The following is a redacted version of the original report. See inside for details.

European Utilities: The Power Shift

Electrify Everything

By 2050, the EU targets reducing greenhouse gas emissions (GHG) 80% to 95% compared to 1990 levels, implying nearly full decarbonisation of the economy. With about three-quarters of this effort still to go (and not insignificant challenges ahead), we see electrification as the most effective route to achieve this objective. The process has already started in power generation – the largest contributor of GHG – where substituting fossil fuel with wind and solar would almost fully "clean up" the power system. At that stage, the generating capacity could be scaled up so that more industries could be electrified (transport, buildings, manufacturing, etc.), offering the potential for the near-complete elimination of fossil fuel power plants, extinction of combustion engines, major upgrades to buildings, a major reduction in oil & gas consumption and overhauls in manufacturing practices. Besides helping the climate, the process could also bring tangible benefits for Europe, which include a potential boost to GDP, more predictable (and lower) energy bills and higher energy self-sufficiency.

Alberto Gandolfi
+44 20 7552-2539
alberto.gandolfi@gs.com
Goldman Sachs International

Ajay Patel
+44 20 7552-1168
ajay.patel@gs.com
Goldman Sachs International

Manuel Losa
+44 20 7774-8817
manuel.losa@gs.com
Goldman Sachs International

Baptiste Cota
+44 20 7774-0042
baptiste.x.cota@gs.com
Goldman Sachs International

Matteo Rodolfo
+44 20 7051-8860
matteo.rodolfo@gs.com
Goldman Sachs International

Pragna Kataria, CFA
+1 212 934-6393
pragna.kataria@gs.com
Goldman Sachs India SPL

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The Goldman Sachs Group, Inc.

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Note: The following is a redacted version of "European Utilities: The Power Shift: Electrify Everything" originally published March 21, 2019 [61pgs]. All company references in this note are for illustrative purposes only and should not be interpreted as investment recommendations.

Europe's **Electrification** in Numbers

80% - 95%

greenhouse gas emissions reduction under the EU's long-term strategy.

90%

of power generation will need to come from renewables and flexible storage.

100%

of internal combustion engines would have to disappear.

80%-90%

of buildings refurbished/replaced by 2050 at the current run-rate, providing an opportunity to significantly reduce emissions.

c.2.9%

the benefits from electrification as a percentage of today's GDP vs only 1.7% in total costs.

c.0%

of European electricity from imported resources vs >50% today, implying a €235bn trade benefit

c.35%-85%

increase in power demand from electrification until 2050.

50%

lower gas demand as a result of electrification and industrial decarbonisation.

4.5%

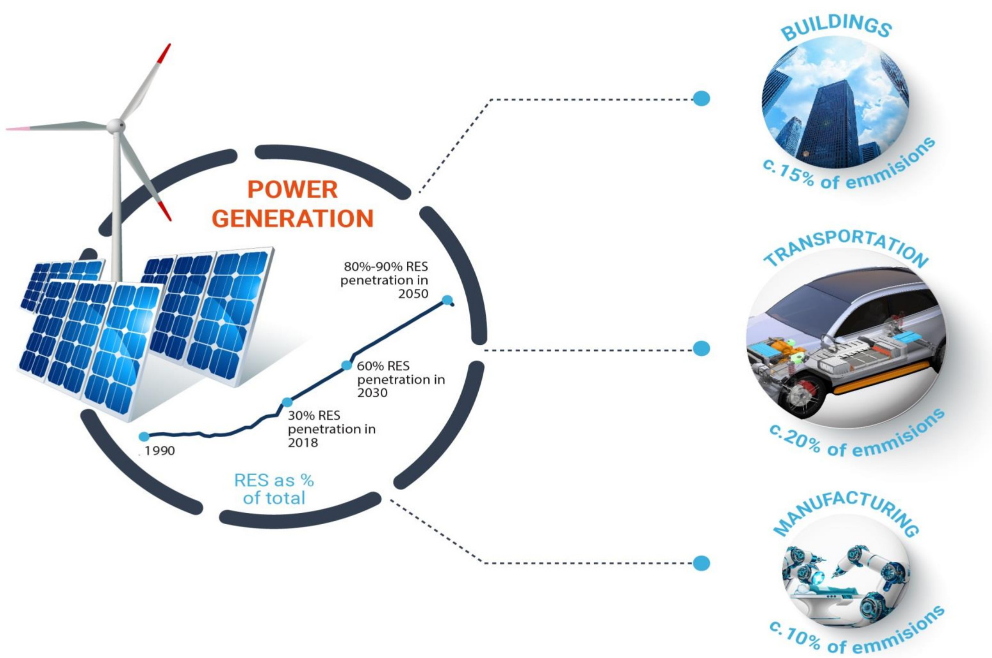
Sustainable EBITDA CAGR for the electrification winners.

Source: Goldman Sachs Global Investment Research

Executive Summary

By 2050, the EU targets a reduction in greenhouse gases (GHG) between 80% and 95% against 1990 levels; if met, this would almost fully decarbonise the European economy. About three-quarters of the objective is still to come, and we see electrification playing a pivotal role in its achievement. In power generation — the main source of emissions, accounting for nearly one-quarter — electrification is already well under way as wind/solar replace fossil fuel in the mix; continuing this process (i.e. c.90% RES) would almost entirely eradicate emissions from the industry. Meanwhile, industry could increasingly rely on electricity to reduce emissions, making electrification a pervasive process across all sectors of the economy: Transport (through the elimination of combustion engines, for example), Buildings (major upgrades on heating/insulation) and Manufacturing (major process redesign). We see electrification bringing several tangible positives, including a potential c.1% boost to GDP, lower emissions, more predictable (and gradually deflating) energy bills and, on our estimates, an incremental positive benefit on the EU's balance of payments, all else equal, through greater energy independence.

Exhibit 1: The combination of renewables and pervasive electrification should allow the European economy to decarbonise



Note: Renewable penetration from 2018 onwards is a GS forecast; shares in total GHG emissions expressed in 2016 data.

Source: Eurostat, Goldman Sachs Global Investment Research

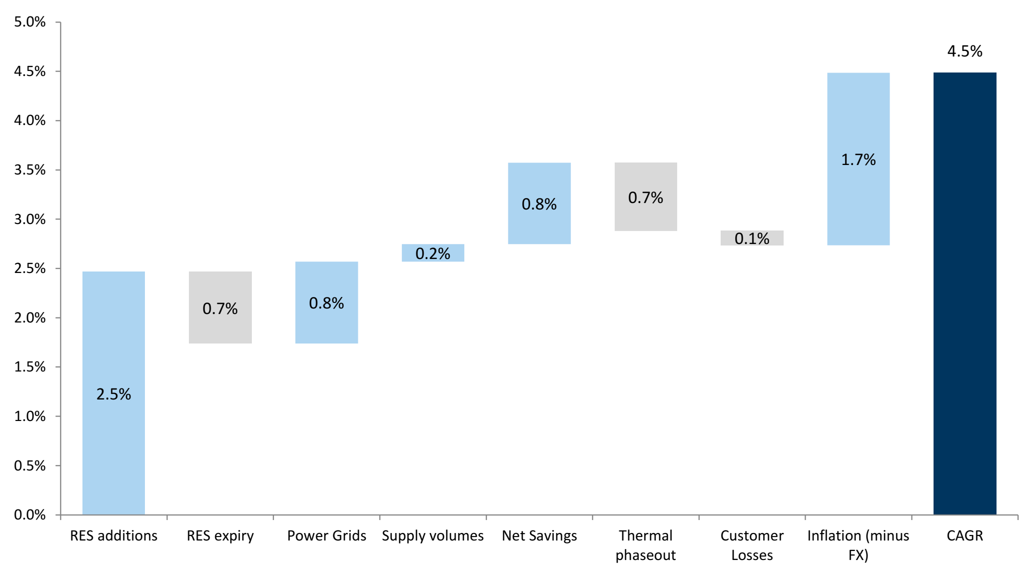
In this report, we address the following questions: (i) What are the main drivers that are encouraging the EU to take a leadership role in climate change? (ii) Could the EU achieve a near-full decarbonisation of its economy, and if so, what would be the main implications? (iii) Could the electrification process be affordable and cost effective?

E-winners vs the disrupted

As about one-quarter of the effort towards meeting the EU 2050 emissions reduction target will fall on power generation, the electrification of Europe could kick start a 'golden era' for some utilities names in our coverage (and disrupt others). Higher investments in renewables and grids, coupled with increased consumption, would upgrade organic growth – we estimate these E-winners could deliver organic EBITDA CAGR of 4.5% to under our electrification scenario. Besides legacy generation, gas supply and gas grids are at risk of disruption, and we estimate that gas consumption in Europe could fall by c.50% through 2050.

Exhibit 2: E-winners to generate a sustainable EBITDA CAGR of 4.5% to 2050E under our electrification scenario

E-winners' EBITDA CAGR to 2019-2050E (nominal) under electrification scenario



Source: Goldman Sachs Global Investment Research

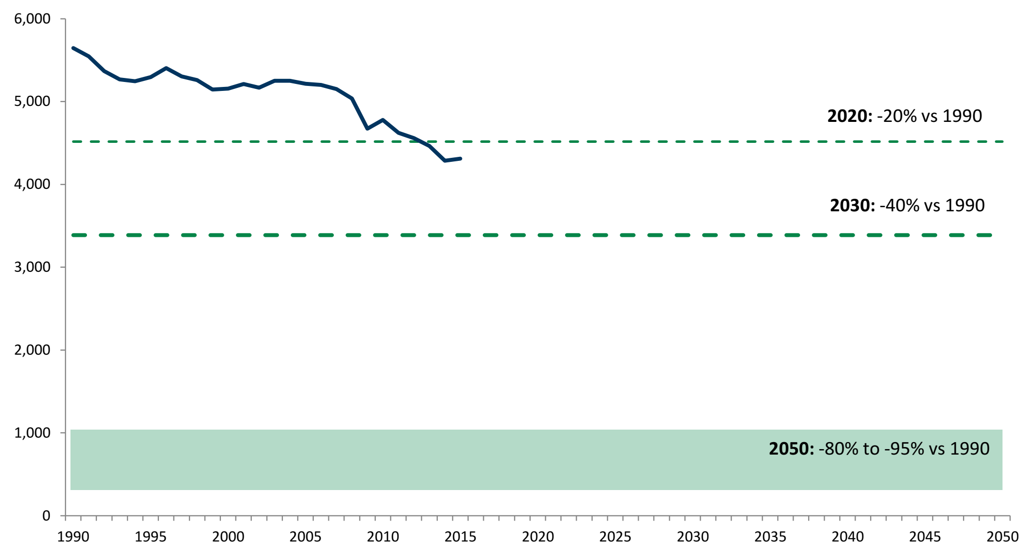
The EU takes leadership on climate change

The EU has put climate change at the core of its agenda for nearly twenty years when it introduced the EU Climate Change Programme (2000) to translate the Kyoto protocol. Since then, GHG emissions have fallen by c.20%, renewables now account for c.30% of power production and the output from coal plants has shrunk by about 35%.

We believe the EU's leadership on climate change is also the function of the lack of natural resources (c.70% of commodities are imported), lower economic growth (it could be harder for developing economies – where power demand is still growing mid to high single digit pa – to give up fossil fuel), the lower share of heavy industries relative to the US or China (it is harder to electrify furnaces for steel companies, for instance) and evidence that renewable generation is already much cheaper than fossil fuel alternatives, as demonstrated by several wind/solar PV auctions in 2018.

The EU has already surpassed its 2020 emissions reduction target of 20% vs 1990 and, appearing well on track to meet its 2030 objective (-40% GHG vs 1990), is proposing an upgrade to this target, to -55%. The faster-than-expected pace in decarbonising the economy is a function of the structural shift in the economy (i.e. lower industrial production and power consumption) and thanks to an unexpected reduction in renewables costs – solar PV and wind LCOEs have fallen by c.85% and c.60%, respectively, since 2010. However, as the long-term energy strategy is 80% to 95% reduction in GHG by 2050, the task of decarbonisation is still at an early stage.

Exhibit 3: EU is ahead on 2020 targets, but mostly thanks to the economic slowdown and RES economics ... there is still a long way to go to 2050
EU GHG emission targets (mt)

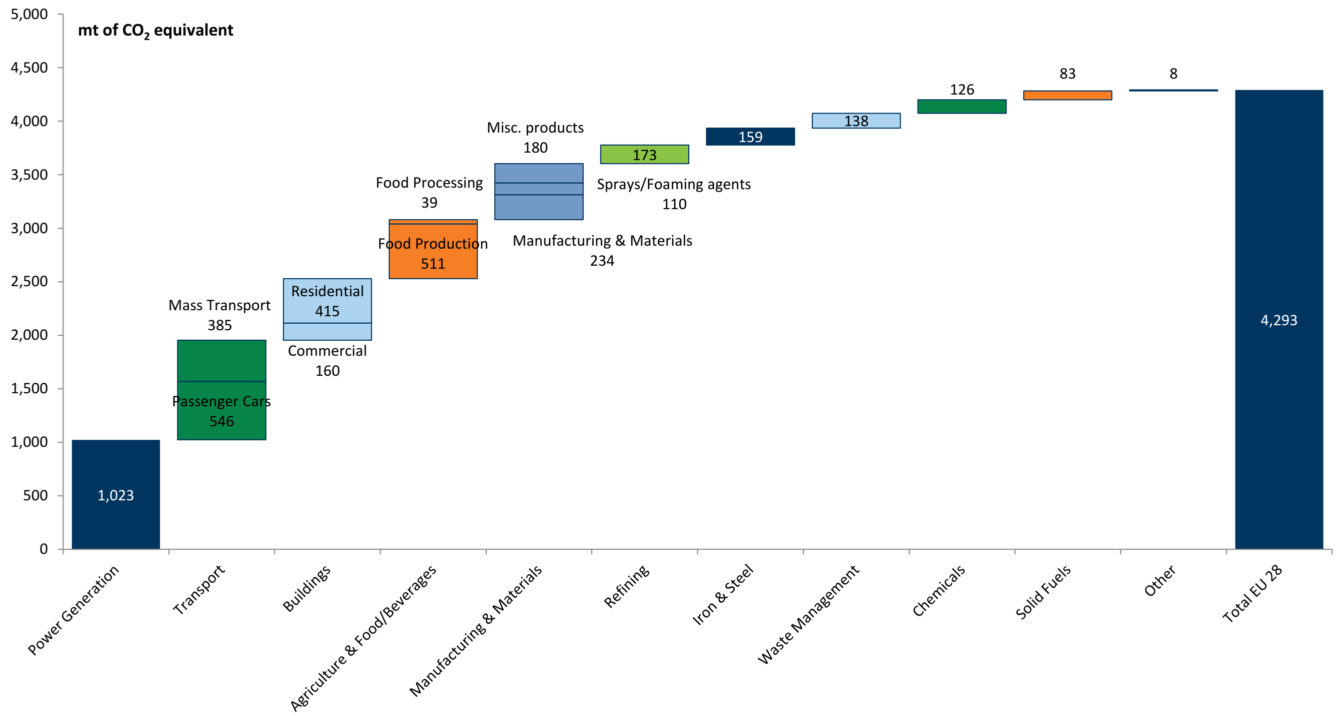


Source: Eurostat

Just a handful of industries in the spotlight

The main sources of emissions are concentrated in seven industries which jointly account for nearly 95% of EU greenhouse gas emissions. Amongst these, power generation, transport and buildings are the largest constituents and in aggregate put out nearly two-thirds of total EU emissions.

Exhibit 4: EU GHG emissions: Seven industries are the main sources
EU28 greenhouse gas emissions (2016)



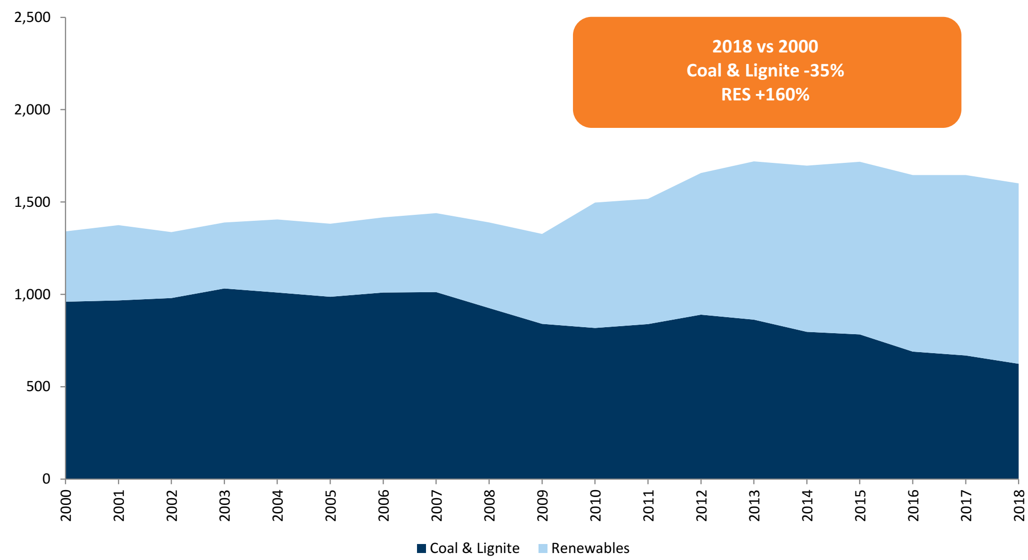
Source: Eurostat, Goldman Sachs Global Investment Research

- **Power generation (c.25% of EU GHG emissions)**. Emissions come from lignite, coal and gas fired power stations. Switching to wind/solar, deploying batteries, investing in electrolysis (hydrogen/fuel cells) and potentially carbon capture sequestration could play a major role in emissions reduction.
- **Transport (c.20%)** emissions are mostly from passenger cars, making e-mobility and hydrogen/fuel cells the primary drivers for reductions.
- **Buildings (c.15%)** account for about 40% of primary energy consumption. Insulation and heat pumps are likely to be most relevant here.
- **Food & agriculture (>10%)** for which fuel combustion and organic emissions are the main contributors. Potential solutions could include levies on certain foods, the electrification of machinery and heat, and capturing fugitive emissions.
- **Manufacturing (c.10%)** where the electrification of processes and energy efficiency could be the main tools to lower emissions.
- **Refining (c.5%)** could reduce its carbon footprint by eliminating fugitive gas emissions as well as by capturing and storing process-related carbon emissions.
- **Iron & steel (<5%)** are heavy energy users, mostly coal and gas for their furnaces. Moving to electric arc furnaces could support a material reduction in GHG, in our view, but the economics of fuel switching remain challenging.

Electrification alone can get us a long way

The decarbonisation of power generation – the largest contributor to emissions in the EU (c.25%) – is already under way: Currently about 30% of production comes from RES (was less than 10% in 2000), and we estimate this could reach 60%-65% by 2030; concurrently, coal production has fallen by c.35% since 2000. Moving away from fossil fuels could almost entirely eliminate carbon emissions from power generation, with c.20%-25% of EU emissions effectively dissipating.

Exhibit 5: Electricity production from coal & lignite has fallen by 35% since 2000
Power output from coal & lignite and renewables (hydro, solar, wind) for EU28 (TWh)

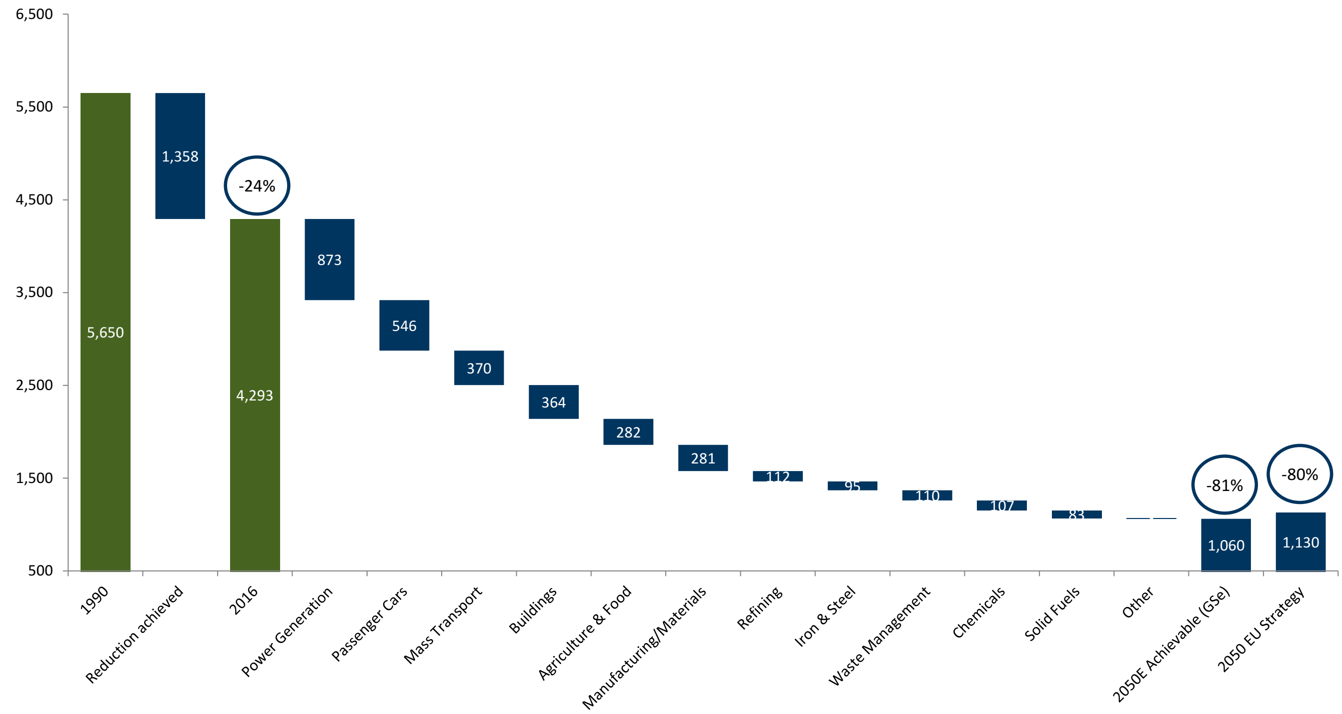


Source: IEA

As this shift takes place over the coming decades, renewables will be able to grow the amount of power we produce with almost no climate impact and at a significantly lower marginal cost, allowing other sectors to increasingly rely on electricity for their processes. We detail how this 'power transfer' could permeate the other major emissions contributors: Transport (combustion engines in the region could virtually disappear), Buildings (major upgrades in insulation and heat pumps (HP)) and Manufacturing (overhauling gas/coal-based processes).

Our analysis suggests that overall electrification could lower GHG by c.80% by 2050E vs 1990, thus attaining the lower end of the EU 2050 energy strategy. We estimate this through a bottom-up approach simulating the decarbonisation potential for each major industry. We primarily focus on the three largest polluters — power generation, transport and buildings, and also highlight anecdotal evidence from several industries (steel furnaces, chemicals, refining, etc.) in which companies are leading the way on the electrification process.

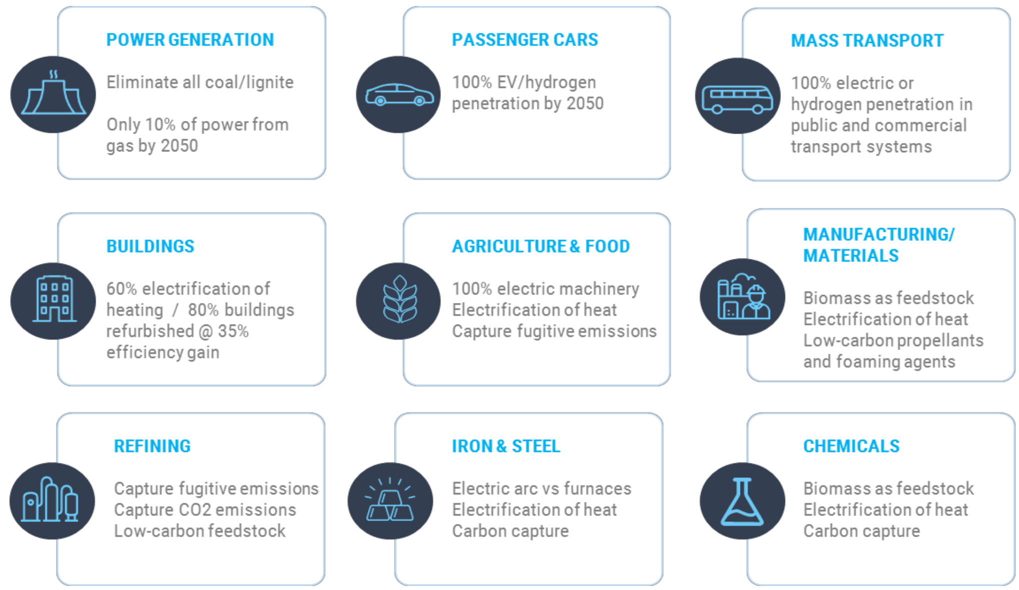
Exhibit 6: Our analysis identifies emission reductions to 2050 that could lead to >80% reductions in emissions vs 1990
EU emissions evolution (mtCO2e) under our electrification analysis



Source: Eurostat, Goldman Sachs Global Investment Research

- **Power generation**. Switching to a RES-based generation mix could eliminate >20% of Europe's GHG emissions. To reach 90% production from renewables by 2050 (the assumption in our electrification analysis, where the remaining 10% is satisfied by gas), we believe the system would also require upgrades in power grids, the deployment of storage (including the hydrogen and battery technologies) and carbon capture sequestration for the few remaining gas power plants.
- **Transport**. Our analysis suggests that to reach the lower end of the EU's 2050 reduction strategy (-80%), combustion engines would have to be fully phased out. This would imply replacing passenger cars and mass transport (buses, trucks, trains) with EVs or hydrogen-based engines.
- **Buildings**. We estimate that policies to support insulation and the roll out of heat pumps (the Netherlands and the UK, for example, are adopting bans on new gas boilers from 2020 and 2025, respectively) could lower emissions from buildings at least 60% by 2050.

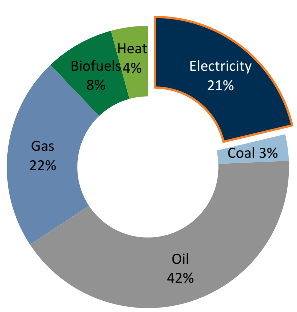
Exhibit 7: Only a few industries to tackle to achieve a major decarbonisation
Electricity specific measures we have simulated in our analysis of achieving the 2050 EU LT Energy Strategy (emissions reduction of 80% to 95% vs 1990)



Source: Goldman Sachs Global Investment Research

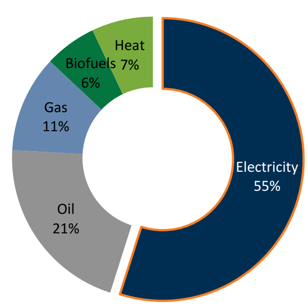
We estimate that electricity could satisfy c.55% of the EU countries' primary energy needs by 2050 compared to c.20% today.

Exhibit 8: Electrification of the European economy is just above 20% at the moment...
Primary energy consumption by source in EU28 (2018)



Source: Eurelectric, Goldman Sachs Global Investment Research

Exhibit 9: ...but we estimate could increase to c.55% by 2050
Primary energy consumption by source in EU28 (2050E)



Source: Goldman Sachs Global Investment Research

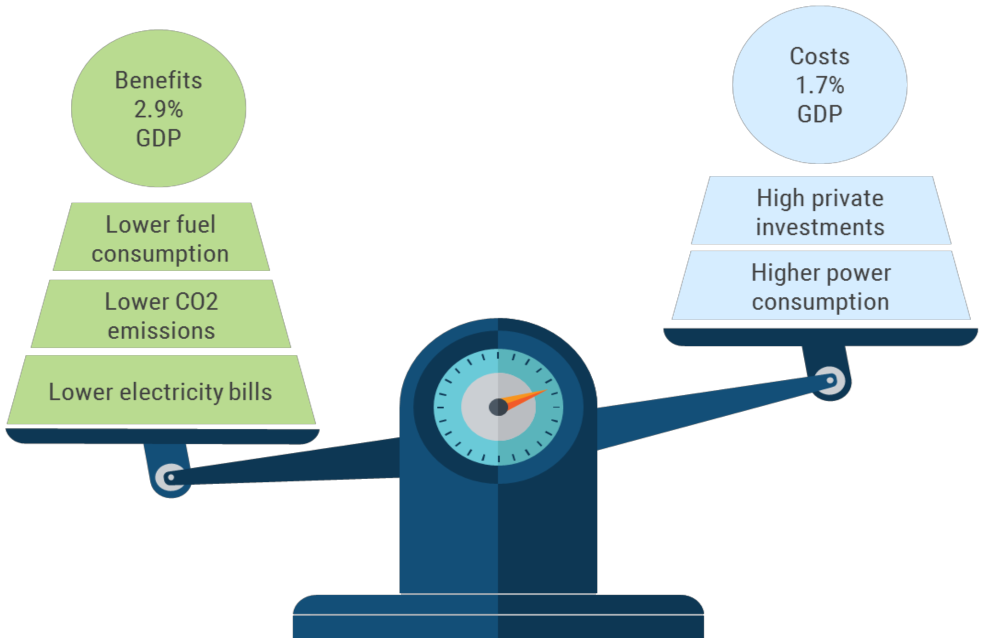
Benefits to outweigh the costs of electrification

Our cost-to-benefits analysis suggests that, by 2050, the net benefits of electrification for the EU28 could exceed 1% of today's GDP. On our estimates, the electrification process would cost c.€300 bn per year (equivalent to c.1.7% of 2018 GDP), more than offset by benefits of c.€450 bn per year (equivalent to c.2.9% of GDP).

The costs would mostly relate to developing wind/solar, grids, storage and insulating buildings as well as providing tax breaks for EVs and HPs. Quantifiable benefits come from lower fuel purchases, energy bills and carbon costs. Longer term, we see electrification leading to more predictable (and gradually deflating) energy bills and, on our estimates, an incremental positive benefit on the EU's balance of payments from greater energy independence.

Exhibit 10: We estimate that the cumulative benefits of decarbonisation will offset the costs by >1% of GDP by 2050

Annual costs/benefits of electrification as % of EU28 GDP (2018, nominal)



Source: Eurostat, Goldman Sachs Global Investment Research

The other benefits of electrification

Increase the predictability of energy bills. On our estimates, electrification could grow the share of electricity to c.55% of primary energy consumption (2050E) vs just over 20% currently. As power bills get increasingly fixed (power grids and contracted generation will account for most of it), energy bills would become less volatile and more predictable.

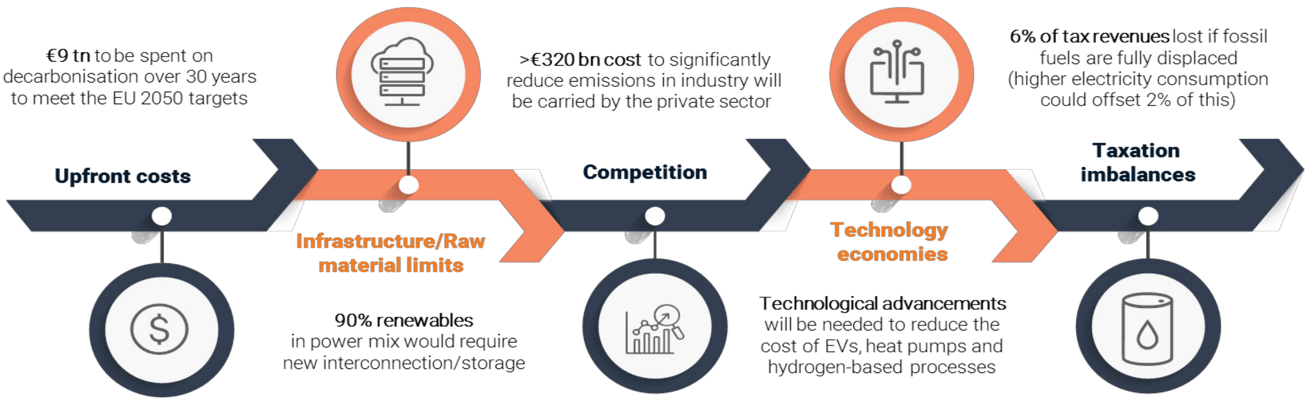
The path to electrification is paved with lower energy bills. We forecast that on average European power bills will be largely unchanged over the next 10 years as: (i) the rising share of RES puts downward pressure on wholesale prices; (ii) legacy RES subsidies gradually expire; and (iii) energy efficiency contains electricity consumption.

Improve energy independence. According to the International Energy Agency (IEA), the EU currently imports nearly 100% of its oil needs, c.80% of its gas needs and c.40% of its coal needs. In a decarbonised world (2050), we envision the EU sourcing nearly all of its primary energy needs domestically. About half of the power generated in Europe is currently "indirectly imported" (i.e. produced by utilising imported coal and imported gas).

The main roadblocks

Achieving electrification to the extent we envision by 2050 would require supportive government policies (e.g. levies on polluting industries, tax incentives for carbon free measures) and significant investment (we estimate c.€300 bn per year) and could face some technological/supply chain restrictions (e.g. cobalt on batteries). Also, electrification might create some taxation imbalances, mostly as tax receipts from oil, gas and coal would not be fully offset by higher tax receipts from higher electricity consumption and from higher GDP under our analysis.

Exhibit 11: We identify five main roadblocks in the electrification process



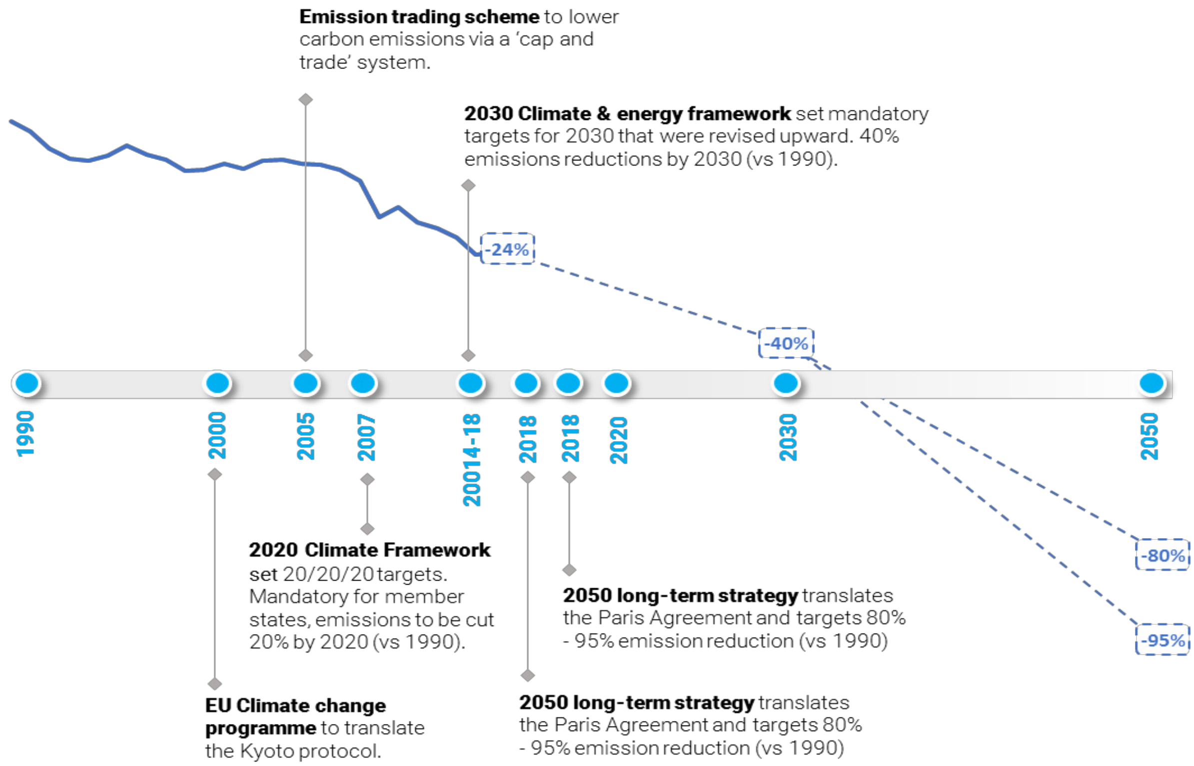
Note: All estimates on 2050 basis

Source: Goldman Sachs Global Investment Research

The EU targets near-full decarbonisation by 2050

The EU has put climate change at the core of its agenda for nearly twenty years – and since 2000, emissions have fallen by c.20%, renewables (RES) are now 30% of the generation mix and the output from coal plants has shrunk by one-third. In our view, the EU's leadership role may be the result of the lack of natural resources, low economic (and power demand) growth, the low share of heavy industries and evidence that RES are cheaper than fossil fuel.

Exhibit 12: Timeline of EU climate policy



Source: European Commission, Goldman Sachs Global Investment Research

European Union: Nearly 20 years of climate change planning

EU Climate Change Programme (2000). The EU officially launched its Climate Change Programme (ECCP) in June 2000 with the intent of developing a strategy to translate the Kyoto Protocol.

Emission Trading Scheme (2005). In 2005, the EU launched its Emission Trading Scheme (ETS), which aims at lowering carbon emissions via a "cap and trade" system. Put simply, companies covered by the scheme (c.45% of EU's total greenhouse gas emissions, equivalent to 11,000 installations) receive or buy emission-allowances within a "cap" and such allowances can be bought and sold ("trade") in a carbon market. According to the ETS system, emissions from the covered sectors would drop by 21% in 2020 and by 43% by 2030 (vs 2005).

2020 Climate & Energy framework (2007). In 2007, the EU set the 20/20/20 targets which envisaged: 20% emissions reductions by 2020 vs 1990 levels, 20% primary energy from renewables, and 20% energy efficiency. This was enacted in 2009 and is mandatory for member states.

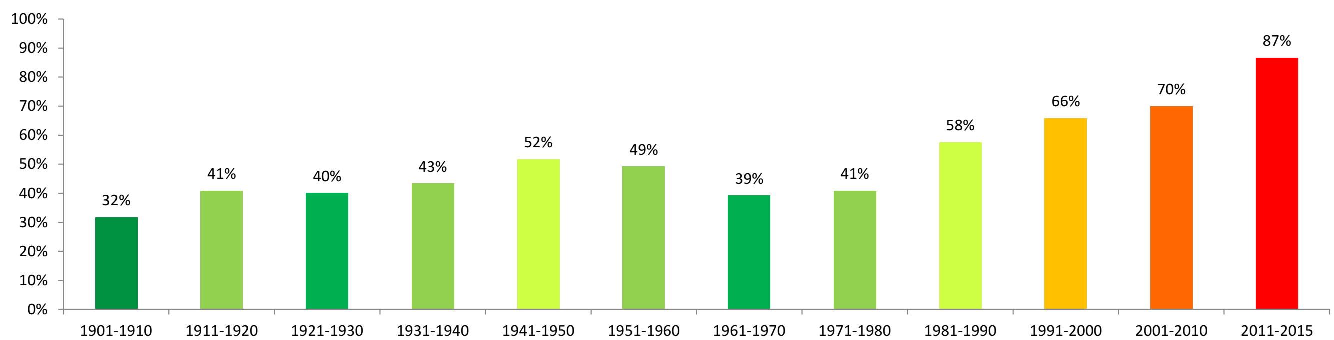
2030 Climate & Energy framework (2014-18). In 2014, the EU approved its 2030 strategy (targets were revised upward in 2018), which requires: at least 40% emissions reductions by 2030 vs 1990 levels, 32% primary energy from renewables, and 32.5% energy efficiency. These are mandatory targets.

2050 long-term strategy (2018). At the end of 2018, the EU presented its long-term strategy to 2050 of 80%-95% reduction vs 1990; this is consistent with the "Paris Agreement" objective to keep global temperatures well below 2 degrees Celsius (vs pre-industrial levels) and strive to keep them to 1.5 degrees.

Why the EU goals matter in a global context

The Paris Agreement (2015) was adopted by 195 countries. Besides containing a limitation on the rise of global temperatures (below 2 degrees Celsius above pre-industrial levels, with the intention to settle at 1.5 degrees), the agreement reached during COP21 also envisaged the need to have global emissions peak as soon as possible and undertake rapid reductions thereafter. Although we take no view on the wider climate debate, we show a statistic below which is frequently used in this context to support the need to pursue a green agenda. Exhibits 13 shows that the frequency of "hot months" – when temperatures exceeded their long-term average – has substantially increased in recent decades, and in the last five years in particular.

Exhibit 13: In recent decades, the frequency of above-average temperatures has substantially increased
Percentage of months with mean temperatures above the long-term average



Long-term average calculated as the average temperature for each month between January 1901 and December 2015

Source: World Bank

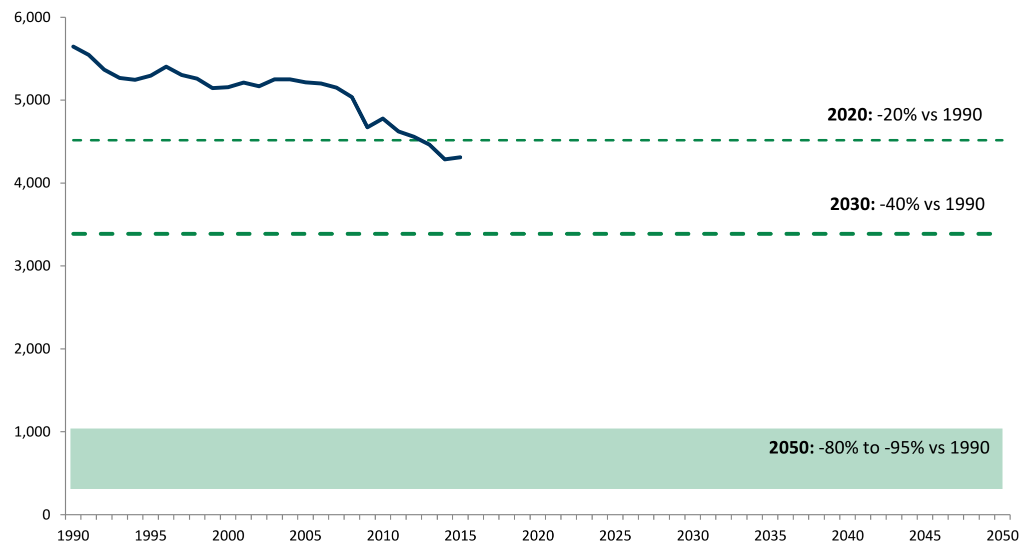
We are only one-quarter of the way to the long-term decarbonisation goal

The European Union has set three main decarbonisation landmarks. Starting from 1990 levels (c.5,600mt), the EU targets lowering emissions by 20% by 2020 and 40% by 2030. These are mandatory targets. By 2050, the long-term strategy is a reduction in emissions between 80% and 95%. In other words, halfway through this century, the EU is planning to almost fully eradicate GHG from the economy.

The exhibit below shows that while current pace of emissions reduction puts us on track for the long-term strategy, we are still only one-quarter of the way there. We stress too that the greatest acceleration in emissions reduction took place in 2008 on the back of the great financial crisis, which led to a double digit drop in industrial production and power demand (i.e. lower fossil fuel generation).

Exhibit 14: EU is ahead on 2020 targets, but mostly thanks to recession and RES economics: a long way to go to 2050

EU GHG emission targets (mt)

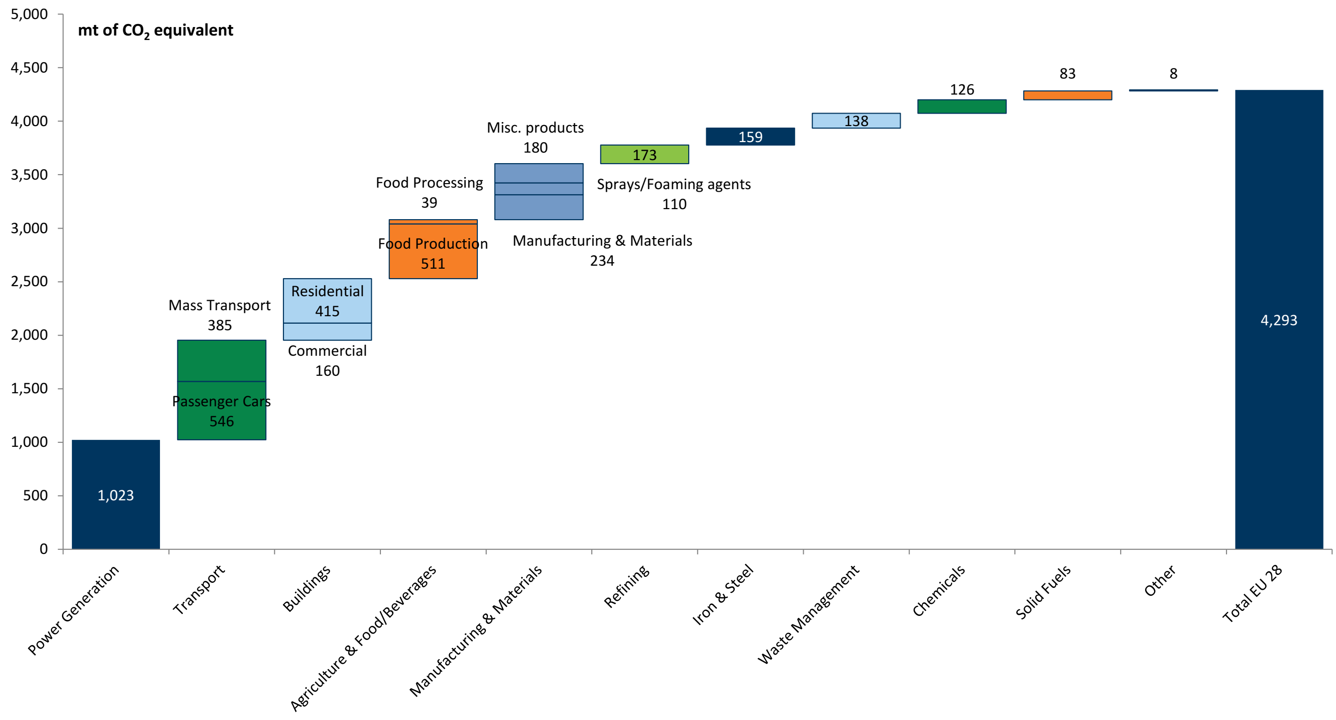


Source: Eurostat, Goldman Sachs Global Investment Research

Emissions highly concentrated in a handful of industries

As shown in the exhibit below, more than 90% of the greenhouse gas emissions in the European Union are from seven industries. Power generation (the largest by far; it accounts for c.25%), Transport and Buildings are the main contributors, and jointly account for c.60% of total GHG.

Exhibit 15: EU GHG emissions: Seven industries are the main sources
EU28 greenhouse gas emissions (2016)

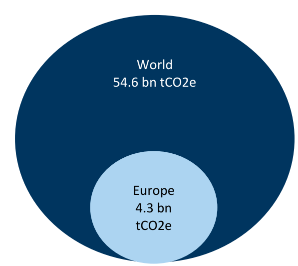


Source: Eurostat, Goldman Sachs Global Investment Research

Europe accounts for less than 10% of global emissions

Although cutting Europe's emissions to near zero by 2050 does seem a monumental undertaking, at the global level this would have only a minor impact as the continent accounts for less than 10% of the world's atmospheric pollution.

Exhibit 16: Europe accounts for less than 10% of global GHG emissions
Annual greenhouse gas emissions by region (bn tCO2e, 2016)



Source: European Environment Agency, Global Carbon Project, World Bank

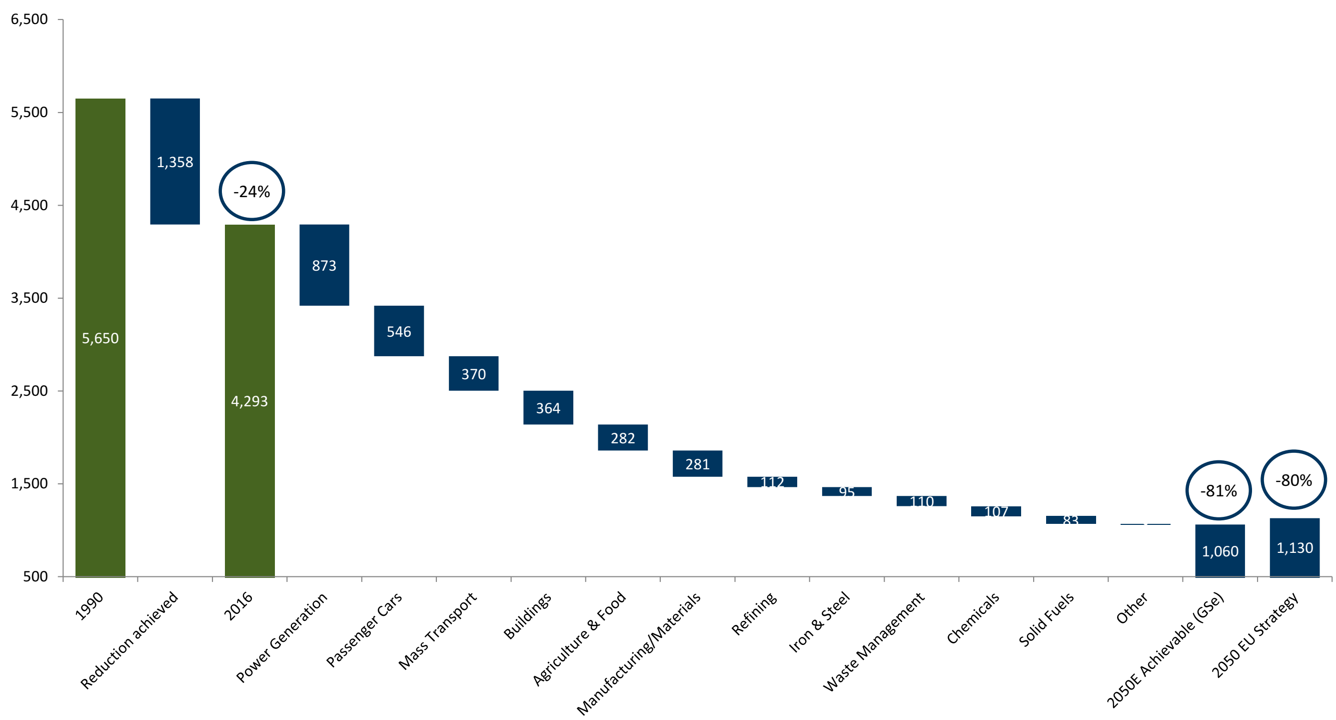
Electrify Everything: 2050 EU targets in reach

We argue that electrification could become a very pervasive process (with ramifications across many industries) and likely could be the main tool to achieve the 2050 emission reduction targets. Our scenario analysis suggests that Europe "going electric" would lower 2050E GHG by 80% (vs 1990), single handedly (so to speak) satisfying the EU 2050 target.

We see switching to a RES-based generation mix (with very limited contribution from gas); promoting the phase out of combustion engines; introducing heat pumps on a mass scale (coupled with buildings insulation); and supporting the transition to electricity-based industrial processes (displacing coal/gas) as necessary steps to achievement of the 2050 decarbonisation goals.

Exhibit 17: Our analysis identifies emission reductions to 2050 that could lead to >80% reductions in emissions vs 1990

EU Emissions evolution (mtCO2e) under our electrification analysis



Source: Eurostat, Goldman Sachs Global Investment Research

Electrification: A "concentrated" effort in a few industries

In our analysis, we estimate the potential for GHG reduction by 2050 using a bottoms up approach, going industry by industry (as noted above, seven industries account for more than 90% of emissions). We detail this later in the note, and in the exhibit below provide a visual summary of the electricity-specific measures we stimulate in our forecast model. Our focus is primarily on the "big three" polluters: Power generation, Transport and Buildings.

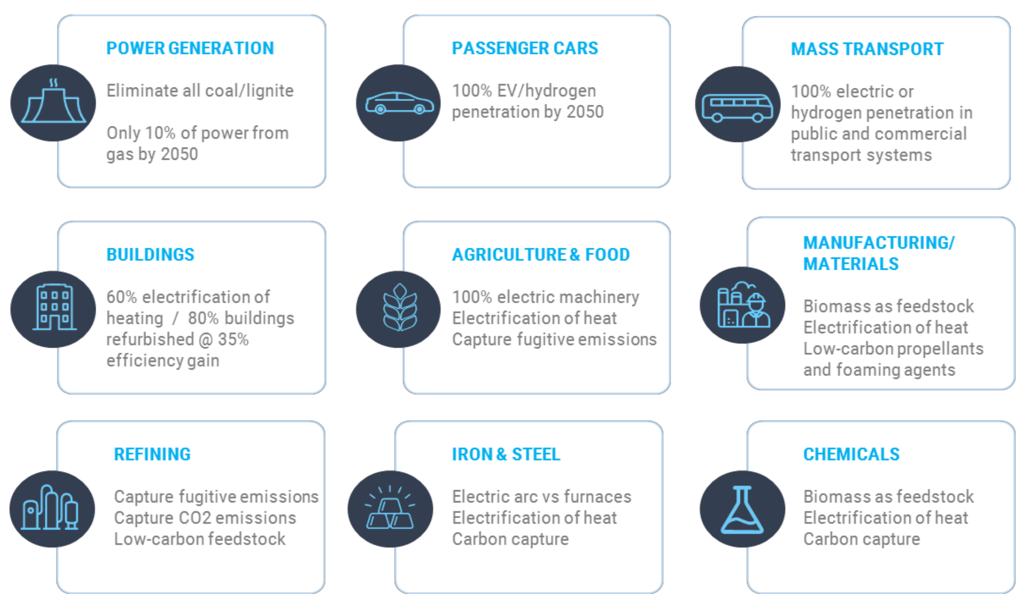
Power generation. We see the rising share of renewables in the system (c.30% of output today) as the main driver in the electrification process; replacing fossil fuel with wind and solar would effectively eliminate the share of EU emissions from power generation, or c.20%. By 2050, we assume that >80% of production will come from RES, 10% from gas fired plants and the rest from batteries and fuel cells.

Transport. As Europe imports c.80% of its oil needs and transport is a key driver of GHG, moving to electric (and hydrogen) cars would be a requisite to achieve decarbonisation, in our view. By 2050, we simulate the full conversion of the combustion fleet.

Buildings. Buildings account for nearly 40% of primary energy consumption. We assume emissions reduction will be achieved via: (i) gradual deployment of heat pumps (c.60% market share by 2050 vs c.10% today) and (ii) insulation (c.80% of the buildings refurbished by 2050, c.35% average reduction in consumption per unit).

Exhibit 18: Only a few industries to tackle to achieve a major decarbonisation

Electricity specific measures we have simulated in our analysis of achieving the 2050 EU LT Energy Strategy (emissions reduction of 80% to 95% vs 1990)

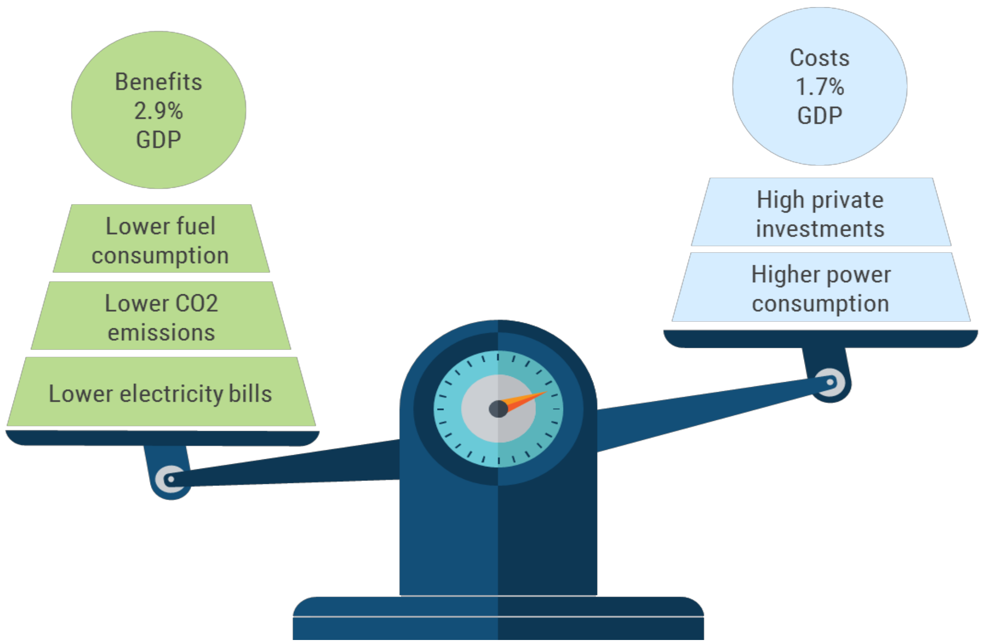


Source: Goldman Sachs Global Investment Research

Costs-to-Benefits analysis supports electrification

Our cost-to-benefits analysis suggests that, by 2050E, the net benefits of electrification for the EU28 could reach >1% of GDP (2018). On our estimates, the electrification process would cost c.€300bn per year (equivalent to c.1.7% of 2018 GDP), more than offset by benefits of c.€450bn per year (equivalent to c.2.9% of GDP).

Exhibit 19: We estimate that the benefits of decarbonisation will offset the costs by >1% of GDP by 2050
Annual costs/benefits of electrification as % of EU28 GDP (2018, nominal)



Source: Eurostat, Goldman Sachs Global Investment Research

Estimating costs

Costs are easier to visualize and in our analysis mostly relate to developing wind/solar, grids, storage, insulating buildings and tax breaks for EVs and HPs. We estimate costs at c.€300 bn per year to 2050.

- **Power generation**: We estimate that to achieve c.90% production from RES by 2050, wind and solar additions would be about 40GW per year. In line with the energy plan proposed by the Spanish government, we estimate annual storage development could reach 5GW for the EU; this would imply an installed base in batteries equivalent to nearly 10% of the total wind/solar installed base by 2050. We only assume that 10% of volumes will come from non-renewables (gas fired plants).
- **Transport**: To achieve the low end of the 2050 emissions reduction strategy (80%), the EU would most likely have to strive for a full phase out of combustion engines. The bulk of this might be replaced by EVs, whilst hydrogen is likely to take a larger role on long distance travel (e.g. trucks) as this technology would allow for better range and quicker refuelling/recharging.
- **Buildings**: Considering the current rate of new builds in Europe is c.0.5% and the rate of refurbishments is c.2.5%, by 2050 80%-90% of buildings could be newly

built or refurbished. We assume energy efficiency at 20%-30% on refurbishments and up to 50% on new buildings. We also assume that one gas boiler in four is replaced over the period will be substituted by a heat pump.

Estimating benefits

The benefits might appear less tangible, but are still readily identifiable: lower fuel purchases (mostly petrol, diesel, gas and coal), deflating energy bills and lower carbon costs. We estimate benefits at c.€450bn per year to 2050.

- **Fuel consumption**: The reduction in petrol/diesel consumption on passenger cars and mass transport as well as the decline in gas and coal consumption account for the bulk of the benefits in our analysis (c.90%).
- **Electricity bills**: The expiry of legacy renewable subsidies, coupled with the downward pressure on wholesale prices (triggered by the rising share of cheaper RES), would lead to lower unitary electricity bills.
- **CO_2 emissions**: Lower emissions would clearly lower carbon costs. We assume an average carbon price of €20/t over the period.

Electrification supported by lower and more predictable energy bills

We present two country case studies to illustrate our view that electrification would underpin deflationary energy bills. In our scenario analysis, we assume that over 2018-30, electricity bills across the EU remain broadly flat in nominal terms but realise 1%-1.5% annual drop in real terms (we would expect this trend to continue - albeit at a slower pace - to 2050). This would be the result of two main factors: (i) the disappearance of legacy renewable subsidies and (ii) the substitution of expensive fossil fuel power stations with cheaper wind/solar.

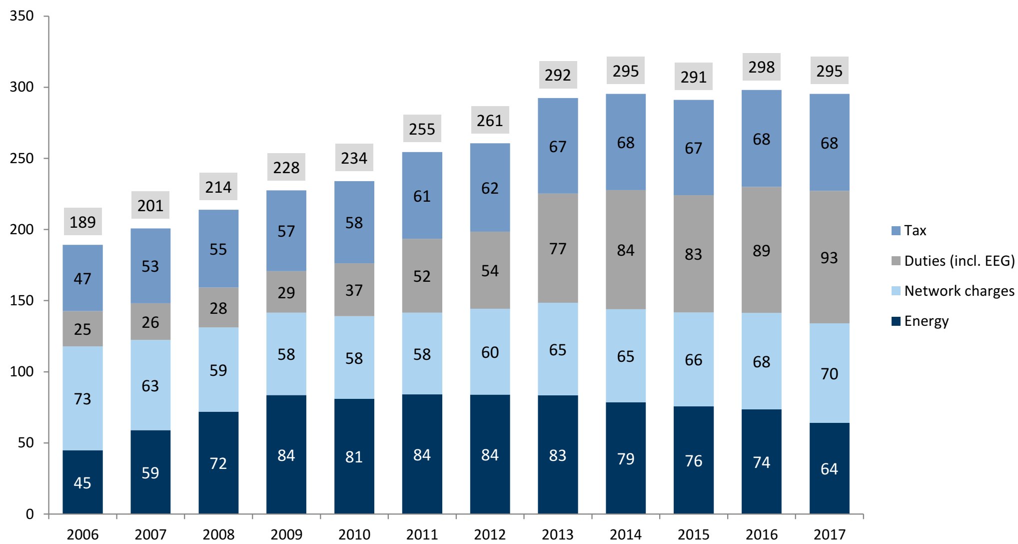
Power bills: Moving to a world with no inflation

We present detailed estimates for two representative countries, Germany and Italy, to support our view that during 2018 and 2030 European power bills are likely to remain broadly flat in nominal terms and decline by 1.0%-1.5% in real terms. In detail, we estimate that Europe would face rising bills until 2023 (c.2%-4% pa) owing to the unwinding of forward hedges (i.e. higher achieved power prices), rising carbon prices and previously awarded renewables subsidies. Beyond 2023, disappearing RES subsidies and the normalisation in carbon prices would lower bills by c.1%-2% per year in nominal terms.

Germany: Business as usual to 2023E, then c.2% annual decline

Between 2006 and 2017, German electricity bills for residential customers rose at a +4% annual pace, or +61% cumulatively. Besides higher power prices, the main driver behind this move was the surge in renewable subsidies, which nearly quadrupled during the period and accounted for about two-thirds of the increase.

Exhibit 20: German retail bills are +61% since 2006, two-thirds of which was due to higher RES subsidies ("EEG", included in Duties)
Germany residential power bills (€/MWh)

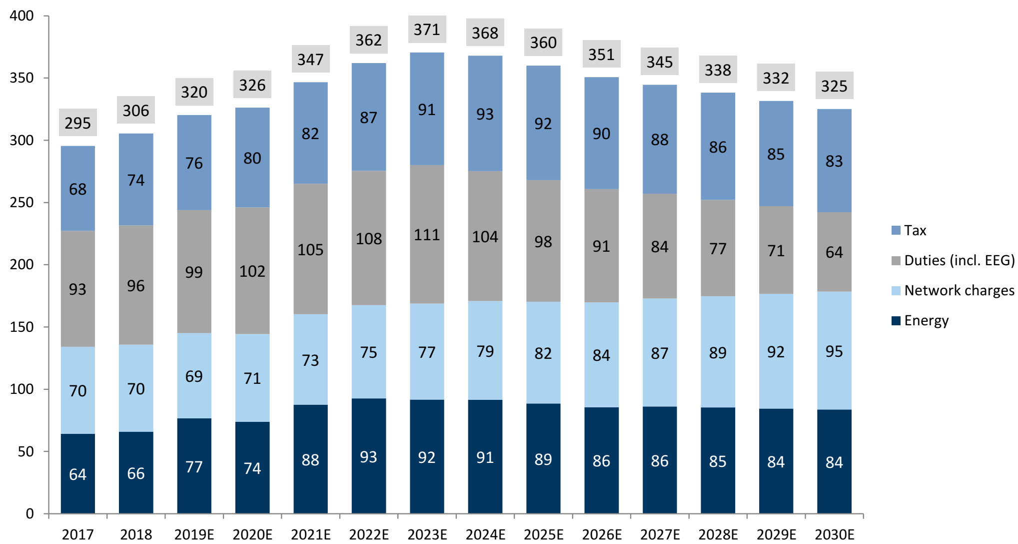


Source: BNetzA, Goldman Sachs Global Investment Research

During 2018-23, we assume power bills will keep rising at a similar pace (c.4% per year, nominal) owing to the unwinding of forward hedges, rising carbon prices (which we estimate could hit €30/t), higher dark/spark spreads owing to the tightening in the S/D power market (c.30% of baseload capacity to shut by 2023) and previously auctioned renewables (with subsidies).

Beyond 2023, the gradual phaseout of RES subsidies (new additions as of 2021 will no longer require incentives), the larger share of (cheaper) RES in the system (c.60%-65% of output vs c.40% currently) and the gradual normalisation in carbon prices lead to c.2% annual decline in power bills until 2030 on our estimates. In real terms, this implies c.25% cumulative reduction.

Exhibit 21: Germany residential bills could face c.20% reduction during 2023 and 2030, we estimate
Germany residential power bills scenario (€/MWh)



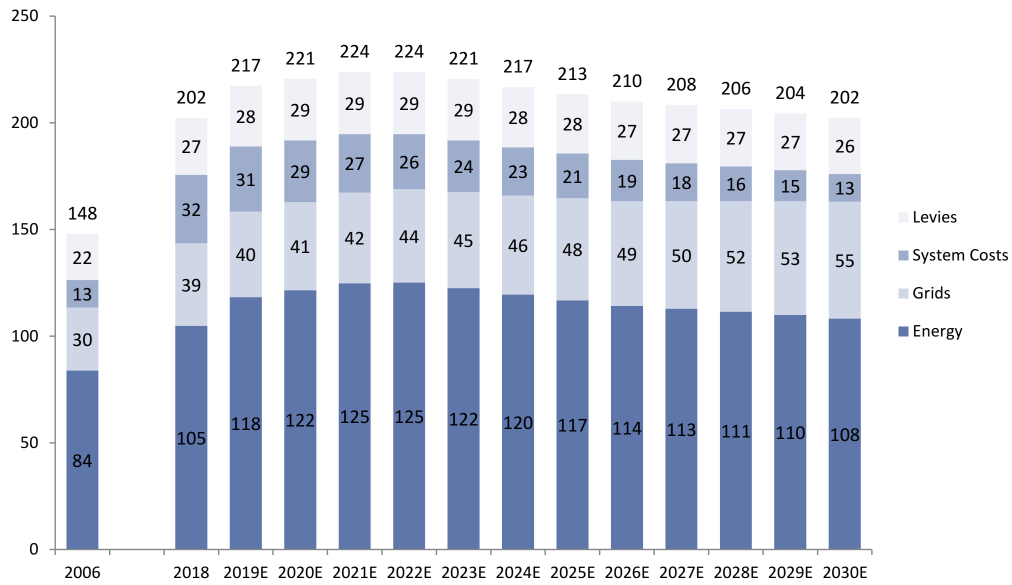
Source: BNetzA, Goldman Sachs Global Investment Research

Italy: Flat (nominal) power bills during 2018 and 2030E

In 2006-18, Italy power bills for households rose at c.2.5% annual pace, or +37% cumulatively. Higher power prices and the surge in renewable subsidies explain most of the increase. Up until 2022, we forecast that electricity bills for retail customers would still increase at c.2% per year owing to the unwinding of forward hedges and rising carbon prices (which we estimate could hit €30/t).

Thereafter, we estimate that the gradual phaseout of RES subsidies, the larger share of (cheaper) RES in the system (c.60%-65% of output produced by 2030 vs c.30% currently) and the gradual normalisation in carbon prices lead to c.1% annual decline in power bills. In real terms, this implies c.10% cumulative reduction to 2030.

Exhibit 22: We estimate Italy residential bills decline beyond 2022 by >1% per year
Italy residential electricity bills scenario (€/MWh)

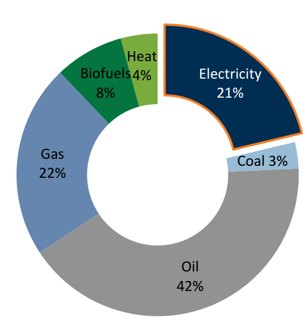


Source: Arera, Goldman Sachs Global Investment Research

Electrification could improve EU's energy independence

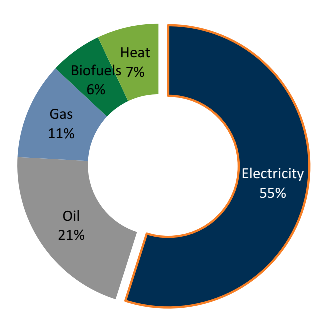
According to the IEA, the EU currently imports nearly 100% of its oil, c.80% of its gas and c.40% of its coal, implying that only 30% of the EU's primary energy is sourced domestically. In a decarbonised world, we see this ratio significantly improved. We estimate electricity would satisfy c.55% of the EU's primary energy needs by 2050 compared to c.20% today.

Exhibit 23: Electrification of the European economy is just above 20%...
Primary energy consumption by source in EU28 (2018)



Source: Eurelectric, Goldman Sachs Global Investment Research

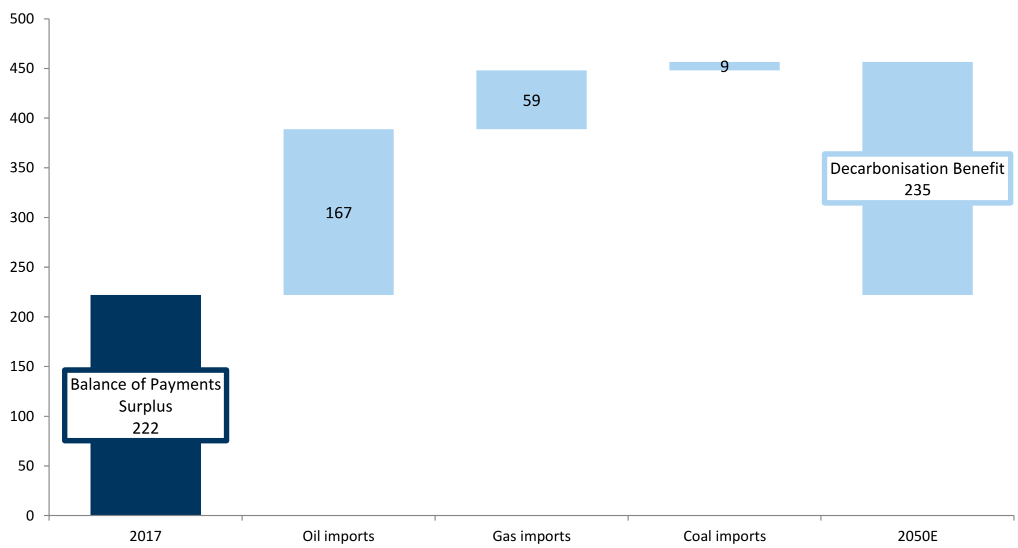
Exhibit 24: ...but we estimate would increase to 55%
Primary energy consumption by source in EU28 (2050E)



Source: Goldman Sachs Global Investment Research

We estimate that fully eliminating the need for fossil fuel imports will positively benefit the EU's balance of payments to the tune of €235 bn; this compares to a balance of payments surplus of €222 bn in 2017.

Exhibit 25: Decarbonisation would cut reliance on fossil fuels, generating a potential €235 bn trade benefit for the EU28 by our estimates
Data in € bn



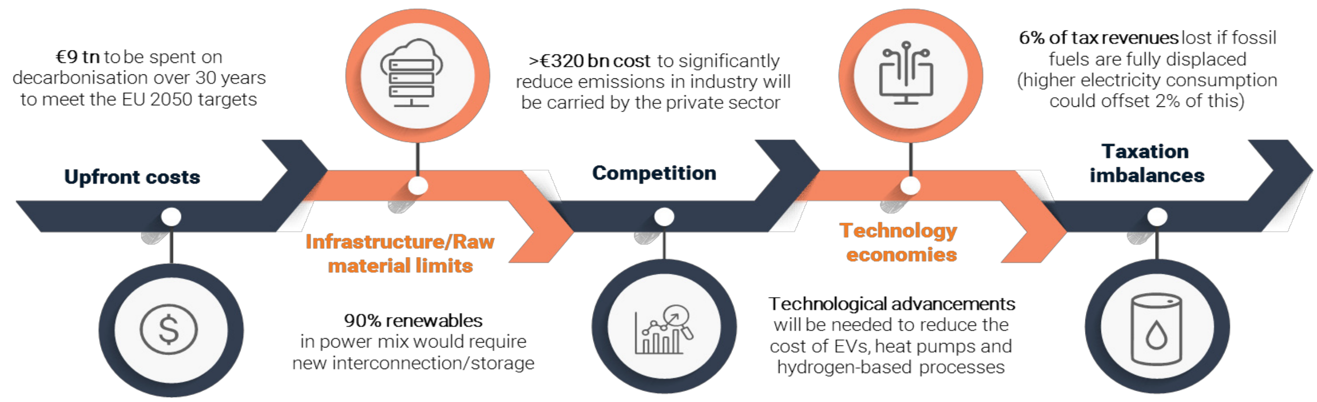
Note: Estimates based on current commodity price curves and 2017 fossil fuel import volumes

Source: Eurostat, Goldman Sachs Global Investment Research

The main roadblocks to electrification

Achieving electrification to the extent we envision by 2050 would require supportive government policies (e.g. levies on polluting industries, tax incentives for carbon free measures) and significant investment; we estimate at c.€300 bn per year the combined effect. We also highlight that the electrification process could face some technological/supply chain restrictions (e.g. cobalt on batteries).

Exhibit 26: We identify five main roadblocks in the electrification process



Note: All estimates on 2050 basis

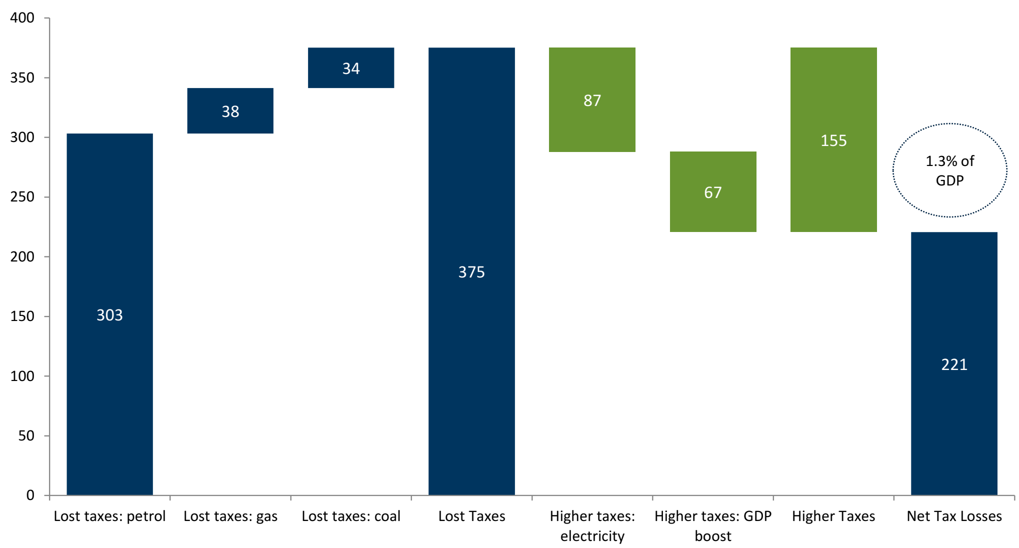
Source: Goldman Sachs Global Investment Research

- **Upfront costs**. We estimate the 30-year decarbonisation process could cumulatively cost c.€300 bn per year to 2050. The public sector would play a major role in this - for instance, governments could lead by example on the decarbonisation of buildings, as one in three non-residential buildings is state-owned or utilised by public administration. However, the vast majority of investments required to reduce emissions would have to come from the private sector (e.g. corporates investing in electrical machinery; end users buying HPs and EVs). To incentivise these, the governments could take on some cost by providing tax breaks.
- **Technology economics**. Even if the cost of solar and wind is now more competitive (in some cases, to the tune of 50%-60%), other technologies, such as electric cars, air heat pumps, hydrogen fuel cells and electric arc furnaces, remain more costly vis-à-vis mainstream options (internal combustion engines, gas boilers, conventional gas fired power plants, blast furnaces). An improvement in the cost curve would have to be registered for these measures to become more viable.
- **Infrastructure and raw material limitations**. Some transitions would be more revolutionary than others. For instance, switching to EVs could put tremendous pressure on some key input costs, such as cobalt. Also, infrastructure investments to electrify parking spaces would have to be carried out. To reach 90% electricity from renewables, Europe would have to be better interconnected to contain "output losses" and improve security of supply - we estimate this could cost nearly €300 bn.
- **Competition in global markets.** Particularly in the case of industry, paying for decarbonisation investments potentially could reduce European businesses' competitiveness in international markets, in our view. As such, offsets may be

required - or subsidisation of investments - in order to retain the competitiveness of European industries and protect jobs.

- **Taxation imbalances**. The electrification process could potentially create tax imbalances. For example, our analysis suggests that in a decarbonisation scenario lower tax receipts from petrol/diesel/gas/coal would partially be offset by higher tax receipts on electricity (owing to higher consumption) and higher corporates taxes (owing to the GDP boost that we expect electrification to bring).

Exhibit 27: Electrification could create tax imbalances
Europe's annual tax receipts (2018E for lost taxes, 2050E for higher taxes) analysis, in € billions



Note: Our €375 bn estimate is equivalent to c.6% of 2017 EU28 tax revenues; €221 bn is equivalent to c.4%

Source: Eurostat, Goldman Sachs Global Investment Research

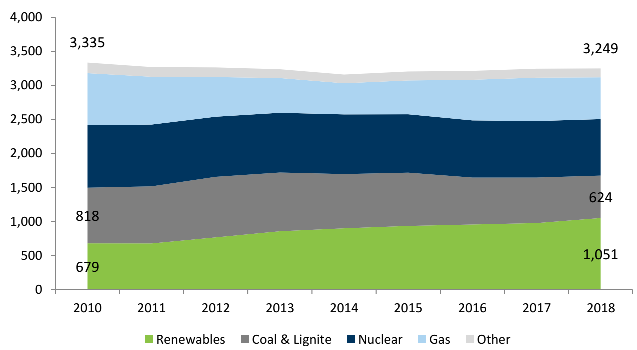
Power Generation: RES at 90% in the mix by 2050E

The rising share of renewables in the system (c.30% of output today) stands out as the main driver in the electrification process. Replacing fossil fuel with wind and solar — effectively fully de-carbonising power generation — would remove its share of EU emissions (c.25%). In our analysis, we assume that 90% of production would come from RES and 10% from gas fired plants by 2050 (implying a c.20% reduction in emissions).

Renewable installations to continue ramping up in the EU

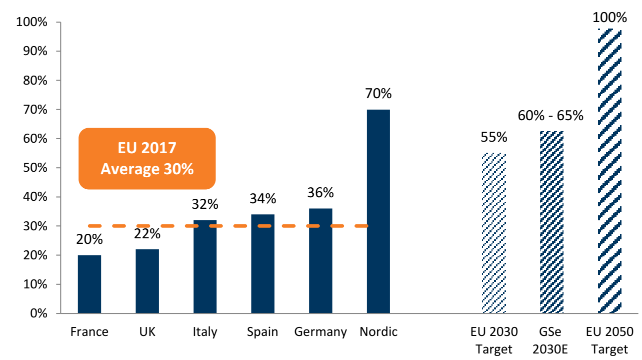
Renewables already account for 30% of power generation in the EU. Renewable output has increased more than 50% since 2010 driven by wind and solar installations. Looking forward, the EU targets imply reaching 55% by 2030 and 100% by 2050. Yet owing to improved economics and the rising practice of "corporate PPAs" (i.e. LT offtakes between RES developers and corporate clients), we estimate the share of renewables could reach 60%-65% by 2030.

Exhibit 28: RES now account for 30% of power generation
European power generation source by technology



Source: Eurostat

Exhibit 29: Share of renewables in EU power system set to nearly double by 2030E (vs. 2017)
Renewables as % of total electricity generation



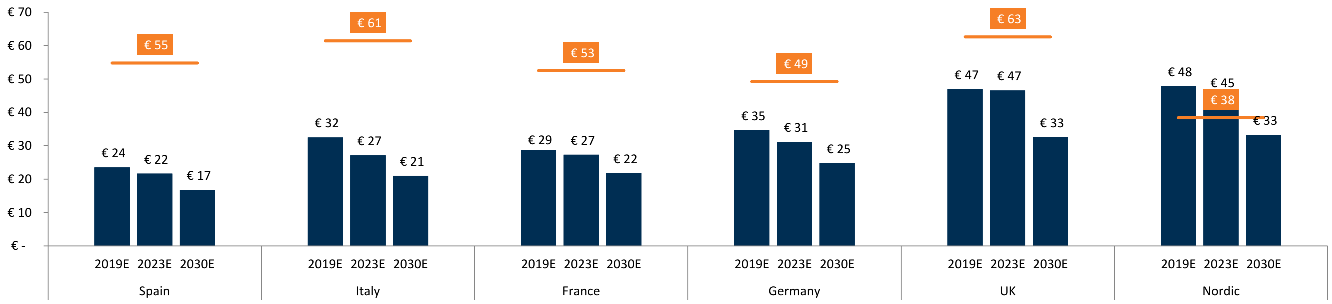
Source: Eurostat, EU, Goldman Sachs Global Investment Research

Solar is already much cheaper than merchant prices

Solar levelised cost of energy (LCOE) is already at a significant discount to wholesale power prices in most EU countries. In particular, across Southern Europe solar energy is c.50% cheaper than forward curves. We factor into our analysis a gradual decrease in capex/MW and that a widespread switch to bifacial trackers could lower costs further by up to 30%.

Exhibit 30: Solar PV costs are already significantly below forwards in most European countries

Solar PV LCOEs in blue, 2020 forwards in orange, €/MWh



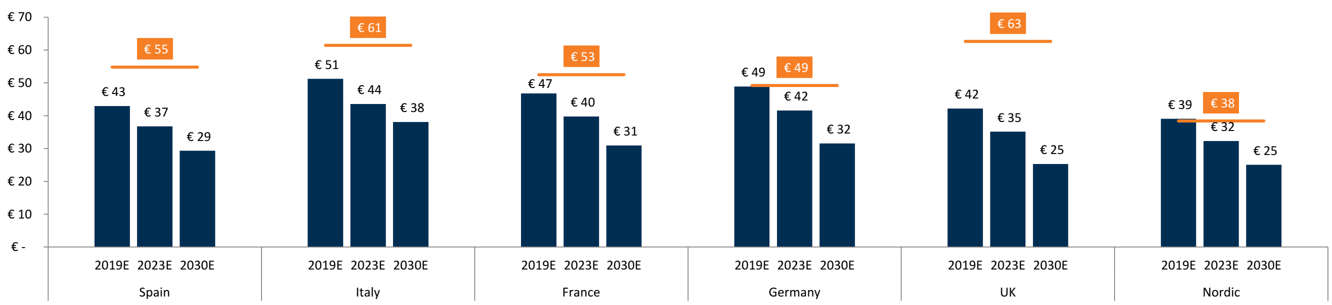
Source: Bloomberg, Goldman Sachs Global Investment Research

Wind is now starting to widen the gap with power prices

Onshore wind LCOE has more recently reached or dipped below forward power prices across Europe. This implies that all new onshore wind installations would be deflationary for electricity bills. Looking forward, we continue to expect LCOE to fall, driven by turbine efficiency and size.

Exhibit 31: Onshore wind is at or below grid parity in all major regions

Onshore LCOEs in blue, 2020 forwards in orange, €/MWh

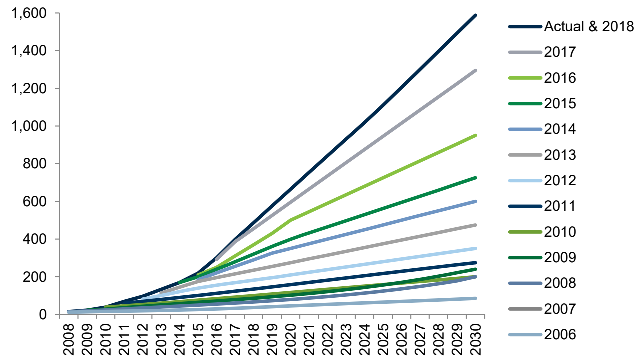


Source: Goldman Sachs Global Investment Research

Renewable development consistently underestimated

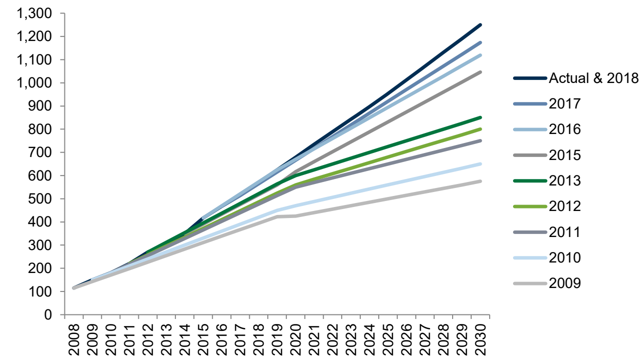
Renewable growth has been surprising to the upside for the past 10 years. The charts below shows that the International Energy Agency (IEA) has consistently revised upwards its solar and wind capacity forecasts. It is interesting to observe that just over 10 years ago, for 2030, the IEA was expecting less than 100 GW of solar PV, globally. In its latest update, the IEA is forecasting c.1,500 GW.

Exhibit 32: Solar installations have far outpaced IEA forecasts...
IEA solar PV forecasts to 2030 by year of publication, data in GW



Source: IEA

Exhibit 33: ...as have wind installations since 2008
IEA wind forecasts to 2030 by year of publication, GW

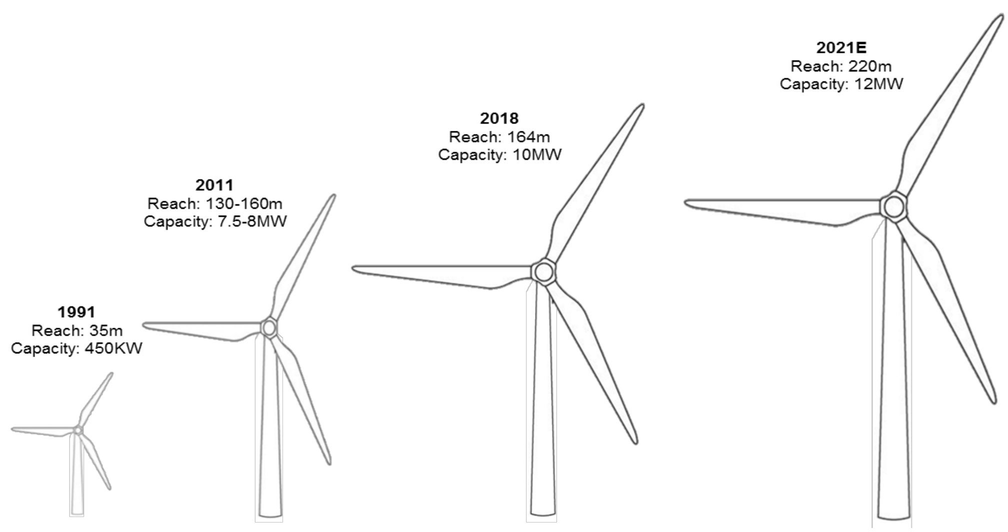


Source: IEA

Renewable technology should continue to improve

We believe renewable LCOE will continue to fall driven by technology improvements. In wind, the main driver is larger turbines with larger blades (see below). Larger turbine capture more wind energy and lead to lower capex/MW. In solar, bifacial panels which can generate electricity from both sides combined with trackers which allow the panel to optimally face the sun have the potential to lower LCOE by up to 30% as discussed in our report "Solar: Plummeting costs and the rise of incumbents" here.

Exhibit 34: Larger turbines offer more MW and higher load factors reducing LCOE
Turbine technology history

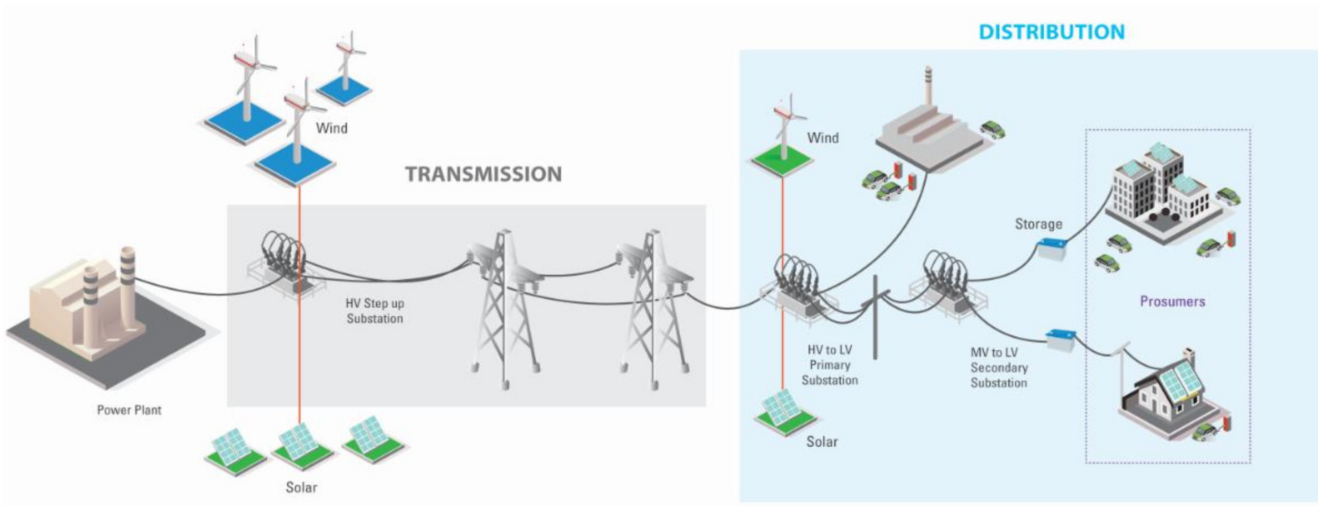


Source: Company data, Goldman Sachs Global Investment Research

Networks: A key infrastructure to support electrification

Evolving technology and digitalisation should change the way companies operate, especially in terms of asset productivity and labour intensity. To fully embrace renewables, storage, demand-side management, remote controlling and real-time demand forecasting, power grids will have to be digitalised. European utilities currently employ (nearly) one million people (at an annual cost of c.€70 bn, equivalent to about two-thirds of sector EBITDA), 20% of whom will retire over the next ten years. Digitalisation could allow for a 15% reduction in controllable costs (c.€10 bn savings) by 2050, on our estimates.

Exhibit 35: How the power complex is evolving (newer elements in colour)

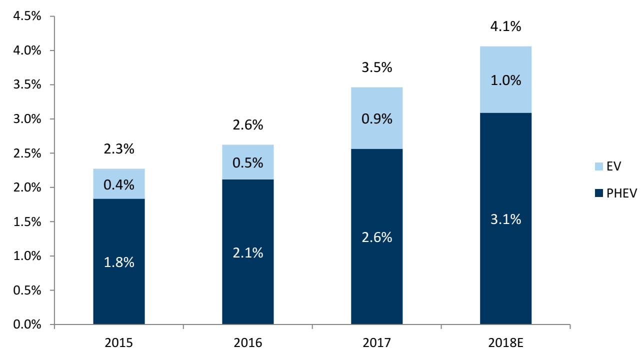


Source: Goldman Sachs Global Investment Research

Higher (regulated) investment in grids and cost savings

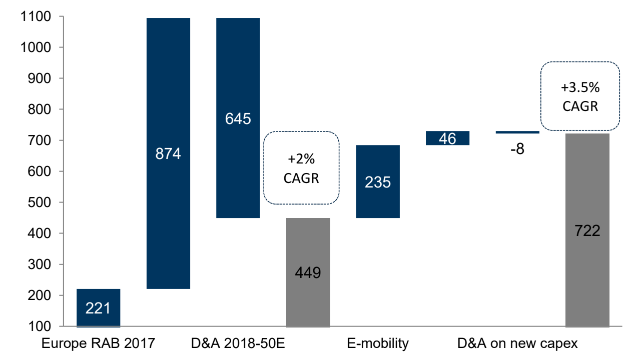
We see material upside to current run-rate grid capex levels driven by continued renewable deployment and the increasing penetration of electric vehicles. We estimate that an extra €280 bn needs to be spent in Europe by 2050, which should accelerate European RAB growth from 2% pa (on run-rate capex) to 3.5%. New IT systems in supply, fully digitalised networks and the utilisation of predictive algorithms to manage grids and power stations could allow for a 15% reduction in controllable costs (c.€10 bn of net savings), we estimate.

Exhibit 36: Plug-in vehicle penetration is rising in Europe
Share of plug in vehicles in European fleet, full electric (EV) and plug-in hybrids (PHEV)



Source: IHS, Goldman Sachs Global Investment Research

Exhibit 37: We expect 3.5% annual RAB growth through 2017-50
European electricity distribution RAB bridge, € bn



Source: Goldman Sachs Global Investment Research

The Electrification Evidence

- **Record low auctions:** Recent solar auctions have reached below €20/MWh vs €150-200/MWh in 2010. Offshore wind auctions went from €200/MWh in 2012 to €60/MWh in 2018 (source: Platts, Bloomberg, BNetzA, IRENA PPA database).
- **Corporate PPA** volumes increased by 5x in 2018 vs 2017 in Europe as renewables costs fell below power prices .
- **Increasing electricity grid capex in Europe:** According to the European Energy Industry Investments study by the European Parliament, capex levels in transmission grids are forecast to increase from €5bn per year today to more than €10bn over 2021-2050 and distribution grids capex will go from €25bn annually to above €40bn.

Energy storage: An enabler of RES deployment

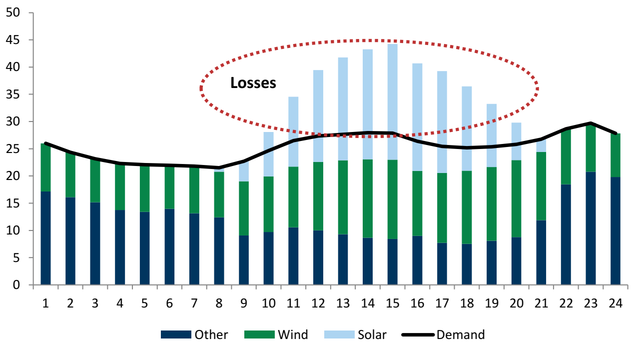
Energy storage deployment helps reduce greenhouse gas emissions mainly by enabling further renewable deployment. It is needed to integrate high levels of volatile power sources both on an hourly and seasonal basis. Two technologies are likely to be used together, battery storage (hourly) and power to gas (seasonal). We estimate the total cost at €150 bn or €5 bn per year to 2050.

Issue: High renewable penetration leads to losses

As previously discussed, we expect renewable penetration will continue to increase driven by wind and solar installations. These technologies are the cheapest way of producing electricity but come with the disadvantage of being volatile and linked to resource availability (wind and sun). Today the electricity system can manage this volatility by adjusting the output of conventional power plants such as gas, coal and hydro plants. However, going forward we estimate the penetration of wind and solar will be too high, leading to periods where output is higher than demand as shown in Exhibit 38. In Germany, losses cost the electricity system €1.4 bn per year and are growing, according to BNetzA. We think such losses could grow exponentially, as seen in the following exhibits, which simulate losses from RES by 2030E in the Spanish market.

Exhibit 38: As solar installations grow, solar output in the summer will be lost

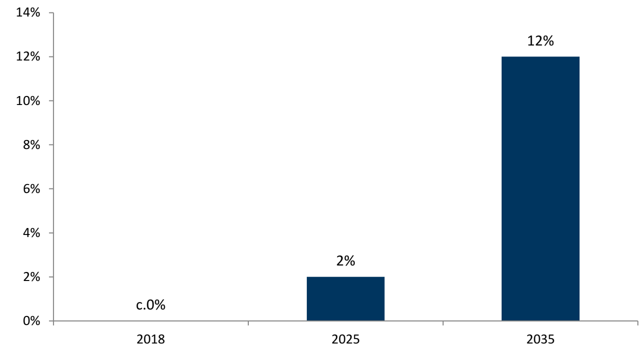
Spanish power demand and output for a typical day in May in 2030, GW



Source: Goldman Sachs Global Investment Research

Exhibit 39: We expect this will start to be material over the next few years

Losses as a share of wind and solar power generation on an annual basis for Spain



Source: Goldman Sachs Global Investment Research

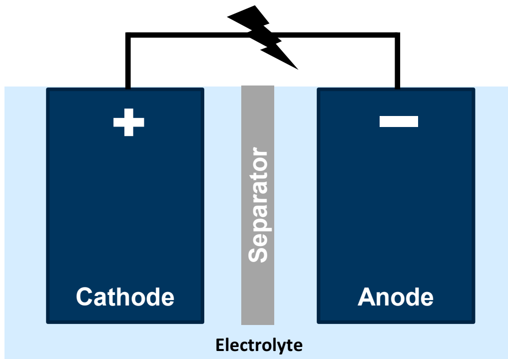
Solution: Lithium-ion batteries can be used

A battery converts electrical energy into chemical energy which can be stored. Later the reaction can be reversed with chemical energy being converted back to electricity. Lithium-ion batteries are currently mainly used for consumer products but are now seeing growing uptake in electric vehicles, residential storage and grid scale storage. For grid scale applications, lithium-ion batteries are well suited to manage hourly output volatility on timescales of 30 minutes to 4 hours.

250GW of battery storage needed in Europe

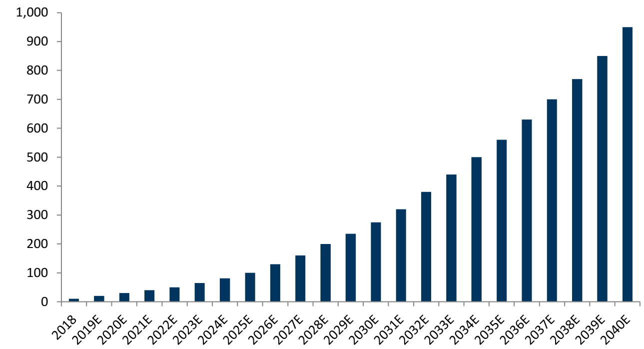
Bloomberg New Energy Finance (BNEF) expects battery storage capacity to pick up during the next decade to reach nearly 300GW by 2030. Looking further out, the BNEF sees energy storage growing to a point where it is equivalent to 7% of the total installed power capacity globally in 2040. This represents a $620 bn investment opportunity by its estimates. In Europe, using a study ran by the European Association for Storage of Energy, we estimate a need for c.250GW of battery storage by 2050 to achieve our electrification scenario.

Exhibit 40: Basic diagram of a battery



Source: Goldman Sachs Global Investment Research

Exhibit 41: We are on the cusp of large scale battery storage deployment
Global battery storage capacity, GW

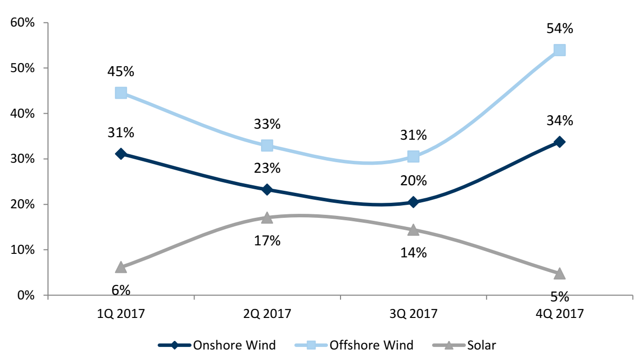


Source: BNEF

A need for long-term storage

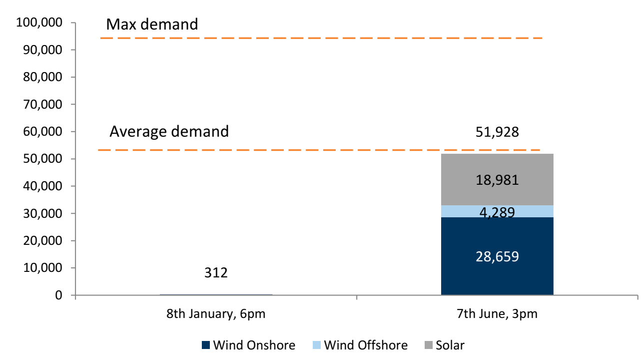
Not only are renewables volatile on an hourly basis, they have seasonal volatility. Naturally, solar panels produce more electricity during the summer while wind produces more in winter. This can create huge differences in renewable output between the seasons. We show below that in Germany the highest hour of RES generation was 166x times higher than the lowest. Worse, the lowest level was reached in winter when demand is the highest. Solving this balancing issue requires long-term storage to store energy on a seasonal basis. For example, it could be used to store solar energy during the summer in order to use it in winter.

Exhibit 42: RES output varies on a seasonal basis
UK load factor by quarter for onshore wind, offshore wind and solar in 2017



Source: DECC

Exhibit 43: Highest RES output hour of the year was 166x higher than the lowest point
Highest and lower power production over an hour of German renewable sources and demand max/average (2017), MW

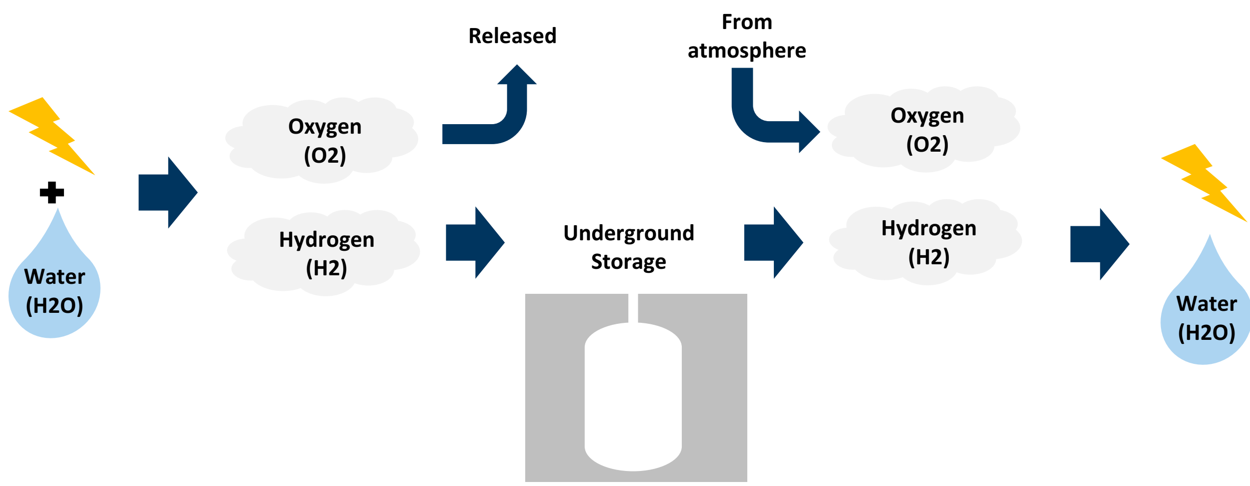


Source: BNetzA

Could power to gas be the solution?

Power to gas is another technology that can be used for electricity storage. More precisely called electrolysis, it uses electricity to split water molecules into its components: hydrogen and oxygen. Hydrogen can then be stored and later on converted back into electricity by reversing the chemical reaction. The advantage of the technology is that hydrogen can be stored at large scales similarly to natural gas. The key difference to battery storage is that the fuel source is not stored inside the "battery" but can kept externally. It can be compressed and stored underground in salt caverns, aquifers and depleted gas & oil fields. This would provide the electricity system with much-needed long-term seasonal storage. As of today, it remains at the research stage with high costs impeding large scale adoption.

Exhibit 44: Basic diagram of a power to gas storage system

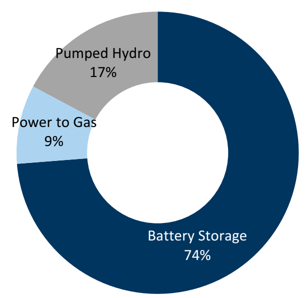


Source: Goldman Sachs Global Investment Research

We expect a mix of battery storage and power to gas

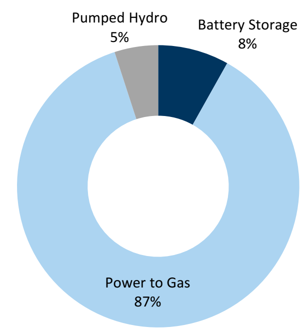
We believe that by 2050 we will see the deployment of a combination of battery storage and power to gas capacity. Battery storage is likely to be deployed first given the need to stabilise volatility and the readiness of the technology. Longer term, as conventional capacity starts to close down, the need for back-up generation will drive power to gas adoption, also leaving time for the technology to mature. Power to gas can store energy outside of the system, and hence it is more efficient for bulk (seasonal) storage. However, battery storage with its faster response time will dominate from the power side, in our view. Our cost/benefit analysis assumes a total cost at €150 bn or €5 bn per year to 2050.

Exhibit 45: Battery storage to dominate from a "power" standpoint
Split of battery storage technology based on GW in 2050E (=Power)



Source: Goldman Sachs Global Investment Research

Exhibit 46: Battery storage to dominate from an "energy" standpoint
Split of battery storage technology based on GWh in 2050E (=Energy)



Source: Goldman Sachs Global Investment Research

The Electrification Evidence

- **Spain targets 6GW of energy storage by 2030:** As part of the new Spanish energy strategy, Spain targets 6GW of energy storage, 3.5GW of which is from pumped hydro and 2.5GW from energy storage.
- **Arenko 41MW merchant battery:** Arenko is commissioning the UK's largest battery at 41MW with revenues mainly derived from merchant exposure (rather than a fixed contract). We estimate the battery cost for utiliity scale energy storage is around £500/kw which is lower than a CCGT.
- **Germany: Large-scale batteries to support renewables:** Germany's four transmission network operators are considering the commissioning of up to 900MW of battery storage to allow a 65% renewable penetration by 2030. This could reduce redispatch costs - currently around €1.5 bn pa - by over 10%, according to the latest *Netzentwicklungsplan.*
- **Tesla builds 100MW battery in Australia:** Tesla built a lithium-ion battery storage unit in Australia with a capacity of 100MW/129MWh back in 2017. Data from the local market operator (AEMO) shows the battery has been successful at managing renewable volatility and has reduced balancing costs in the region materially.

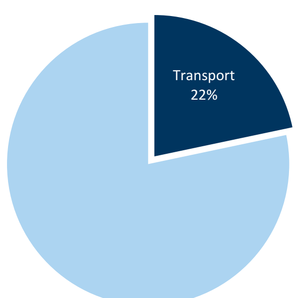
Transport: e-mobility and hydrogen eclipse combustion

Transport is the second most carbon-intensive sector in Europe and accounts for c.20% of emissions. In our view, reducing carbon emissions through electrification would be with either battery powered vehicles or hydrogen (fuel cell) based ones. In our cost/benefit analysis, we estimate carbon emissions could be cut by 95% for upfront costs of c.€80 bn pa to 2050 (mostly to provide tax breaks to fund EV purchases). Benefits include savings on running costs and energy independence, which on our estimates come to €330 bn pa.

Transport is the second most carbon-intensive sector in Europe

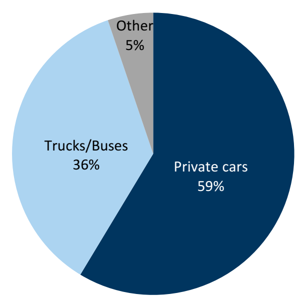
Reaching the EU's 2050 GHG reduction targets will require efforts across the board, not only in power generation but also in transport. Transport is the second most carbon-intensive sector in Europe and accounts for c.20% of emissions. Within transport, the lion's share of emissions is generated by passenger vehicles, which we believe will need to shift from internal combustion engines to electric vehicles. Similarly, trucks and buses will need to transition to either electricity or hydrogen.

Exhibit 47: Transport accounts for c.20% of emissions
Share of greenhouse gas emissions from transport (2016)



Source: Eurostat

Exhibit 48: Cars are the main emissions source followed by Trucks & Buses
Split of transport emissions by source (2016)

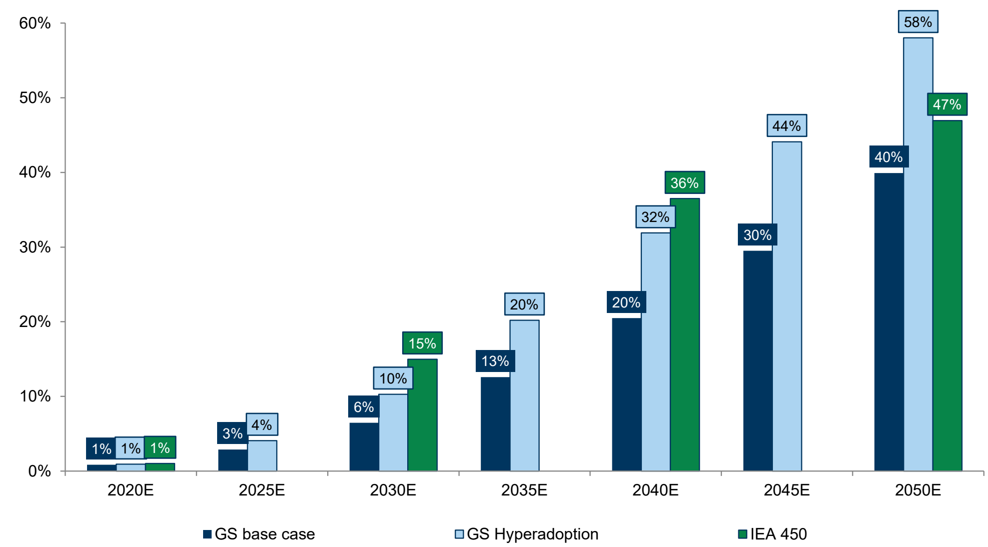


Source: Goldman Sachs Global Investment Research

EV adoption to pick up in the next decade

According to our Autos team and IEA, EV adoption for passenger vehicles will pick up in the next decade. This is driven by economics: the payback period for buying a more expensive EV with cheaper running costs falls below three years by our Auto team's estimates. Trucks and buses will also need to switch to clean fuels. Although electric vehicles are becoming the standard for "green" passenger vehicles, hydrogen is in use for buses and soon for trucks. Hydrogen offers high energy density, fast refuelling and longer ranges than batteries.

Exhibit 49: EV adoption to reach tipping point between 2025-2030E
PHEV and BEV share of stock globally

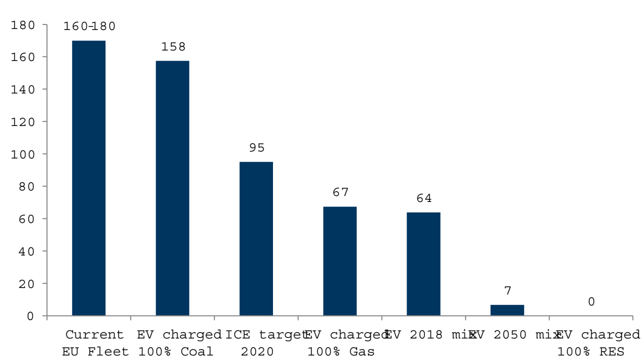


Source: IEA, Goldman Sachs Global Investment Research

Full EV adoption to lower emissions by 95% by 2050E

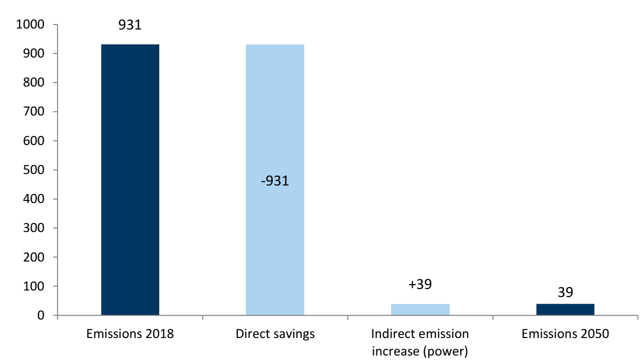
We estimate that if we were to reach full EV adoption by 2050, emissions from transport would fall by 95%. Indirect emissions relate to gas-fired production which would still be present in the energy mix by 2050. This is based on the carbon intensity of power being much lower than that of oil, in particular with RES growth.

Exhibit 50: CO2 intensity of passenger vehicles to fall
Emissions CO2 g/km in the EU; ICE = internal combustion engine



Source: Eurostat, Goldman Sachs Global Investment Research

Exhibit 51: We expect a full transition to EV would cut emissions by 95%
Estimated impact of switch to EV on European transport emissions (mtCO2e)

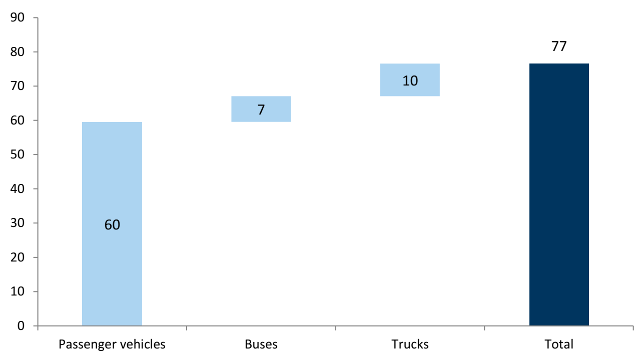


Source: EEA, Goldman Sachs Global Investment Research

Benefits of EV adoption also include savings and energy independence

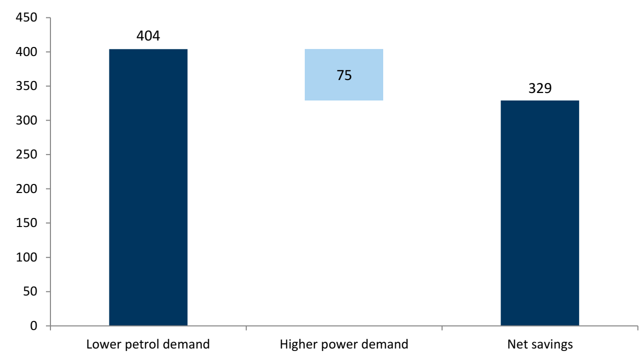
We estimate that the upfront cost of EV adoption will be almost €80 bn per year to 2050. This takes into account subsidies to fund the higher upfront cost of an EV vs an internal combustion engine cost. However, annual run-rate savings would be much higher as petrol is more expensive than electricity. We assume power demand would go up by 25% but cost only c.20% of petrol.

Exhibit 52: We estimate EV adoption would have an upfront cost of c.€80 bn pa...
Upfront cost of EV adoption, €bn



Source: Eurostat, Goldman Sachs Global Investment Research

Exhibit 53: ...but with annual running cost savings at €330 bn per year
Savings of passenger vehicle running costs pa at 100% EV adoption, €bn



Source: Goldman Sachs Global Investment Research

The Electrification Evidence

- **Passenger vehicles:** In Norway, electric car sales have reached record levels in 2018. Half of the cars sold were plugin hybrids or full EVs and 1 in 3 were full electric. This is driven by electric vehicle subsidies with the country aiming to reach full electrification by 2025. Volkswagen plans to launch 70 new electric models by 2028 (source: Clean Technica, Company data).
- **Trucks:** Nikola Motor is launching full hydrogen trucks with a range of up to 1,200km; beer giant Anheuser-Busch has already ordered up to 800 of these trucks. Tesla is launching an electric truck with a range of up to 800km (source: Company data).
- **Buses:** In London, all new buses have to be at least hybrids or cleaner (full EV or hydrogen). Transport for London aims to have 240 electric buses by the end of 2019 and already has 8 hydrogen running in Central London.

Buildings: Electrification of heating a pivotal step

Most of the emissions from buildings are the result of the combustion of gas and oil for heating/cooling purposes. As most electricity production will come from clean sources, switching heating to electric (via heat pumps) would lower emissions. We assume that electrification could impact more than half of the buildings by 2050.

How to electrify buildings

Currently, c.85% of buildings in Europe are gas (the vast majority) or oil heated. The penetration of electric heating is thus low.

Exhibit 54: We estimate the electrification of buildings could reduce emissions >60% by 2050
Electricity as % of primary energy consumption by use

	Current Electrification	2050E Electrification
Heating	15% - 16%	c.60%
Cooking	c.20%	100%

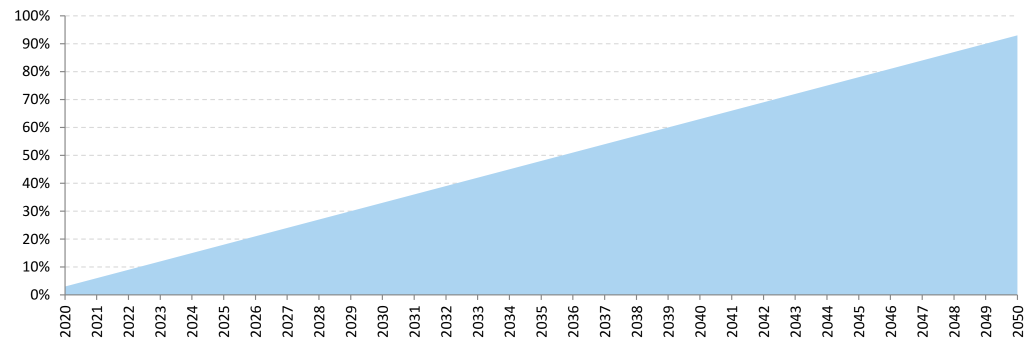
Note: Current electrification refers to 2015 data

Source: Eureelectric, Goldman Sachs Global Investment Research

According to data from the EU Buildings Database, every year the share of new builds is about 0.5%, whilst the share of refurbishments is 2%-3%. Holding these rates constant, we estimate that by 2050 over 90% of buildings would be new built or refurbished. The development of energy efficient materials, better awareness on running costs (efficient homes are cheaper to heat and cool to the tune of up to 50% and policy support (e.g. tax credits) for insulation could together significantly reduce emissions from buildings.

Based on these new builds and refurbishments rates, and assuming that 1-in-4 gas boiler upgrades (every eight years) would be replaced by a HP, we estimate that by 2050, HP could reach c.60% market share.

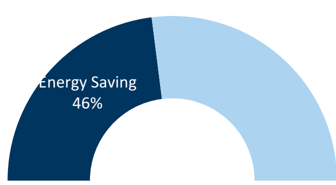
Exhibit 55: We estimate that by 2050 more than 90% of the apartments could be refurbished/newly built
Cumulative percentage of new builds (0.5% pa) and refurbishments (2.5% pa) until 2050E



Source: Goldman Sachs Global Investment Research

According to published data from German residential landlord Vonovia, across 17,623 modernisations of residential units that the company undertook during 2017 (covering c.1.1 mn sqm of usable floor area), the average reduction in energy consumption and emissions was around 50%.

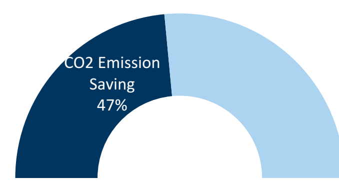
Exhibit 56: The average refurbishment reduced energy use by nearly 50%...
Average reduction in energy consumption post modernisation (2017)



Based on a sample size of 17,623 modernisation projects

Source: Vonovia

Exhibit 57: ...as well as CO2 emissions by nearly 50%
Average reduction in CO2 emissions post modernisation (2017)



Based on a sample size of 17,623 modernisation projects

Source: Vonovia

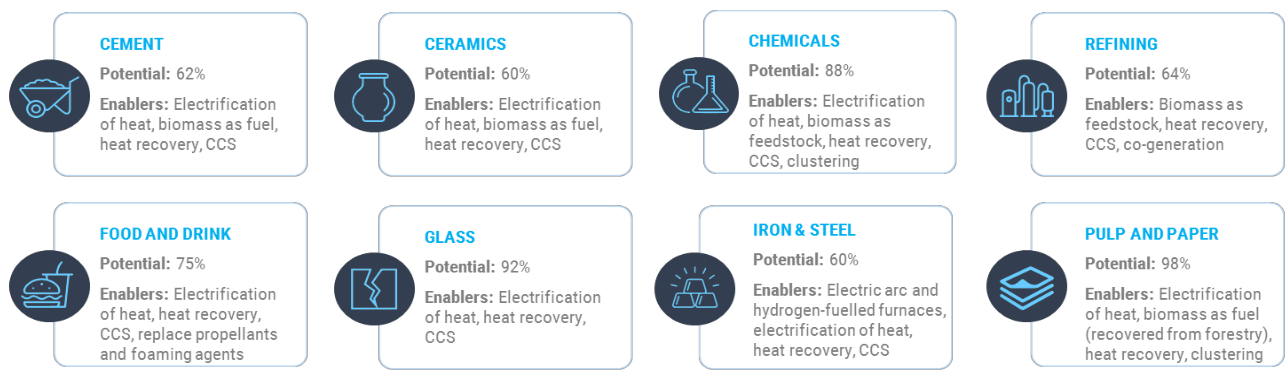
The Electrification Evidence

- **Dutch ban on gas boilers (2020):** As part of its 2050 Energy Agenda - which aims to ban fossil fuels by 2050 - the Netherlands is planning to ban the installation of new gas boilers by 2020.
- **UK ban on gas boilers (2025):** The UK has banned the installation of gas boilers in newly built homes from 2025 onwards.
- **Italy insulation:** In Italy, any residential refurbishment which proves to have lower energy consumption and which costs up to €80,000, receives a 50% tax break, recouped over 10 years (i.e. lower taxes paid to the tune of €4,000 pa).

Industrials: Fuel switching and CCS maximise decarbonisation potential

An extensive set of studies by the UK Department of Energy (now BEIS) shows a plethora of technologies and alternative industrial processes which - over the coming 30 years - they see helping industry decarbonise by c.75%. The electrification of heat, the use of biomass as feedstock and carbon capture sequestration (CCS) play pivotal roles in this. Further technological developments over the coming years could make these technologies both more effective and cheaper to implement.

Exhibit 58: Industry studies suggest that current technologies offer a vast decarbonisation potential of c.75%
Decarbonisation potential by sector based on maximum implementation of currently available technologies



Source: UK Government (DECC), Goldman Sachs Global Investment Research

The Electrification Evidence

- **Chemicals: Biomass as feedstock.** Reducing the use of fossil fuels as feedstock in industry remains a major hurdle to decarbonisation. BASF – in partnership with TÜV Süd – has developed a certification approach which allows the use of biomass as a renewable feedstock to be allocated to end products. Consumers are thereby incentivised to recognise and opt for the certified low carbon product (similarly to organic products in a supermarket), which in turn could push producers to increase adoption (source: Company data).
- **Refining: Cutting unnecessary emissions.** Due to its reliance on the processing of fossil fuels, refining will be one of the most difficult sectors to fully decarbonise. However, evidence from the industry shows that some low hanging fruits exist. By 2025, Eni expects to reduce emissions by cutting to zero the amount of gas sent to flaring (by recycling and reusing it) and reducing by 80% the level of fugitive emissions (source: Company data).
- **Iron & Steel: Alternative furnace technologies.** As reported by the FT earlier this year, Tata hopes to cut emissions by one-fifth at its Dutch steelworks IJmuiden by adopting electric arc furnaces. Swedish steelmaker SSAB is taking a different approach to decarbonisation by building a pilot hydrogen-fuelled facility (to be commissioned in 2020) that will make Sweden the first country in the world to manufacture steel without the use of any fossil fuels (the hydrogen will be produced through electrolysis, using renewable electricity) (source: Company data).

Power demand: Higher volume vs efficiency

The outcomes of electrification

In the following two chapters we discuss the outcome of electrification on the primary energy mix. Our main conclusions are:

Power demand could grow annually by 2% gross and 1% net of energy efficiency by 2050E.

Gas demand could fall by 2% annually, implying a cumulative decline of 50% by 2050E.

During the past ten years, power demand has fallen across Europe. Although this was largely function of the 2008-09 financial crisis, power demand in the past five years has been broadly flat. We believe the electrification process would reverse this, estimating c.2% CAGR in power demand through 2050. That said, we expect energy efficiency to contain such annual compounded growth to c.1% per year.

Power demand growth has been decelerating for over the past decade

During the past ten years, European power demand have been falling by 0.3% per year on average. The decline was particularly steep during 2007-12, whilst during 2012 and 2017 demand was broadly flat. This is a major departure vs history: during 1990 and 2007 for instance, demand had been growing at +1.6% per year.

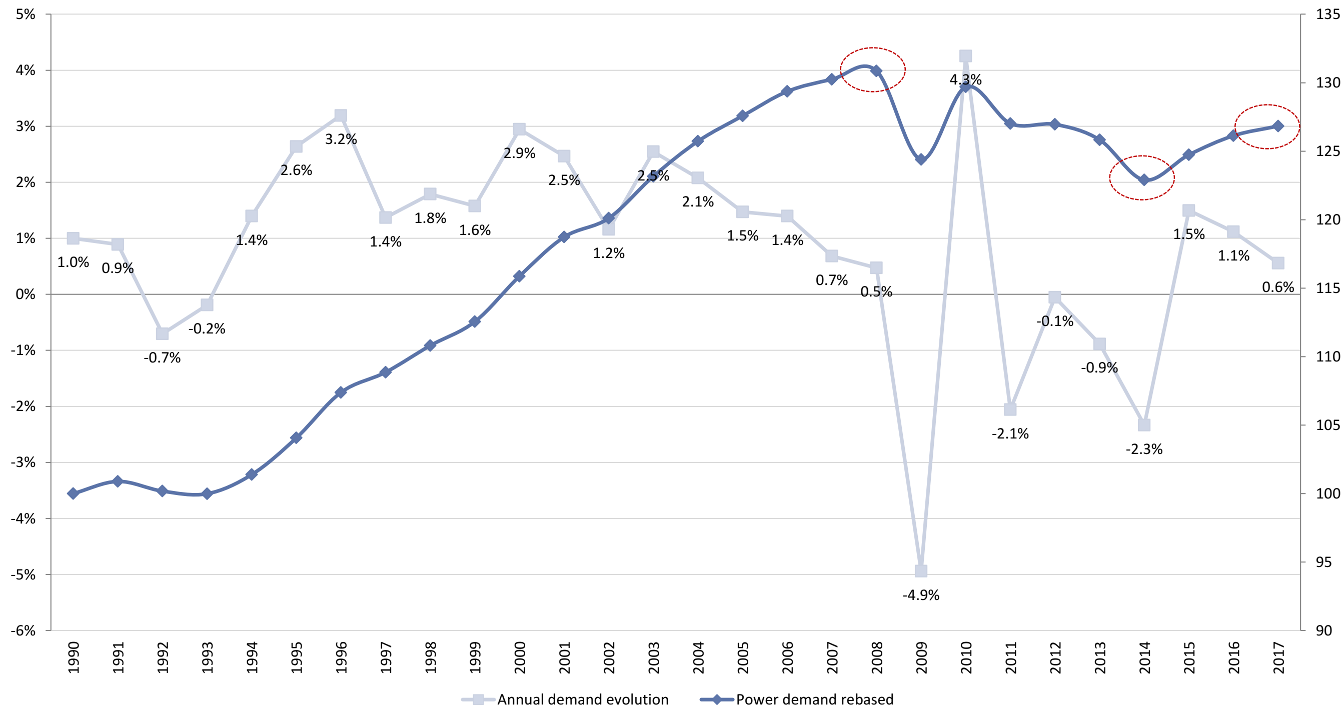
Exhibit 59: European power demand has been pretty weak since 2007
European power demand (CAGR)

	1990-2007	2007-17	2012-2017
Industry	0.8%	-1.0%	0.3%
Residential	1.7%	0.0%	-0.6%
Services	3.4%	0.6%	0.0%
Other	0.0%	-1.0%	0.3%
EU28 Power Demand (CAGR)	**1.6%**	**-0.3%**	**0.0%**

Source: Eurostat, Goldman Sachs Global Investment Research

Today, European power demand is still some 3% below the 2008 peak; in other words, although we bounced from the 2014 trough levels, for the past ten years European power demand has been stale on a cumulative basis.

Exhibit 60: European power demand is still below the 2008 peak even though it has been growing for the past three years
EU28 power demand growth, annual and cumulative (rebased to 100)



Source: Eurostat, Goldman Sachs Global Investment Research

Electrification could lead to acceleration in consumption

On our estimates, the electrification process implies an annual growth rate in electricity consumption at c.2% pa. Despite our assumption of lacklustre demand from industrial customers – the de-industrialisation of Europe and the reduction in energy intensity is likely to continue – we envisage solid growth from residential customers (electric heating) and services. We also expect electric mobility to be a major growth driver.

- **Residential**. During the past ten years, residential demand has been broadly flat (but declining over the past five years). We estimate that electrification could push annual residential consumption to +1.6% pa, largely owing to the electrification of heating. We base our conclusion on a 60% penetration assumption for Heat Pumps by 2050 (we assume that 1 gas boiler in 4 will be replaced by HP, as useful life expires).

Exhibit 61: Electrification could accelerate power demand growth to +2% pa (vs 0.5%-1.0% currently)
Europe power demand growth owing to electrification analysis (TWh)

	Resid.	Svc	Industry	EV	Total
2018 TWh	808	845	1,272	0	2,925
EU28 Homes (mn)	256				
Homes with HPs (%)	40%				
Homes with HPs (mn)	103				
Heat Consumption per home (kWh)	12,000				
Power Consumption per home (kWh)	4,000				
Power Consumption all homes (TWh)	410				
2018-2050 increase	**51%**				
Buildings electrification 2018	34%				
Buildings going electric 2020-50	50%				
Buildings electrification 2050	51%				
2018-2050 increase	**48%**				
Industry electrification 2018	34%				
Factories going electric 2020-50	20%				
Industry electrification 2050	41%				
2018-2050 increase	**18%**				
EV cars by 2050 (mn)	253				
Km driven pa	16,500				
Conversion to kWh pa	2,888				
EV consumption pa (TWh)	731				
Underlying growth pa 1998-2018 (%)	0.00%	0.50%	0.25%		
Increment from Electrification pa	1.6%	1.5%	0.6%		
Annual growth in power demand	**1.6%**	**2.0%**	**0.8%**		
Power demand 2050 (TWh)	1,337	1,584	1,649	731	5,300
Growth 2020-50	66%	88%	30%	NM	81%
Growth 2020-50 pa	1.6%	2.0%	0.8%	32.1%	1.9%

Source: Goldman Sachs Global Investment Research

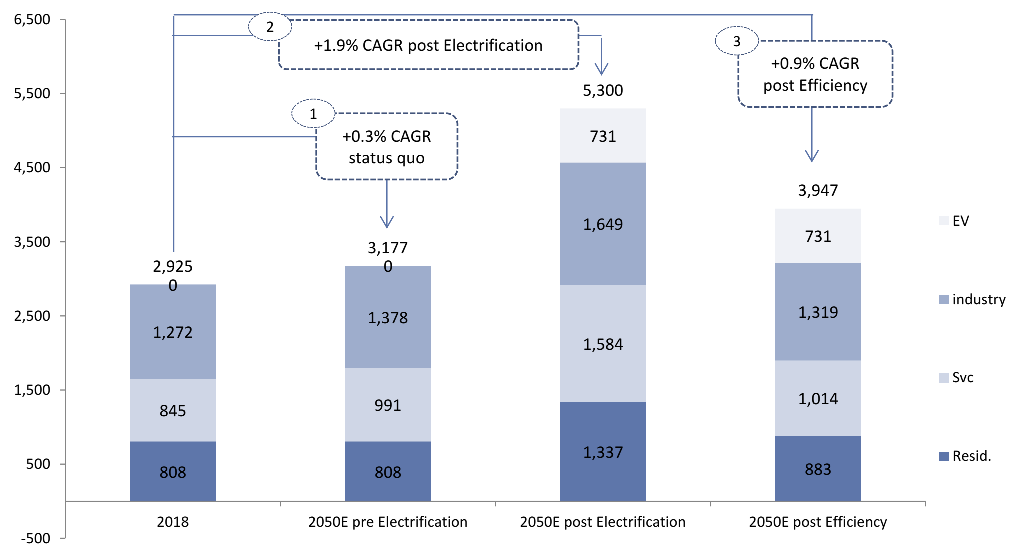
- **Services**. During the past ten years, power demand from services has been increasing by about 0.5% pa. We estimate that the electrification of buildings (c.60% by 2050) could lead to higher demand for electricity and raise the annual growth rate to c.2%.
- **Industry**. Even though annual demand for the past five years has turned positive (c.0.25% pa), power demand from industrial customers has been weak since 1990 following the ongoing shift of the European economies from manufacturing to services. Assuming a modest 20% electrification in factories, annual demand from industrial clients could rise by nearly 1% per year we estimate.
- **E-mobility.** Assuming >250mn passenger electric cars by 2050 (effectively, full penetration), power demand could benefit from c.25% cumulative boost (assuming 16,500 average annual km driven by user).

Efficiency could contain demand to +1% pa

On our analysis, energy efficiency would be a pillar of decarbonisation. Exhibit below shows that although electrification could meaningfully accelerate power demand growth (from just above zero to nearly 2% per year in our estimates above), a successful implementation of energy efficiency measures could contain annual electricity consumption growth at less than 1%. Hereby we explain our methodology.

Exhibit 62: Electrification could lead to c.2% annual demand; energy efficiency could cap growth at c.1% per year by 2050

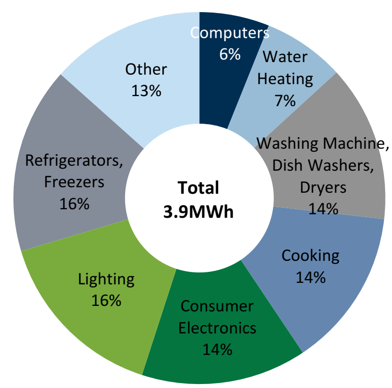
European power demand under status quo, Electrification and Electrification-with-Energy-Efficiency analysis (TWh)



Source: Eurostat, Goldman Sachs Global Investment Research

- **Appliances**. Based on data officially released by the UK Government, we have estimated that during 2010 and 2016 new electrical appliances of a typical household have benefited from annual efficiency improvements of c.2.5%. We apply those savings to our business as usual demand growth from households.

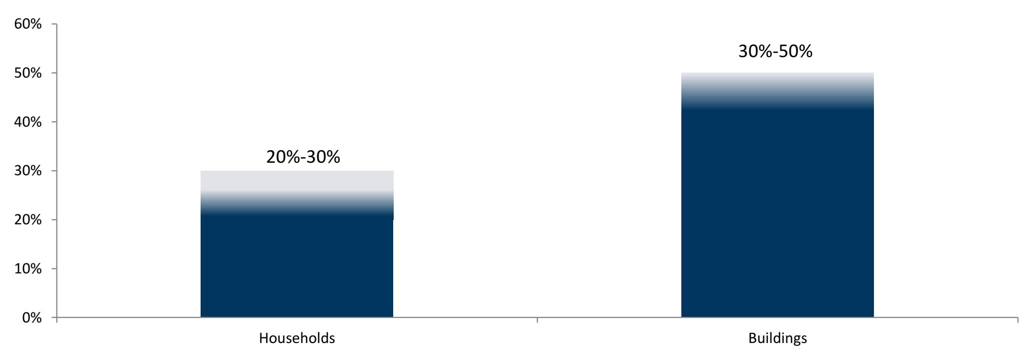
Exhibit 63: Typical UK household consumption: appliances have become c.2.5% more efficient every year since 2010
UK Household consumption split (2017)



Source: UK Government, Goldman Sachs Global Investment Research

- **Buildings insulation**. Based on anecdotal evidence from refurbishment projects, we assume that insulation could lower consumption by at least 20%-30% per home, whilst savings per building (including switching to smart heating/cooling and smart lighting) could be 30%-50%.

Exhibit 64: Consumption savings from insulation range from 20% to 50%
Typical energy consumption savings from insulation



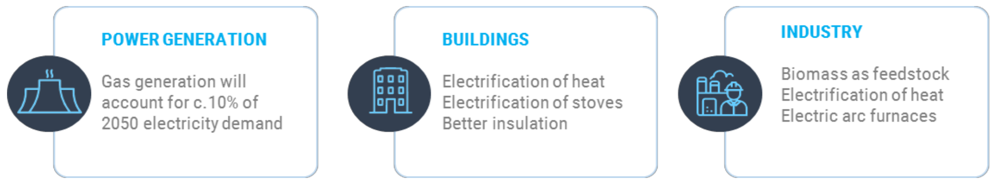
Source: Goldman Sachs Global Investment Research

- **Industry Equipment**. Case studies published by several utilities in our coverage on industrial clients show the potential for at least 20% savings via energy efficiency projects.

Gas demand: To nearly halve by 2050E

One of the key by-products of electrification would be lower gas demand. We estimate that - by 2050 - Europe's need for gas could shrink by c.50% on the back of the decarbonisation of power generation, the gradual electrification of heating and the partial electrification of industrial processes.

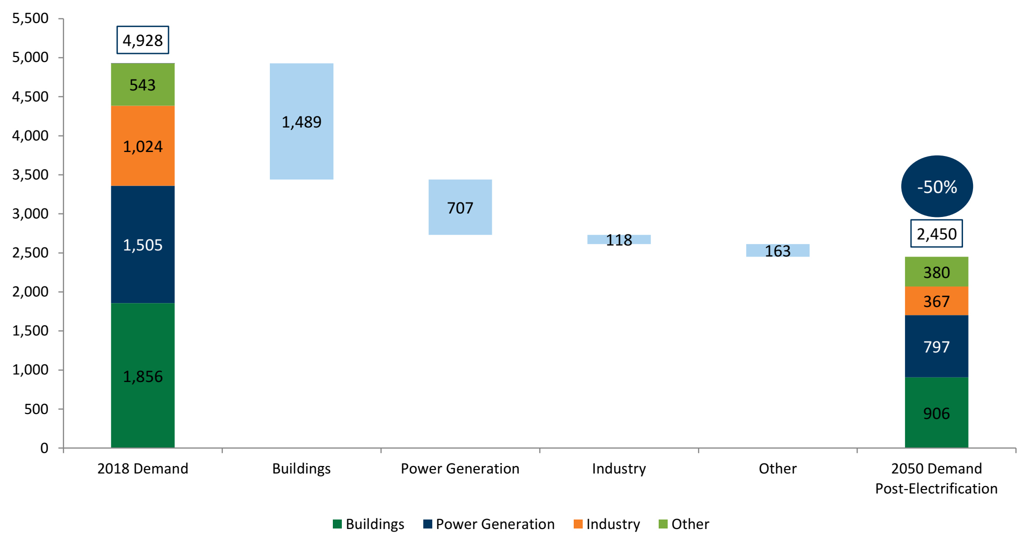
Exhibit 65: Electrification could significantly reduce the need for gas across sectors of the economy



Source: Goldman Sachs Global Investment Research

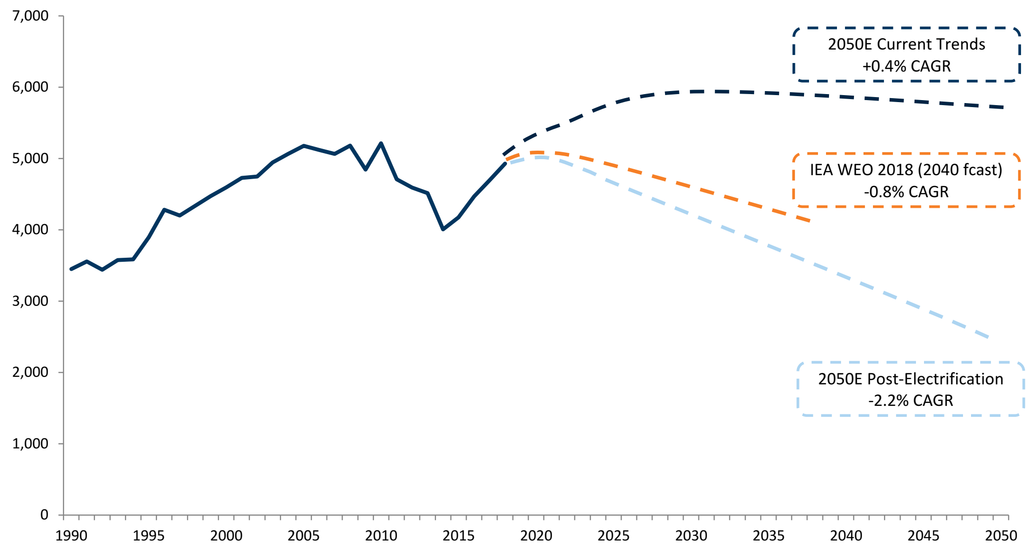
In our view, the single largest contributor to the reduction in gas demand would come from heating, which has the potential to be 100% electrified in the long term (we assume 60% by 2050 in our analysis). Power generation is second in line - we estimate that a mere 10% market share for gas will be needed by 2050 to complement an almost fully renewable electricity mix.

Exhibit 66: We estimate that electrification could reduce gas demand by c.50%...
Gas demand evolution (TWh)



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 67: ...shaving off >2.5% pa from the current growth trend in the market
Gas demand CAGRs by sector, pre- and post-electrification



Source: IEA, Goldman Sachs Global Investment Research

The Electrification Evidence

- **Bans on gas boilers:** As part of its 2050 Energy Agenda - which aims to ban fossil fuels by 2050 - the Netherlands is planning to ban the installation of new gas boilers by 2020. The UK announced it will follow suit with a similar ban starting in 2025.
- **Refurbishment tax credits:** Several countries in Europe - such as Italy and Germany - have made refurbishment expenses - such as mortgage interest costs and investments in modernisation of homes including labour costs - tax deductible.

Disclosure Appendix

Reg AC

We, Alberto Gandolfi, Matteo Rodolfo, Baptiste Cota, Pragna Kataria, CFA, Ajay Patel and Manuel Losa, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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Alberto Gandolfi: Europe-Utilities. Baptiste Cota: Europe-Utilities. Ajay Patel: Europe-Utilities. Manuel Losa: Europe-Utilities.

Europe-Utilities: A2A SpA, Acciona SA, Centrica, ContourGlobal Plc, E.ON, EDF, EDP Renovaveis SA, Enagas, Endesa SA, Enel SpA, Energias de Portugal, Engie, Fortum OYJ, Iberdrola SA, innogy SE, Italgas SpA, National Grid Plc, Naturgy Energy Group, Nordex SE, Orsted A/S, Pennon Group, Red Electrica de Espana, REN, RWE, Severn Trent Plc, Siemens Gamesa Renewable Energy, Snam SpA, SSE Plc, Suez, Terna, Uniper SE, United Utilities Group, Veolia Environnement, Vestas Wind Systems A/S.

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