Paris Agreement Compatible
Scenarios for Energy Infrastructure

No time to lose:
Short-term measures to minimise impacts of the severe energy crises in Europe and Germany

Some thoughts on indicative pathways

Discussion Paper

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DISCLAIMER

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The coming winter will decide who is the winner between Putin's Russia and the Western world, in particular the European Union and European national democratic structures. Ukraine is only the physical battlefield of a much larger conflict. At the same time, energy scarcity is not a new phenomenon, and it is not only caused by the war in Ukraine. This paper analyses short-term measures to overcome the coming winter, while also suggesting that we use this crisis as an opportunity to implement mid- and long-term measures to make the energy system more sustainable and resilient.

1. CONTEXT

The invasion of Ukraine has led to massive disruption in energy supplies. Europe's heavy dependency on Russian energy imports is already starting to shake European economies, European institutions and world geopolitics. Despite many warnings, Europe has steadily increased dependency on primary energy from Russia during the past decades, as shown in figure 1. This fact is well known in the case of natural gas, but it also applies for oil, coal and, for some countries, uranium for nuclear power plants.

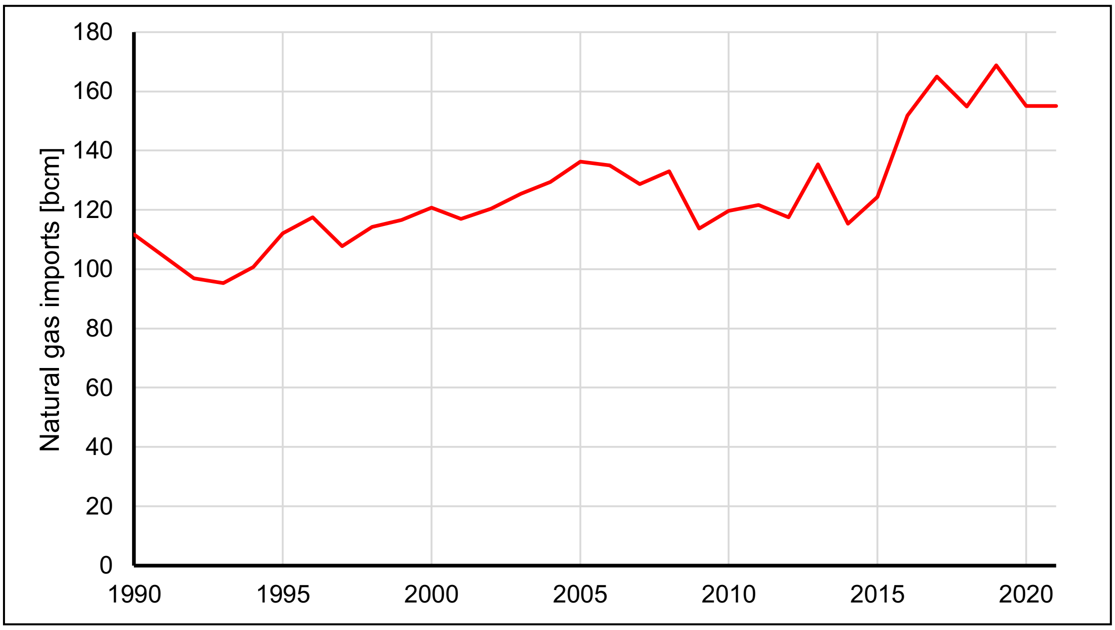

Figure 1. EU-27 imports of natural gas from Russia (sources: Eurostat, IEA)

Historically, Europe has capitalised on access to cheap energy from Russia as a competitive advantage for its economies, both ignoring the external cost caused by a predominantly fossil-based energy system and the strategic risks of dependency from one single source. Heavy and increasing dependencies on natural gas, which is still wrongly considered to be comparably clean and sustainable (while ignoring the carbon footprint caused by the upstream sector and transportation losses), have shaped European policies - consolidating the power of fossil industries, delaying and endangering the transition to full decarbonisation, and establishing or cementing severe lock-ins. The recent inclusion of gas (and nuclear) as a “green” energy source in the EU taxonomy is another clear sign of the inability and unwillingness of policy makers to shift to more sustainable, reliable, and local energy options.

The current energy crisis is not the first to hit Europe. In past decades, there have been several waves of energy scarcity. Indeed, the current energy crisis did not begin in February 2022, but already in summer of 2021, when supply did not follow the post-Covid recovery of demand. Hence, the discussion on how to become more resilient against volatile energy markets is a much more fundamental one than just overcoming the current geopolitical crisis.

The first large energy crisis was the oil price shock of 1973. It resulted in immediate and unprecedented responses of the buying countries, including prolonged rationing. Many countries and industries used the oil crisis to fundamentally change their utilisation of energy. Industries, over decades focused on energy efficiency, both for their own consumption of energy and in the products they offered. This, for the first time in human history, resulted in decoupling of economic growth from growth of energy demand. As such, the oil crisis resulted in a huge learning with stable benefits for all consumers. Thus, the current energy crisis should be turned into an opportunity to come up with new solutions and approaches that will not only benefit our societies, but also address other crises we face: climate, biodiversity, and security.

Today, with eight billion people living on Earth and knowledge of the devastating impacts mankind inflicts to the climate, biodiversity and all kind of ecosystems, our current economic system centred on growth needs to be immediately abandoned. Indeed, the age of plenty is over: resources are limited and accepting and dealing with scarcity is key to developing a truly sustainable and socially fair future, while fostering peace across regions and continents.

Replacing natural gas, within the coming six months, is a major challenge due to gas dependency and infrastructure needs, namely pipelines and LNG terminals. However, this is the task that needs to be addressed ahead of winter. This paper presents a rough analysis of current European gas supply and demand to derive proposals for actions to quickly reduce dependency on natural gas from Russia by the winter of 2022/23 and, of course, in the long run from imported fossils in general. Moreover, the paper also analyses the entire energy system and looks for structural opportunities to reduce energy demand. To achieve that, efforts to share resources across Europe will need to be intensified, requiring a stronger Europe and solidarity across Member States as well as an optimal use of available resources. Optimisation, savings, and system efficiency, which together can increase Europe's resilience, are the mantra of this preliminary analysis.

2. ANALYSIS

In this preliminary analysis, we consider the energy system of the European Union to be one integrated system with unlimited transport capacities for all types of primary energy. We complement it with a granular overview of the energy situation in Germany, as one of the countries most hit by Russian fuel disruption. We also assume that all types of gas, oil or coal can be equally used everywhere in the system. Both are simplifications resulting in maximum estimates of substitution potentials. In other words: in reality, more will need to be done to achieve the required saving than indicated by this first estimate.

Figure 2 summarises the energy flows in the European Union (EU-27) in 2020. The right side of the picture provides a comparative overview in energy demand in 2019 and 2020. In this comparison, the impacts of the Covid-19 pandemic on demand are used to derive some of the saving measures suggested below in the paper.

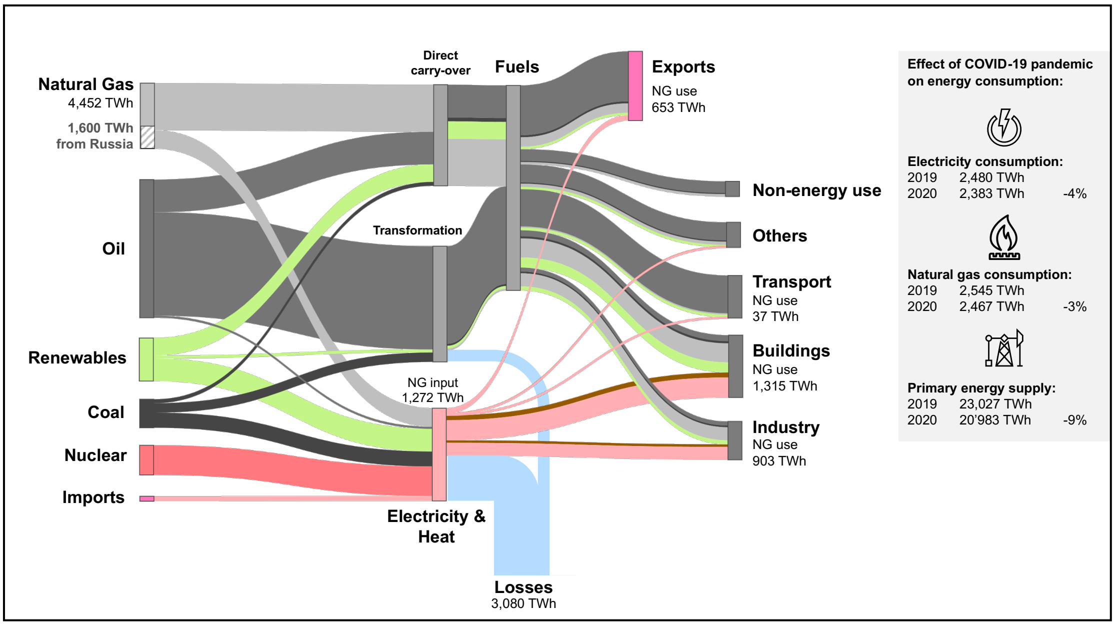

Figure 2. Energy flows in the European Union (EU-27) in 2020 (source: Eurostat).

In Europe, three main sectors depend on gas supply: electricity and heat generation, buildings, and industry. The greatest impact of the Covid pandemic was on the primary energy demand due to reduced activities in the transport sector. Transport therefore plays an important role in our suggested saving measures.

The most important message of figure 2 is the massive conversion losses in the electricity sector due to thermodynamic processes used in thermal power plants. The additional similar level of losses in other supplied sectors highlights the very high potential of reducing primary energy demand by curbing conversion losses through direct electrification wherever possible.

Figure 3 takes a closer look at the sources of natural gas in Europe and its utilisation in the different demand sectors. Close to 40% of imports originate from Russia. The biggest demand sector is buildings for heating purposes, which accounts for around 30% of natural gas supply, followed by electricity and heat at around 29%. The importance of the latter is underlined by breakdown of gas usage by sectors as shown in figure 4.

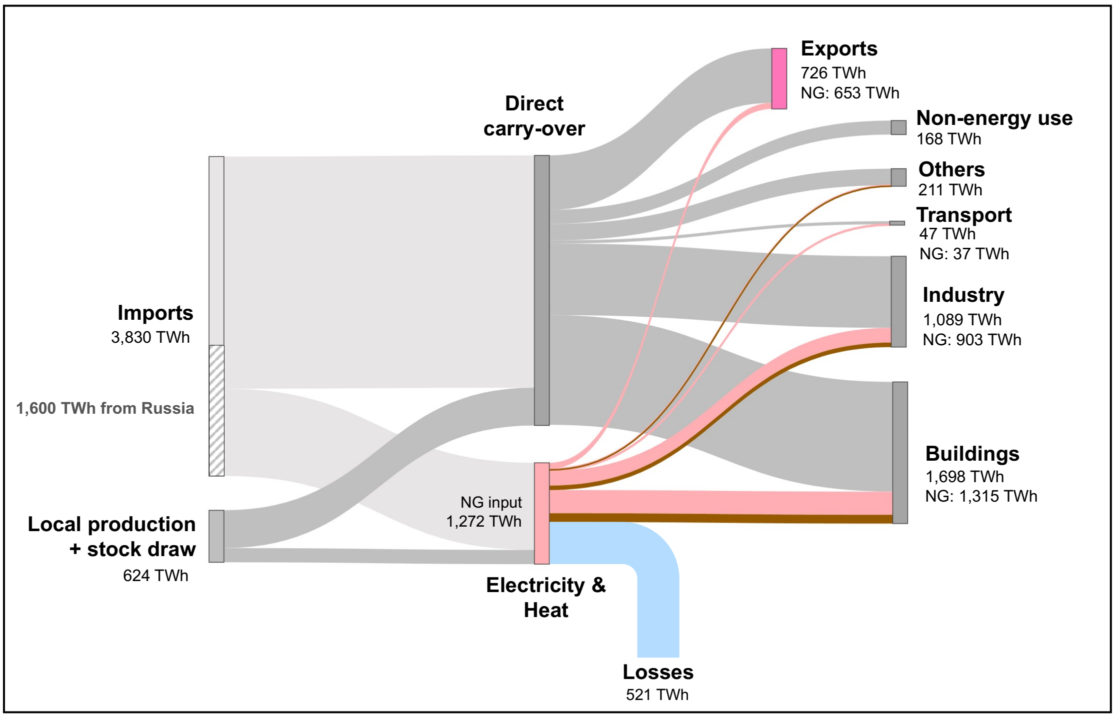

Figure 3. Sources of natural gas in the European Union (EU 27) and distribution to demand sectors (source: Eurostat)

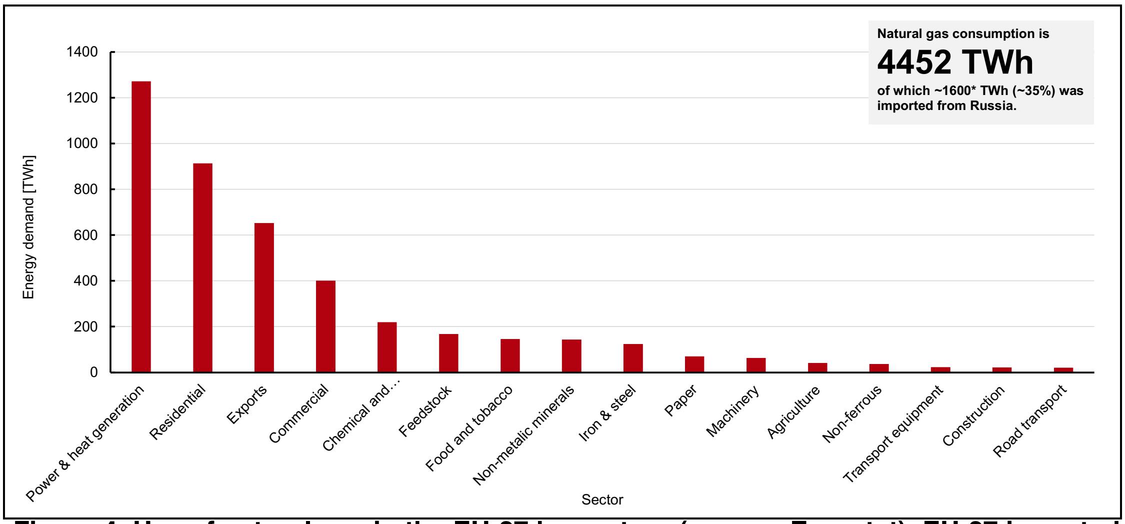

Figure 4. Use of natural gas in the EU-27 by sectors (source, Eurostat). EU-27 imported 152.6 bcm of natural gas from Russia in 2020, GCV of Russian gas is 37.83 MJ/m3 (at 15 °C))

3. MEASURES TO REPLACE GAS SUPPLY FROM RUSSIA AND REDUCE OVERALL GAS DEPENDENCIES

In this section we start highlighting the measures that needs to be implemented immediately to reduce pressure of shortages over winter. We then provide an overview that will need to drive actions in the medium to long term to assure a sustainable and safe energy transition.

3.1 IMMEDIATE ACTIONS BY SECTORS

Politics is waking up to the fact that energy shortages in winter will bring a level of disruption unprecedented in times of peace — though arguably this is not a time of peace at all. A number of measures are already being considered and implemented, others are not yet on the table because, while they are practically possible to implement at a very short notice, they present political difficulties. Failure to act immediately will bring major societal and economic disruptions and, eventually, redefine geopolitical power structures.

In comparison to the electricity system, the gas system has huge storage capacities. This fact allows for some of the measures to be implemented now without waiting for winter. One practical example to illustrate this (and at the same time showing inter-sectoral links): by reducing fuel consumption in transportation in summer, we reduce demand on the oil market, which could in turn substitute gas in power generation, thus freeing up some gas to be stored for usage in winter.

Measures are grouped in two parts: the first relates to measures on the **demand side** with large potentials and long-term impacts, including the measures which are complementary and essential in order to obtain the societal behavioural changes that are needed. The mantra here is preparedness, as citizens will need to get ready and contribute their share. The second group are measures on the **supply side**, including measures necessary for addressing expected winter shortages and with immediate effect, allowing states to fill up gas storages.

3.1.1 Power and heat generation

Power and heat generation includes supply with electricity (primarily) and district heating, which often is provided by combined electricity and heat generation and, therefore, is recognised as one sector. The first substitution of gas will come from measures that are already planned, i.e. the further growth of renewable energies. Newly installed wind and solar PV will generate 81 TWh, which can potentially displace 147 TWh[1] of primary natural gas supply. Out of the 81 TWh, solar PV will contribute 42 TWh, based on an additional capacity of 32 GW (25% growth vs. 2021) operating at a capacity factor of 15%. The remaining 39 TWh will come from additional 15 GW of installed wind capacity (also 25% growth vs. 2021), whereof ¾ is onshore and ¼ offshore (with capacity factors: onshore 25% and offshore 45%).

As accelerating deployment of renewables will increase the pressure on grid enforcement, which is today already delayed, this measure implies that all short-term opportunities to unleash additional grid capacity should be used. Digital grid solutions and flexible grid assets (FACTS) can help here. Their utilisation therefore needs to be enforced wherever helpful in order to maximise grid capacity and reduce curtailment.

While this first substitution potential is in line with the EU's long-term targets, the second and largest one — changing the fuel mix in power generation in order to minimise gas consumption — is not. Based on the assumption that utilisation of all power plants could be increased up to a minimum of 80%, the following amounts of gas could be substituted:

- Coal: 108.8 GW of installed capacity can generate 762 TWh. Coal based generation in 2021 was 436 TWh, thus, additional 326 TWh of coal generation can be added to the grid, which can potentially displace 593 TWh of primary natural gas supply.

[1] Assuming an average efficiency of 55 % for combined cycle gas turbines (CCGT) (which is the most conservative approach, as it results in least substitution potential due to the high efficiency).

- Oil: 16.5 GW can generate 115 TWh. Oil based generation in 2021 was 31.5 TWh, thus, additional 84 TWh of oil generation can be added to the grid which can potentially displace 153 TWh of primary natural gas supply.
- Nuclear: 100.5 GW can generate 704 TWh. Nuclear based generation in 2021 was 733 TWh, i.e., the utilisation of the existing plants was above the assumed minimum value already. Hence, no additional nuclear generation is possible.

Changing the merit order within the three fossil fuels offers a substitution potential of 846 TWh but comes at the price of higher CO_2 emissions. Therefore, such measures would need to be compensated in the near future and within this decade. They should be temporarily allowed within clear timeframes, and they should only be accepted if they do not require additional investments conflicting with long-term objectives. Moreover, changing the fuel mix from gas to other fossil fuels is highly dependent on availability of alternative resources.

An additional 326 TWh of **coal** generation will require an additional 42.4 Mt of hard coal and an additional 127.4 Mt of lignite[2]. Assuming an average thermal efficiency of 37%, an input of 881 TWh of primary coal supply is needed. While it can be assumed that additional hard coal can be sourced from international markets, lignite is usually mined on site. Further analysis is required to determine whether the European lignite industry can ramp up lignite production fast enough.

Additional 84 TWh of **oil** generation will require 17 Mt of crude oil, assuming a heating value of oil of 12.5 TWh/Mt and an average thermal efficiency of oil-fired power plants of 40%. Compared to overall crude oil imports of 446 Mt in 2020, 17 Mt represent less than 4%. To put this in a perspective: introducing a temporary speed limit reduction of 20 km/h on European motorways may result in 20.5 Mt of crude oil savings[3]. Therefore, only with such a measure could enough oil be shifted from transport to power generation. According to some behavioural analyses the actual compliance with speed limit regulation could be in the order of 85-90%. This would still be sufficient to provide the required 17 Mt of crude oil saved.

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[2] Assumptions: Average thermal efficiency of 37 %, resulting in an input of 881 TWh of primary coal supply. Heating values of coal are assumed as 6.66 TWh/Mt for hard coal and 4.72 TWh/Mt for lignite. Coal distribution/proportion would be the same as of today: hard 25 %, lignite 75 %.

[3] Assumptions: Of the 240 million cars in EU-27, each car drives ~14,000 km annually; 50% of the driven distance is on motorways (7,000 km); fuel consumption of 7l/100 km on motorways; fuel saving of 20 % for a speed limit reduction of 20 km/h resulting in 100 litres saving per car and year; 1 barrel of oil = 136 kg of oil = 159 l of gasoline

Figure 5 summarises contributions within the power and heat generation sector. Although a high share of natural gas can be substituted, there is a residual gap of 328.4 TWh, representing about a quarter of natural gas imported by this sector from Russia.

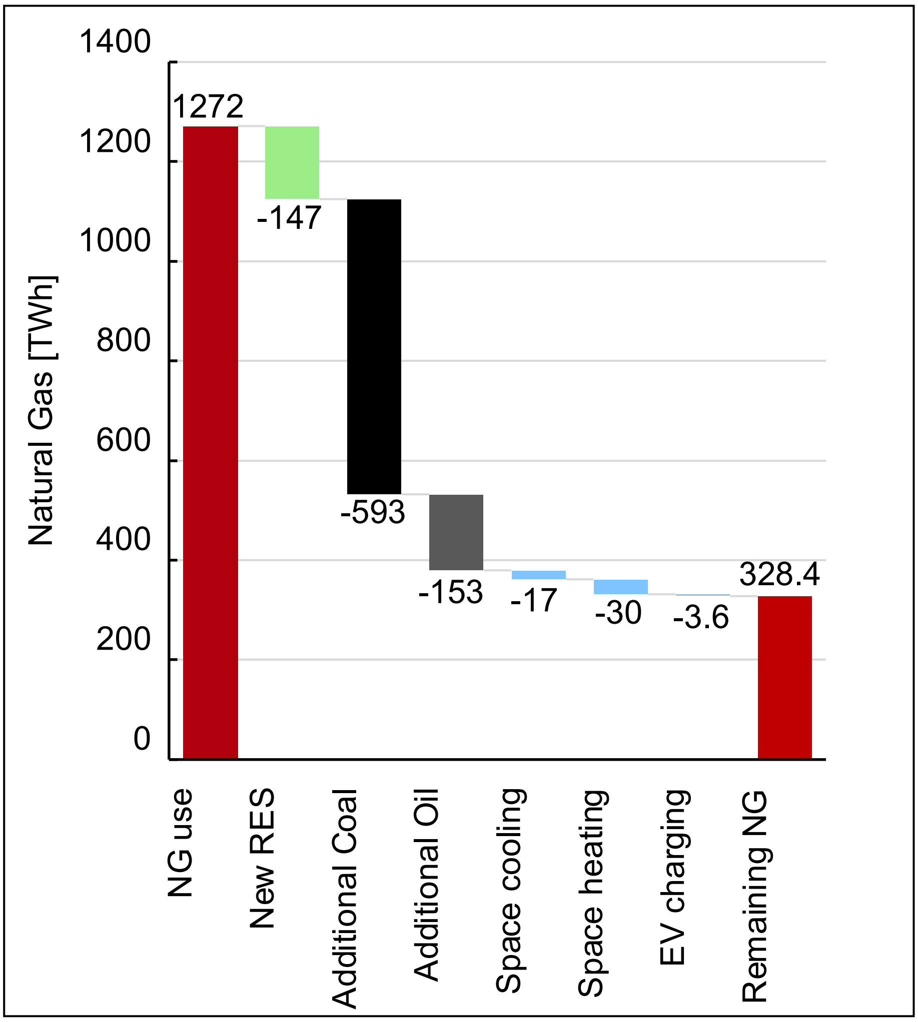

Figure 5. Potential natural gas savings in the power and heat sector (EU-27) (source: Eurostat 2020 data)

3.1.2 Measures on the demand side

Short-term measures on the demand side are more difficult to implement, partially because they require behavioural changes and partially because they require rollout of supporting technical infrastructures. Nevertheless, there are some opportunities which should be addressed. Without a change in awareness on the demand side, the energy transition is likely to fail in the long run.

3.1.3 Space and water heating

Space and water heating is a significant sector of energy use, in which natural gas plays an important role. While the following thoughts indicate the potential of these savings, the implementation measures would need to elaborated further.

Reducing room temperature setpoint of **residential buildings** by 2°C may save up to 15 bcm or 145 TWh of natural gas. On the other hand, water heating consumes 176 TWh of natural gas. If we assume that around 10% can be saved by shortening use of hot water or selecting more economic programs for washing, this results in additional 18 TWh of natural gas savings.

Applying the same logic to service and commercial buildings results in savings of around 50 TWh of primary natural gas for space heating and around 5 TWh for water heating. If we foresee the possibility of closing off some services during the winter heating season, e.g., an additional two weeks without heating (assuming 20 weeks of heating season), this may result in an additional 35 TWh (10%) of savings.

In a scenario of severe scarcity, we recommend considering the shutdown of selected industries for a period of, for example, five weeks during winter. Such measures, which could also be asked for by tendering flexibility, are assumed to represent a saving potential of another 10% of primary energy (incl. natural gas savings). Such measures would also result in some reduction of electricity demand, but this has not been considered here.

3.1.4 Transportation

As previously discussed under power and heat generation, introducing a temporary speed limit reduction of 20 km/h on European motorways could theoretically result in 20.5 Mt of crude oil savings. Considering typical compliance with speed limit regulations in the range of 85-90%, around 17 Mt of crude oil could be realistically saved. In addition, assuming 5 million battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) will drive at reduced (-20 km/h) speed on motorways about 10% of charging energy can be saved. This results in 2 TWh of less electricity consumption and 3.6 TWh less primary consumption of natural gas.

3.1.5 Impacts of exports

Assuming that European countries receiving gas exports from the EU27 will implement similar measures of switching power and heat generation fuels, energy savings and power generation shifting, exports could also be lowered by about 10%.

All options summarised in figure 6 together represent a savings potential of 1,354 TWh, which correspond with 85% of natural gas imports from Russia in 2020. The biggest contribution comes from a fuel shift in power and heat generation. Seizing this opportunity implies intensive cooperation and a truly European and solidary approach to power supply in order to benefit from regional, complementary differences and resource optimisation.

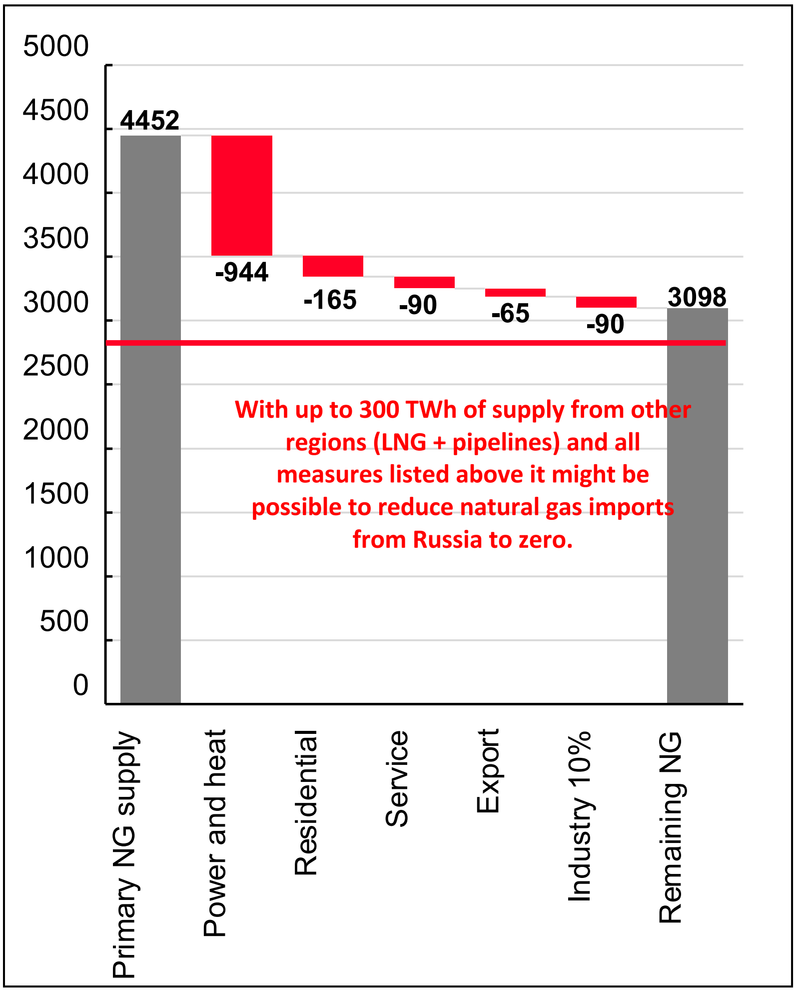

Figure 6. Potential natural gas savings across all demand sectors (EU-27) in comparison to the target of making imports from Russia obsolete (source: Eurostat 2020 data)

3.1.6 A short, exemplary look at country level: Germany

Due to its economic size, its location closer to the Eastern border of the European Union and its long tradition of importing primary energy, particularly natural gas, from Russia, Germany is one of the most threatened EU countries with respect to disruption of Russian gas imports. Modelling and calculated outcomes presented in figure 7, following the same methodology applied and described above for EU27, show significantly different results. The measures to reduce 85% of Russian gas imports for the aggregated European economies, only deliver 58% potential for Germany. This implies that Germany needs to expand and anticipate the suggested measures while also preparing society for disruption and rationing.

Comparing the national with the European result clearly shows that European solidarity and a strong transmission grid is instrumental for overcoming this crisis. Furthermore, other large European countries are strongly impacted by the energy shortages. For example, Italy is strongly dependent on natural gas and has, contrary to Germany, nearly no coal-fired power plants to substitute gas in the electricity sector. Meanwhile, France has been hit by shortages especially in the electricity sector due to outages of a major part of its nuclear power plant fleet, leading to already very high electricity prices.

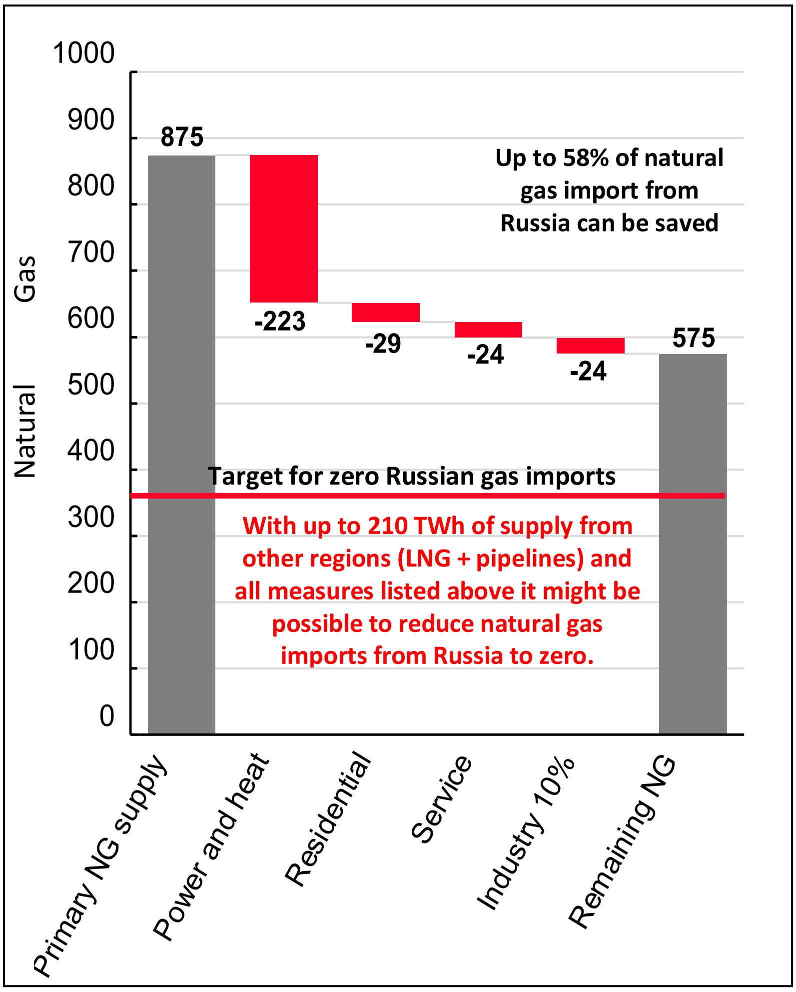

Figure 7. Potential natural gas savings in Germany across all demand sectors in comparison to the target of making imports from Russia obsolete (source: Eurostat 2020 data)

3.1.7 Mid- and long-term orientation: Improving system efficiency

In the long run, Europe needs to increase the resilience of its energy system by increasing the share of domestic sourcing and by eliminating or, at least substantially reducing, inefficiencies in the energy system. The only sustainable domestic resource of energy are renewable energies, mainly wind, solar and existing hydro resources, which can be best used as electricity. Thus, deep electrification is essential in increasing the energy system's resilience and eliminating inefficiencies. The Paris Agreement Compatible (PAC) energy scenario [1] developed by Climate Action Network (CAN) Europe and the European Environmental Bureau (EEB), within a project coordinated by the Renewables Grid Initiative (RGI e.V.) (PAC Project) shows the potential of system-wide efficiency improvements through more efficient use of end-use energy and through electrification. The results are summarised in figure 8 in total and per sector in figure 9.

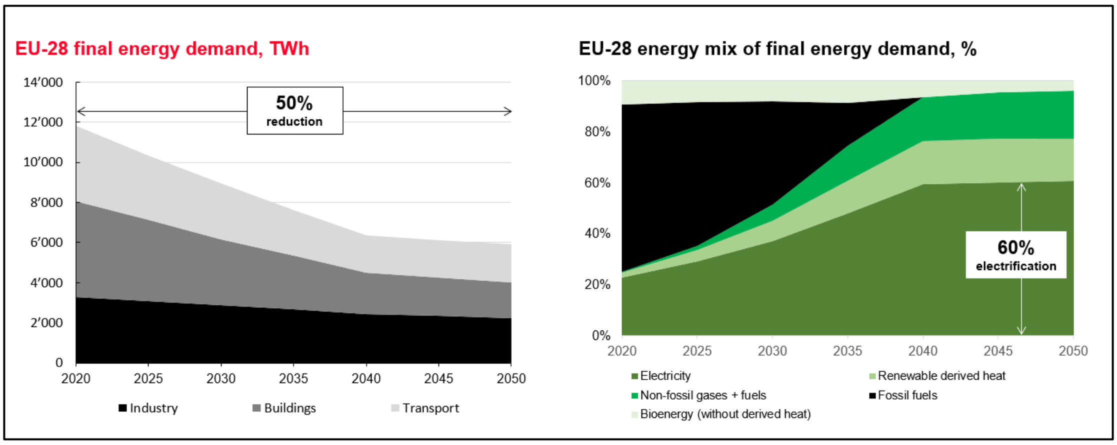

Figure 8. Reduction of final energy demand via direct electrification and more efficient use of energy across all sectors according to the Paris Agreement Compatible (PAC) energy scenario developed by CAN Europe and EEB [1]

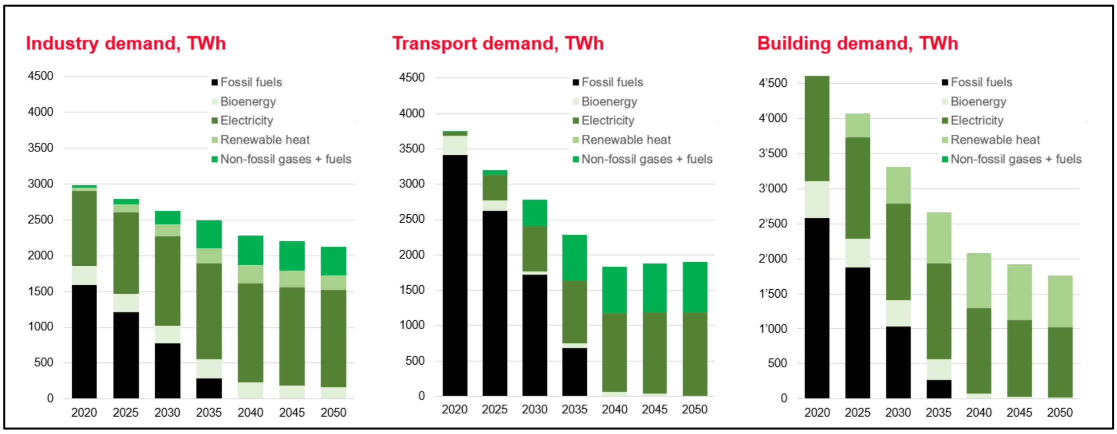

Figure 9. Demand reduction by sectors in the PAC scenario (based on [1])

The largest reduction in final energy consumption is in the building sector due to better insulation of buildings, more efficient appliances, and a stronger role of heat pumps, which will replace electric and fossil fuel boilers. The second largest gain in lowering demand is in the road transport sector through the internal combustion engine's displacement by batteries.

While these findings should be considered for defining mid- and long-term goals and strategies, they cannot help in solving the challenge of energy scarcity in the coming winter of 2022/23. However, they should also serve as orientation for short-term measures, which should not contradict or undermine the long-term development path.

4. NO TIME TO LOSE: CONCLUSIONS AND RECOMMENDATIONS

The coming winter will decide who is the winner between Putin's Russia and the Western world, in particular the European Union and European national democratic structures. Ukraine is only the physical battlefield of a much larger conflict.

It is essential to implement saving measures immediately on both the generation and demand side. Significant savings can be activated on the demand side, putting citizens at the centre of the energy transition and making them active actors in managing the current energy crisis. There are a number of actions to be taken with high urgency:

- Prioritise electrification of demand across all sectors and users. This will substantially reduce waste energy and therefore the need for primary energy.
- Incentives and costs reduction measures should be abandoned immediately as they stimulate consumption when we need to save every possible drop of fuel. Cost reduction measures should be replaced with saving bonuses. These are easy to implement and much fairer than the current model. Saving bonuses are to be paid to consumers and based on reduced consumption, i.e. "The less you consume, the more you get back." Consumption over certain levels should be penalised. (This is already partially the case but prices for additional kWh should increase substantially.) This will incentivise savings in buildings and service buildings with immediate substantial results. Public buildings should also be part of the saving schemes. Low income families should be protected by social policies and mechanisms, not by energy policies.
- If gas supplies are not resumed as scheduled, non-essential service buildings and minor industries should be shut down, with temperature

level set at non-freezing point, during the coldest winter months, for a period of at least 4 weeks.

- Speed limits on highways should be introduced or reduced from now until the end of March 2023, at least. Introducing a temporary speed limit reduction of 20 km/h (which in fact results in a general speed limit of about 100km/h) on European motorways can save about 17 Mt of crude oil. Additionally, the same measure will reduce electricity consumption of about 5 million battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) by 2 TWh, equalling to 3.6 TWh of saved natural gas. Drive free weekends could be introduced to further reduce oil demand and contribute to behavioural changes.
- Grid connection for already built or soon-to-be-completed solar and wind parks should be given connection priority, supported by deploying digital and flexible technologies aiming at increasing grid transport capacity. Digital technologies able to increase and optimise grid capacity should be immediately deployed strategically, bearing in mind the location of congestion in the grid. Energy regulators have an important role to play in facilitating and enabling fast deployment.
- Solidarity across the European Union is essential, as well as across regions within a country.
- Electricity grids, as the main backbone of the future energy system, need to be planned with priority and holistically, with a truly European approach and across all voltage levels. This has been elaborated more in detail in [2]. Gases, including hydrogen, are complementary energy carriers and should be treated as secondary to electricity.
- Optimisation across the entire energy system is required to deal with scarcity, including scarcity of space and resources.
- Managing conflicts at local level requires strong communication and commitment in each country. Communication is key to preparedness.

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LIST OF FIGURES