (read 'electrified') industry rise first, or does it not make sense before the energy transition takes place in Europe?

*

MARTIN VLACHYNSKÝ

Analyst at the INESS. He is interested in economic policy, business environment, and competitiveness, with special focus on health care and energy sectors. Creator of the Bureaucracy index and Health for Money Index

Table 3: Complete list of decarbonization levers in Slovakia

No.	Sector	Lever name	Y-axis – abatement cost (EUR/tCO2e)	X-axis – abatement (ktCO2e)
1	Other industry	Closing Nováky mine	-605	203
2	Transport	Cars' electrification	-312	248
3	Transport	Cars electrifcation (ambitious scenario)	-200	83
4	Res. & com.[27]	Heat pumps and fuel switch	-142	111
5	Heat	Bratislava HP[28] improvements	-118	27
6	Cement	Cement alternative fuels	-85	154
7	Res. & com.	Thermostats and smart meters	-84	119
8	Transport	Cars fuel efficiency	-83	176

[28] Heating plants.

No.	Sector	Lever name	Y-axis – abatement cost (EUR/tCO2e)	X-axis – abatement (ktCO2e)
9	Heat	Košice HP burning waste	-78	23
10	Iron and steel	Plasma Furnace	-48	10
11	Res. & com.	Insulating buildings without CHS[1]	-39	167
12	Petroleum refining	Flaring reduction	-32	73
13	Transport	Increase freight diesel efficiency	-19	160
14	Cement	Waste heat reuse	-13	71
15	Petroleum refining	Power and heat from biomass	-13	755
16	Other industry	Reduce methane leaks	-11	82
17	Heat	Košice Geothermal energy	-6	71
18	Heat	Improvements in Košice HP	-6	52
19	Agriculture	Livestock reduction	0	126
20	Transport	Lower speed limit	0	52
21	Power	Decommissioning Nováky	1	1 662
22	Power	Decommissioning Vojany	1	524
23	Iron and steel	Lower fuel consumption	3	194
24	Iron and steel	Optimized transport routes	4	285
25	Cement	Cement materials substitution	5	162
26	Waste	Biogas from landfill	5	116
27	Heat	Small HPs improvements and fuel switch	13	49
28	Chemicals	Cooling device for absorption column	13	37
29	Iron and steel	Electric blower	14	147
30	Chemicals	Tertiary catalytic reduction	21	33
31	Petroleum refining	Energy efficiency	22	158
32	Heat	Insulating buildings with CHS	26	150
33	Agriculture	Food additives for animals	30	59
34	Iron and steel	Electric arc furnace 1	33	2 309

[29] Central heating system.

No.	Sector	Lever name	Y-axis – abatement cost (EUR/tCO2e)	X-axis – abatement (ktCO2e)
35	Iron and steel	Electric arc furnace 2	33	2 309
36	Iron and steel	Expansion turbine	39	18
37	Agriculture	Improved fertilization practices	40	189
38	Iron and steel	Lower steam and hot water consumption	41	51
39	Transport	Mode shift for passengers	48	646
40	Iron and steel	Hatch annealing	49	39
41	Heat	Žilina HP fuel switch	59	95
42	Iron and steel	Direct Cast and Roll	82	1 464
43	Agriculture	Improved manure management	84	60
44	Petroleum refining	CCS petrochemicals	84	477
45	Chemicals	CCS ammonia production	87	876
46	LULUCF	Afforestation	93	147
47	Transport	Shifting freight from road to rail	111	374
48	Transport	Freight alternative fuels	112	140
49	Other industry	CCS aluminum	126	271
50	Cement	CCS lime	133	332
51	Cement	CCS cement	133	1 559
52	Iron and steel	CCS steel	139	1 092
53	Iron and steel	CCS ferroalloys	139	159
54	Petroleum refining	CCS refining	148	366
55	Heat	CCS large HPs	156	372
56	Power	CCS Malzenice	156	442
57	Petroleum refining	H2 production	177	39
58	Transport	Aviation shift to alternative fuel	274	9
	TOTAL			**20 174**

Source: Decarbonization of the Slovak Economy by 2030