

# SPECIAL EDITION EUROPEAN ENERGY DECARBONISATION

JULY 2022



## ALL EYES ON GERMANY

Welcome to the first of a series of Special Editions on low carbon solutions for the energy transition. The first two focus on energy; this a higher-level exploration of the European energy system, the next a deep dive on long duration energy storage. These will be followed by an edition on decarbonising heat, and then one on transport.

In this first edition we take a look around Europe at the differing strategies being drawn up to transition to a Net Zero energy system, many catalysed by the global energy crisis and Russia's invasion of Ukraine. We ground this analysis with a deep dive into the specific case of Germany.

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# THE LOGIC OF THE ENERGY TRANSITION AND THE LAWS OF THERMODYNAMICS

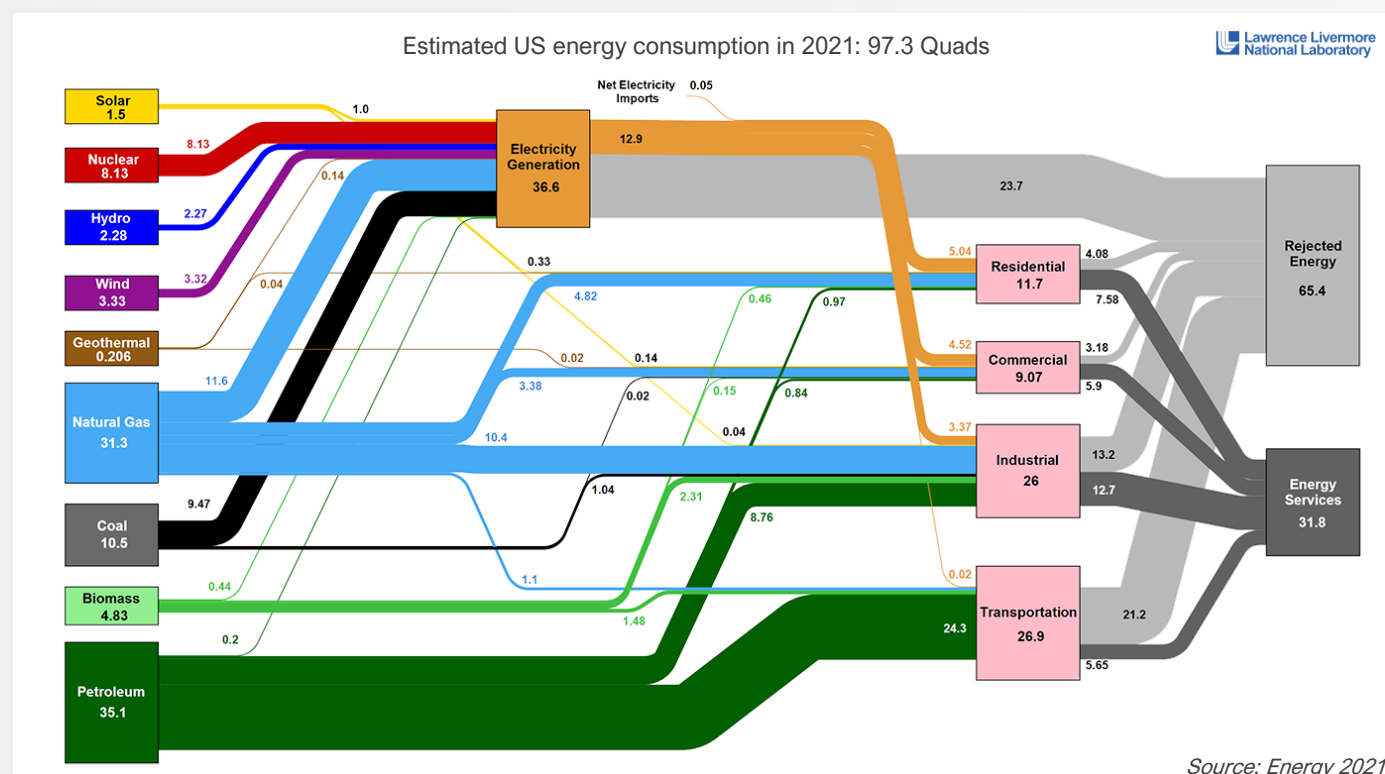
We will be publishing a Special Edition series on the low carbon solutions for the energy transition. We start with how to decarbonize electricity, which includes a deeper dive on the long duration energy storage solutions necessary to firm intermittent renewables, followed by the electrification of heat and lastly of transportation. Our hypothesis is that, assuming fossil fuel commodities remain at current levels and key renewable technologies (solar panels, wind turbines, batteries and electrolyzers) continue to fall in price, then alternative low emission solutions (from renewable energy to long duration energy storage, and heat pumps to electric vehicles) will become increasingly price competitive. Consequently, accelerating the adoption of deflationary, safe, decarbonizing solutions make the energy transition a rational decision. Here we also want to highlight a common reason for the favourable price comparison between business-as-usual high emissions technologies and their low carbon alternatives: the level of 'rejected energy' across the high emission processes. Across electricity, transportation and heat (and therefore, indirectly, buildings) we don't believe it is talked about enough that the laws of thermodynamics make fossil fuel-based solutions extremely inefficient.

Physics tells us that energy cannot be created or destroyed, only transformed. Mechanical energy is used to do work, while thermal energy can heat an object or space, can be transformed to electrical energy, or it can also be stored as potential or chemical energy.

Rejected energy is the portion of energy that goes into a process (to generate electricity and heat, or combusted in engines for transportation) but comes out as wasted heat.

Our global power industry was built around large, centralized power stations, mostly coal and natural gas fired. Electricity is brought to users via long, high voltage transmission lines that are connected to substations that lower the voltage and connect to a distribution network. The U.S. electric power grid, for example, is the world's largest machine. Scale is needed for the very capital-intensive projects to achieve returns which usually happen in the long term. This complex machine is based on large scale power plants, and the reality of these installations is that much of the energy content of fuel sources like coal, diesel or natural gas are wasted by inefficiencies in the conversion of energy and losses in the transmission and distribution processes. What is the size of the overall rejected energy?

The Lawrence Livermore National Laboratory has been estimating the sources of energy production in the U.S. and how much waste exists since the mid-1970s. Their most recent estimate is for 2021 (image below), when 97.3 quadrillion British thermal units (BTUs) were consumed for overall energy needs, of which 65.4 quadrillion BTUs were wasted. In other words, out of the U.S.'s total energy needs, 67% was rejected energy, mostly lost as waste heat.



Source: *Energy 2021*

For electricity generation in particular, 36.6 quadrillion BTUs were needed, of which 65% was wasted as rejected energy. Therefore, when we talk about Germany replacing Russian fossil fuel commodities with renewable energy, the daunting goal becomes more achievable when taking into account that

the vast majority of the natural gas imported from Russia goes to waste. As Michael Barnard summarized in a [recent article](#), "we don't have to replace all the primary energy we use today, we have to replace the energy used productively."

## GERMANY, LCOE AND FIRING RENEWABLE ENERGY

Rather than a theoretical discussion on how adoption could unfold, we want to focus on likely pathways for the countries that are accelerating the energy transition. That is why in this report we look at Europe and the differing strategies being drawn up to transition to a Net Zero energy system, many catalysed by the global energy crisis and Russia's invasion of Ukraine. We follow this with a deep dive into the specific case of Germany. Similarly, we want to compare the cost of operating a fossil fuel based grid, including the expensive Rejected Energy, with a grid that is predominantly green, including the cost to build long duration clean energy storage.

Why Germany? In April 2022, the German government announced that it would bring forward its target for reaching a fully renewable grid from 2050 to 2035, a 15-year acceleration of their energy transition. The catalyst for this move, Vladimir Putin, was perhaps an unlikely candidate, but the sands have been shifting ever since 2011 when Angela Merkel pledged a nuclear phase out by 2022. This move was cemented when the green party won a historic place in the governing coalition at the 2021 election.

On the 6th of April, the German coalition government passed a raft of policy measures to support the headline announcement. This new legislation encompasses a Renewable Energy Act, an offshore wind law, an energy industry law and new rules to expedite the development of the transmission grid. The core item in the "Easter Package" was the principle that the use of renewables is of 'overriding public interest', and thus takes priority over other matters until carbon neutrality is achieved. It is hoped that this will remove hurdles such as local opposition, lengthy planning procedures, or conflicts with other strategic goals. In a similar vein, the package includes changes to grid rules

which allow for a faster permitting process. More specifically, the plan is to dedicate 2% of land area to renewables. The package was sent to parliament and it was approved in early July. Germany thus presents a unique test run for the raft of countries pledging to reach fully renewable grids and being the 4<sup>th</sup> largest economy on the planet, their energy transition will represent a material permanent cut in the demand for fossil fuels.

The case study is also a very welcome one for us at iClima. For months we have been researching the constituent parts of a fully renewable grid, in order to ascertain the volume of investment needed in each technology, and the policy support that could encourage that to happen. We have been particularly intrigued by the case of long duration energy storage, which is vital if a grid based on intermittent renewable energy (RE) sources is to sufficiently support demand.

As we dive into the case of Germany, our aim is to understand what such a grid looks like in practice, and the likely path of investments that Germany will need to make. In particular, we are interested in the level of renewable energy penetration that will trigger the need for long duration energy storage (LDES) and, crucially, the overall wholesale electricity price once the grid reaches its 2035 milestone of 100% renewable energy. This requires estimating the levelized cost of energy (LCOE), the levelized cost of storage (LCOS), and transmission costs. As we will show, this proved very difficult, but we are eager to at least capture the direction of travel, and to gain further insight into the cost of a fully renewable grid versus a fossil fuel powered one. For Germany to be in a downward slope electricity price curve it needs to monetize what otherwise would be curtailed renewable energy. We forecast the LCOE in 2035 in Germany at US \$51-77/MWh.

LCOE = (Capex + Opex) / MWh generation  
Note: LCOE is not equal to wholesale electricity prices.



# A PATHWAY FOR THE EU, AS MODELLED BY EMBER: BIGGER, CLEANER, CHEAPER

Before we get into the specific case of Germany, we would like to give context and discuss the overall pathways for the EU member state countries. Germany is accelerating their energy transition to move away from Russian fossil fuel dependency, but the entire block is committed to decarbonization. We summarize the findings of Ember, an UK based energy research group, to highlight the level of investments required, the composition of the clean assets to be developed, and the major milestones along the way . Ember started its operations in 2008, after identifying coal power as Europe’s biggest climate problem. The data driven policy advocacy not for profit group has recently released three scenarios for the EU energy transition, a massive modelling exercise.

In June 2022 Ember modelled and published three scenarios. The results show that Europe can decarbonize its power supply, grow its electricity generation capacity and reduce the overall cost of electricity, all while adding stability to its economies by not being subject to fossil fuel volatility. The decline in electricity costs takes place in all of the three cases modelled. The transition case is of course based on the accelerating development rates of solar, onshore wind and offshore wind. In the least-cost case, solar + wind will provide 70-80% of all electricity generation in 2035, with solar + wind growing 4 times by 2025. From 2025 to 2035 ca 165 GW of S+W to be added(vis a vis the 24

GW annual additions recorded between 2010 and 2020). In the least cost case the installed capacity of wind quadruples to 800 GW by 2035 while solar grows 5 to 9 fold, between 800GW and 1,400GW.

In all cases modelled by Ember interconnection across countries increases, coal is phased out, European’s fossil fuel consumption decreases materially and a green hydrogen economy develops. The three cases are summarized below:

- **Stated Policy:** Energy system evolving in line with existing government plans until 2035;
- **Technology Driven:** A medium ambition pathway, in line with Paris Agreement 1.5C reaching Net Zero by 2050;
- **System Change:** The highest ambition case, also in line with Paris Agreement 1.5C but reaching Net Zero by 2040;

Solar + Wind becomes the predominant source of electricity supply for Europe in each pathway. The difference in each case is the speed at which the key renewable energy sources are developed. In 2019 S+W represented 17% of electricity generated across the EU, in the Stated Policy S+W would reach 52% in 2035, while in the Technology Driven the two technologies would generate 68% and, in the System Change they would produce 78%. The table below shows the key outcomes in each of the cases:

## Summary of three cases modelled by Ember – figures as of 2035, for EU27

	Stated Policy (SP)	Technology Driven (TD)	System Change (SC)
Power Generation (in TWh)	3,823	5,047	5,454
Generation Mix	86% clean 52% S&W 14% FF	94% clean 68% S&W 6% FF	96% clean 78% S&W 4% FF
Onshore Wind (GW)	369	584	632
Offshore Wind (GW)	142	200	213
Solar (GW)	530	802	1,424
Nuclear (GW)	90	62	21
Electrolysers (GW)	84	192	415
Green H2 Production (TWh)	109	480	920
Battery Storage (GWh)	148	246	842
Unabated Gas (GW)	310	228	118

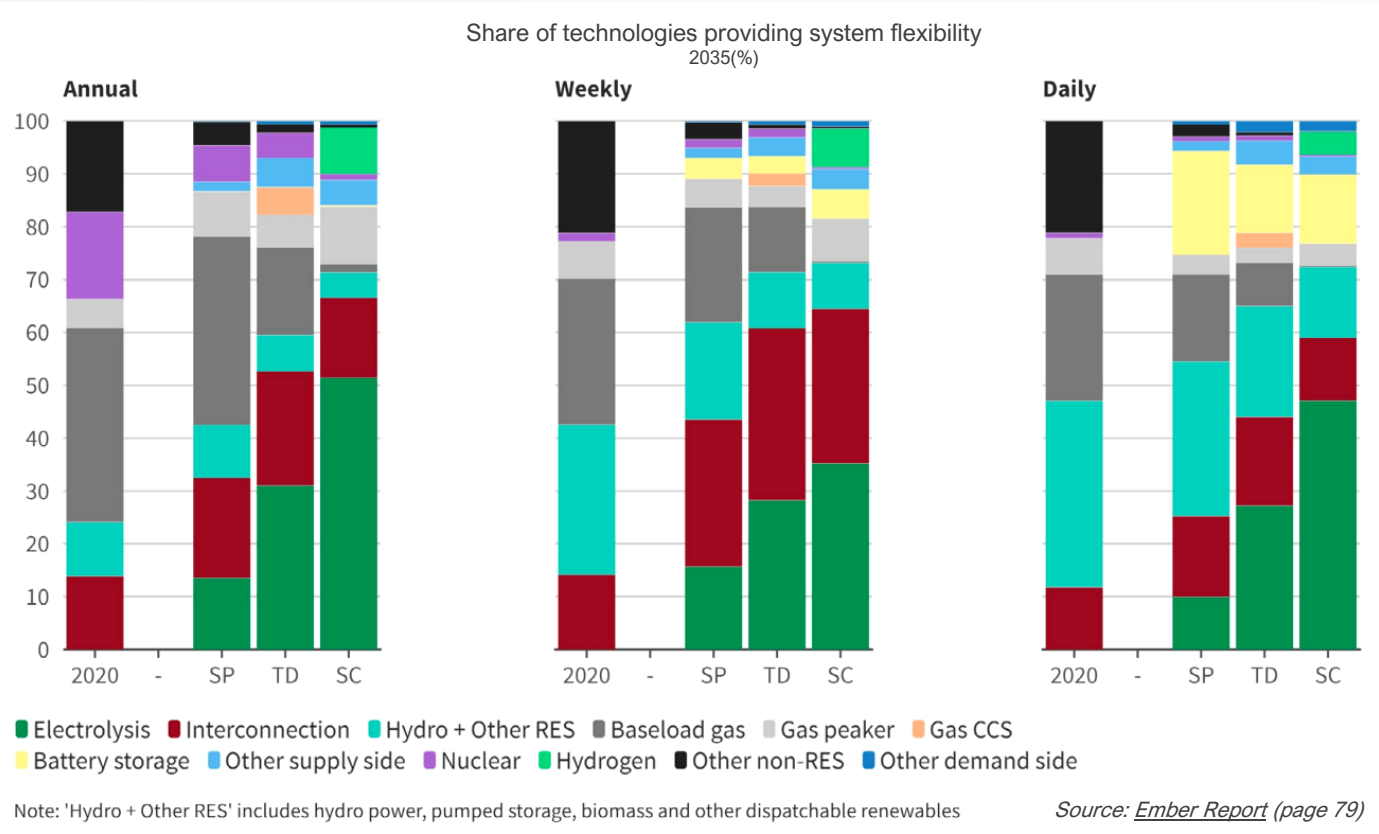
Note: Battery storage in the table above refers to GWh/day

There are a few key points to summarize, as they are critical elements of how the new clean capacity is to be added while retiring the high emission assets:

- **Coal capacity:** Total coal capacity in the EU was 140 GW in 2020 (according to [Europe Beyond Coal](#) Germany commissioned a new coal plant in 2020, followed by Poland and Greece in 2022). In the Technology Driven pathway coal shrinks to 28 GW by 2030 and in the System Change it is completely phased out. In the Stated Policy some new coal takes place in the Western Balkans but coal capacity is still reduced by 75% by 2035, so coal energy capacity reaches 35GW;
- **Electrification of heat and transport:** Ember forecasts new electricity needs from the electrification of transport and heat to total 660 TWh by 2030 (18% of demand) in System Change, while representing 420 TWh (11% of demand) in the technology driven case
- **Nuclear does not compete:** The size of the nuclear fleet in 2020 was 121 GW and is reduced according to decommissioning plans of the different member states and no new nuclear capacity is assumed because nuclear is just not price competitive with renewables + LDES;
- **Hydrogen turbines:** Are assumed from 2030 onwards, and in all three pathways are assumed to operate as peaking facilities, at capacity factors that range from 7% to 15% in 2040;

## LDES to come from different solutions:

Material differences in use of FF in the Cross Stated Policy (SP), Technology Driven (TD) and System Change (SC)

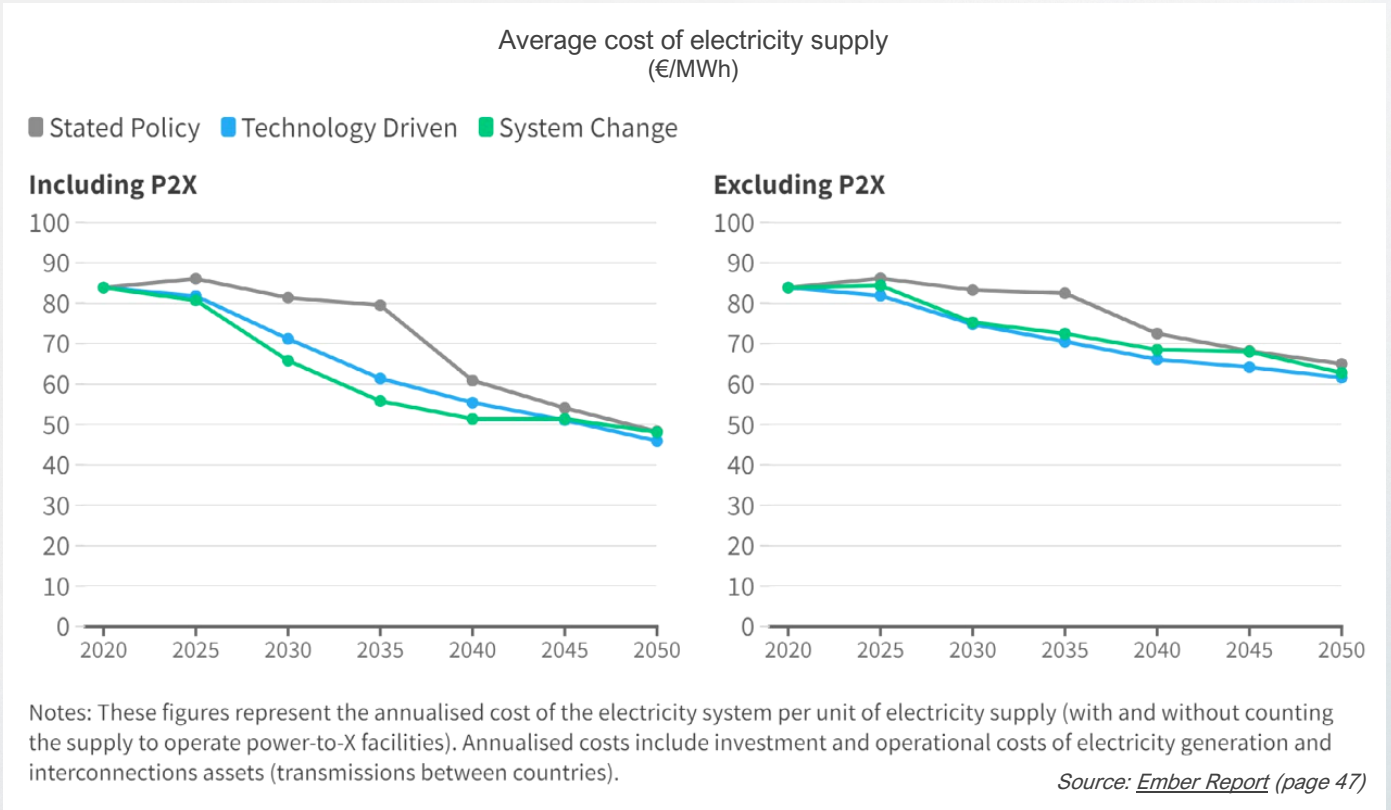




In Ember’s model, the total systems cost of creating 2035’s grid includes operational and investment costs relating to electricity supply and additional transmission (including interconnections), as well as costs related to hydrogen supply and the additional electrification of industry, transport and buildings. In the Stated Policy case the overall investment required would be ca. €8.1 trillion, while in the Technology Driven case it drops to €7.6 trillion and to €7.1 trillion in the System Change pathway. The fact that the overall cost is lower in the most aggressive case may seem counterintuitive, but it is because in the Stated Policy case fossil fuel utilization is prolonged and expensive nuclear assets continue to operate, limiting the deployment of price competitive solar and wind.

Lastly, we come to a crucial point of this exercise: the forecast for the overall cost of energy from 2030-2050 in the three pathways that ember has modelled’. We would like to emphasize Ember’s results: in all pathways the average electricity costs decline as inexpensive wind and solar progressively dominates the system. When including the cost to run electrolyzers to create green hydrogen for clean energy storage purposes, which ember refers to one application of “P2X”, the average cost of electricity across the EU27 countries drops from €80/MWh in 2022 to ca. €50/MWh. The noticeable discrepancy across the three cases would take place around 2035 as the cost to run the P2X would drive the overall cost of electricity 23% to 30% below the Stated Policy case.

Electricity can become cheaper in a decarbonized and expanded EU grid





# GERMANY'S ELECTRICITY MIX:

## THE ACCELERATED DEPLOYMENT OF S+W CAPACITY FROM 2021-30 AND RAMPING UP OF LDES TO REACH A GREEN GRID BY 2035

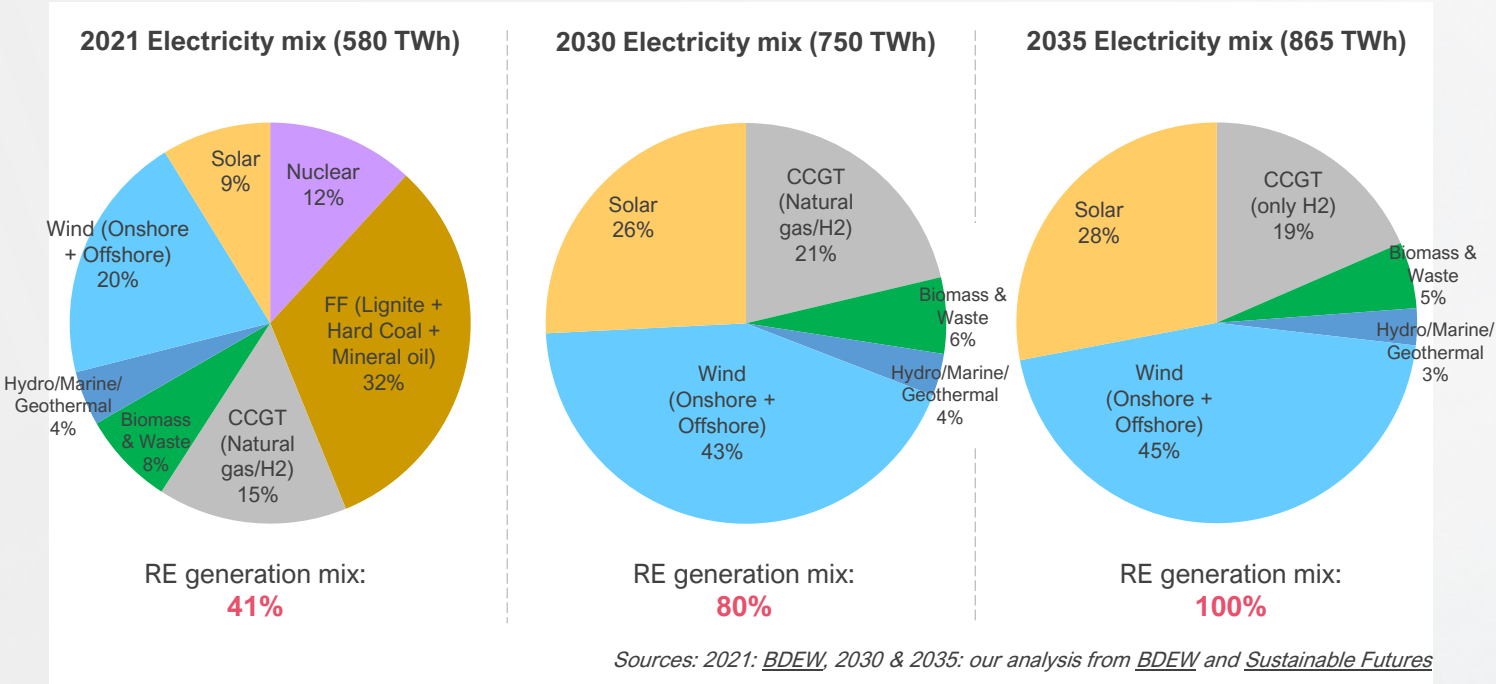
Here, we zoom in on Germany. According to Clean Energy Wire, Germany's installed electricity generation capacity in 2021 was 223 GW, of which 136 GW was renewable energy. Despite therefore representing 61% of total installed capacity, only 41% of total demand (around 580 TWh) was actually met by these renewable sources because of their lower capacity factor. Capacity factor is the proportion of theoretical energy capacity that is actually produced. Wind and solar have lower capacity factors compared to, say, nuclear and coal, because of the simple fact that the wind doesn't always blow and the sun doesn't always shine.

So where is Germany right now, as it accelerates its energy transition? As the graph below shows, wind and solar still met almost

30% of Germany's total electricity demand in 2021. If taking into account biomass and hydro, renewable sources accounted for 41% of the electricity produced. In 1Q22 that figure has increased due to favourable weather conditions. The Federal Association of Energy and Water Industries ([BDEW](#)) reported the share of renewable energy in relation to gross electricity consumption reached 50% in the first quarter of the year. Electricity consumption of 146.5 TWh was met by onshore wind (25%), biomass (9%), offshore wind (5%), solar PV (6%) and hydropower (3%).

The German coalition government target is **80% renewable electricity by 2030** and a **Net Zero power sector by 2035**

Germany electricity sources, 2021, 2030 and 2035



The key question becomes how will Germany jump from the current 50% renewable penetration to 80% by 2030 and a completely green grid by 2035? Germany as a nation has had a strong anti-nuclear movement for decades, and in 2011 - in the wake of the Fukushima nuclear disaster - Chancellor Merkel announced the closing of all remaining nuclear plants. Germany joins Italy and Ireland who have already banned nuclear energy, while Switzerland and Spain have committed to no new facilities. These countries are at odds with other European powers such as France and England and present a fascinating case study into the potential of wind and solar,

which will be the main resources used to drive them towards a zero-carbon economy. By 2025 it is estimated that over a third of the EU's current operational nuclear reactors will need to be shut down, Germany's pathway will be a crucial reference for the replacement of the dated nuclear sites. At iClima, we do not see the need for nuclear to play a role in any future energy mix with its long lead time and excessive costs making Germany, once again, the perfect example.

## SPECIFIC PLANS FOR POWER, HEAT, TRANSPORTATION & INDUSTRY

The government has outlined some details of its strategy, which are summarised in the picture below. Gross electricity consumption is expected to reach 690-750 TWh by 2030, 80% of which will be met by renewable energy. The path ahead is a dual track of acceleration of the development of the key solutions, from solar and wind to EV adoption

and charging network to the key piece of the puzzle – long duration clean energy storage predicated on the roll out of green hydrogen infrastructure. In parallel there is the process of decommissioning and shutting down fossil fuel related assets – coal fired power plants and natural gas ones, but also nuclear assets.

### Key initiatives and targets – Germany by 2030

Power 2022 Coalition treaty

**80% Clean Electricity by 2030**

- 200 GW solar roof on every new building (mandatory)
- 98-124 GW onshore wind (secure 2% land)
- 30 GW offshore windfarm (40-75GW by 2035-2045)
- Municipalities earn revenue of RES in their territories
- All nuclear power plants to decommission in 2022
- Coal-fired power plants phasing out by in 2030

**No Natural gas in power generation by 2045**

**15 million Zero emission Vehicles by 2030**

- 1 million charging points publicly available (2021: 44,000 points)

**75% of the rail network will be electrified (2021: 61%)**

**50% of Heat shall be produced climate neutrally by 2030**

**10 GW Hydrogen production capacity : Leading market for hydrogen technologies**

- Financial support for hydrogen grid infrastructure and domestic production of green hydrogen
- Acknowledge the need of hydrogen imports to foster the market ramp-up of hydrogen

**Companies have to pay at least 60 EUR/ton of CO2 under the European emission trading system (EU-ETS) No new license of O&G Exploration and Production by 2030**

**Storage Solutions**

- Li-ion BESS for response
- New CCGT (which able to convert to H2 once ready) to replace coal-fired and nuclear for reserve

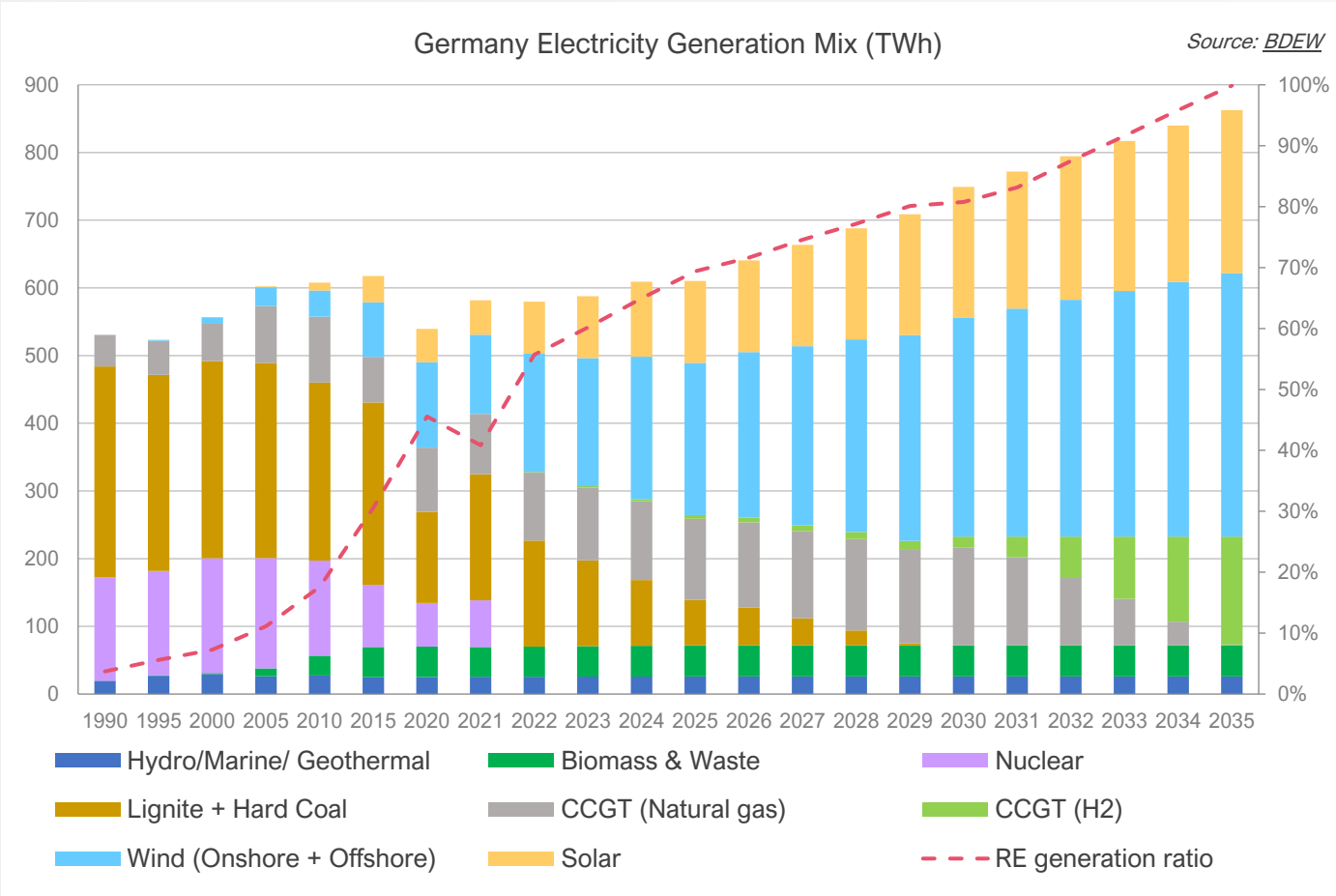
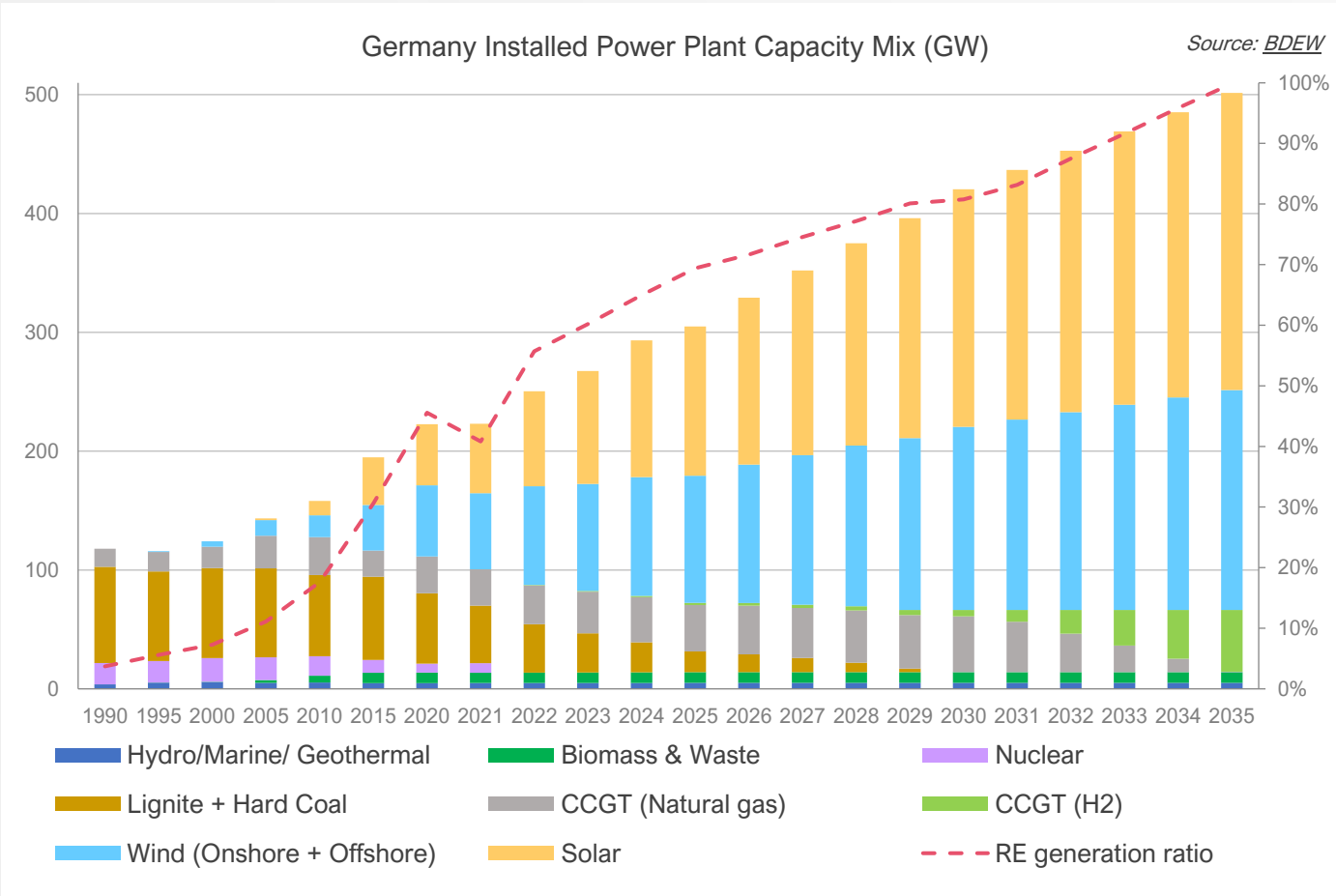
Reference: Linklaters



THE PATH TO A GREEN GRID FOR GERMANY  
120 GW OF NEW WIND + 192 GW OF NEW SOLAR TO 2035

In terms of additional installed capacity for wind (onshore and offshore) and solar, the key numbers are as follows: Germany is to jump from 64 GW of wind (both forms) in 2021 to 83 GW by end of 2022, to 154 GW by 2030 and finally 185 GW by 2035.

In terms of solar, figures would be 58 GW in 2021 to 80 GW by year end 2022, to 200 GW by end of 2030 finally reaching 250 GW by 2035. The tables below summarize the overall electricity mix in terms of capacity and electricity generated.



PROBLEMS WITH INCREASING THE PERCENTAGE  
OF RENEWABLE ENERGY IN THE GRID

While fossil fuels suffer from major conversion losses, it is not all plane sailing for renewables either. Solar and wind are both intermittent and unpredictable. This has a number of consequences for stakeholders in the energy system:

**System operators:** When highly variable renewable energy supply sources are added to the grid, it can cause a mismatch between supply and demand in certain periods, which causes electricity generation frequency to leave the acceptable range. If it does so, operators must shut down the system to avoid damage to downstream residential appliances. This means more peaking plants are required to pick up excess demand. Additionally, network reinforcement can be required to stabilise voltage and frequency in the transmission system, which can jump around with renewable sources.

**Generators:** As the percentage of energy generated from renewable sources increases, capacity factors fall for both existing renewable energy and fossil-fuel based assets. In order to have the spare capacity to step in when the wind doesn't blow or the sun doesn't shine and supply falls below demand, fossil fuel power stations have to run at part-load. Thermal power plants are designed to operate at full load, so when they don't, their efficiency falls, reducing their capacity factor. Additionally, each unit of energy produced is subsequently more emissions intensive. On the chance that demand is lower than supply, renewable sources will be curtailed first in order to maintain a grid frequency of 50Hz, because fossil fuel power plants have higher marginal costs than solar and wind. This results in a lower capacity factor for renewable sources as well.

HOW CAN WE OVERCOME THESE PROBLEMS OF INTERMITTENCY?

There are four major solutions that can provide the necessary flexibility in generation: dispatchable generation, interconnection, demand side response and energy storage systems. Each one has pros and cons as per the following table:

Technologies	Concept	Pros	Cons
Dispatchable Generation	Steam turbine generator, combined cycle or open cycle gas turbine generator and hydro turbine generator	<ul style="list-style-type: none"><li>Very fast response to load</li></ul>	Contradicting climate goals: high emissions/kWh
Demand Side Response (DSR)	Shift customer demand to match available supply	<ul style="list-style-type: none"><li>Less CAPEX</li><li>No energy loss as with ESS</li></ul>	Can be politically challenging: often relies on individual behaviour
Interconnection with smart network	Receiving renewable energy supply from other countries or regions where supply is more plentiful	<ul style="list-style-type: none"><li>Make optimal use of physical resources</li><li>No energy loss as with ESS</li></ul>	Geopolitics: energy security Multi-stakeholder Very high CAPEX
Energy Storage System (ESS)	5 main ESS technologies Store the excess and supply when needed. Makes variable sources dispatchable	<ul style="list-style-type: none"><li>Many applications including reducing transmission costs</li><li>LCOS declining</li></ul>	Lower round-trip efficiency (energy loss during charge and discharge)

**Dispatchable generation:**  
Uncontrollable generation powered by the sun and the wind is not dispatchable, and therefore is not able to meet fluctuating real time demand cycles. Dispatchable generation capacity could be added through diversified sources such as gas, biomass, or hydroelectric. Depending on the source chosen, however, this is likely to lead to higher emissions than the other solutions, and could contradict the goal of a zero carbon grid. In Germany’s case, the government plans to increase gas power generation by 50%, from 90 TWh in 2020 to 120-150 TWh in 2030 to replace the coal and nuclear plants that are being phased out to maintain grid flexibility;

**Demand Side Response (DSR):**  
Shifting and distributing the peak demand for EVs, smart home heaters, appliances etc to match the availability of renewable supply has also been considered. However, this solution lowers flexibility in operation because of the uncertainty of renewable energy supply sources and requires carefully constructed policy to change consumer behaviour. Politicians have thus far been wary of demand side response, particularly in the US and UK, where there is often a sense that such policies are an overreach of government, infringing on individual liberties;

**Interconnection and Smart grid:**  
Another option is expanding the interlinkages

HOW MUCH CLEAN ENERGY STORAGE WILL GERMANY NEED AND HOW MUCH WILL IT COST?

Answering this question is not a simple exercise. In the graph below the left axis shows the volume of clean energy that will need to be stored, in TWh. As the grid becomes more than 50% green (as depicted in the red line) the need for short duration (few hours), cross day and seasonal storage materially increases. In 2026, when the grid becomes more than 70% renewable energy based, the seasonal storage will need to be in

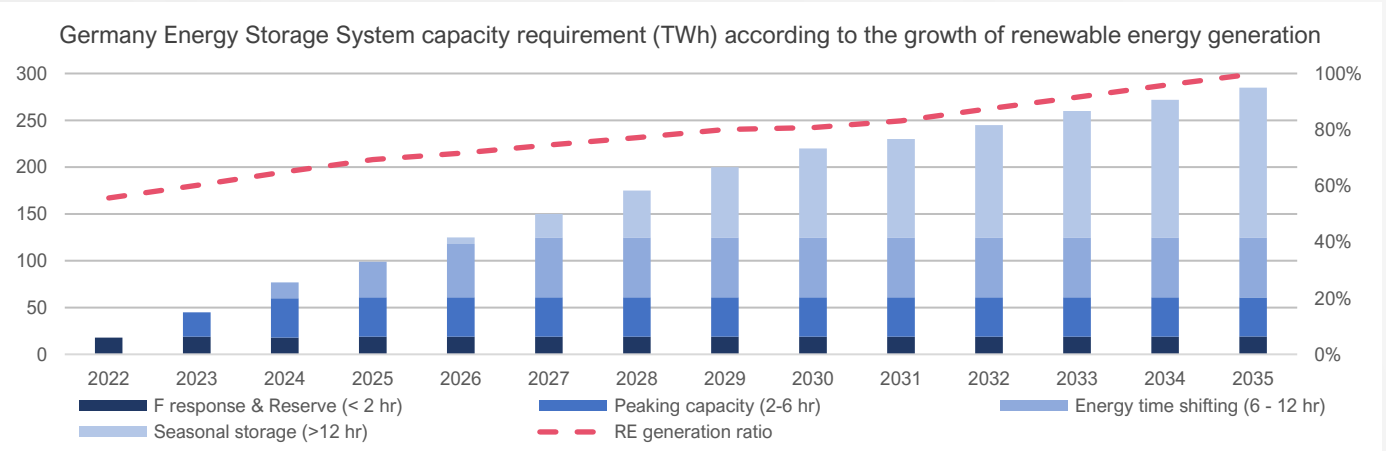
of cable supply to connect areas with high volumes of renewable energy supply to areas of high demand. With an intelligent control system needed to balance supply and demand at a regional scale, such projects have been costed at billions of dollars and require the government to support infrastructure investment. Even still, geopolitics might be the main barrier to connectivity, particularly at an international scale. As we have seen during Russia’s invasion of Ukraine, energy security is a major global concern, and countries will deliberate carefully over whether they want to enter into arrangements that will see them reliant on others for this security;

**Energy Storage Systems (ESS):**  
This solution can increase system flexibility by storing excess energy during periods of high generation and low demand, then dispatching power to the grid during the dominant demand period. This will be an important solution, and there are many options (outlined later) for different applications, however each risks lowering energy efficiency due to losses during charging, storing and discharging;

**Overall, energy storage systems (ESS) are the most obvious choice for overcoming renewable energy intermittency, paired, where politically possible, with targeted demand side response.** It is the solution that we dive into in next month’s special edition.

place. iClima estimates that in 2030 ca. 220 TWh of storage, representing almost 30% of the electricity demand in Germany will need to be in place. This energy storage capacity estimation for Germany is based on the energy balance without interconnections and demand side response. A ca. 32% of total generation as storage is similar to what Ember modelled for the EU27 (ca. 33%).

Building up LDES is a pre-requisite for Germany to get to over 70% RE grid



Source & References: Flexible to inflexible generation ratio at 60:40. We allocate the ESS capacity requirement for each application based on the % allocation from NREL report

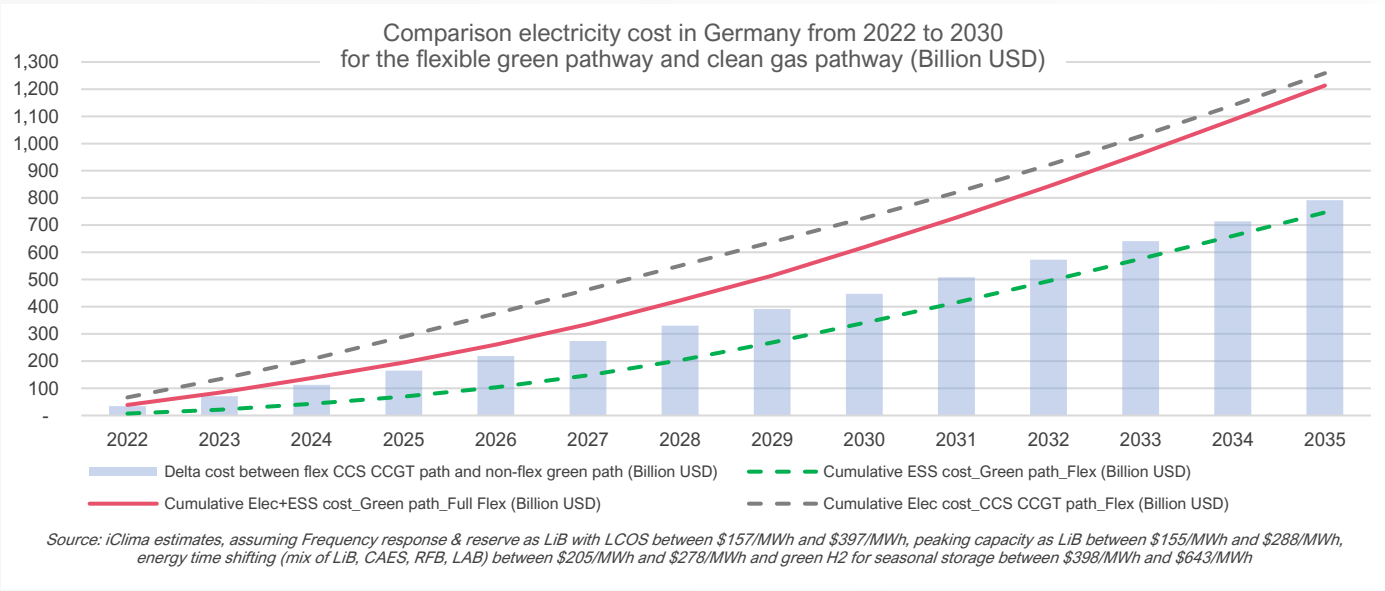
Equally complex to determine is the cost required to build up all the LDES necessary to make all the intermittent energy that Germany will be adding to its grid dispatchable. The quantification exercise involves not only the estimation of the cost to build the different types of clean energy storage needed, but also a comparison to the alternative of keeping a dated centralized dispatchable fossil fuel-based grid.

In the graph below, the Y-axis represents cumulative electricity costs (it is not a Capex only figure). We compare the cost to run a CCGT (with CCS) dispatchable system (dotted grey line) versus the cost of running

renewable (dotted green line). If grids don't add ESS as S+W increases, the capacity factor for the renewable assets would decrease, because of higher curtailment. The bars represent the difference in cost between the flexible but fossil fuel based grid and the inflexible (i.e. non dispatchable) renewable based capacity, this delta being the amount the German electricity mix would be able to spend towards LDES.

As we show, we expect a green grid, complete with the necessary LDES (solid red line) to solve the problem of intermittency, to be more competitive than the CCGT alternative.

Over €1 trillion investments needed to build LDES by 2035, but overall cost still below the natural gas CCGT based alternative



Source: iClima estimates, assuming Frequency response & reserve as LiB with LCOS between \$157/MWh and \$397/MWh, peaking capacity as LiB between \$155/MWh and \$288/MWh, energy time shifting (mix of LiB, CAES, RFB, LAB) between \$205/MWh and \$278/MWh and green H2 for seasonal storage between \$398/MWh and \$643/MWh

IN CONCLUSION: ALL EYES ON GERMANY

Empowered by the motivation to solve its “trilemma” of how to decarbonize its grid while providing affordable energy and security of supply, Germany is on the right path to solve the conundrum. As we saw, Ember’s technology driven case forecasts the EU block reaching 802 GW of solar PV by 2035 and 784 GW of wind (both onshore and offshore) installed capacity by 2035. Germany may be able to reach 250 GW of solar and 185 GW of wind in the same time frame, but unlike the EU27, Germany would be a 100% green based grid. That security of supply and zero emission grid does not come at the expense of higher cost, quite the opposite even with all the LDES required to solve the RE intermittency, the overall cost of electricity may still be below the fossil fuel based alternative when considering natural gas at \$100/MWh.

For Germany to surpass 75% S+W electricity generation while decommissioning coal fired plants it must build up ESS, to start operating as early as 2026. This is a potential case of a self fulfilling prophecy as H2 is seen as the chosen cross seasonal solution, becoming more price competitive the more we build GH2 storage. The pace of increase from 1 month to potentially 2 months of storage will depend on the actual way that demand shifts, with EVs and heat pumps adding to demand, vis-a-vis the amount of inflexible electricity supply in the grid.

What needs to happen for investors to stop discounting the fast energy transition case of Germany? We believe that this will happen when 10GW of new capacity is added to the grid in a 12 month period and when the ramp up of storage becomes clear and visible.

All eyes on Germany.

This report was a team exercise but the modelling efforts by Chanwith Buntoengpesuchsakul were instrumental in particular for the detailed case of Germany.