IAM COMPACT

Expanding Integrated Assessment Modelling:
Comprehensive and Comprehensible Science
for Sustainable, Co-Created Climate Action

Three Policy Responses to the Energy Crisis:
The Co-benefits of Energy Efficiency

April 28, 2023

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Executive Summary

The ongoing war between Russia and Ukraine has created an energy crisis, which has impacted the EU, given its significant reliance on Russian natural gas. This brief explores three scenarios to replace Russian natural gas: increasing gas imports from other regions, increasing domestic production, and accelerating energy efficiency. The scenarios are benchmarked against a baseline scenario that reflects mitigation efforts implied by Nationally Determined Contributions and Long-Term Strategies. The brief aims to provide insights into the trade-offs between the different approaches to replacing Russian gas and their implications for energy sustainability, affordability, and emissions.

Using four Integrated Assessment Models (GCAM, TIAM, MUSE, PROMETHEUS) and two sectoral models (MARIO, EXPANSE), we find that eliminating reliance on Russian natural gas can drive emissions reductions in hard-to-abate sectors and speed up the transition to renewables and electrification. Replacing Russian gas with other imported gas would have a very small impact on EU energy-related emissions, while replacing it with domestic clean energy alternatives would lead to an interplay between demand-side energy-related emissions decreasing and supply-side energy-related emissions increasing. Energy efficiency could lead to the highest emission cuts in the demand side, although concerns remain over a post-2040 rebound. Other benefits of energy savings and energy efficiency measures include reduced investment needs and lower electricity prices.

There are consequential trade-offs for policymakers to consider as the EU enters an uncharted energy landscape. Europe's single largest supplier of gas has proven to be undependable, leading to a structurally different supply situation. New possibilities on the demand-side have been demonstrated as consumers sought to save energy. Results from the scenario analysis demonstrate that sustaining efficiency capabilities on the demand side to manage the supply situation can deliver valuable co-benefits.

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1 Introduction

IAM COMPACT is a Horizon Europe research project, with the objective to support the assessment of global climate goals, the collective progress towards them, and the feasibility space in delivering on those goals. Among others, its mission includes modelling analysis based on a large ensemble of simulation and optimisation tools, allowing to feed into the design of the next round of Nationally Determined Contributions (NDCs) and policy planning beyond 2030 for the European Union (EU), other major emitters, and non-high-income countries. The project's scope, however, is dynamic and its operational capacity flexible enough to assess emerging issues of importance to energy and climate policy. Among these issues has been Russia's invasion of Ukraine in February 2022.

Russia's war against Ukraine has exacerbated an ongoing energy and resource crisis [1], disproportionately affecting the EU and highlighting its considerable dependence on Russian natural gas. This has put energy sustainability and affordability at risk and reduced Europe's geopolitical room for manoeuvre. Unless sufficiently resolved, these significant overlapping challenges could contribute to a 'polycrisis' [2] that eventually risks impacting global financial markets and possibly delaying or reversing progress to climate goals, sustainable development, and future resilience. In the light of this multi-faceted crisis, the EU released its REPowerEU strategy shortly after the invasion, aiming to rapidly attenuate its ties to Russian fossil fuels and to become fully energy-independent by 2027, along with a mandate on gas storage obligations. Ongoing and planned LNG infrastructures are projected to increase EU's terminal capacity by 48% until 2030, with risks of possibly becoming stranded assets due to mismatch with projected reductions in gas import demand [3]. Meanwhile, Russia continued to further reduce its gas supplies to the EU, essentially "weaponising" energy – a behaviour already observed in the run-up to the war since summer 2021[1]. Many EU countries also prioritised decoupling their economies from Russian fossil fuels at the national level, adopting a range of energy and fiscal measures towards mitigating the impact of higher costs on consumers and businesses, stabilising wholesale prices, and securing their energy supply. Although the coordinated European response entails measures to reduce energy vulnerability, entirely replacing Russian gas imports remains challenging in the near-term.

Pre-war Russian pipeline exports to Europe accounted to 1,463 TWh in 2021, which amounted to 41% of the EU's 3,630 TWh. At the beginning of 2023 Russia still exports some 5 TWh per week via Turkstream and Ukraine (15% of pre-war volumes) as well as some 3.5 TWh as LNG—which would over the year sum up to around 440 TWh. While global LNG markets are fungible, a potential full stop of Russian pipeline exports would deprive Europe of about 1,500 TWh of imports. Assuming that this reduction is permanent, the EU must try to optimally replace this loss. In this brief, we have explored three 'corner' options for replacing Russian natural gas:

(a) increasing gas imports from other regions to make up for the lost gas supply,

(b) increasing domestic production to make up for the lost energy, and

(c) accelerating energy efficiency across sectors to reduce energy consumption.

Our modelling approach represents each 'corner' option as an individual scenario on top of an NDC baseline that accounts for the socioeconomic impact of the recent crises (e.g., on GDP). We use four established integrated assessment models (IAMs), a dedicated electricity system optimisation model, and an Input-Output model to explore the energy-system, economic, and emissions implications of a complete and rapid phaseout of Russian gas imports in the EU by the end of 2023. Our aim is not to shed light on the optimal course of action, but rather to understand what each direction could entail, thereby providing insights for policymakers and other stakeholders into the trade-offs (and potential synergies) between the different approaches to replacing Russian gas.

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[1] See Bruegel's 'European natural gas imports' tracker for more details.

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2 Scenario design

We consider three narratives/scenarios prescribing different 'corner' options for replacing the lost Russian gas. As the goal has been to understand the implications of the three strategies in Europe (EU27 + UK), not only from an energy security and socioeconomic perspective in the near term, but also from a climate policy perspective in the longer term, we use 2050 as our time horizon, with the aim to comprehend any impacts on the EU's path to net zero.

The baseline scenario (annotated as 'NDC_Default')[2], against which all other scenarios are benchmarked, reflects mitigation efforts implied by Nationally Determined Contributions (NDCs) and Long-Term Strategies (LTSs) on top of current policies. **It is assumed to describe the climate policy context before Russia's invasion of Ukraine**: we draw from the current climate targets and NDCs of all regions until 2030, and LTSs post-2030 and until 2050. All pledges announced until COP26 in Glasgow are considered in this modelling exercise, including the revised NDC target of the EU, for which the baseline scenario assumes that the bloc achieves its NDC target of (at least) 55% GHG emission reductions in 2030, relative to 1990 levels, and climate neutrality (NZ) by 2050. Socioeconomic assumptions for GDP and population are drawn from the latest short-term socio-economic outlook of IMF until 2027 (extrapolated to 2050 according to a commonly used socioeconomic pathway reflecting historic trends, called SSP2 [4]) to account for the recent implications of the COVID-19 shock and recovery as well as the onset of the energy crisis—i.e., without reflecting Russia's invasion of Ukraine and associated policy responses. All scenarios prescribing ways to replace the lost Russian gas are benchmarked on top of this baseline scenario.

The 'Gas Imports' scenario (annotated as 'NDC_NoRus_Imp') assumes that the EU **replaces** the Russian gas imports with energy and primarily **gas imports (pipelines and LNG) from other trading partners**—including LNG from the USA. This scenario explores the expected increasing pressure emerging in LNG and pipeline gas markets, to cover for the loss of Russian gas. Policy decisions to encourage this strategy include gas infrastructure developments and gas supply deals. Many European countries have taken both approaches since the beginning of the energy crisis[3].

The 'Domestic Production' scenario (annotated as 'NDC_NoRus_Dom'), assumes that the EU replaces the Russian gas imports with **increased domestic energy production** (accelerated electrification, increased gas/hydrogen production, new infrastructure in domestic renewable/nuclear power options, etc.), without increasing imports from non-EU regions.[4] The EU could encourage this approach through establishing higher and legally binding renewable energy targets[5] or by providing additional funding for clean electricity and electrification of heat and transport.

The 'Energy Efficiency' scenario (annotated as 'NDC_NoRus_Eff'), assumes that the EU replaces the Russian gas imports, essentially **reducing gas demand with enhanced energy efficiency**—including renovation, relocation of emissions-intensive trade-exposed (EITE) industries across the EU, demand-side response (DSR), and behavioural changes. Stronger energy efficiency targets, improved building standards, and funding for retrofitting could spur energy efficiency improvements, for example.

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[2] Socioeconomic assumptions for the world until 2050 (i.e., GDP and population) draw from a narrative describing a continuation of historic trends ('SSP2' in IAM jargon), updated to reflect the COVID-19 implications, recovery, energy crisis from IMF near-term projections to 2027.

[3] See Bruegel's 'National energy policy responses to the energy crisis' tracker for more details on gas projects and supply deals.

[4] Energy trade from other regions is assumed identical to the 'NDC_NoRus' (model cost-optimal) scenario.

[5] The European Parliament, European Commission and European member states reached a political agreement on 30 March 2023 on a target of 42.5% of the share of renewable energy in the EU's overall energy consumption by 2030.

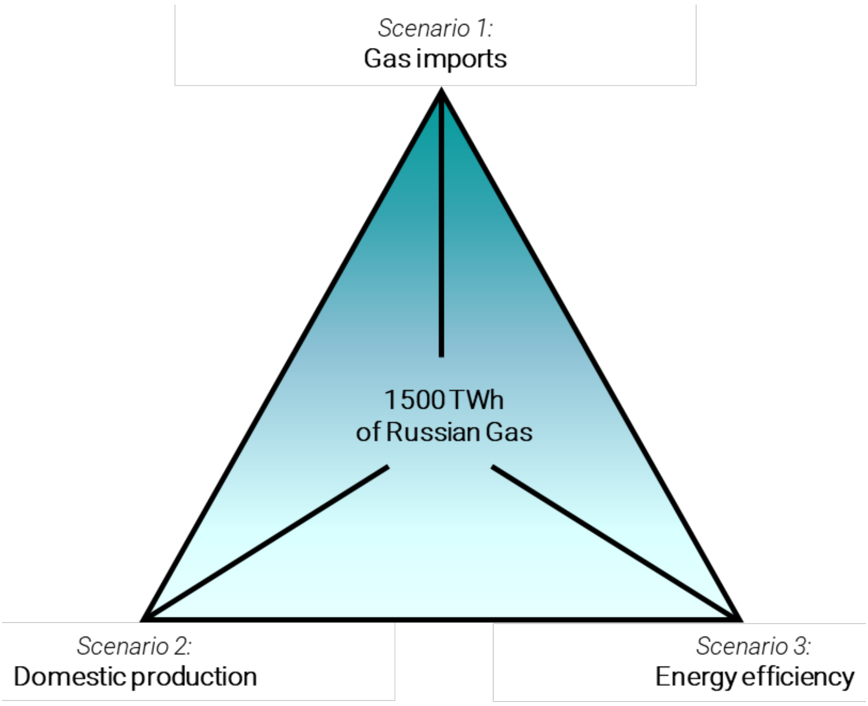

Figure 1: Three “corner” scenarios of Russian gas replacement

Aside from the three ‘corner’ options, we also include a ‘Model-optimal’ scenario (annotated as ‘NDC_NoRus’), allowing the four IAMs to identify their own “optimal” way of replacing the lost gas imports while still meeting the EU’s climate targets for 2030 and 2050. To implement this scenario, Russia pipeline gas into Europe is switched-off completely in 2023, but current policies, NDC targets for 2030, and NZ targets for 2050 are retained.

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3 Model insights

Each of the IAMs in our model suite (GCAM, TIAM, MUSE, PROMETHEUS) provided specific insights into the potential consequences of replacing Russian gas with specific 'corner' options, including implications on emissions, energy demand, investment costs, gas imports and energy and carbon prices. Sectoral models provided insights for electricity (EXPANSE) and employment impacts (MARIO).

3.1 Emissions from the energy sector

Russian gas supply to the EU is equivalent to ~ 303 Mt of CO_2 emitted [5]. This amounts to roughly 6% of current EU CO_2 emissions, and more than 10% of energy-related CO_2 emissions. Gas demand reduction in response to the crisis has in some countries led to fuel switching to coal, which will cause increased emissions, while other forms of gas demand reductions may instead reduce emissions. In 2022, Germany actually saw lower GHG emissions, as reductions in industrial emissions and household energy demand dominated increased coal usage [6]. Poland boosted renewable electricity generation to a record while cutting coal and gas, with its power sector emissions decreasing, while Spain's natural gas and coal consumption for power generation doubled, leading to a ~7% increase in GHG emissions compared to 2021 [7].

Overall fossil CO_2 emissions, which reach levels of fossil energy CO_2 emissions between [1.4 – 2.3] $GtCO_2$ in 2030 and [-0.4 – -0.03] $GtCO_2$ in 2050 (an average decline of 8% per year over 2020-2050), do not vary markedly among the different scenarios. This is because aggregated emissions in the EU are largely driven by the 2030 and 2050 (NZ) targets rather than impacted by any response to the energy crisis. There are, however, observed differences on emissions in different sectors, with the most relevant being residential/commercial and industry, depending on how Russian gas is substituted in each scenario.

Results from the scenario implementation show greatest reductions in the 'Energy Efficiency' scenario, especially in the residential/commercial sector, compared to the baseline. This is attributed to a reduction in overall energy use with energy savings and efficiency measures deployed sooner, along with industrial relocation of EITE industries across the EU. Emissions cuts are also observed in the 'Domestic Production' scenario in both industry and residential/commercial sectors, critically as the share of low-carbon energy increases, outcompeting fossil sources in the domestic market. The smallest emissions cuts (and in some cases even increases) are obtained in the 'Gas Imports' scenario, in which the emissions levels remained close to the default scenario, as Russian gas is substituted by other forms/sources of imported gas using either different pipelines or LNG; as such, from an emissions perspective, there are no significant deviations, apart from some changes in the demand caused by higher gas import costs. In this case, industrial emissions are projected to slightly increase, as coal/oil replace the more expensive gas; on the other hand, residential/commercial emissions slightly drop, with gas being substituted by electrification, especially since coal and oil use in the EU are in long-term decline in these sectors and there are limited prospects for EU consumers to return to coal and oil use in buildings.

This hints at an interplay between demand-side CO_2 reductions and increases in emissions from the supply side when substituting Russian gas, to be in line with the 2030 and 2050 targets, which entails reconsidering EU's sectoral pathways to carbon neutrality in the light of the war.

Differences in the models point to the representation of certain technologies in each model. For example, the constraint on EU emissions has the dominant role of driving energy system transformation in MUSE, and thus the reduction in natural gas; in addition to the overarching decarbonisation target, which is embedded in a system carbon price, sectors would react differently depending on how the natural gas price would vary in each scenario (notably, in the 'Energy Efficiency' scenario emissions cuts are impacted by EITE industry relocations and higher carbon prices to offset natural gas with electrification). On the other hand, the PROMETHEUS model covers a wider set of energy efficiency measures and technologies, thus better explores the potential of energy efficiency in the building and industrial sectors (emissions cuts continue until 2050, as technology push e.g., for heat pumps, is assumed to continue post-2030, reducing total gas consumption and the need for gas imports).

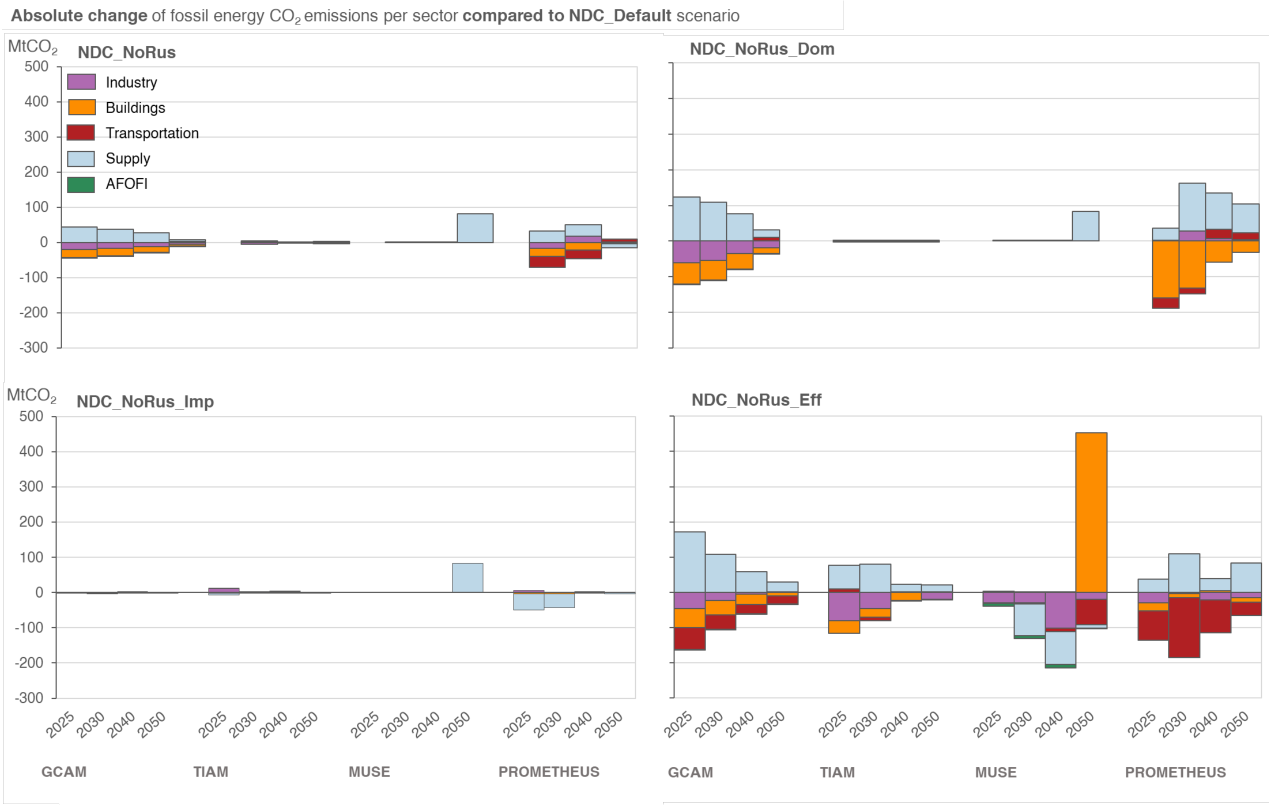

Figure 2: Absolute change of fossil energy CO_2 emissions across scenarios compared to NDC_default **(2025 – 2050).** AFOFI includes emissions from fossil fuels combustion in the agriculture, fisheries, and forestry.

3.1.1 Highlights

- Eliminating reliance on Russian natural gas can drive emission reductions in hard-to-abate sectors and speed up the transition to renewables and the electrification of heat and transport.
- Replacing gas imports from Russia by other gas imports would have a very small impact on EU energy-related emissions.
- Replacing gas imports from Russia by domestic clean energy alternatives (and especially RES-based electrification) would lead to an interplay between demand-side energy-related emissions decreasing, and supply-side energy-related emissions (e.g., on the electricity generation sector) increasing.
- Replacing gas imports from Russia through energy efficiency could lead to the highest emission cuts, although concerns remain over a post-2040 rebound making up for reductions in the mid-term.
- Overall, replacing Russian gas with imports of fossil fuels from other regions will not accelerate the energy transition in Europe, but focusing on domestic sources and electrification to make up for the lost energy and the deployment of energy efficiency measures can both replace the Russian gas imports and further enhance decarbonisation efforts.

3.2 Energy and electricity demand

Energy demand reduction requirements are subject to the Recast of the Energy Efficiency Directive, which entails a target of 846 Mtoe of final energy demand across the EU by 2030 [8]. Demand reduction has played a critical role as a first-level response to the energy crisis. The European Council introduced a voluntary 15% gas demand reduction target (compared to the average of the previous five years) in August 2022, which was extended in March 2023 to last for an additional year [9]. An emergency regulation was also introduced in October 2022 that, among other measures, set electricity demand reduction targets between December 2022 and March 2023 [10].The

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calculated 2025-2050 final energy evolution varies, but we mostly project a decrease in final energy demand compared to the baseline scenario. The highest demand reductions are observed in the 'Energy Efficiency' scenario, ranging in 2030 from -11% to -4% and in 2050 from -5% to -2% compared to the baseline, mainly driven by reductions of demand for electricity, gases, and liquids. To a lesser extent, this is also the case for the 'Domestic Production' scenario, where decreases range from -5% to -1% in 2030, and from -2% to -1% in 2050, compared to the baseline. One model (MUSE) showed, in the 'Energy Efficiency' strategy, a ~4% demand increase could be observed in 2050 due to increased demand for liquids post-2040 (rising gases and biomass demand in the industrial sector, and gases in the residential sector) in response to higher electricity prices. Finally, the 'Gas Imports' scenario overall has a minor effect in end-use demand, as Russian gas is almost entirely substituted by LNG & pipeline gas from other regions; even in this case, though, the technology-richer PROMETHEUS model foresees demand reductions, implying high potential for demand-side reductions and potential benefits through learning-by-doing and learning-by-research: the more one invests in certain technologies (e.g., heat pumps) this decade, the lower their costs and thus the higher their uptake in 2030-2050.

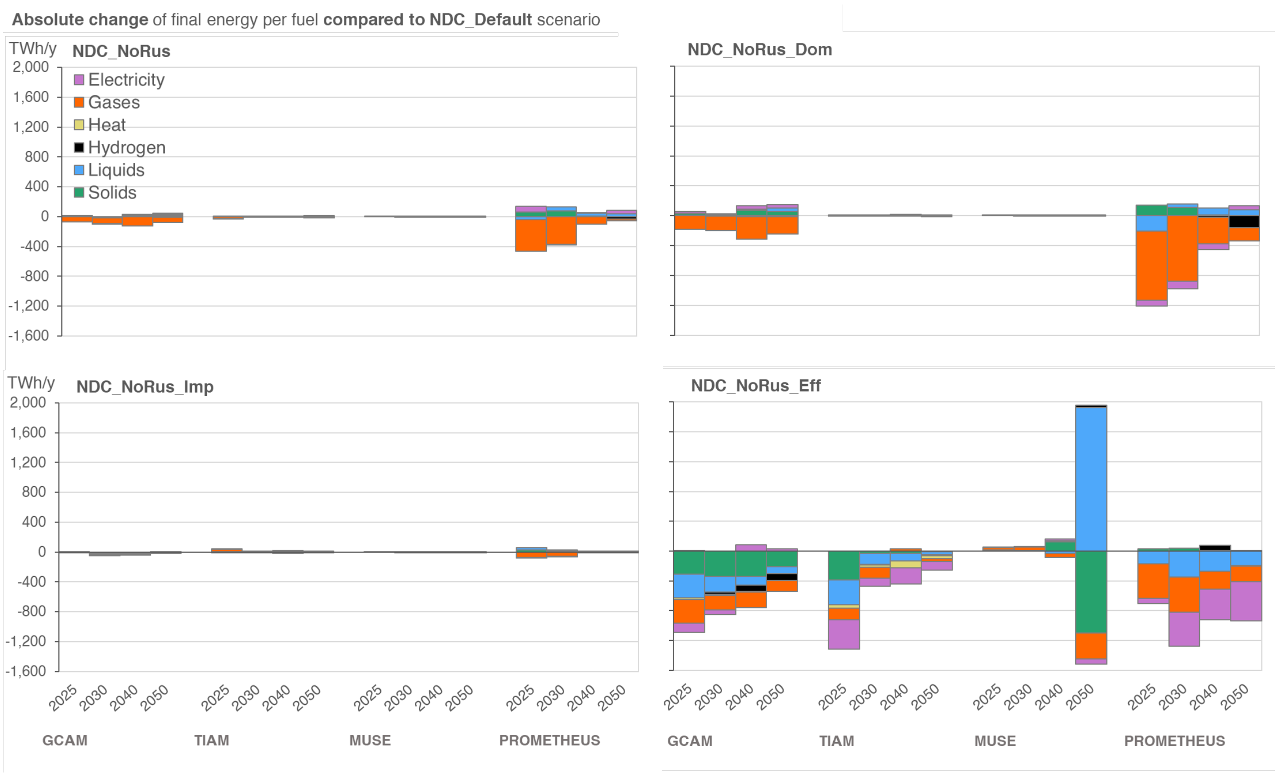

Figure 3: Final energy per fuel compared to NDC_Default scenario (**2025 – 2050**).

3.2.1 Highlights

- Focusing on measures to incentivise energy efficiency can lead to lower overall energy demand in 2030 and 2050, when a rich selection of efficiency options is considered.
- Unless Russian gas is substituted with imports from other regions, a significant decrease in gas demand can offset the loss, highlighting a shift on the future use of natural gas as a transition fuel to achieve long-term (net-zero) targets.

3.3 Costs, investments, and employment

3.3.1 Energy system costs

An indication of energy system costs required in each scenario is available in Figure 4.

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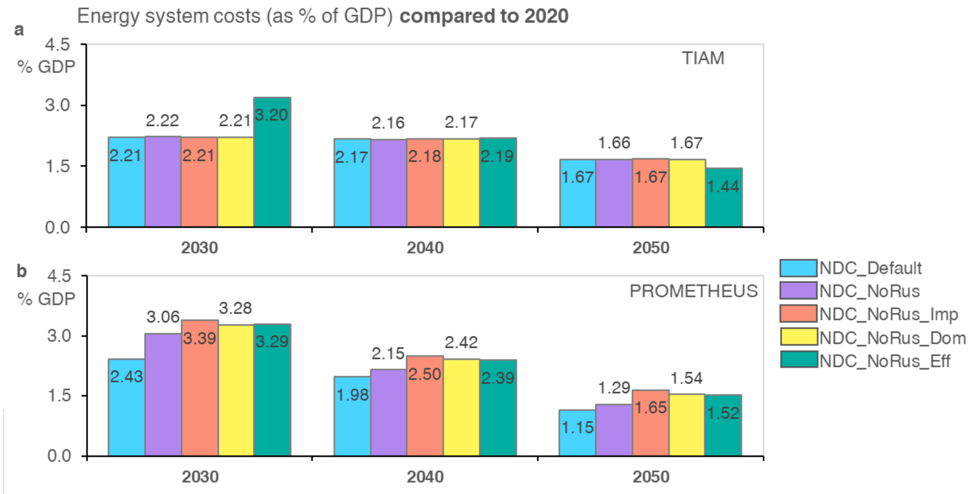

Figure 4: Energy system costs (as % of GDP) compared to 2020 from (a) TIAM and (b) PROMETHEUS

Expectedly, the 'model-optimal' pathway is de facto cheaper than all other 'corner' options. We also see that the 'Domestic Production' pathway is consistently moderate; in TIAM, costs are higher in the 'Energy Efficiency' scenario in the short-term but become the lowest in the long run, while in PROMETHEUS costs are consistently higher in the 'Gas Imports' scenario due to higher cost of imported fuels. This traces to model dynamics and the role of natural gas the two models envisage in their baseline scenarios; in TIAM, gas would radically phase out post-2030, meaning there is considerable need to invest in *energy efficient technologies* to offset the loss of Russian gas imports until then. Nonetheless, eventually the 'Energy Efficiency' scenario is the cheapest.

3.3.2 Electricity system & investment costs

As industry, transport, and heating are electrified, the electricity system will become the backbone of Europe's decarbonised energy system. The investments needed (Figure 5) to simultaneously decarbonise and meet increasing electricity demand are considerable. Renewable capacity and the cleantech needed to complement it must be deployed at significant scale.

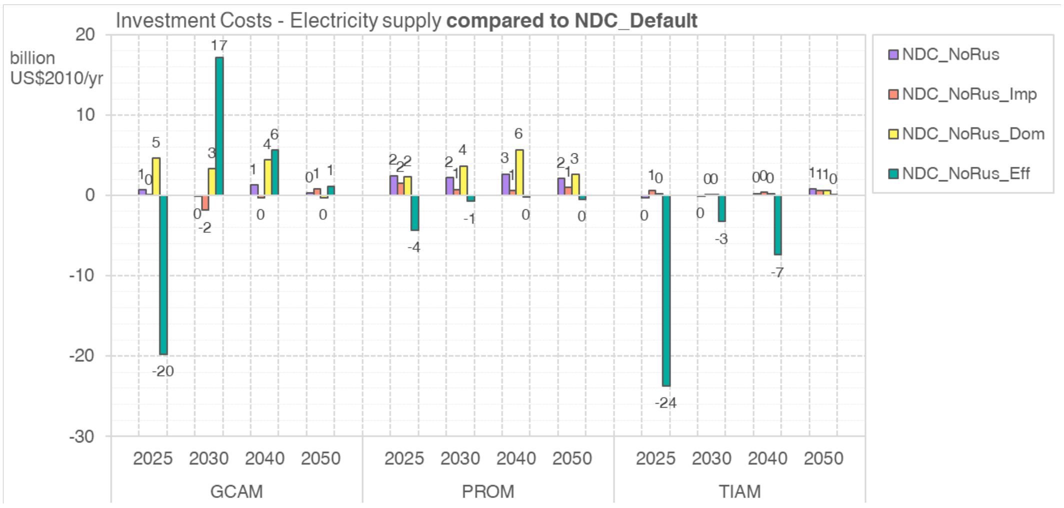

Figure 5: EU electricity supply annual investment costs (in billion US$/2010) compared to NDC_Default **(2025 – 2050)**

Our modelling runs found high annual investment costs for electricity supply in the 'Domestic Production' case, due to the investments required for ramping up domestic supply to make up for lost Russian pipeline gas, as well as consistently low costs in the 'Energy Efficiency' scenario due to decreased demands—although one model (GCAM) projects strong rebounds towards the end of this decade, associated with increased electrification to satisfy end-use demands with reduced energy amounts. These investment cost changes are also reflected in the electricity

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prices (Figure 6), which are lowest in the 'Energy Efficiency' scenario as improving efficiency leads to lowest electricity prices (except for GCAM, which shows opposite trends due to increased electricity demand). Conversely, increasing domestic production and importing gas from elsewhere can both lead to high electricity prices. Italy appears to be the country facing the highest electricity price spikes, followed by the Western Balkans.

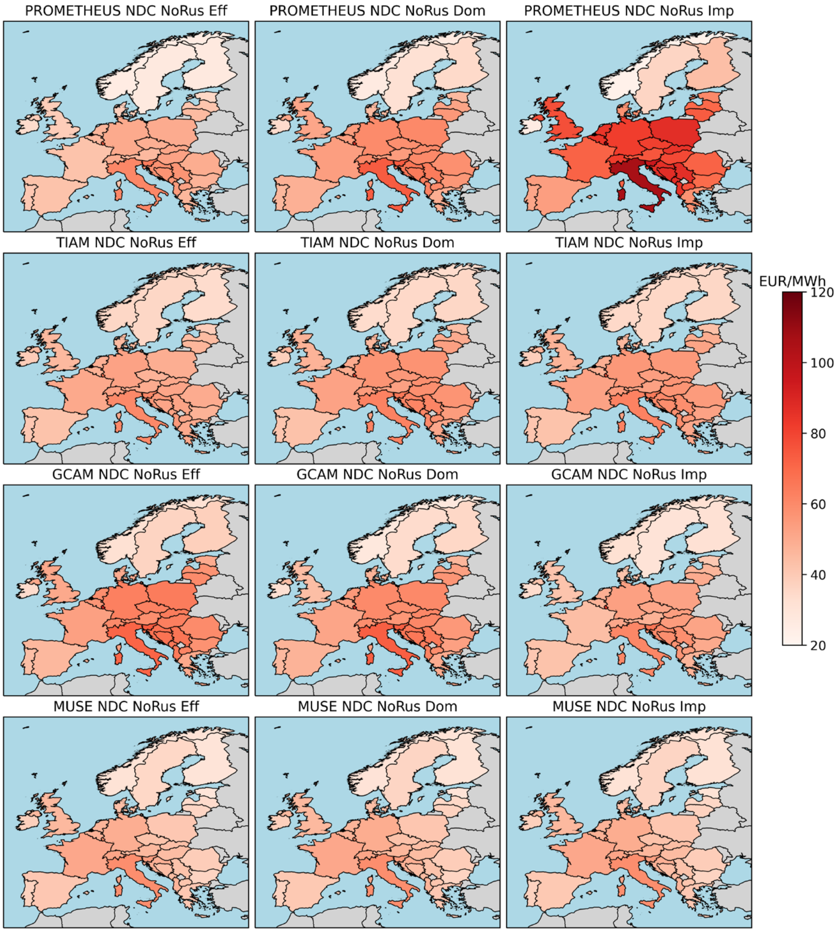

Figure 6: Average electricity prices across EU countries (**2035**)

Figure 7 performs a deep dive into the electricity system (capacity and generation per technology, system-wide costs, storage, grid expansion, emissions, etc.) across our model ensemble. Indicatively, the two technology-richer models—PROMETHEUS, TIAM—see highest electricity demand in the 'Gas Imports' scenario. However, PROMETHEUS also sees increased (hydrogen) storage capacity, grid expansion, intermittent RES capacity, and prices in this scenario (the opposite to 'Energy Efficiency') and the latter in 'Domestic Production'. In the less technology rich models, there is less variation electricity system configuration between scenarios.

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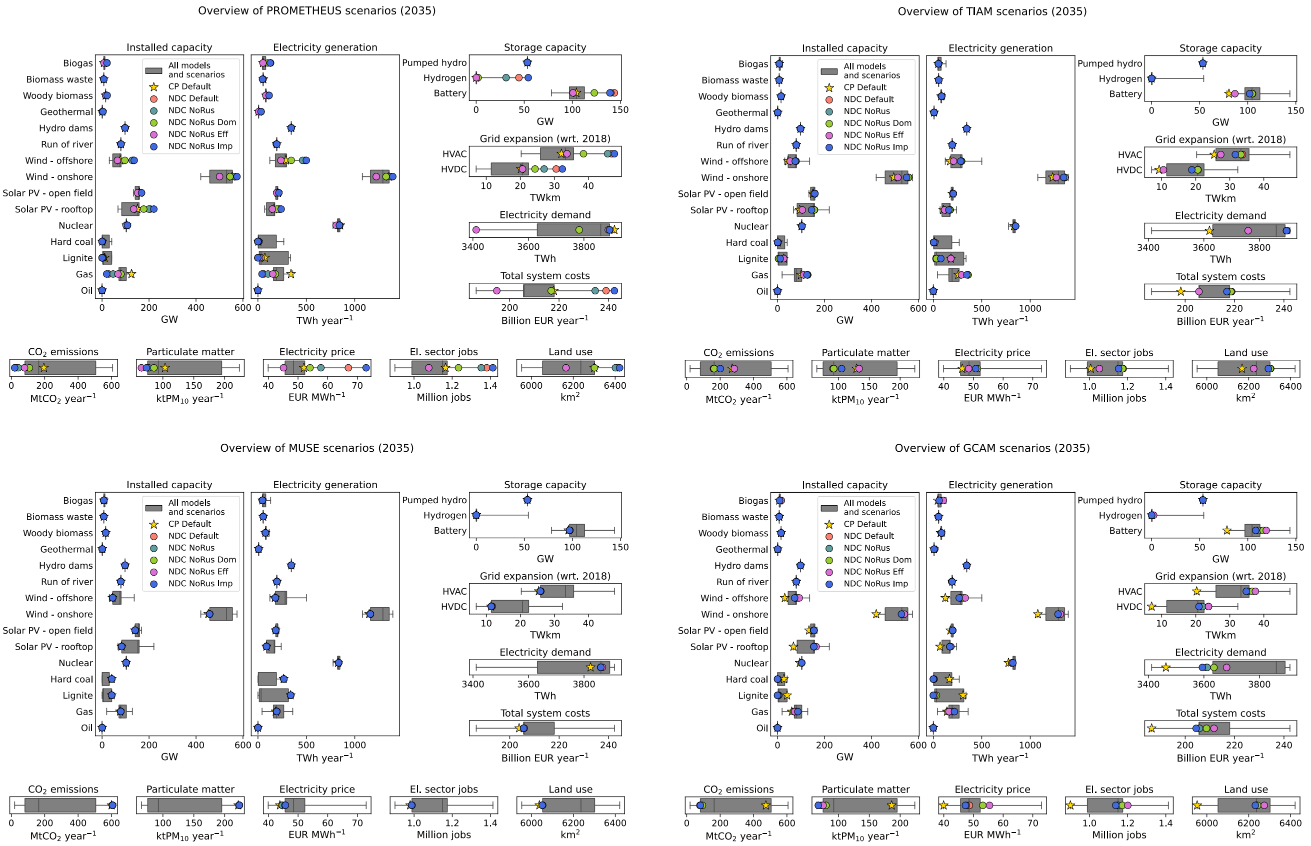

Figure 7: Overview of EXPANSE model results (**2035**)

Finally, Table 1 summarises the capital (CAPEX) and operational expenditures (OPEX) compared to the baseline, across all scenarios and models. Again, we see opposite trends between TIAM and PROMETHEUS on the one hand and GCAM on the other, in terms of total electricity system costs due to low electricity demand in the former and high in the latter, in the 'Energy Efficiency' case – reversed cost trends for the 'Gas Imports' case. Increasing domestic gas production also leads to relatively high system costs.

Table 1: Electricity system costs (**2035**) – Difference compared to NDC_Default

Model Name	**Costs [MEUR/yr]**	**Scenarios**			
		NDC_NoRus	NDC_NoRus_Imp	NDC_NoRus_Dom	NDC_NoRus_Eff
GCAM	OPEX	-429	90	-1,551	-939
TIAM		-88	-424	-94	-2,829
MUSE		137	137	138	224
PROM		1,664	-951	3,358	-1,038
GCAM	CAPEX	684	-1,219	4,639	7,066
TIAM		-244	-1,544	-257	-10,466
MUSE		-185	-184	-184	8
PROM		-6,061	4,345	-25,580	-43,218

3.3.3 Employment

MARIO provides insights into employment impacts by sector. Figure 8 shows the variation in EU employment with respect to the baseline case. Encompassing fossil fuel extraction activities, mining and quarrying constitute essentially the only sector experiencing employment losses. The electricity-sector structural differences (Section 3.3.2) lead to diverging insights into employment in the power sector across the two IAMs, GCAM and TIAM, driven also by different labour intensity for each technology. Power-sector employment shows over 1.5-fold increase in

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the ‘Energy Efficiency’ scenario by 2050 in GCAM, while TIAM showcases a mid-term employment decrease across all scenarios, in fact with a steeper decline (followed by a post-2040 increase) in the ‘Energy Efficiency’ scenario owing to the high decrease in investments in the sector as a short-term response. Nonetheless, both models project an overall positive impact on electricity-sector employment in the long term, also considering the decrease in fossil-dominated sectors.

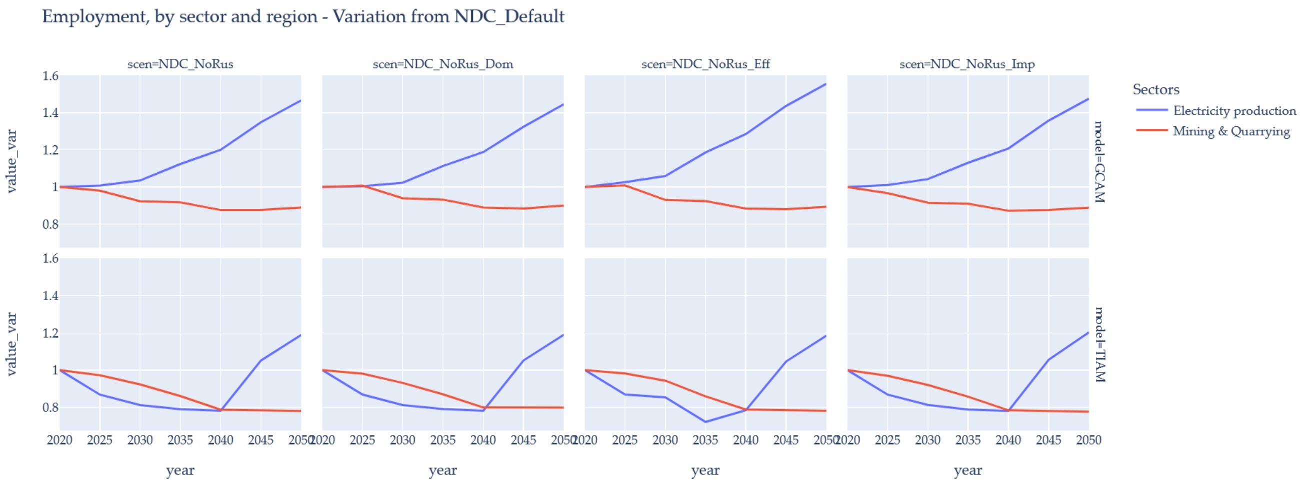

Figure 8: Employed population in electricity production and mining & quarrying sectors compared to NDC_Default in the EU (**2020 – 2050**) in GCAM (up) and TIAM (down)

3.3.4 Highlights

- Focusing on energy efficiency could lead to lower costs in the electricity system, on the order of 10s of millions of euros per year—although increased electrification costs in the longer run may prove costlier, depending on the model perspective.
- Southern Europe regions are more vulnerable to high electricity prices.
- Short-term needs should be aligned with long-term climate and societal goals to avoid stranded investments of fossil-powered capacities.
- When coupled with investments in the electricity sector, energy efficiency could also positively impact employment in the electricity sector, a finding consistent with other modelling studies [11].

3.4 Natural gas imports and prices

The role of natural gas in Europe’s energy system envisaged in the transition towards net zero has been fundamentally changed in response to the energy crisis. Here, we focus on the ‘Gas Imports’ scenario, which explicitly describes the impact of Russian gas losses on diversified import sources. Results from GCAM (the only IAM in our analysis with increased granularity for the bloc) show that, should a direct substitution of natural gas from other sources be pursued, the EU will reduce its net natural gas imports by almost 40% in 2030, compared to 2020. In most regions, the remaining imports may be provided either by European pipeline gas (predominantly from Norway) (+28.5% EU-wide in 2030 compared to 2020) or by LNG (+33.3% EU-wide in 2030 compared to 2020)—except for southwestern Europe, where pipeline gas from Africa and Middle East covers 30% of gas imports—leading to EU-wide imports doubling from 2020 to 2030. Demand for LNG would also increase in all regions, with considerably higher imports in the central and eastern EU member states (see Figure 9).

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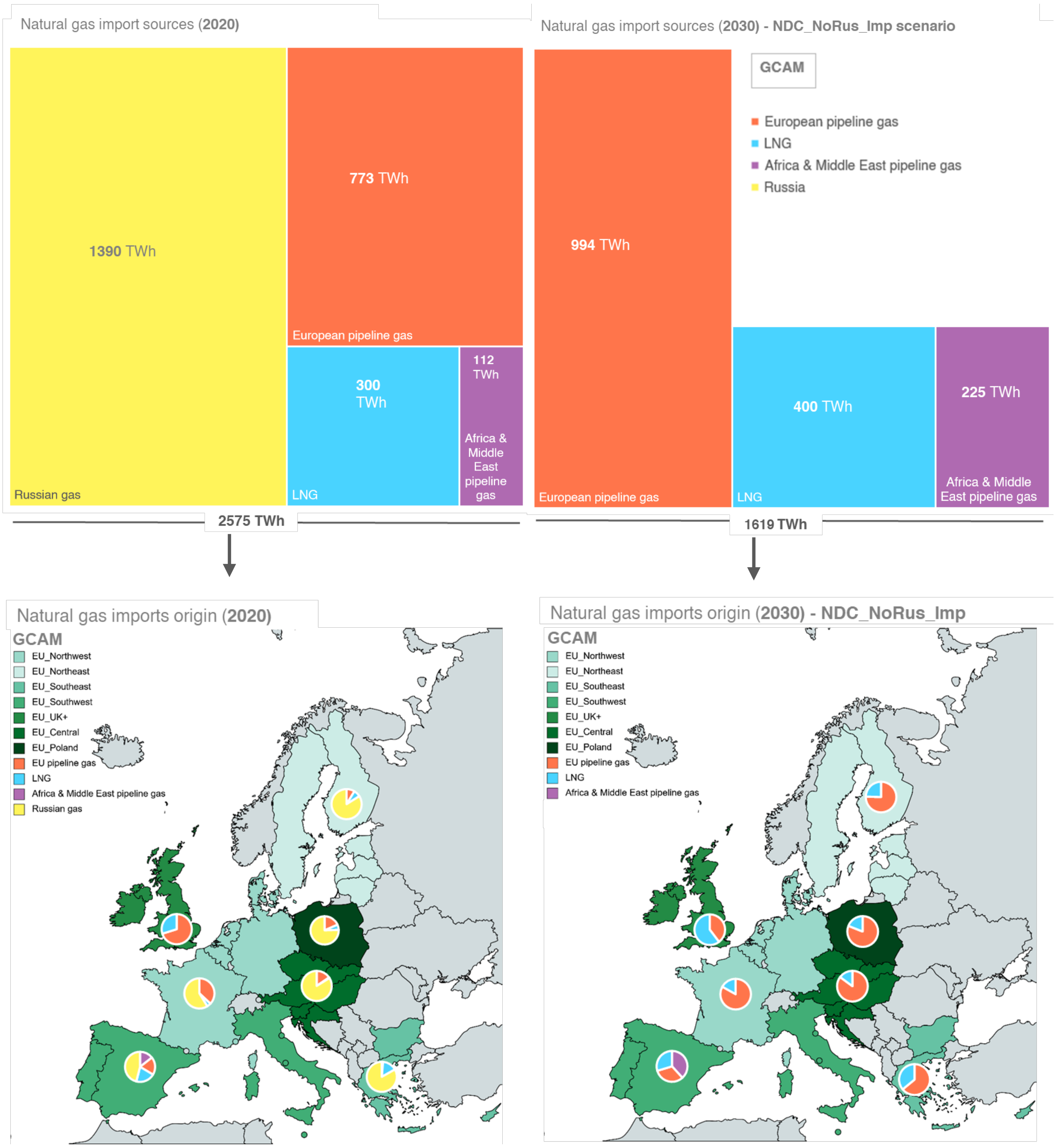
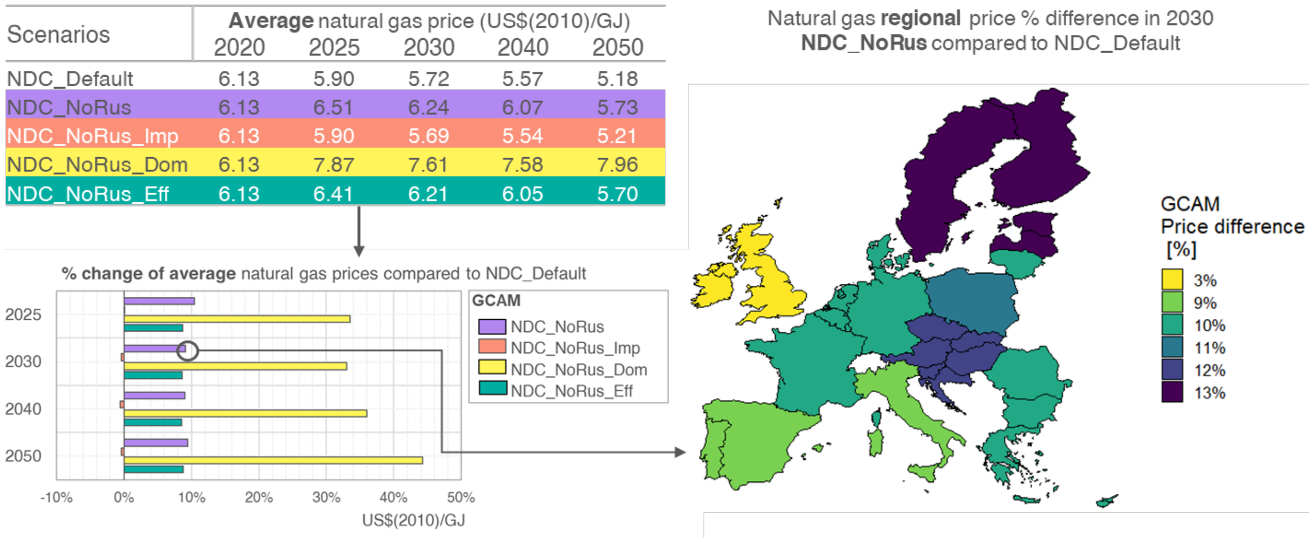


Figure 9: Natural gas import sources (up) & regional disaggregation (down) in **2020/2030** for the 'Gas Imports' scenario

Average natural gas (entry) prices across scenarios are shown in Figure 10, along with the % change compared to the baseline (left). The 'Domestic Production' scenario leads to the highest gas prices until 2050, owing to the reduced supply based on the cap on imports. The 'model-optimal' and 'Energy Efficiency' scenarios arrive at similar mid-range prices, while the 'Gas Imports' scenario leads to the lowest prices, even lower than the baseline. The regional disaggregation of price difference for the mid-range 'model-optimal' scenario is also shown (right). In general, regions with the highest Russian gas imports in 2020/2021, low LNG capacity, and insufficient storage capacity are the most vulnerable to higher natural gas price spikes [12]. Modelling results suggest that the highest gas price differences in 2030 compared to the baseline are observed in Finland and the Baltic countries, followed by Central Europe, then Poland, and then Northwest, Southeast, and Southwest EU.



Scenarios	Average natural gas price (US$(2010)/GJ) 2020	2025	2030	2040	2050
NDC_Default	6.13	5.90	5.72	5.57	5.18
NDC_NoRus	6.13	6.51	6.24	6.07	5.73
NDC_NoRus_Imp	6.13	5.90	5.69	5.54	5.21
NDC_NoRus_Dom	6.13	7.87	7.61	7.58	7.96
NDC_NoRus_Eff	6.13	6.41	6.21	6.05	5.70

Figure 10: Average natural gas entry price (left) and regional price difference in NDC_NoRus scenario for **2030** (right)

In 2021, Europe's natural gas import dependency rate was 83%. In 2030, the average rate—estimated as the ratio of imported natural gas to gas primary energy [15]—is projected to decrease to 73% in the baseline scenario, 69% in 'Gas Imports', 58% in 'Domestic Production', and 62% in 'Energy Efficiency' (see Figure 11). Only one model (MUSE) projects an uptick, in the 'Energy Efficiency' scenario in 2050, owing not to higher import shares but to higher decrease in primary gas consumption.

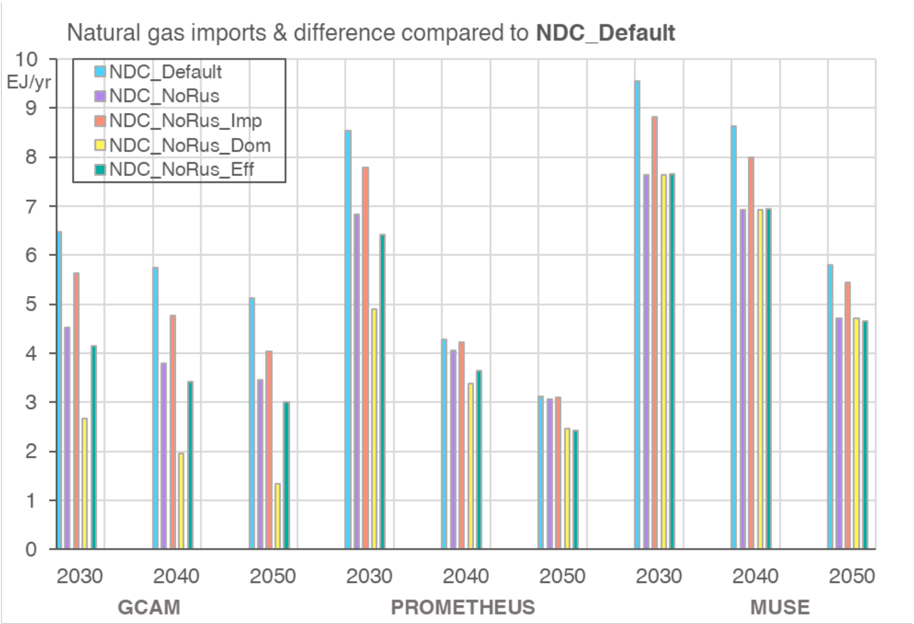


Figure 11: Natural gas imports across scenarios in **2030**, **2040** & **2050**. Percentages show difference from NDC_Default.

Natural gas import deviations from the baseline are affected by technoeconomic assumptions on costs and resource availability (not fully harmonised across models). However, some overall trends can be seen across models, while a reduction in natural gas imports over time can be observed as an effect of the fossil fuel phase-out, justified by decarbonisation efforts. In MUSE, the deviations of natural gas price are smaller across scenarios, as the decarbonisation targets proxied by the carbon price primarily drive the energy system transition. Natural gas price differences across scenarios depend on the technology cost assumptions and the relative difference in costs of the development of domestic resources as opposed to increasing imports.

3.4.1 Highlights

- Focusing on electrification will drive degasification faster than replacing the lost Russian gas with imports from other sources.
- Further growth of domestic production infrastructure is characterised by higher natural prices compared to increased efficiency and electrification.

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4 Policy implications

4.1 Gas Imports

Entirely replacing Russian pipeline gas with gas imports from other sources, such as LNG from the USA or pipeline gas from North Africa and Norway, misses an opportunity to accelerate decarbonisation of the European economy. The 'Gas Imports' scenario promises very little emissions reduction from energy sectors, whereas the 'Domestic Production' and especially the 'Energy Efficiency' scenarios indicate the potential for enhanced emissions cuts (Figure 2). As a long-term strategy, substituting Russian gas by gas from other origin risks locking the EU into a dependency on fossil fuels, when alternative approaches are feasible and more beneficial from an emissions standpoint. The 'Gas Imports' scenario also sees minimal reductions in demand for energy carriers in all scenarios compared to the baseline, with all demand for Russian gas replaced from other sources, and mostly no impact on the demand for other carriers (with some indications even for an increase in electricity demand).

The challenge of balancing the need to resolve the short-term energy supply and demand mismatch, with the long-term aims of a cost-optimal energy transition, are highlighted by model results showing energy system costs to be higher in the 'Gas Imports' scenario than in all other scenarios, due to insistence on gas alongside the higher costs of imported fuels (Figure 4). These costs could also plausibly affect the electricity system costs (and correspondingly the price for end users). Given the higher system costs in the 'Gas Imports' case, also driven by fossil-fuel infrastructure needs, there is an evident conflict with the long-term goals of decarbonisation. Such a strategy risks creating sizeable, stranded assets in the fossil-fuel sector, for example in LNG infrastructure. This is further illustrated in Figure 11, which showcases the largest demand for natural gas imports in this scenario.

Nevertheless, even the 'Gas Imports' scenario should lead to a reduction in overall gas demand and even significantly in imports themselves, with a 40% reduction from present day by 2030. LNG demand is observed to increase across all regions in the EU. This scenario also features the lowest gas price uptick among all 'corner' options (due to the relatively increased availability of gas), making it perhaps an attractive proposition from a political perspective as end use heating costs for consumers might be lower. The 'model optimal' approach also finds notable discrepancies in gas prices across Europe, with the southern and Atlantic regions seeing lower prices than the northern regions by 2030, as regions previously dependent on Russian gas imports but with low LNG capacity are susceptible to gas price volatility going forward. Understanding such distributional effects of the new energy landscape in Europe is critical if EU energy and climate policymaking is to obtain sufficient buy-in from Member States to achieve the Union's decarbonisation ambitions.

4.2 Domestic Production

More emissions reductions are projected when replacing Russian gas by domestic energy production, rather than by gas imports. The emissions cuts are observed in industry and buildings, as low-carbon energy outcompetes fossil fuels in these sectors. However, the emissions in energy supply increase relative to the baseline. In all 'corner' scenarios, less gas is imported to the EU than in the default scenario, but this effect is most pronounced in this 'Domestic Production' scenario, thereby leading to the fastest degasification of the European economy.

Energy system costs in the 'Domestic Production' scenario are more expensive than the 'model optimal' pathways, as expected, but more moderate than in the other 'corner' scenarios. However, high annual costs for electricity supply are seen in this scenario, as significant investments must be made to directly replace the lost Russian gas. High electricity prices are also observed in the model runs based on this scenario, as the costs of meeting the higher demand for electricity must be recovered from consumers. Highest natural gas prices are also observed in this scenario, but this is mainly due to restricted supply implemented in the models through a cap on imports.

4.3 Energy Efficiency

The 'Energy Efficiency' scenario results highlight the added benefits of focusing on this approach to replace the lost

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energy from Russian gas. The greatest emissions reductions, compared to the default, are observed in this case, mainly because of a reduction in overall energy use. This scenario shows the largest overall demand reduction, especially in the models that have a rich selection of energy efficiency options (Figure 3). Demand for natural gas is also reduced in this scenario compared to the 'Gas Imports' scenario.

Crucially, increased efficiency leads to lower energy system costs in the long-term, and all models agree that the investment needs in the electricity sector are lowest in the 'Energy Efficiency' scenario, on the order of 10s of millions of euros per year. These results emphasise that policy measures that incentivise energy efficiency will likely reduce the costs of the energy transition. When coupled with investments in the electricity sector, energy efficiency can also positively impact employment in the energy sector. As a consequence of the lower demand for energy, the models also found that electricity prices would be lowest in 2035 in this scenario (Figure 6).

Despite the numerous advantages of responding to a structural loss in gas supply by reducing demand for energy, there are notable risks with this approach as well. For example, one model achieved emissions reductions in part through the relocation of energy intensive industries, something that is of paramount concern to European policymakers. There is also the issue of rebound effects, as observed in the model results, in relation to both emissions and investment needs. As energy efficiency measures are deployed and it becomes possible to deliver the same energy services with less energy, the demand for those services may increase, wiping out the gains from efficiency and in fact negating the value of the investments.

4.4 Conclusion

This multi-model study demonstrates that sustaining the demand reduction delivered during the energy crisis through energy efficiency and energy savings shows multiple co-benefits beyond helping to manage the short-term supply and demand mismatch, including contributing to emissions cuts, saving investment costs through diminished demand, and lowering electricity prices. However, benefits from energy savings must be interpreted with caution, as they could entail negative macroeconomic and societal impacts if driven by industrial demand destruction. Importing gas from international partners, while necessary to balance supply and demand of energy in the aftermath of the crisis, runs the risk of contradicting the EU's decarbonisation goals if implemented as a long-term strategy. Producing more domestic energy, primarily through renewables and electrification, is effective at reducing emissions and may not involve the competitiveness risks of domestic energy demand reduction, although substantial investment must be mobilised to do so. In terms of employment impacts, although all scenarios foresee a net positive impact on EU energy-sector jobs, employment shifts from fossil to renewable energy require reskilling of the workforce, improved labour conditions, and safeguards for employees negatively affected by the transition.

Overall, the results show that structurally replacing lost Russian molecules with imports of fossil fuels from other regions will miss an opportunity to accelerate the energy transition in Europe. Focusing on electrification and the use of domestic energy sources, combined with committed deployment of energy efficiency measures, can effectively replace the lost energy from Russian gas and further enhance European decarbonisation.

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Annex

Table 2: Scenarios

Scenario Name	Description
NDC_Default	No constraint on EU imports, situation as before the Russian invasion to Ukraine. Emissions are constrained by NDCs to 2030 and NZ to 2050.
NDC_NoRus	No Russian gas imports from 2023 onwards. Models chose their “optimal” way to replace these gas imports. Emissions are constrained by NDCs to 2030 and NZ to 2050.
NDC_NoRus_Imp	Lost Russian gas is replaced with imports from other sources/regions (pipelines and LNG). Emissions are constrained by NDCs to 2030 and NZ to 2050.
NDC_NoRus_Dom	Lost Russian gas is replaced with increased domestic energy production. Energy trade from other regions remains at scenario NDC_NoRus levels. Emissions are constrained by NDCs to 2030 and NZ to 2050.
NDC_NoRus_ Eff	Replace lost Russian gas with enhanced energy efficiency. Emissions are constrained by NDCs to 2030 and NZ to 2050.

Table 3: Models

Model Name	Model Type	Solution Horizon	Detailed documentation in I^2AM PARIS
GCAM	Partial equilibrium	Recursive dynamic (myopic)	https://www.i2am-paris.eu/detailed_model_doc/gcamv2022
PROMETHEUS	Partial equilibrium	Recursive dynamic (myopic)	https://www.i2am-paris.eu/detailed_model_doc/prometheus
TIAM	Partial equilibrium	Intertemporal optimisation (perfect foresight)	https://www.i2am-paris.eu/detailed_model_doc/tiam
MUSE	Partial equilibrium – Agent based	Recursive dynamic (myopic)	https://www.i2am-paris.eu/detailed_model_doc/muse
EXPANSE	Electricity system	Intertemporal optimisation (perfect foresight)	https://www.i2am-paris.eu/detailed_model_doc/expanse
MARIO	Input – Output	Comparative-static simulation	https://www.i2am-paris.eu/detailed_model_doc/dynerio

Table 4: GCAM regions relevant to this analysis

Region	Countries
EU_Central	Austria; Czech Republic; Hungary; Slovakia; Slovenia; Croatia
EU_Southwest	Italy; Malta; Portugal; Spain; Andorra; Gibraltar; San Marino; Vatican
EU_Southeast	Romania; Bulgaria; Cyprus; Greece;
EU_Northwest	Belgium; Germany; France; Monaco; Netherlands; Luxembourg; Denmark;
EU_Northeast	Finland; Sweden; Estonia; Latvia
EU_UK+	United Kingdom; Ireland; Channel island; Faroe island; Guernsey; Greenland; Jersey; Saint Helena
EU_Poland	Poland
EU_Lithuania	Lithuania

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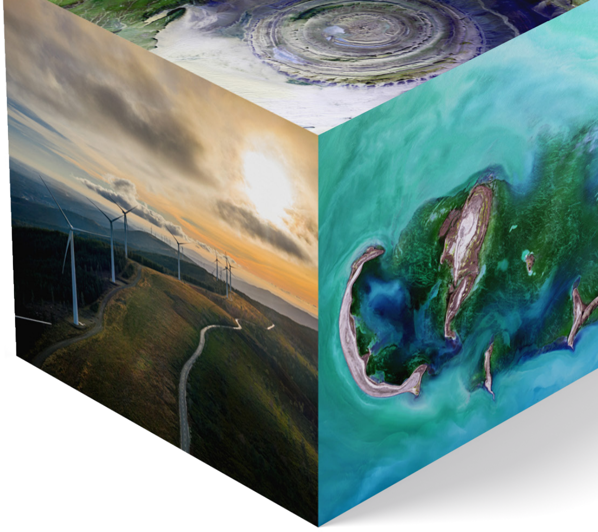

Policy Brief

Three policy responses to the energy crisis: The co-benefits of energy efficiency

In a nutshell

IAM COMPACT supports the assessment of global climate goals, progress, and feasibility space, and the design of the next round of Nationally Determined Contributions (NDCs) and policy planning beyond 2030 for major emitters and non-high-income countries. It uses a diverse ensemble of models, tools, and insights from social and political sciences and operations research, integrating bodies of knowledge to co-create the research process and enhance transparency, robustness, and policy relevance. It explores the role of structural changes in major emitting sectors and of political, behaviour, and social aspects in mitigation, quantifies factors promoting or hindering climate neutrality, and accounts for extreme scenarios, to deliver a range of global and national pathways that are environmentally effective, viable, feasible, and desirable. In doing so, it aligns climate action with broader sustainability goals, while developing technical capacity and promoting ownership in non-high-income countries.

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