EUROPE

Ripe for Closure:

Accelerating the energy transition and saving money by reducing excess fossil fuel capacity

September 2021

CREA
Centre for Research on Energy and Clean Air

TransitionZero

About the Authors

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TransitionZero combines financial and industry expertise with technology to help power a clear and timely transition to zero carbon in the power and heavy industry sectors. Using satellite imagery, machine learning, and financial modelling, we gather real-time insights into the economic vulnerability of fossil fuel assets. We give key decision-makers the solutions they need to reach their zero-carbon targets.

The work of TransitionZero has been made possible by the vision and innovation shown by Quadrature Climate Foundation, Generation Investment Management, Google.org, and Bloomberg Philanthropies. For more information: transitionzero.org

Acknowledgements

This report was written and researched by Andrei Ilas, Isabella Suarez, Lauri Myllyvirta, and Matt Gray.

The methodology was developed by Andrei Ilas, Lauri Myllyvirta, Matt Gray, Stefan Lavelle, and Sriya Sundaresan.

Cover design by: Lauren Austin (Cover Photo by YIUCHEUNG)

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01 Executive Summary

In this report, we estimate excess fossil fuel-fired capacity in the electricity grids of nine European countries. It aims to contribute to the identification and genesis of operating fossil fuel plants whose retirement could yield savings for energy consumers without compromising the security of supply while expediting a 2030 coal phase-out in Europe and avoiding carbon emissions.

Fossil fuel overcapacity demonstrates that additional demand in the countries can also be met by zero-carbon technologies instead of coal, oil, and gas capacity. The timeline for phasing out coal and decreasing the share of fossil fuels in Europe will be crucial in the rapid transition to a carbon-neutral economy. Redirecting capital from fixed operations and maintenance (FOM)[1] costs that would otherwise be spent on maintaining the unneeded fossil fuel capacity could instead be redirected to efforts in line with a just energy transition.[2]

Key Findings

- **48.8 Gigawatts (GW) of excess fossil fuel capacity in the 9 European countries modelled [3] – 17% of the European Union's total installed fossil fuel capacity, and more than Germany's total operational coal fleet in 2019 — can be retired without endangering the security of supply.[4]** Fossil fuel overcapacity represents the difference between the planning reserve – the net non-fossil firm capacity and variable renewable capacity – and the total installed capacity of coal, gas, and oil in each country.[5] The highest shares of excess capacity occur in Czech Republic (38%), Spain (36%), and Romania (28%).
- **€1.9 billion EUR ($2.13 billion USD) annually in savings from phasing out excess fossil fuel capacity in the 9 countries, 88% of which could come from retiring excess coal.** Overcapacity has capital, operating, and opportunity costs. Coal, oil, and gas capacity incur fixed operating and maintenance (FOM) costs, regardless of their generation. Retiring excess capacity could free up finances spent on FOM, which can either reduce energy costs or foster more productive investments.
- **Retiring the 38 GW of overcapacity from coal-fired plants would avoid approximately 200 million tonnes of carbon dioxide (CO_2) annually — the equivalent of the UK's total CO_2 emissions in 2019.** Spain, Italy and Germany account for more than half of fossil fuel overcapacity, comprising 10 GW, 3 GW and 8 GW of excess coal capacity, respectively. Between 2019 and 2021, 7.1 GW of coal plants were retired; retiring a further 41 GW of excess capacity would yield annual savings of €1.6 billion EUR, freeing up financing and resources that can support reduced energy costs for consumers and investments in low-cost zero-carbon generation.

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[1] FOM costs are those incurred at a power plant which do not vary with generation. FOM costs typically include routine labor, materials and contract services and administrative and general expenses.
[2] According to the International Energy Agency's World Energy Outlook, solar is the cheapest form of energy.
[3] Modelled countries include: Bulgaria, Czech Republic, Germany, Italy, Netherlands, Poland, Romania, Spain, and Turkey.
[4] According to Eurostat, the EU's total combustible fuel capacity in 2019 was 397 GW.
[5] See page 8 of the report for an overview of the methodology. A detailed account of the methodology and source material is outlined in the Methods & Materials section of this report.

- **The current high power prices and tightness in the European power markets show that fossil fuels are no longer reliable in a carbon-constrained world.** Conventional fossil fuel generators are often shielded from market forces and receive payments regardless of whether or not they are available to service demand. This saddles ratepayers with the costs of excess capacity and creates a perverse incentive not to close plants down before being ordered by regulators. Switching from coal to gas-fired power will do little to remedy the problem and only increases stranded asset risk.

- **Some fossil fuel-dependent countries like Poland face a paradox of overcapacity, where despite adequate or excessive installed generation capacity, power outages or rationing occur.** Unplanned outages of generators are brought about by aged coal plants and inefficiencies in systems planning that has also resulted in overbuilding of fossil fuel infrastructure.

Energy planning must keep the lights on in an economically efficient way and deliver rapid emissions reductions to address climate change. Given the enormous potential savings in maintenance costs and benefits to human and planetary health, negotiations over the proposed Fit for 55 package and the reformed Emission Trading Scheme, in particular, should aim for an ambitious outcome that will accelerate the retirement of excess fossil fuel capacity in Europe.

The report recommends that governments, utilities, and operators reevaluate the share of fossil fuel-based capacity in the energy mix, cancel planned fossil fuel capacity, and prioritise low-carbon energy sources in planning, policies, and investments. Retirement guidelines for fossil fuel power plants will be crucial in ensuring that incumbent generators do not continue to keep unnecessary fossil plants on life support.

This report hopes to support policymakers in planning for a zero-carbon electricity system, increasing economic competitiveness, and meeting broader development priorities by providing consumers with access to the cheapest electricity possible amidst larger decarbonisation goals.

02 Introduction

Rapid retirements of fossil fuel infrastructure and realignment of investments towards zero-carbon electricity sources are vital in meeting the temperature goal in the Paris Agreement.[6] The 2021 Intergovernmental Panel on Climate Change (IPCC) report emphasised the need for ambitious climate policies and solutions — particularly in carbon-intensive sectors like electricity — to avoid the worst impacts of climate change. According to the IEA, a global pathway to net-zero emissions by 2050 requires no new investments in coal capacity by 2021 and an end to unabated coal use in developed countries by 2030.[7]

Under the European Union's new "Fit for 55" package, countries will aim to increase the share of renewables to 40% of the combined energy mix and improve energy efficiency.[8] Countries' domestic policies are lining up to comply but to varying degrees of urgency and efficacy. Across Europe, coal-fired generation has fallen over 50% between 2012 and 2020 due to increased renewable energy deployment, higher CO_2 prices, and coal-to-gas switching.[9] However, coal accounted for almost 35% of Europe's electricity generation in 2020.[10] Experts warn that current pledges are not on track to meet the 55% emissions reduction target.

Today, only 65% of coal-fired power capacity operating in Europe is covered by a scheduled phase-out. As a result, countries like Poland, Czechia, Bulgaria and Germany will have electricity grids that may maintain a high share of fossil fuels longer than necessary, or even feasible. Research also shows that by 2025, the short-term cost of operating all existing coal will be uncompetitive compared with a combination of onshore wind, utility-scale solar PV, and battery storage.[11]

With the energy transition underway, a significant amount of fossil fuel generation assets have entered technical overcapacity — or capacity that is no longer needed for a system to operate reliably and cost-efficiently to meet demand. Security of supply requires a buffer of capacity, but excess overcapacity has negative economic consequences and can result in stranded assets.[12] This is especially true in the electricity sector, where large infrastructure investments are long-life assets. For instance, coal-fired power plants have useful lives of 30 to 40 years. In addition, the current high power prices and tightness in the European power markets show that fossil fuels are no longer affordable or reliable in a carbon-constrained world.

In countries where excess capacity is a result of excessive investment in new fossil fuel capacity, overcapacity indicates that projects fueled by carbon-intensive sources are allocated financing

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[6] The Paris Agreement is an international treaty on climate change. It was adopted by 196 countries at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016. Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels.
[7] International Energy Agency (IEA), 2021
[8] Climate Analytics, 2021
[9] Agora and Ember, 2021
[10] BP Statistical Review of World Energy, 2020
[11] RMI, Carbon Tracker and the Sierra Club, 2020
[12] According to Carbon Tracker (2017), stranded assets are those assets that at some time, prior to the end of their economic life, are no longer able to earn an economic return – as a result of changes associated with the transition to a zero-carbon economy.

regardless of whether or not they are necessary to maintain energy security and meet the needs of consumers.

In countries where overcapacity is a result of falling demand for fossil-fired generation, as a result of increasing supply from clean electricity or of contracting overall electricity demand, redundant generators are protected by inefficient power systems and markets, usually at the expense of consumers.

European countries have competitive electricity markets that should ensure that investors rather than consumers bear the costs of overcapacity. However, conventional fossil fuel generators are often shielded from market forces and receive payments regardless of their actual output. For example, Poland and Italy have mechanisms that pay power plant owners for simply existing, with Spain proposing to create one. Romania subsidises its coal plants; and even in their retirement, governments in Germany and the Netherlands have compensated coal plants for closure, saddling consumers with excess capacity costs and creating a perverse incentive not to close plants before being ordered by regulators. Such payment policies raise the overall cost of electricity.[13] In addition, there is little incentive or accountability for operators to ensure that plants operate reliably and responsively on an oversupplied grid, which can lead to unplanned outages or plants being unwilling to generate when fuel prices are high.

This report estimates fossil fuel overcapacity in nine European Union countries: Bulgaria, the Czech Republic, Germany, Italy, the Netherlands, Poland, Romania, Spain, and Turkey. The amount of excess fossil fuel capacity estimated in our research shows that the phase-out of coal-fired capacity in Europe lags behind what the grid can handle and what the climate emergency demands.

To do this, we calculate the amount of fossil fuel overcapacity and the associated cost by fuel at the end of 2019.[14] Identifying the state of excess fossil fuel capacity can inform system-level planning processes in each country to ensure the proper allocation of financial resources that enable a more rapid coal phase-out, diversification of generation sources, and overall system efficiency. Finally, identifying the cost of underutilised and unneeded assets can help policymakers plan for a *least-cost* electricity system, increase economic competitiveness, and meet more comprehensive climate and development priorities.

This report calls for a phase-out of unrequired fossil fuel capacity in Europe, the acceleration of zero marginal cost power sources, and the increased flexibility of the power grids. The consequence of these policy choices will be a reduced reliance on volatile fossil fuel prices and more predictable and overall lower power prices than currently observed. Moreover, as proposed by the European Commission as part of the FF55 package, a more ambitious phase-out of coal assets also provides a significant opportunity for these countries to address their overcapacity problem and save money.

[13] Moret S. et al, 2020
[14] Ember Climate, 2020

03 Methodology

COVID-19 disrupted regular demand and operations in the power sector. As such, this report uses 2019 data from various public and commercial databases, except Turkey, which uses 2021 data due to an increase in both peak demand and installed capacity in the last two years.

The process of estimating fossil overcapacity and the associated costs were as follows:

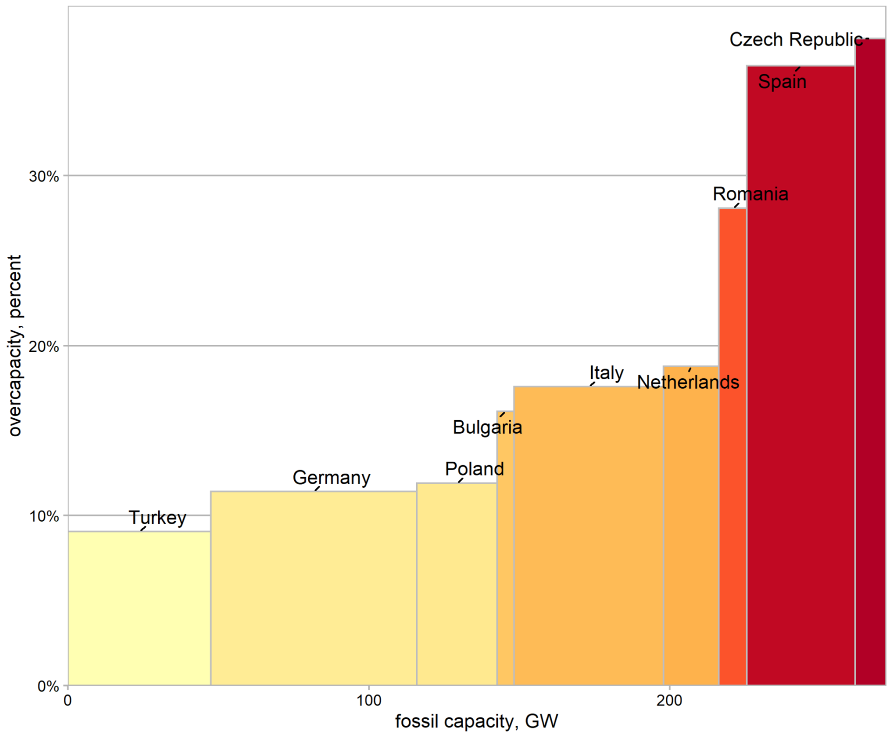
1. **Planning reserve.** On the demand side, a planning reserve — the required capacity at which the electricity system can operate safely during peak demand — results from multiplying peak demand to an appropriate planning margin based on the country's generation fleet and market structure. The result is the required total firm capacity needed to service peak demand and operate the electricity system without compromising the security of supply. The planning margin serves as a buffer in the event that some power plants or transmission lines are unavailable during peak demand.
2. **Available firm capacity.** Realised generation per source results from multiplying the adequacy ratio (%) by the specific fuel type's installed capacity (MW). The adequacy ratio (AR) is the percentage of firm capacity (MW) available during peak demand, which overwhelmingly occurs during wintertime in European countries. Adequacy ratios for fossil fuel-based generators are assumed to be 100% in line with previous research and the potential technical availability of dispatchable generators (Kahrl, 2016). Adequacy ratios of variable renewable energy resources resulting from a probabilistic assessment of solar, wind and hydro capacity availability over seven years using hourly demand, generation data, and installed capacity.
3. **Planning reserve met by fossil fuels.** The difference between the planning reserve (*step 1*) and the available firm capacity of non-fossil electricity sources (i.e., nuclear, hydro, wind, solar, biomass, geothermal, and import capacity) provides the remaining capacity that would need to be met by fossil fuel plants.
4. **Fossil fuel overcapacity.** The difference between the total firm capacity of coal, gas, and oil, and the remaining planning reserve (*step 3*) results in fossil fuel overcapacity. In most of these situations, coal accounts for most of the overcapacity. In liberalised markets, coal, gas, and oil capacity enter the generation stack towards the middle and end of the merit order, given their high marginal costs.
5. **Cost of overcapacity**. The fixed operation and maintenance (FOM) costs of keeping excess coal, oil, and gas capacity online are estimated from publicly available sources. FOM costs do not vary with generation. According to the US EIA, FOM typically includes routine labour, material and contract services, and administrative and general expenses, all of which are avoidable by retiring excess fossil fuel capacity.

The Methods & Materials section of this report provides a detailed account of the methodology and source material.

04 Saving on Excess Capacity & Addressing the Issue of Pricing

Our analysis found that approximately 48.8 GW — or 18% of the total operating fossil fuel capacity in the nine modelled European countries — can be considered overcapacity. Retiring excess capacity could yield annual savings of €1.9 billion EUR ($2.1 billion USD) in fixed operating & maintenance (FOM) costs, which do not vary with generation and are incurred regardless of whether the plants are not needed to service demand. FOM costs include routine labour, materials and contract services, and administrative and general expenses.[15]

Figure 1: *Share (%) and amount (GW) of fossil fuel overcapacity by country*



Almost 38 GW of excess overcapacity comes from coal-fired power plants (*Figure 2*). Therefore, an expedited coal phase-out to urgently reduce emissions with no disruption to supply is technically feasible and economical. Early retirement of excess coal plants alone could yield €1.67 billion EUR ($1.87 billion USD) in savings and avoid nearly 200 million tonnes of CO_2 that would be emitted annually by these coal plants. This would also eliminate harmful pollution from coal burning, yielding additional health and economic savings and further decarbonisation goals.

Investment in new fossil fuel capacity and FOM costs of excess capacity drain the resources of utilities and protect the market share of fossil fuels. Moreover, the maintenance and expansion of fossil fuel capacity happens at the expense of investments in zero-carbon technologies and grid improvements.[16]

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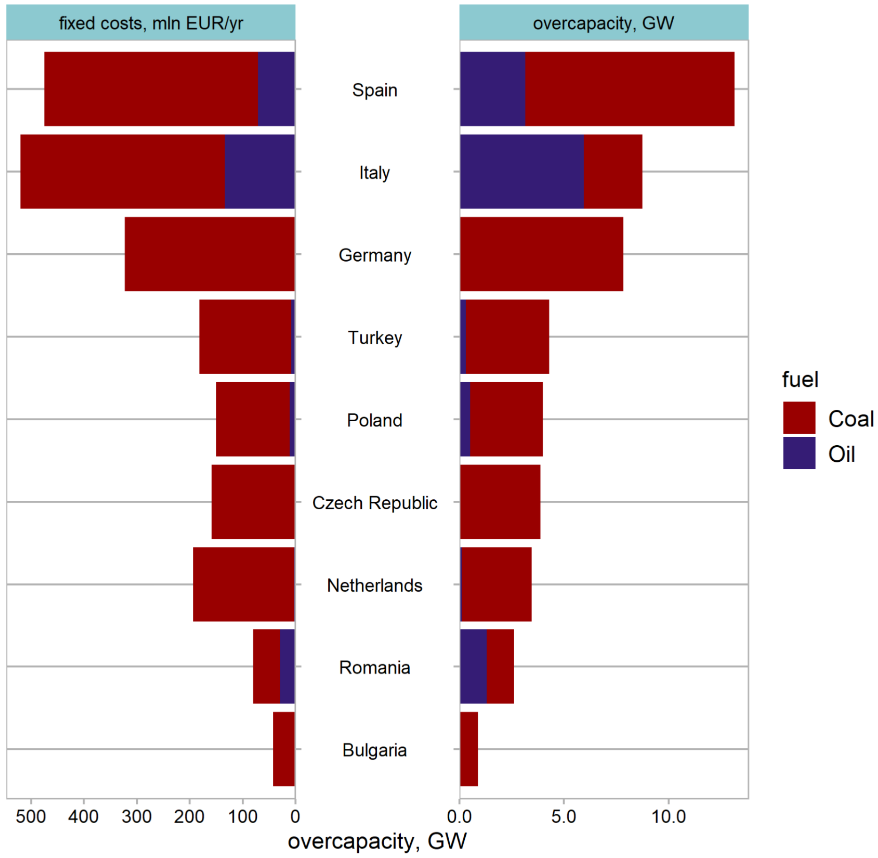
[15] There are several costs associated with running power plants. These costs include: fuel, variable operations and maintenance (VOM) costs, fixed operations and maintenance (FOM) costs, annual capital additions and costs associated with installing and operating control technologies to meet environmental regulations.
[16] Energy Information Administration (EIA), 2020A

***Figure 2:** Fixed cost (million EUR/yr) and amount (GW) of overcapacity by fuel*



How Excess Fossil Capacity Affects Power Prices

In the European Union, the last power plant called to meet demand in a specific hour sets power prices. This power plant is a flexible gas or a coal power plant in most countries and over most of the hours of a year. With carbon emission prices in play, alongside a rise in coal and gas prices in 2021, high electricity prices on European exchanges were a major cause for concern. This evolution showcases the high exposure of European electricity prices to volatile fossil fuel prices and the importance of identifying idle or excess capacity that may exacerbate the issue.

In power systems where the number of generating hours for fossil fuel plants is low, spot prices are lower — simply put, the more hours you burn fossil fuels for electricity, the higher the price you need to pay to do so. The current fossil fuel prices signal the high risk of exposing electricity systems to volatile fossil fuel prices for most of the generating hours in a year — a feature of a fossil fuel-dominated grid.

In 2021, key markets across the European continent saw record-high power prices as a result of significant price rallies in three commodities that determine the price-setting mechanism in the European markets: CO_2 emissions, coal, and gas. In Germany, day-ahead power prices traded at an average of €57 EUR/megawatt-hour (EUR/MWh) in the first seven months of 2021. This was a 240% increase from €24 EUR/MWh in 2020, which was already up from a 153% increase in comparison to the €37 EUR/MWh in 2019.[17]

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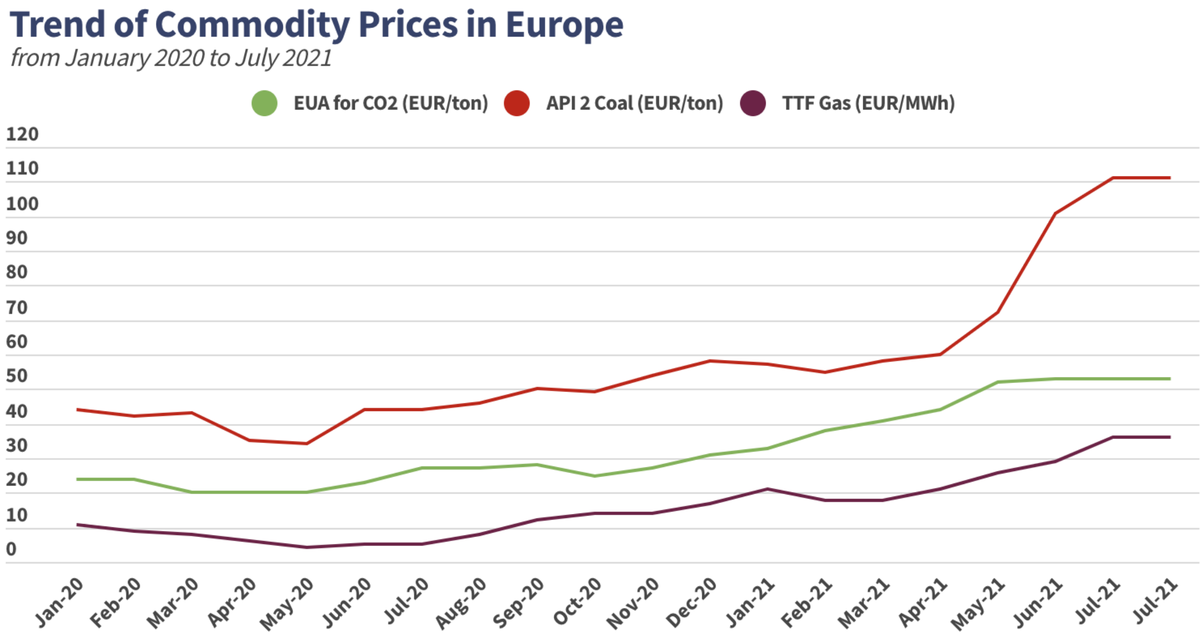
[17] Energy-charts.info, 2021

According to the latest statistics, European electricity demand reached pre-pandemic levels in the first six months of 2021. While the share of installed technologies on the grid remained relatively the same, the increase in the three commodity prices since that time created a surge in electricity prices. In July 2021, CO_2 emission prices were more than double (219% higher) prices in January 2020; coal prices were 250% higher, and gas prices were tripled (332% higher) over the same period (*Figure 3*).

Figure 3: *Increasing trend in Commodity prices of CO2 emissions, coal, and gas in Europe*



Sources: IMF, ICE, Ember

CO_2 prices rallied mostly on institutional investors' demand betting on a more ambitious decarbonisation target implemented through higher EU Emissions Trading System (ETS) prices and additional demand from gas generators who had a competitive advantage against coal for most of 2020. A significant demand following the first pandemic wave met by a dwindling global coal supply led to a sharp increase in coal prices. A substantial increase in gas demand in China, South East Asia, and South America led to a rally in gas prices. In South America, demand for gas increased due to a drought that reduced hydro production in Brazil — an example of weather-related disruptions that are likely to occur more frequently due to climate change. On the European continent, gas prices were affected by reduced flows of Russian gas, in the context of the Nord Stream 2 pipeline commissioning after a long heating season in 2021.

These events underscore the urgent need to deploy zero marginal capacity to have lower and more predictable electricity prices. Recent research from BloombergNEF estimated that as a consequence of renewable energy additions displacing gas generation on the Spanish grid by 2025, power prices in Spain could decline by as much as 58% from current levels.[18]

Overcapacity differs per country, and the sensitivity of electricity prices into the future reflects the ongoing changes to the individual electricity mix. We detail the implications of excess fossil fuel

[18] Bloomberg News, August 2021

capacity in 9 European countries in the subsequent section of this report. We also provide potential savings stemming from retiring excess fossil fuel plants by technology, focusing on coal.

Utilization vs. Availability

In estimating the available capacity to service peak demand in each country, the availability of a specific technology is used. Availability represents the potential technical ability of a power plant to produce firm electricity when required. For properly maintained fossil fuel power plants, availability can be fully counted on to fire up during service peaks. Most dispatchable technologies, such as nuclear and fossil fuel plants, are not dependent on variables like weather as a fuel, thus availability can reach 100%.

Such availability differs from utilization, which represents the actual number of hours a power plant operates or is called upon to service demand. In many countries, like Poland or Germany, the utilization rate of plants falls below that of its technical availability. The main factors behind utilization rates are commercial decisions, driven by market conditions for dispatchable power plants. In some cases, plant constraints related to their age, efficiency, and economics - such as outages for maintenance - contribute to the decrease in utilization.

Potential technical availability is the boundary used for our adequacy ratios to assess power plant contribution to meeting peak demand.

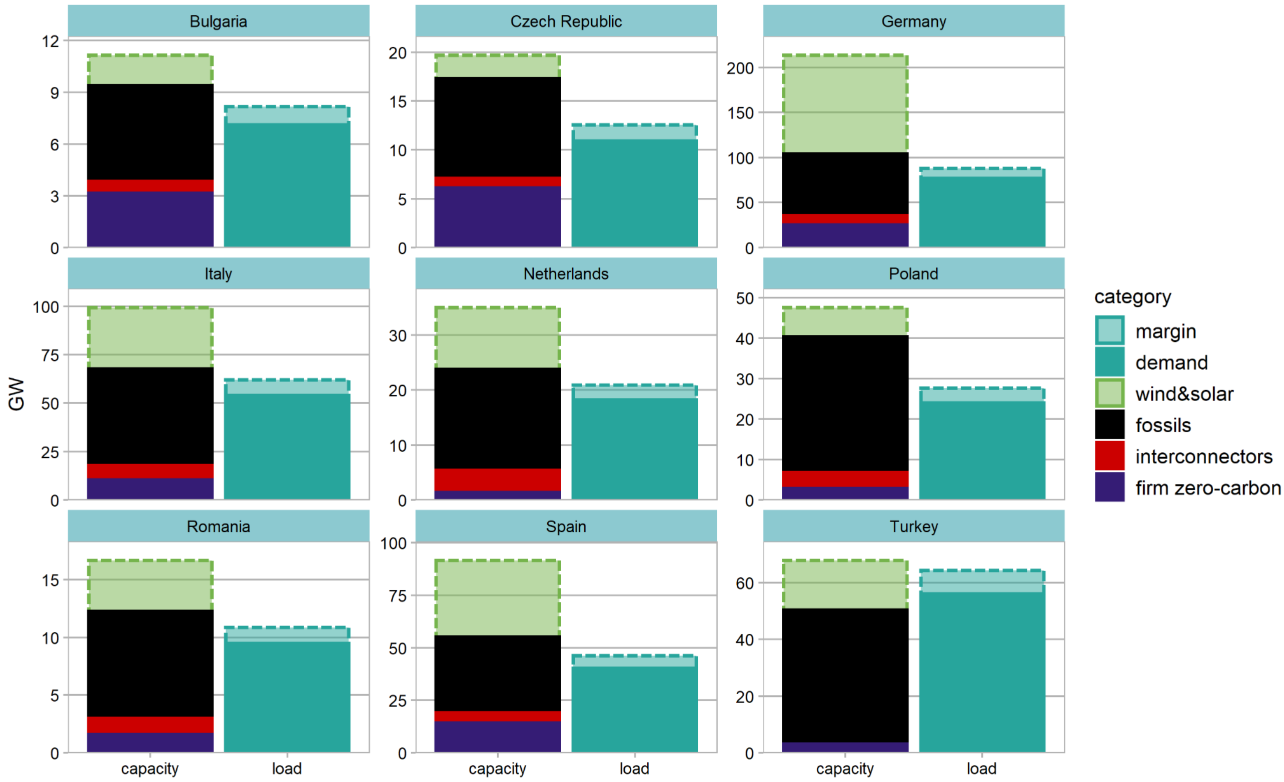
05 Results by Country

We analysed the amount of excess fossil fuel generating capacity and the impacts of the trends discussed in the previous section of this report in nine European countries, namely: Bulgaria, the Czech Republic, Germany, Italy, the Netherlands, Poland, Romania, Spain, and Turkey. In addition, we assessed the available capacity to meet electricity peak loads, or the highest level of demand, including a planning margin to provide a buffer in the event that some plants or transmission lines are unavailable.

With the exception of Spain and Germany, the share of fossil fuel in these countries is above 35% of their installed capacity. The amount of overcapacity indicates high reliance on carbon-intensive sources, which — according to this study — can be retired earlier while retaining sufficient capacity to keep the lights on. Thus, capacity added to meet future demand should, and can, be zero-carbon technologies.

As of July 2021, only Poland and Turkey have coal capacity still in the pipeline. Turkey has the most by far; approximately 1.5 GW are under construction and expected to come online by 2022, and over 12 GW of coal are in permitting and pre-permitting stages.

Figure 4: *Total installed capacity vs peak loads in 9 of the modelled European countries, 2019*



firm zero-carbon sources include hydropower, nuclear, geothermal and biomass

margin refers to a 15% planning margin over peak load

Source: CREA & TransitionZero calculations

Bulgaria

With around 40% of its electricity generated from coal, Bulgaria is one of the European countries most heavily reliant on fossil fuels. Thus far, the country has been a laggard in an early coal phase-out and may remain one of the most highly polluting electricity grids in 2030 if ambitious action is not taken.[19]

Approximately 16% of installed fossil fuel capacity in Bulgaria is more than what is needed to maintain the security of supply. This is equivalent to 900 megawatts (MW) of coal-fired capacity, most of which comes from highly polluting lignite plants that have been operational for more than 50 years. Aside from being highly inefficient and contrary to climate goals, major coal plants such as the Bobov Dol and Brikel have avoided paying as much as €32.2 million EUR in CO_2 emission expenses between 2017 and 2020 by publishing inaccurate data.[20] It highlights the issue with financing plants that avoid accountability in order to keep them in operating condition when they are no longer essential to service demand.

Recently, the government proposed a National Recovery and Resilience Plan that directs €970 million EUR in grants and €1.12 billion EUR in co-financing to the energy sector, including a goal to at least doubling the capacity of solar power plants with battery storage. Retiring the excess coal capacity from the 900 MW of coal plants whose average age approaches 60 years would save the country €37.7 million EUR ($42.2 million USD) in FOM costs per year. The savings from their retirement could boost programs under the NRRP, and ensure that investments to meet future demand are directed towards renewables.

Czech Republic

The economics of coal-based generation have declined in the Czech Republic from 2013 to 2019 and onwards, contributing to the significant coal oversupply in the country. While coal accounts for under half of the country's electricity, our research estimates that over 3.9 GW of this coal — 38% of the country's installed fossil fuel capacity and half of the operating coal fleet in 2019 — can be considered redundant capacity.

An initial proposal by the Czech Republic's Coal Commission recommended a coal phase-out by 2038, but the government has sent back a recommendation to a state commission to examine an earlier exit.[21] In May 2021, the country's largest utility, majority state-owned CEZ, announced a plan to shut most of its coal-fired power plants by 2030, cutting the proportion of coal in its mix to 12.5% from 36% in 2020.[22] Czechia has one of the lowest deployment rates of renewable electricity in Europe. Without these interventions, the share of coal is likely to remain above a third of the electricity mix by 2030. This would make it the second dirtiest electricity grid in the EU and its fourth-biggest power sector emitter.[23]

[19] Ember, 2020
[20] OCCRP, 2021
[21] Politico, 2020
[22] Reuters, May 2021
[23] Climate Analytics, 2020

Retiring 3.9 GW of excess coal capacity could save operators in Czech Republic €142 million EUR ($159 million USD) per year in FOM costs and allow the country to meet the 2030 deadline without disturbing the security of supply.

Germany

Coal-based electricity generation has declined by 40% in Germany, from 288 terawatt/hours (TWh) in 2013 to 172 TWh in 2019. Solar and wind replaced around 75% of the coal generation, and gas another 20%. Still, with over 42 GW of coal operating today, Germany is the EU's biggest electricity sector emitter. To meet emission reductions targets, the country recently overruled its 2038 coal phase-out plan with a new, more ambitious climate law to make a 2030 phase-out inevitable.[24]

In line with Germany's plan to permanently shut down its nuclear plants by the end of 2022, overcapacity estimated in this report does not include the contribution of nuclear capacity to zero-carbon firm capacity. Our research found that fossil fuel overcapacity is 11% of installed fossil fuel capacity. In absolute terms, this is equivalent to 7.8 GW of the country's 44 GW of coal-fired capacity. Retiring the total excess coal capacity calculated in Germany would yield among the highest immediate savings from the retirement of excess coal plants — an estimated €288 million EUR ($323 million USD) per year.

The country's peak demand in 2019 was 77 GW, occurring before noon in the winter — a time serviceable by solar energy. Besides policy-driven solar and wind deployment, EU Emissions Trading System (ETS) reforms and the price increase that followed have significantly worsened the competitiveness of coal-based electricity generation in Germany, leading to the current overcapacity. The country recently adopted an earlier net-zero greenhouse gas emission target of 2045 after a court ruled the 2050 target to be inadequate. The total available coal fleet is likely to decrease by 8 GW - from 38 GW to 30 GW - by 2022.[25] These factors can expedite a coal phase-out.

Italy

Italy's electricity demand had remained stable between 324 TWh and 331 TWh since 2015, bar a 6.3% drop in demand due to the disruptions of the COVID-19 pandemic in 2020. The share of coal in Italy's electricity mix has fallen by 65% since 2015. Overall, fossil fuels still dominate 57% of Italy's electricity production, making it the second-largest greenhouse gas emitter in the EU. Although Italy retired over 14 GW of coal in the last two decades, capacity was replaced mostly with fossil gas, whose market share increased in the electricity mix from 40% in 2015 to 46% in 2020. This increase is twice that of cleaner alternatives such as wind and solar, whose generation grew by only 8 TWh over the same period. The country's ambitious coal phase-out date of 2025 and National Energy and Climate Plan (NECP) target to meet 55% of electricity demand with renewables by 2030 should reverse this trend.

Our research estimates that 18% — or 8.7 GW — of installed coal, oil, and gas in 2019 was above what was required to meet peak demand plus an additional 15% reserve. This indicates that a third

[24] Agora Energiewende, 2020
[25] Agora Energiewende, 2020

of the country's coal fleet can be considered redundant capacity, along with all 5.9 GW of oil-fired power plants in operation.

Retiring the excess fossil fuel capacity would yield almost €465 million EUR ($520 million USD) savings every year. Savings from coal alone is €346 million EUR ($387 million USD), which should encourage an earlier phase-out for projects operating for more than 30 years. With one of the highest absolute MW values of excess capacity estimated in this report, the country should also avoid building additional gas plants to meet future demand, as these plants would only increase redundant capacity on the grid.

Despite being on track to phase out coal by 2025, the country's capacity market auctions distort the market favouring new and existing gas-fired plants, underpinning the development of new fossil fuel power plants that would otherwise be uneconomic. Plans to build 14 GW of new fossil gas plants in the next decade could risk increasing the existing excess capacity and further Italy's reliance on costly gas imports, which could drive increases in electricity prices; 5.8 GW of the planned gas capacity has been awarded and is due to come online by 2023.[26] The proposed gas projects could potentially cost €11 billion EUR in stranded assets and revert the savings and emissions gains obtained through Italy's plan to phase out all its coal plants by 2025,[27] all while renewables are well suited to meet the country's peak demand and should be prioritised to reduce emissions from Italy's electricity sector.

Netherlands

The Netherlands has seen a significant decrease in coal generation over the last five years from 35.8% in 2015 to 7.2% in 2020, having retired over 3.7 GW of coal capacity over the same period. Fossil gas replaced coal generation, which has become the primary source of electricity in the Netherlands. The increase in fossil gas generation and the decreasing production from the domestic Groningen field saw the country become a net importer of gas for the first time in 2018.

Our research estimates that 3.5 GW of fossil fuel can be considered technical overcapacity, 97% of which is excess coal-fired power plants that can be retired as they are no longer needed to meet peak demand. Maintaining these plants cost approximately €173 million EUR ($194 million USD) every year. In 2019, the Netherlands passed a law requiring an end to the use of coal generation by 2030 and 100% renewable electricity by 2050.[28]

Older plants with less than 46% efficiency must be converted to alternative fuels or shut down by January 2024.[29] Notably, only the 650 MW Amer power station would fall under this requirement. The remaining 3.5 GW of estimated excess coal-fired capacity was built in just the last five years. FOM costs are some of the highest of the sampled countries, averaging €51,235 EUR per MW ($57,375 USD per MW).

[26] Carbon Tracker Initiative, 2021A
[27] Ibid.
[28] Climate Home News, 2017
[29] The Dutch Supreme Court reached a decision on 20 December 2019 requiring the government to take immediate action to reduce CO2 before the end of 2020. https://www.urgenda.nl/en/themas/climate-case/

Poland

Coal assets — which account for 70% of the country's installed electricity capacity — are associated with high debt levels for state-run utilities and supply disruptions in Poland. On June 22nd 2021, Poland was close to a blackout due to an unplanned outages from 7 GW worth of coal-fired power units at Bełchatów, Opole, Kozienice, Połaniec and Włocławek among others.[30] Notably, in addition to increased imports and the activation of reserve plants, solar PV generation between 1 to 2 GW an hour helped avoid a blackout, particularly during the hours of the day when demand was at its peak. This indicates that solar PV is a key technology in servicing peak summer demand in Poland, while its continued reliance on large, old coal plants with high increases the risks of blackouts.

The point of reference for our analysis in Poland is the summer peak demand, which at 24 GW is about 8% lower than the winter peak in 2019. From a systems perspective, the summer peaks are more difficult to handle than the winter peaks as Poland experiences tight capacity conditions in the summer. The significant amount of combined heat and power (CHP) capacity operates at significantly lower than total capacity in the summer due to planned maintenance and system constraints; according to the Forum for Energy Analysis research in 2015, about 40% of CHP plants went offline for the summer season. In addition to the low availability of CHP plants, open-loop cooling is often unavailable due to the hot, dry weather conditions.

Such plants contribute significantly to CO_2 emissions and FOM costs in the country, but not to capacity adequacy and should be targeted for closure. Solar PV should be given priority in the coming years. Its high potential to service the increased demands during daytime summer hours in Poland was proven during the events of June 2021 when 7 GW of coal power plants were unable to deliver power when required due to unplanned outage.

Adjusting our adequacy ratios to reflect the summer trends, we estimated a total of 4.4 GW of fossil fuel overcapacity in Poland — or 13% of the firm fossil fuel capacity. The estimated cost of overcapacity amounts to €135 million EUR ($151 million USD) per year, coming almost exclusively from coal capacity (€140 million EUR, or 88% of potential savings from retirement).

Currently, the government has plans for a coal phase-out before 2049. However, given that 4 GW of coal plants averaging more than 50 years in operation can already be considered technical overcapacity, an earlier phase-out date is possible, especially with more diverse non-fossil capacity entering the mix.

Since 2019, Poland has retired 5.7 GW of older coal plants but commissioned 6.8 GW of capacity in the last two decades, resulting in a modest drop in total coal-fired capacity. It is one of the only two countries included in this report with additional coal planned with 560 MW in construction and 500 MW in permitting stage. However, with the excess capacity on the grid, these plants are an unwise investment as coal-fired power plants will become even more expensive to maintain and operate with more stringent EU climate regulations. In 2020, Poland faced the highest baseload electricity prices in Europe, partly due to dependency on coal.

[30] Next Kraftwerke, August 2020

Romania

Romania has one of the highest estimated shares of overcapacity at 28% of installed total coal, oil, and gas. The excess capacity is equivalent to 1.3 GW of coal capacity and 1.3 GW of excess oil capacity, most of which is already scheduled for retirement.

The competitiveness of coal-based generation has decreased significantly after 2013 with additions in solar and wind capacities and higher carbon emissions prices in the country. The 17 TWh of generation from coal in 2013 fell to 13 TWh in 2019; the 20% decline was offset entirely by the additional 4 TWh of solar and wind generation over the same period.

The current oversupply reflects this evolution. Romania has proposed 2032 as the coal phase-out date as part of its negotiations with the European Commission on financial allocations,[31] but the estimated 3.6 GW of excess capacity in 2019, indicates that this timeline can be moved forward.

The country's coal generators receive €250 million EUR per year in subsidies for carbon emissions certificates, channeling financing away from zero-carbon technologies and grid improvements.[32] Retiring the excess fossil fuels would save €72 million EUR ($80 million USD) per year in FOM costs, 63% of which would come from maintaining excess coal-fired capacity.

Spain

Spain has the most significant shares of excess capacity of all the countries included in this report, where 13 GW or 36% of fossil fuels installed in the country was not required to service peak demand in 2019. While Spain boasts a relatively greener grid, the government has kept fossil fuel facilities for backup and increased its use of gas in its move away from coal. With rising natural gas prices seeing the country's power prices reach record highs in 2021, Spain has accelerated its green energy auctions.[33] An accelerated phase-out of excess fossil fuel capacity should be prioritised to further alleviate the cost of fossil fuels on both the system and the consumers.

The country retired over 10 GW of fossil fuel capacity from 2018 and has announced phase-out plans for 4 GW of coal plants by the end of this year.[34] Our research shows that all 10 GW of installed coal capacity was not needed for the Spanish electricity system to service peak demand in 2019, indicating that virtually all of the country's coal can be retired immediately.

Retiring excess fossil fuel capacity would yield total annual savings of €425 million EUR ($476 million USD) from FOM costs. The early retirement of the aging coal capacity alone would save nearly €361 million EUR ($405 million USD) per year.

As of 2021, Spain has already retired 5.1 GW of coal capacity. With most of Spain's coal fleet operating more than 30-years and the potential for savings, phasing out the remaining plants should be done without delay.

[31] CarbonPulse, 2021
[32] Profit.ro, 2021
[33] Bloomberg News, 17 August 2021
[34] El Pais, 2020

Turkey

Electricity demand in Turkey has been increasing steadily, even growing by 0.6% in 2020 amid the economic fallout from the coronavirus pandemic. Its energy mix has a significant share of firm zero-carbon capacity, while coal and oil account for 40%.

The point of reference for our analysis in Turkey is 2021, due to an increase in peak demand and installed capacity. While the European countries' demand grew modestly or remained flat, peak demand in Turkey increased by more than 20% between 2019 to 2021. As such, the analysis of 2021 data allows for a more accurate assessment of overcapacity in Turkey. Our research finds that fossil overcapacity stands at almost 9% of this operating fossil fuel capacity, or 4 GW, indicating that 18% of installed coal-fired power plants were no longer necessary to service peak demand.

Turkey's coal fleet is relatively new in comparison to the others included in this report. Over a third of operating capacity came online in the last ten years, and the government has not retired a single plant, though it has cancelled over 84 GW of projects over the years. Five additional coal-fired units are under construction and expected to become operational by 2022, with dozens more in planning. Given the existing excess capacity, the construction of these plants would only add redundant fossil fuel capacity. The FOM costs in Turkey reported to the IEA are already higher than the average in the EU, despite lower general cost levels in Turkey. The large, old lignite fleet is one major reason for high maintenance costs which average €46,190 EUR/MW ($51,700 USD/MW). Thus, Turkey should prioritise the deployment of renewable energy, especially as maintaining the existing fossil overcapacity amounts to approximately €162 million EUR ($182 million USD) annually in FOM costs.

To meet increasing demand, the country should pivot towards renewable energy sources faster. Turkey's peak demand in 2019 occurred in the afternoon when solar PV generation is also at its highest, indicating high adequacy ratios. Wind and solar production in the country increased from 4.7% to 12% between 2015 and 2020, but displacing fossil fuels will require additional zero-carbon capacity. The Ministry of Energy and Natural Resources revealed plans to reach 20 GW of wind and solar by 2023.[35] Momentum around the Climate Investment Fund's new Accelerating Coal Transition (ACT) program is also an opportunity to dump coal assets and replace them with renewable energy.

[35] Climate Action Tracker, 2020

06 Recommendations

The key objectives of energy planning are to keep the lights in a way that is economically efficient while delivering rapid emissions reductions. This report shows that the transition away from fossil fuels is underway in Europe, and a significant amount of fossil fuel capacity is already in excess of what is needed to meet peak demand. Coal-dependent countries are protecting incumbent generators with high carbon and air pollutant emissions, even when their contribution is not needed to meet current or future power demand with adequate safety margins.

The enormous potential savings in maintenance costs, benefits to human and planetary health, and the poor economic realities around coal build a strong case for a rapid phase out. Retiring excess fossil fuel capacity can jumpstart this, and accelerate efforts to meet the EU's 55% emissions reduction target by 2030. There is a combination of options that can accomplish this. This will differ in each country but should include action to:

- **Retire excess fossil fuel-based generating capacity, especially in countries with a significant number of old coal power plants.** Countries should redesign phase-out plans to adopt an earlier retirement schedule to avoid keeping ageing fossil fuel capacity on life support. Reductions in public health burdens and associated economic costs are unaccounted for in this study but will increase potential savings and benefits that would stem from such retirements. Annual savings from retirements should be directed towards renewable energy deployment and just transition efforts. This includes but is not limited to supporting economic diversification and conversion in local communities, environmental restoration, and reskilling of workers in carbon-intensive industries.

- **Cancel all new fossil fuel power plants that remain in the pipeline.** There is growing consensus that no new fossil fuel projects should be developed if we are to meet temperature goals under the Paris Agreement. Fossil fuel plants are no longer assured operation for the entire duration of their economic lifetime. Pursuing their construction would likely result in more under-utilized fossil fuel capacity and stranded asset risk.

- **Reform the EU Emissions Trading System (EU ETS) to meet the 2030 phaseout deadline.** ETS has driven certain kinds of clean innovation investments and accelerated the phaseout of fossil fuels. Its reform is necessary to ensure that it efficiently and equitably aids in accelerating and incentivising the development of solutions to reduce emissions in the changing landscape.

- **Bring transparency to retirement guidelines and timelines for older and polluting fossil fuel power plants.** Due to the lack of firm guidelines or policy for the retirement of such plants, their operations continue beyond useful life resulting in risky operations leading to accidents and a higher carbon and environmental pollution footprint.

- **Reevaluate fossil fuel-based capacity and its share in the energy mix.** Where capacity expansion is already committed, financiers, suppliers, and planners need to find solutions to convert projects into clean energy.

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08 Appendix: Methods & Materials

The researchers employed a methodology derived from energy planning systems to estimate the megawatt amount of fossil fuel overcapacity in 23 countries — 9 of which are included in this regional report for Europe.

Because COVID-19 disrupted regular demand and operations in the power sector, the data from the end of 2019 were compiled from various public and commercial databases and used in the calculations. The three types of data collected for each of the countries were:

- *Peak demand* (MW) and the *time* of peak demand to the day and hour. ENTSO-E was the main data source for Europe, while data from other countries was collected from various public sources.
- *Historical Generation* data (MW) for each fuel source during peak demand, which was only available for Europe. Variable renewable energy categories included: offshore wind, onshore wind, solar photovoltaic, and concentrated solar power. Firm zero-carbon technologies include nuclear, hydro reservoir, hydro run-of-river, pumped hydro, biomass, and geothermal. Fossil fuels are gas, oil, coal, and combined heat and power (CHP).
- *Installed capacity per fuel source* and *import capacity* (MW) at the end of 2019. Renewable energy capacity was based on International Renewable Energy Agency (IRENA) statistics, as well as official government reports. Data for gas, oil, and nuclear capacity was collected from S&P Global Platts (World Electric Power Plants Database). Data from the Global Energy Monitor (Global Coal Plant Tracker database) was used for coal. Data on interconnection was collected from publicly available sources or estimated from the imported capacity during peak demand (EU countries only).

Estimating the cost of overcapacity relies on the main assumption that any electricity system that has more installed and available firm capacity than the peak demand (MW) plus the appropriate planning margin can be considered as technical overcapacity.[36]

Furthermore, in a least-cost dispatch model, the most efficient and less costly plants are run to meet demand. The estimation of fossil overcapacity is based on observed merit orders of different technologies in the EU where coal, gas and oil are mid to peak merit technologies. Coal, gas and oil capacity enter the generation stack towards the middle and end of the merit order given their high marginal costs.

Thus, the current method allows for the estimation of fossil fuel overcapacity. A more granular estimation per fossil fuel source requires additional modeling of marginal costs of each fossil fuel, which is beyond the scope of the current report. However, one can infer from marginal costs of electricity generation from different fossil fuel sources that most of the estimated overcapacity consists of coal, followed by fossil oil, and finally, gas.

In any electrical system dominated by coal power plants generation or with a significant share of coal generation, almost all the estimated overcapacity can be assigned to coal plants.[37]Older plants that are being kept idle due to lack of demand and high costs of generation are the biggest

[36] North American Electric Reliability Corporation (NERC), 2020.
[37]Carbon Tracker Initiative, 2018

contributors, and have higher fixed and variable operating costs. The implication for overcapacity is that systems with overcapacity from older plants are highly likely to be kept idle due to lack of demand. Yet, the FOM costs of these plants need to be paid for if one expects them to be operational.

Process of Calculating Overcapacity & FOM Costs

Share and amount of overcapacity per country

1. A planning reserve was calculated by applying a factor of 1.15 to peak demand to obtain the required total firm capacity that would have been required to service peak demand and operate the electricity system safely (i.e. cause no disruptions in supply).
2. Available firm capacity, which includes non-fossil electricity sources (nuclear, hydro, wind, solar, biomass, geothermal and import capacity), was assumed or calculated — where available — by dividing realized generation of each fuel during peak demand by total installed capacity. The result is then multiplied by the total installed capacity of each specific fuel source.
3. In order to obtain the planning reserve amount that needs to be fulfilled by fossil fuel capacity, the calculated available firm capacity of non-fossil electricity sources was subtracted from the planning reserve.
4. The fossil fuel overcapacity was estimated by subtracting the remaining planning reserve that needs to be fulfilled by fossil fuels from the total installed capacity of coal, gas and oil in the country.

Cost Estimation

The cost of overcapacity discussed in this report is represented by the FOM costs. FOM costs are those incurred at a power plant which do not vary with generation. According to the US EIA,[38] FOM typically includes routine labour, materials and contract services, and administrative and general expenses. The EIA states:

> "*Routine labor includes the regular maintenance of the equipment as recommended by the equipment manufacturers. This includes maintenance of pumps, compressors, transformers, instruments, controls, and valves. The power plant's typical design is such that routine labor activities do not require a plant outage. Materials and contract services include the materials associated with the routine labor as well as contracted services such as those covered under a long-term service agreement, which has recurring monthly payments. General and administrative expenses are operation expenses, which include leases, management salaries, and office utilities. For the hydro, solar, wind, and battery energy storage cases, all O&M costs are treated as fixed costs.*"

The FOM costs are estimated based on the IEA's 2020 World Energy Outlook (WEO).[39] The IEA does not disaggregate variable operations and maintenance (VOM)[40] and FOM. For this reason, we

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[38] EIA 2020a
[39] IEA, 2021
[40] VOM costs are generation-based costs that vary based on the amount of electrical generation at the power plant. According to the EIA (2020), these expenses include water consumption, waste and wastewater

estimate FOM based on a disaggregate of the IEA data. Specifically, we assume 90% of the "Annual O&M Costs'' in the IEA's 2020 WEO Power Generation Assumptions are FOM. The 90% estimate is aligned with a comprehensive global study undertaken by DIW Berlin.[41] The total cost of overcapacity at country level is calculated from asset level data at plant level and consolidated at country level. We assumed that the oldest plants in the stack are the ones accounting for the overcapacity estimates. Plant level estimates of overcapacity costs were obtained by multiplying the MW capacity by the FOM costs for the specific country and technology. Plant level data was aggregated to country level. For regulated coal capacity in the United States, we used plant level estimates of FOM from S&P Global instead of IEA.[42] The data stems from regulated entities reporting FOM costs as part of regulatory filings.

Table 1A: Fixed Operations & Maintenance Cost Assumptions

Entity	Fixed Operations & Maintenance (US$/MW) by Coal Technology		
	Subcritical	Supercritical	Ultra Supercritical
European Union	40500	54000	58500
Turkey	48000	67000	63000

Source: TransitionZero based on IEA and DIW Berlin

Accounting for Electricity Planning Issues

Electricity systems have two peculiar features that need to be addressed for the system to be managed safely and cost effectively. Firstly, generation must equal demand at any point in time. Secondly, enough firm capacity must exist in order to meet estimated peak demand and — on top of this — a reserve margin of firm capacity must be available in case of forecasting errors or unexpected unavailable capacity during peak demand.

The planning reserve margin ensures that the second feature of electricity systems is met, by providing insights on available capacity and required capacity to manage safely and cost efficient an electricity system. This stems from the Planning Reserve Margin (PRM) defined by The North American Electricity Reliability Corporation (NERC) as a measure of the available capacity to meet peak demand and to safely operate the electricity system. The PRM is a ratio of the difference between available firm generation capacity and peak demand as stated in the (1) formula:[43]

(1) $$PRM = \frac{(G - P)}{P}$$

where G stands for generation and P stands for peak demand.

As an analytical tool to assess the suitability of existing capacity in meeting peak demand, the planning reserve margin and the exact timing of peak demand has an impact on the type and total capacity of different fuel sources that service peak demand and beyond that the demand throughout the year. Its value should always be higher than 1, ranging between 1.1 and 1.2

discharge, chemicals such as selective catalytic reduction ammonia, and consumables including lubricants and calibration gas.

[41] DIW Berlin, 2013

[42] S&P Global, 2021

[43] Kahrl, 2016; NERC, 2019

depending on the characteristics of the electricity system and peak demand. NERC recommends a PRM of 1.15 for thermal based systems and 1.1 for hydro based systems. In the United States, the upper range of the PRM extends to 1.24 in some cases. For this report, PRM used is 1.15 due to the fact that most of the electricity systems analyzed are heavily reliant on thermal capacity. The planning reserve margin has a direct impact on system costs and the type of capacity chosen to fulfil electricity demand in a given country.

Adequacy Ratio Calculations & Assumptions

A set of assumptions for variable renewable energy adequacy ratios were found in earlier research on fossil fuel overcapacity.[44] However, these were deemed dated given advances in variable renewable technology, and increased knowledge in forecasting and integrating higher shares of variable renewable energy sources (VRES) in electricity systems.

To capture the worst case situation in terms of the residual gap between demand and VRE supply that needs to be met with dispatchable capacity, the ELCC approach was used to estimate adequacy ratios for solar, wind, and hydropower. We analyze historical generation data and scale past years' output to current capacity using ENTSO-E data from 2015 to 2020 for every country in Europe. This compares required capacity needed to meet a certain reliability or Loss-Of-Load Probability (LOLP) target with and without the VRE capacity in the system.

To do this, we first extract total load data (ENTSOE name of variable: Actual Total Load [6.1.A]) and generation data for solar, wind onshore and offshore (ENTSOE name of variable: Aggregated Generation per Type [16.1.B&C]), then calculate net load by both hourly and 15- minute increments by subtracting total demand and generation of solar and wind.

The annual difference between peak demand, highest demand, interval in the dataset and the lowest net load is then calculated. The result is divided by the annual cumulative installed capacity of solar and wind. For Turkey, we used an average of European countries' estimated adequacy ratio for onshore wind and 40% for solar PV due to peak demand occuring during daytime hours, a period serviceable by solar power.

In line with previous work, an adequacy ratio of 100% was assumed for geothermal, coal, gas and oil in all countries with the exception of Poland.[45]

Table 2A: Adequacy Ratios Values, 2019

	Offshore Wind	*Onshore Wind*	*Solar PV*	*CSP*	*Hydro Reservoir*	*Hydro (Run of river)*	*Pumped Hydro*	*Biomass*	*Geothermal*	*Coal*	*Gas*	*Oil*	*Nuclear*	*Inter-connectors*
Bulgaria	—	*0.06*	*0.06*	*0.00*	*1.00*	*0.60*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*	*1.00*	*0.99*	*1.00*
Czech Republic	—	*0.09*	*0.09*	*0.00*	*1.00*	*0.60*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*	*1.00*	*0.99*	*1.00*
Germany	*0.07*	*0.07*	*0.07*	*0.00*	*1.00*	*0.60*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*	*1.00*	*0.99*	*1.00*
Italy	—	*0.13*	*0.13*	*0.00*	*1.00*	*0.74*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*	*1.00*	*0.99*	*1.00*
Netherlands	*0.07*	*0.07*	*0.07*	*0.00*	*1.00*	*0.60*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*	*1.00*	*0.99*	*1.00*
Poland	*0.10*	*0.10*	*0.10*	*0.00*	*1.00*	*0.60*	*1.00*	*0.80*	—	*1.00*	*0.92*	*0.60*	*1.00*	*1.00*
Romania	—	*0.11*	*0.11*	*0.00*	*1.00*	*0.82*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*	*1.00*	*0.99*	*1.00*
Spain	*0.17*	*0.17*	*0.17*	*0.10*	*1.00*	*0.60*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*	*1.00*	*0.99*	*1.00*

[44] Kahrl, 2016
[45] ibid.

Turkey	—	*0.10*	*0.10*	*0.00*	*1.00*	*0.60*	*1.00*	*0.80*	*1.00*	*1.00*	*1.00*	*1.00*	*0.99*	*1.00*

Source: ENTSO-E, and CREA & TZ estimates

Caveats

The focus on peak demand to estimate overcapacity can be scrutinized further under the premise that while peak demand is the most consequential event from a systems planning perspective, electricity systems with increasing shares of VRE have to plan for numerous, significant, and short-term declines in electricity generation capacity. These occurrences require flexibility foremost, such as battery storage and demand response. Coal-fired power plants have low flexibility and high start up costs, making them less suitable for contributing to system reliability.

Furthermore, there is growing acknowledgement that systems with high VRE penetration pose challenges that are different from ones faced by systems dominated by large, fossil fuel based power plants. This report employs a simplified framework to account for overcapacity in a power system based on methods developed to assess system risks and reliability in fossil fuel heavy power systems. This type of analysis serves the reliability needs of most systems that are based on large, dispatchable fossil fuel power plants; however, with the growing shares of renewables, updated tools for reliability assessments will be needed as a key feature of dangerous events associated with VRE — namely duration of ramp up or ramp downs — are not captured in more traditional assessments and tools. As recent reports establish,[46] modeling systems' reliability has to incorporate these events as the share of VRE increase in grids around the world. Finally, a more extensive probabilistic modeling based on weather over the years is required to effectively incorporate the changing patterns in climate, which affect weather events. This would strengthen the results presented in our simplified framework.

Lastly, while the FOM costs presented in this report are significant, they are only one part of the overcapacity costs. Another part of the overcapacity costs that is beyond the scope of this report are the depreciation costs and undepreciated value of coal plants that are technically overcapacity. Undepreciated coal power plants bear accounting losses from depreciation that is not offset by generation revenues. As coal power plants are phased out in a carbon constrained world, these costs will be increasingly scrutinized by policy makers in order to inform phase out schedules and compensation of early retirement where necessary.

[46] ESIG, 2021