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Sustainability Research Institute

# Road to a rapid transition to sustainable energy security in Europe

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Life Is On | Schneider Electric

# Introducing the Schneider Electric™ Sustainability Research Institute

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## Progress on energy and sustainability is at an all-time high. How will that momentum fare in a new decade – and under radical new circumstances?

It is our responsibility, as a large organization, to make a positive impact by reducing our energy consumption and $CO_2$ emissions, and contributing to societal progress, while being profitable.

At Schneider Electric we have set ambitious targets with our 2021–2025 Schneider Sustainability Impact (SSI), in line with the United Nations Sustainable Development Goals; our technologies reconcile growth, access to energy for all, and a carbon-free future for our planet. Our climate commitments aim to minimize carbon emissions for both our customers and our own company. For Schneider, this means the neutrality of our business ecosystem by 2025, net-zero carbon from our operations by 2030, and net-zero carbon of our end-to-end supply chain by 2050.

With pioneering technology and end-to-end solutions for sustainability, we've been building momentum.

The Schneider Electric™ Sustainability Research Institute examines the issues at hand and considers how the business community, as well as societies and government, can and should act. We seek to make sense of current trends and what must happen to maintain momentum, and preview the changes that we believe are yet to come.

In this study, we explore the electrification potential of the European Union. We find that, by focusing on key sectors where electrification is both technologically feasible and attractive, the share of electricity in the overall energy mix could jump from around 20% to 50%. As this transformation happens, the supply of natural gas and oil would drop by around 50%, significantly reducing current energy security concerns, while cutting carbon dioxide emissions by around 1,300 $MtCO_2$/y. The road to a rapid transition to sustainable energy security in Europe is definitely up for grabs.

To achieve the sustainability goals set out by hundreds of global organizations, bold steps are required to reduce emissions and operate more sustainably.

Join us in this series where we explore compelling predictions and conclusions in the areas of energy management, digital innovation, climate action, goalsetting and confidence, and fresh financing mechanisms.

**It is time to embrace sustainability as a business imperative, and to capture the momentum now, for the future.**

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# Executive summary

Decarbonization and energy security in Europe are two faces of the same coin. They are both related to the large dependency of the European Union economy on fossil fuels, which today represent around 70% of the total supply of energy. The bulk of these energy resources are imported, with Russia being the largest supplier, accounting for 40% of natural gas and 27% of oil imports. However, fossil fuels are also the primary root cause of greenhouse gas emissions, and the European Union is committed to reduce those by 55% by 2030 (versus 1990).

This report is based on the landmark research from the Joint Research Center of the European Commission, the "Integrated Database of the European Energy Sector", which for the first time mapped actual energy uses for each country within the European Union, across 17 sectors of activity, with data granularity at the level of each process step (or end-use) of each of these sectors.

Our approach here has been to systematically review these process steps (or end-uses) and qualify the extent to which they could be electrified, effectively removing the demand for fossil fuels as a result. We have focused only on those process steps where technology was already widely available and for which we evaluated the switch to be relatively easy (or attractive). In other words, we estimated the impact of rapid electrification of "easy to abate" activities.

**The conclusion of this evaluation is that the share of electricity demand in the final energy mix could jump from around 20% today to 50%, which would drive a reduction in emissions at end-use of around 1,300 Mt$CO_2$/y, as well as a drop in natural gas and oil supply of around 50%.**

As a result of such transformation, electricity demand would nearly double, with the bulk of that growth materializing in the building sector. Short-term, the challenge of addressing climate targets while providing for energy security is thus intimately connected to buildings. While such transition would certainly require major infrastructure upgrades, which may prove a roadblock to rapid deployment, we find that the combination of energy efficiency measures (notably digital) and distributed generation penetration (rooftop solar) could significantly tame the issue, and hence help accelerate the move away from fossil fuels, with energy spend savings as high as 80% across some building types; a major driver of change.

Beyond this, further potential exists for electrification. Other measures on the demand-side will include deeper renovations of the industrial stock (notably in the automotive, machinery, paper, and petrochemical industries for which our current assessment may be underestimated) and further electrification of mobility (trucks). The transition of the power system away from coal (and ultimately natural gas) will then also play a key role, followed ultimately by feedstocks substitution in industry. Some of these transitions are already on the way and will likely bring further improvements.

The key message, however, is that a significant opportunity revolves around buildings to both quickly decarbonize and reduce energy dependencies in Europe. Rapid transformation of the energy system may be more feasible than we think. We notably estimate that, **by 2030, an ambitious and focused effort could help displace 15% to 25% of natural gas and oil supply and reduce emissions by around 500 Mt$CO_2$/y** (note that these savings would come on top of additional measures regarding energy efficiency and flexibility, which are not the object of this study). **For this to happen, approximately 100 million buildings will need renovating, and a similar number of electric vehicles would need to hit the road.**

# Decarbonization and energy security – two faces of the same coin

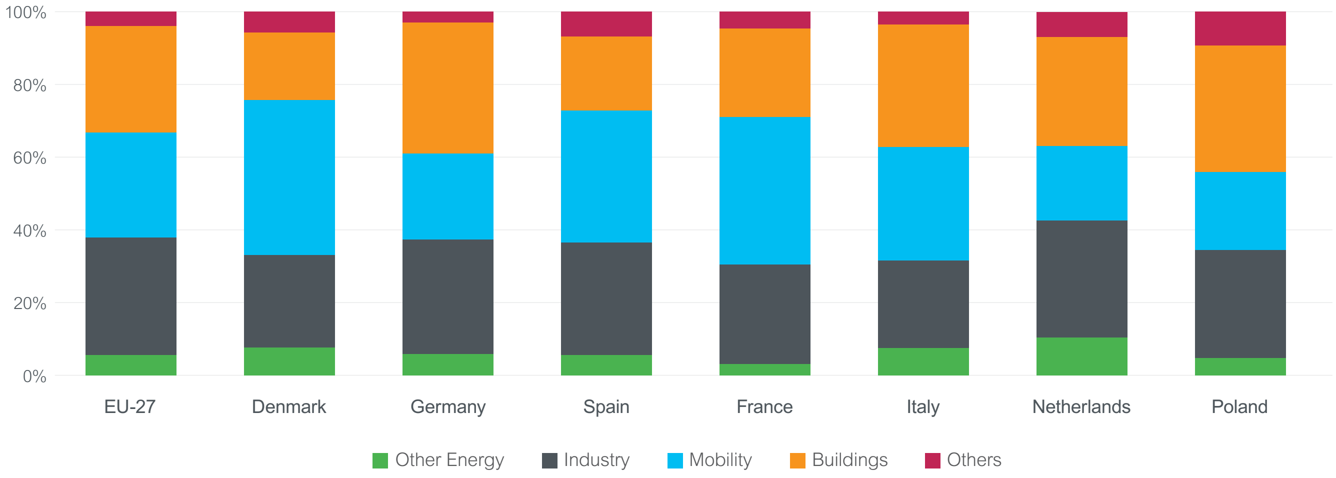
## Decarbonization

The European Union emits today around 2,900 Mt$CO_2$/y[(1)]. Germany leads the pack with around 700 Mt$CO_2$/y, followed by France, Italy, and Poland at around 300 Mt$CO_2$/y. The seven countries we choose to specifically review here represent around 73% of total $CO_2$ emissions of the EU-27 (Figure 1).

At the European level, buildings, mobility, and industry contribute almost equally in share[(2)]. The share of buildings in total emissions is typically higher in Germany, Italy, the Netherlands, and Poland, due to more important emissions related to fossil-based space heating.

The European Union has set itself a target to reach climate neutrality by 2050 and reduce those emissions by at least 55% by 2030 (versus 1990), or roughly an additional 1,000 Mt$CO_2$/y on the scope covered here[(3)]. Such a significant effort will require progress across most sectors of activity.

**Figure 1 – $CO_2$ emissions**




(1) Eurostat, 2019a. We focus here only on $CO_2$ emissions and discard other greenhouse gases. $CO_2$ emissions include all energy-related emissions as well as industrial process emissions. Agriculture, waste management, land use and forestry, and bunkers are excluded.
(2) There are minor variations across sources on these figures. This notably has to do with the share of electricity emissions associated to each sector. A similar allocation with data from the International Energy Agency shows a share of building emissions closer to 35%, which translates into nearly 40% of total emissions when accounting for embodied emissions. © OECD/IEA, 2021.
(3) This is extrapolated from greenhouse gas (GHG) emissions targets as disclosed in the GHG inventory from the EU-27. We have noted minor discrepancies due to scope accounting between sources. The figure is thus just an order of magnitude of the effort required. European Environment Agency, 2021.

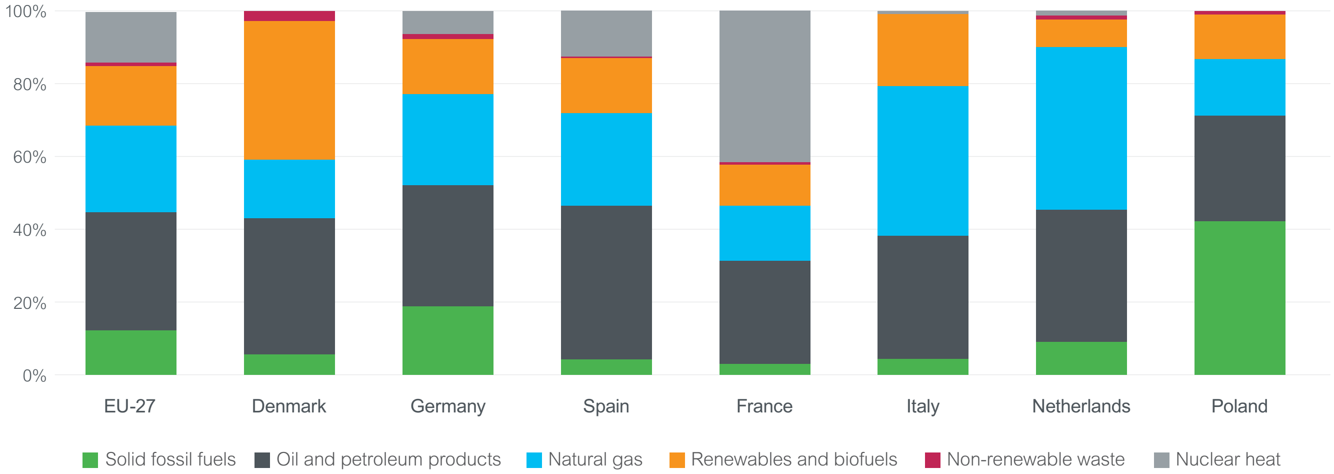
# Energy security

These emissions essentially stem from the consumption of fossil fuels. At the level of the EU-27, fossil fuels represent around 70% of total energy supply[4]. Oil represents one-third of the total, natural gas 25%, and coal around 10%. The remainder of the energy supply is provided by renewable energies and nuclear heat, at around 15% each.

Energy supply mix also varies across countries. Denmark and France stand out with a predominant role for renewable energies (for the former) or nuclear heat (for the latter). The Netherlands and Italy are extremely dependent on natural gas (around 40% of their mix), although Germany represents the largest dependency in absolute value. Poland and Germany also rely on massive quantities of coal, notably for their power generation (Figure 2).

Overall, the 7 countries covered in this issue represent 71% of total energy supply of the EU-27.

**Figure 2 – Energy supply**



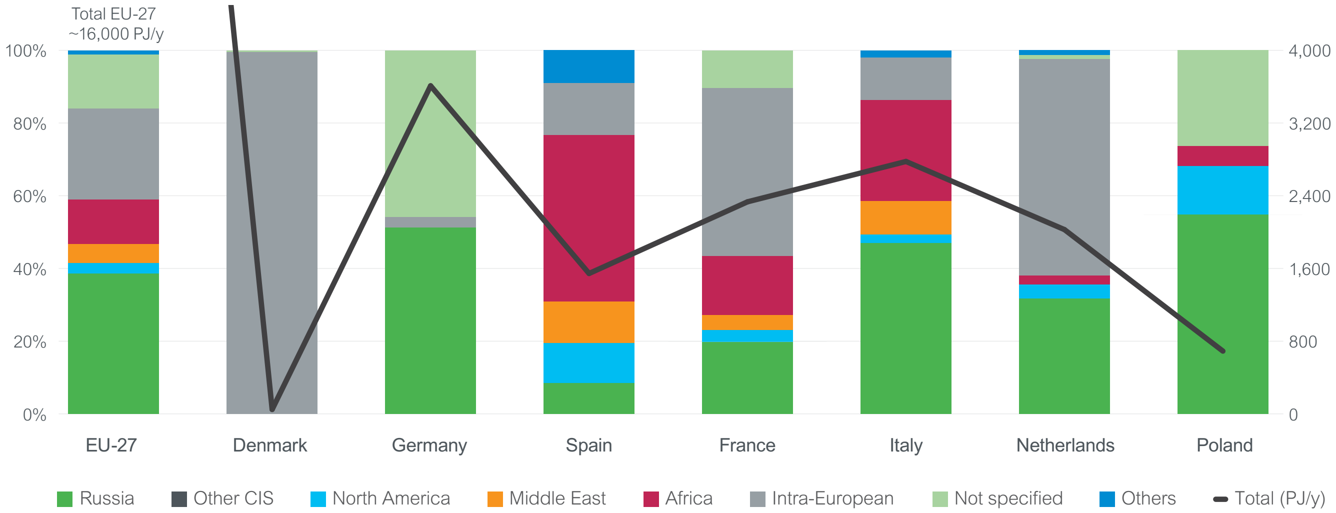

A large proportion of these fuels are imported, creating significant dependencies on other regions of the world[5]. The EU-27 is producing only around 15% of its natural gas and 5% of its oil (but 60% of its coal). The total volume of imports represents around 13,000 PJ/y for natural gas, and 19,000 PJ/y for oil, if we exclude Intra-European imports.

(4) Eurostat, 2019b.
(5) Eurostat, 2019c.

## Natural gas (Figure 3)

- Russia represents 40% of imports for natural gas at the EU-27 level, a figure which jumps to around or above 50% in Germany, Italy, and Poland.
- Countries fronting the Mediterranean Sea are typically more reliant on imports from Africa, while countries west of Germany rely more on Intra-European supplies (Norway, the Netherlands, etc.).
- Liquefied Natural Gas (LNG) supplies are also relatively small in share, with Spain and Poland most engaged in international trade(6).

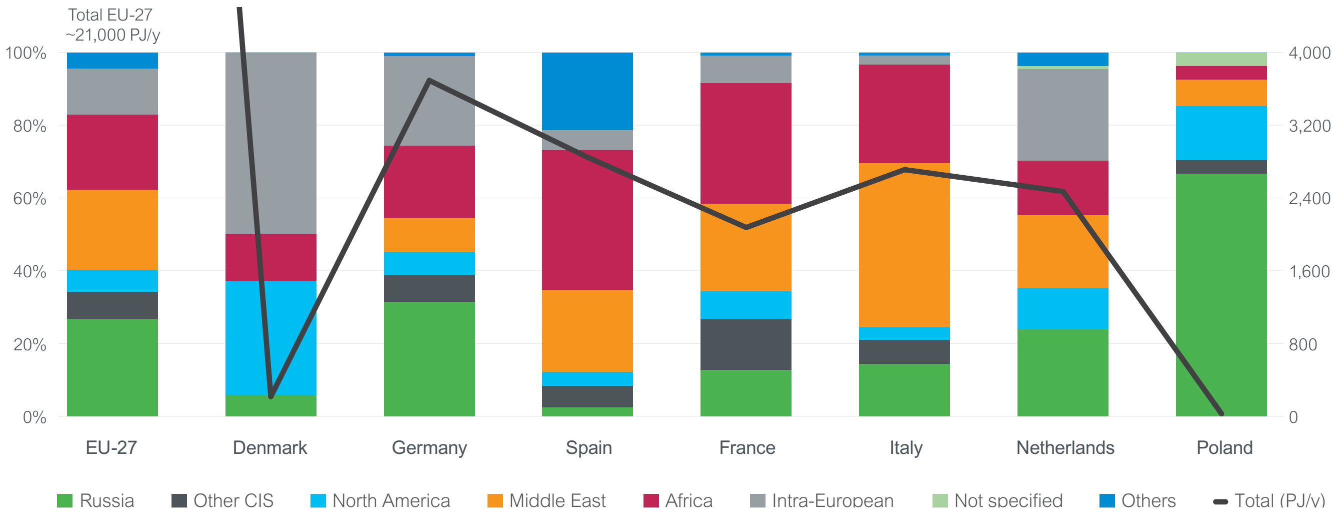
**Figure 3 – Natural Gas imports (%, PJ/y)**




## Oil (Figure 4)

- Imports are more diversified for oil due to the global nature of its trade. Russia represents 27% of oil imports, however, this figure reaches 68% in Poland.
- Unsurprisingly, countries fronting the Mediterranean Sea are also much more reliant on imports from Africa and Middle East.

**Figure 4 – Oil imports (%, PJ/y)**

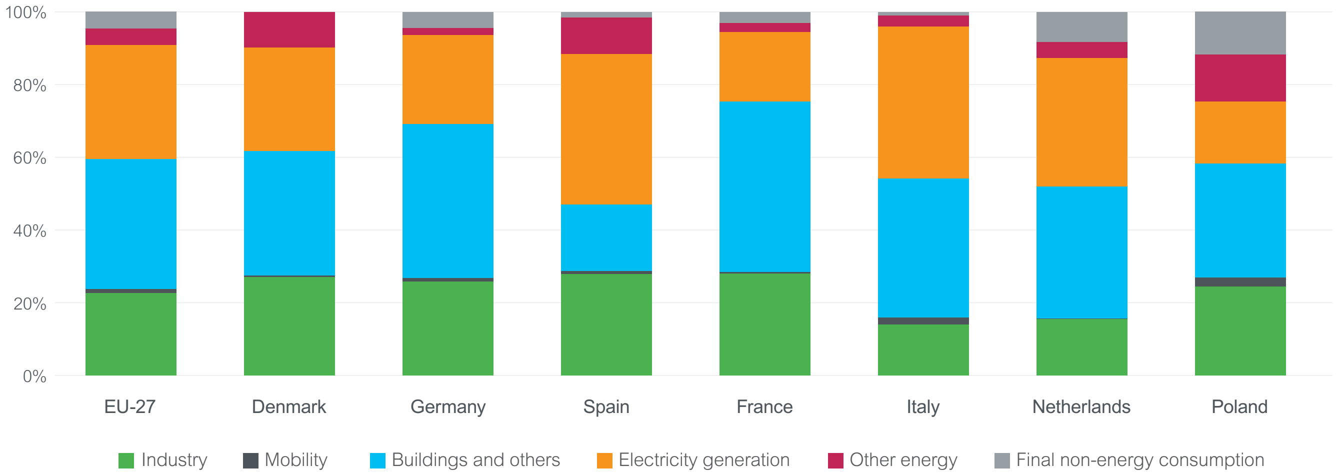



Energy dependencies (on natural gas and oil) are thus significant in Europe, and mitigating their use will help improve security of supply. Another way to look at this issue is to explore where fossil fuels are actually consumed:

- Natural gas is mostly consumed in buildings (40%) and for power generation (30%). These levels vary across countries depending on the choices made in energy mix (Figure 5).
- In buildings, the Netherlands (70% of households' energy demand comes from natural gas), Italy (50%), and Germany (40%) stand out.
- In power generation, the Netherlands and Italy stand out with around 50% of resource inputs (to power generation) coming from natural gas.

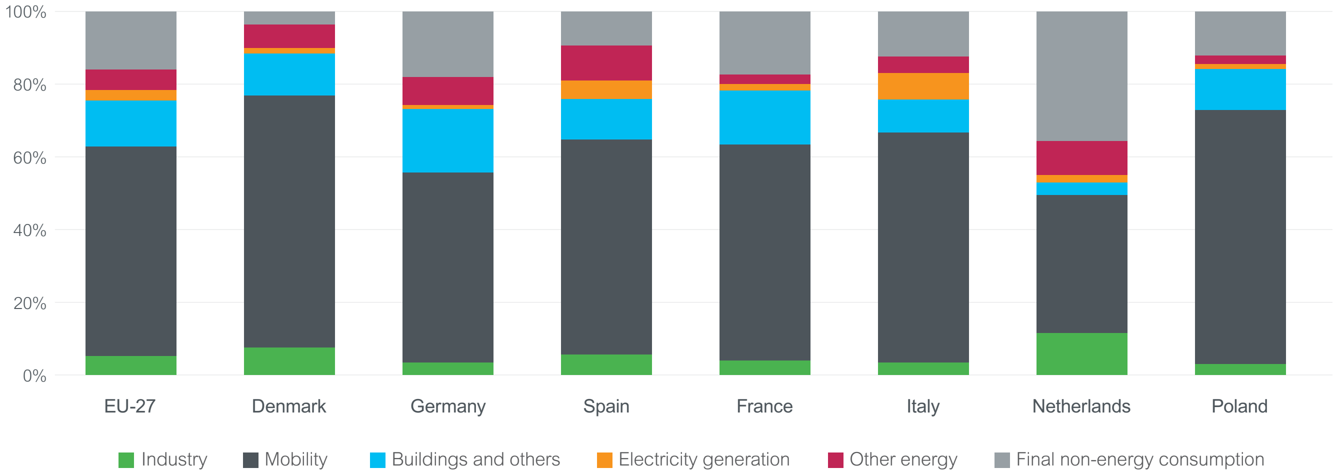
(6) While LNG could be further developed going forward, it also comes with its own set of challenges in terms of both infrastructure and carbon emissions. Carbone4, 2021.

**Figure 5 – Where is natural gas consumed?**




For oil, around 60% of the demand comes from mobility, and in particular road transport, out of which private cars draw the majority of demand (more than half of the 60%). Around 10% of oil goes to buildings, and 15% as feedstock to the petrochemical industry (Figure 6).

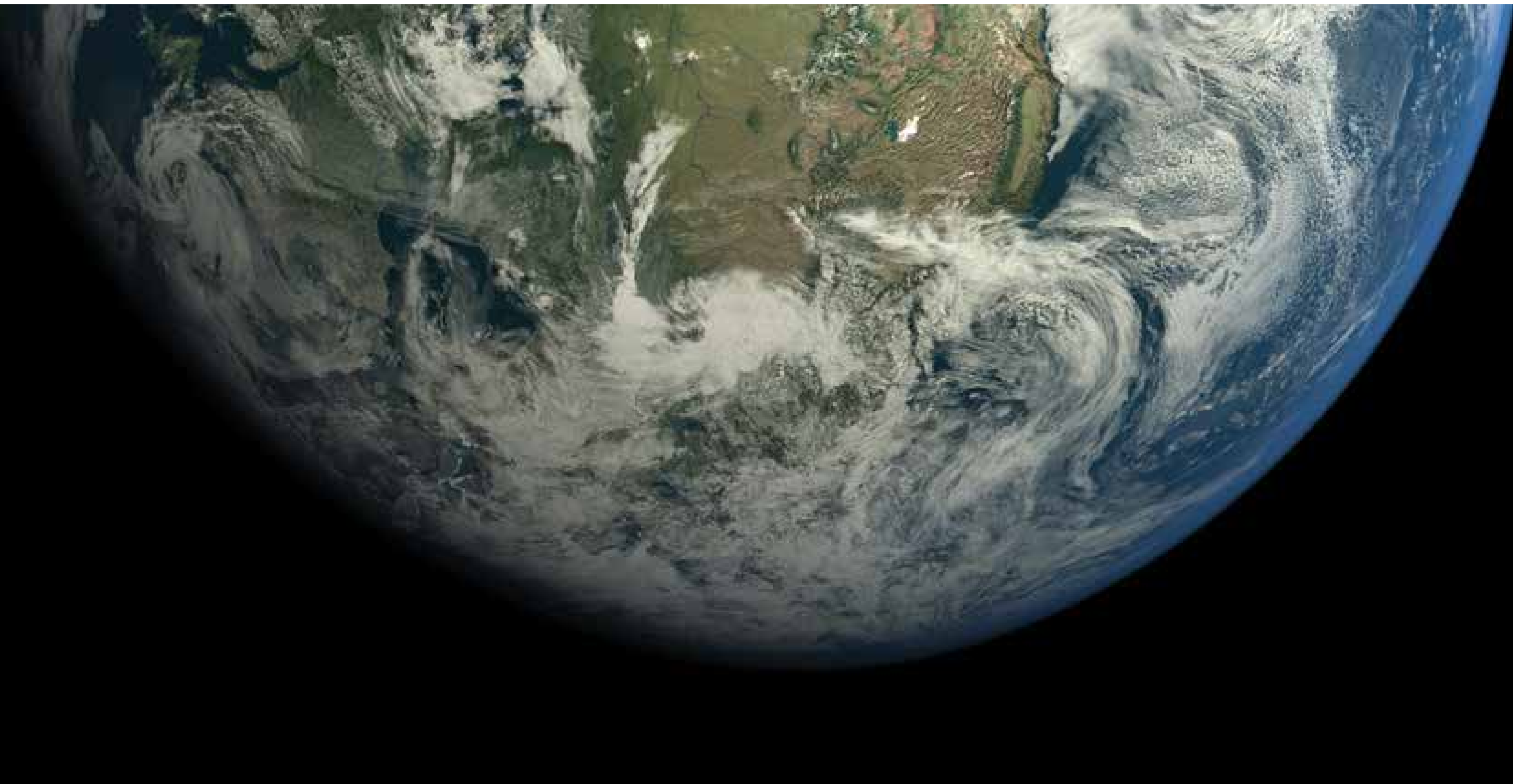
**Figure 6 – Where is oil consumed?**




For coal, the bulk of supply (around 70%) goes to power generation. This is consistent across regions, with the exception of France which relies much more on nuclear heat. The rest is essentially used in several industrial processes, notably steel manufacturing.

As a conclusion of this review, **decarbonization and energy security clearly go hand in hand**. In this regard, **the decarbonization ambition of the EU-27 is the most rationale way to improve energy security. Two sectors stand out when it comes to reducing both emissions and dependencies: buildings (40% of natural gas supply, 10% of oil) and mobility (60% of oil supply).**

# 2 Methodology



# Methodology

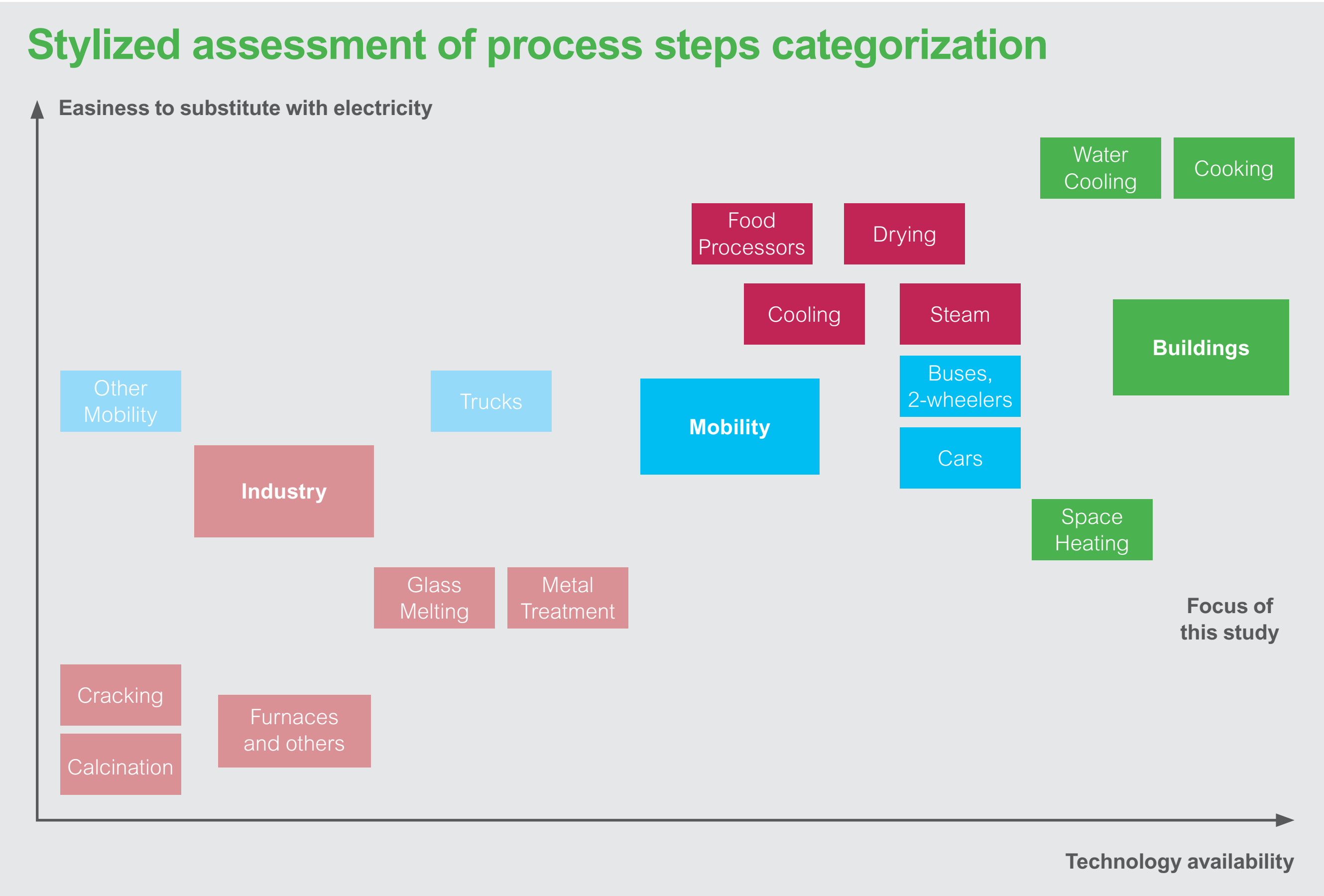
In 2018, the Joint Research Center of the European Union Commission published a landmark research effort on the energy system of the European Union, the “Integrated Database of the European Energy Sector”[7]. This effort aimed at describing the full energy system of Europe (country per country) with high granularity per sector (which is already available from multiple organizations) and per process step (or end-use, which is seldom available). The granularity of the data helps to understand where different types of energy sources are used, and for what process step within each industry of each country of Europe. The baseline data is 2015 energy demand[8].

In this research, we use this database to explore to which extent fossil fuels use can be substituted by electricity in the European Union[8] as a whole and for the seven countries we have identified earlier. This approach is inspired from a similar 2020 academic effort, albeit with a slightly different methodological approach[9].

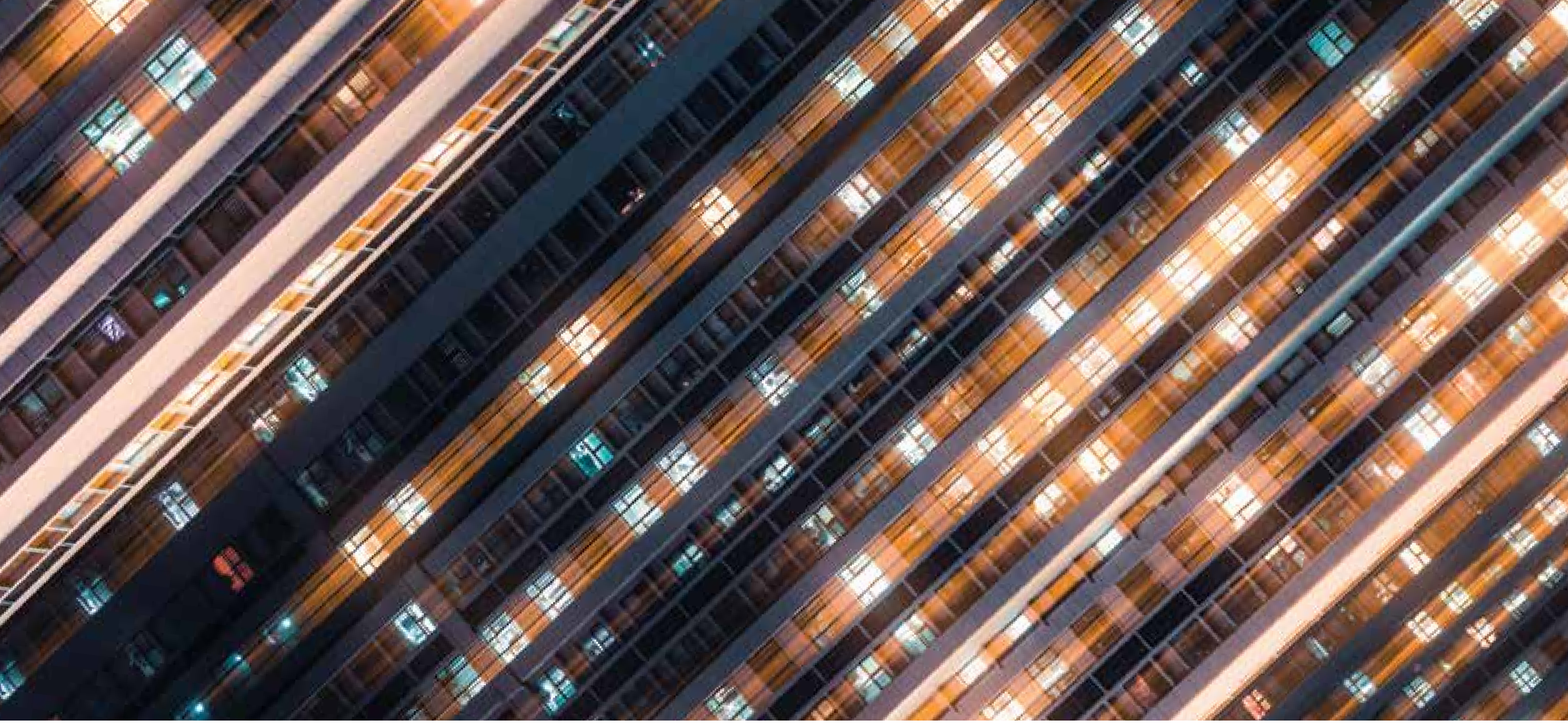
The following approach is followed:

1. Retrieve for each country the detailed energy system per sector of economic activity (17 sectors) and per process step (e.g., automotive: foundries, thermal connections, various drying processes, etc.).
2. Assess the electrification potential of each process step within each industrial sector.
   a. We will focus in this review on those process steps that we consider easily and rapidly electrifiable today.
   b. We define this by assessing each process step in terms of technology availability (Figure 7 – x-axis), i.e., the fact that the technology exists, and is already deployed at scale; and in terms of easiness to substitute (Figure 7 – y-axis), i.e., how simple the substitution can be realized (no significant redesign) and/or whether this substitution brings economic benefits[10].
3. Evaluate the corresponding additional electricity demand and fossil fuels displacement, as well as the resulting share of electricity in total energy mix as a result.

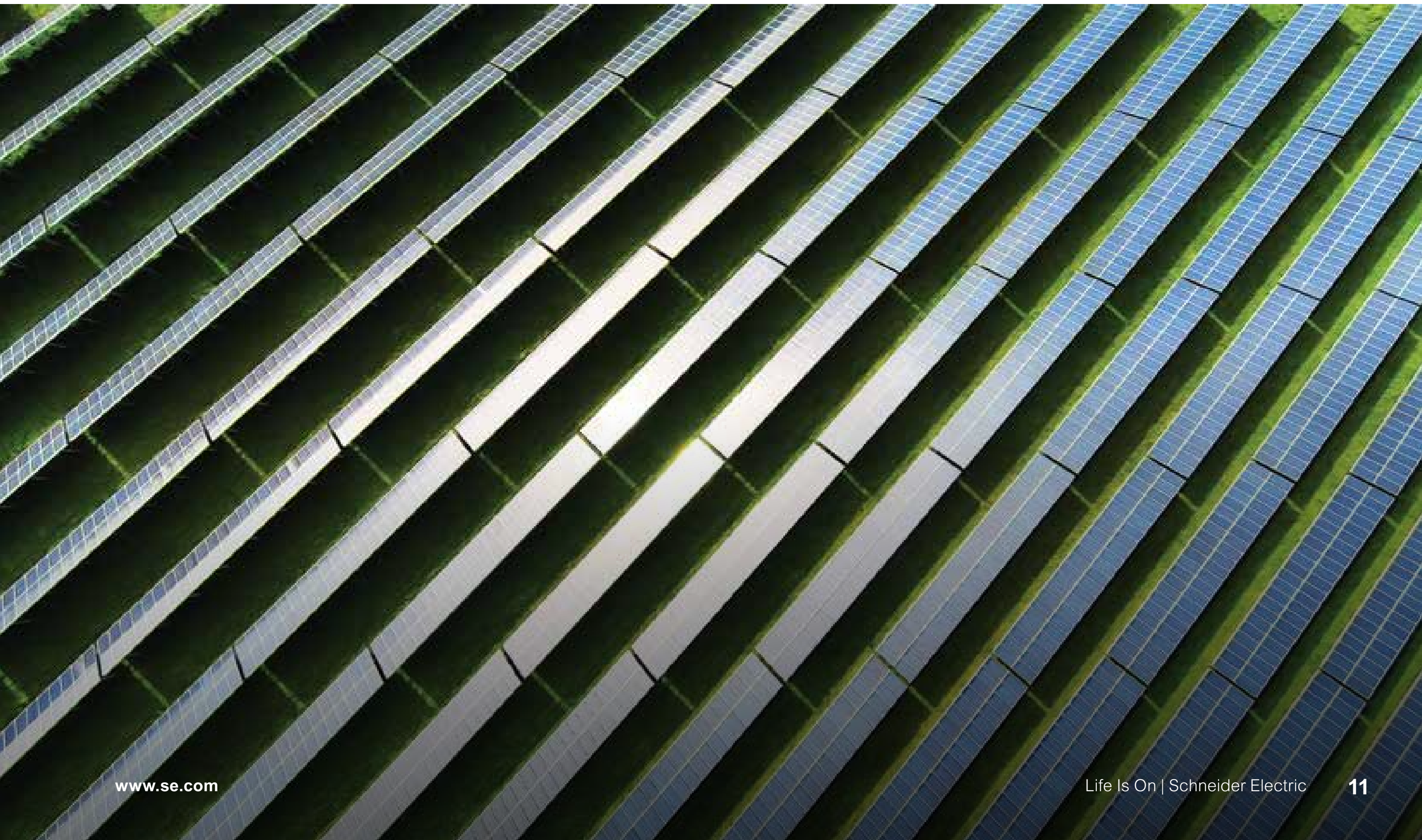
**Figure 7 – Rapid electrification potential**




(7) Mantzos et al., 2018.
(8) The report was published in 2018 based on 2015 data. There has not been an update since, in part because of the unique granularity level which prevents running such an analysis year after year. We consider the conclusions remain relevant, given the slow changes that occur year on year. Since the analysis dates back from 2018, the data for the European Union also covers the 28 member countries at the time, i.e., with the United Kingdom.
(9) We review those differences further down. Maddedu et al., 2020.
(10) See annex for more details.



# 3 The untold potential of rapid electrification



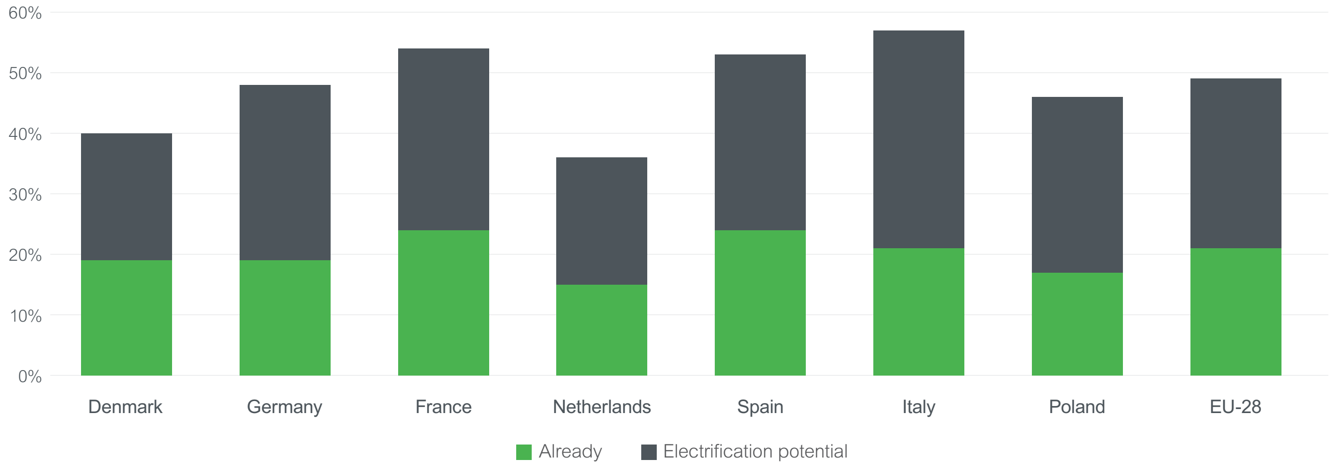
# Electrification could rapidly reach 50% of the energy system

Well-known and often competitive technologies such as heat pumps, electric boilers, electric cooling systems, infrared or microwave heating systems could pervade a multitude of sectors, with limited impact on retrofits, and **boost the electrification of the energy system from 20% today to 50%**[11] [12] (Figure 8). What happens beyond may require more significant process evolution (e.g., metal treatment, chemical pulping, or glass melting) or technological innovation (e.g., electric crackers for petrochemicals, plasma heating systems for cement). For the latter, such solutions may also compete with alternative decarbonization options (such as the use of decarbonized gases or carbon capture, utilization, and storage – CCUS).

This substitution of fossil fuels could provide in numerous cases a positive economic equation[13], and less hindrance on core processes. In other words, a possibly more rapid (and productive) transformation than often envisioned.

This substitution ratio varies across countries of the European Union due to the different distribution of electrifiable processes within those countries. The ratio is highest in Italy (nearly 60%), and lowest in the Netherlands (below 40%). In the Netherlands, this is notably due to the high share of petrochemical industries which affects overall potential (Figure 8). France and Spain already show higher rates of electrification due to the specifics of their energy system as well as past choices in terms of energy mix.

**Figure 8 – Electrification penetration potential, by region (% of final energy demand)**



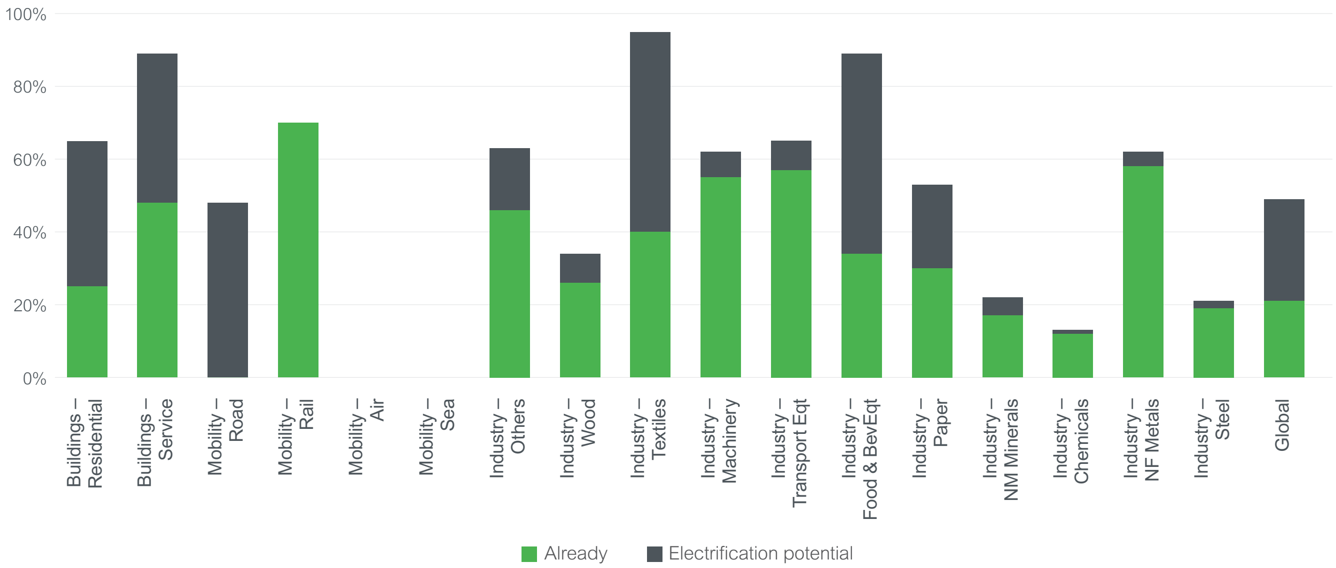

(11) Specific ratios of efficiency are considered to evaluate the corresponding electricity demand from substitution, as 1 joule of energy provided by a fossil-fuel-based system may not translate into 1 joule of electricity demand, since performance of systems may in fact differ. A good example is heat pumps, which are three to five times more efficient than their fossil counterparts. Once the new system is recalculated, the share of electricity in the final energy mix can be retrieved. See annex for more details.

(12) This data (and all that follows) is based on the 2018 report from the Joint Research Center of the European Union Commission. While figures may have slightly changed since, orders of magnitude remain similar.

(13) See notably the work from Beyond Zero Emissions on the electrification of industry: 30% to 75% reduction in cost for prepared meals, 50% to 70% for beer production, 30% to 75% for milk powder, and 0% to 65% for glass. Beyond Zero Emissions, 2018.

This potential does not materialize equally across sectors. Figure 9 consolidates the view at the European Union level. Some sectors show more potential for electrification such as buildings (both residential, up to 65%, and service, up to nearly 90%, with heat pumps and electric cooking systems), road mobility (50%, with private cars substitution to electric vehicles), and several sectors of industry, notably textiles or the food and beverage industry, which have a potential up to 90% (steam production, drying and cooling systems, etc.).

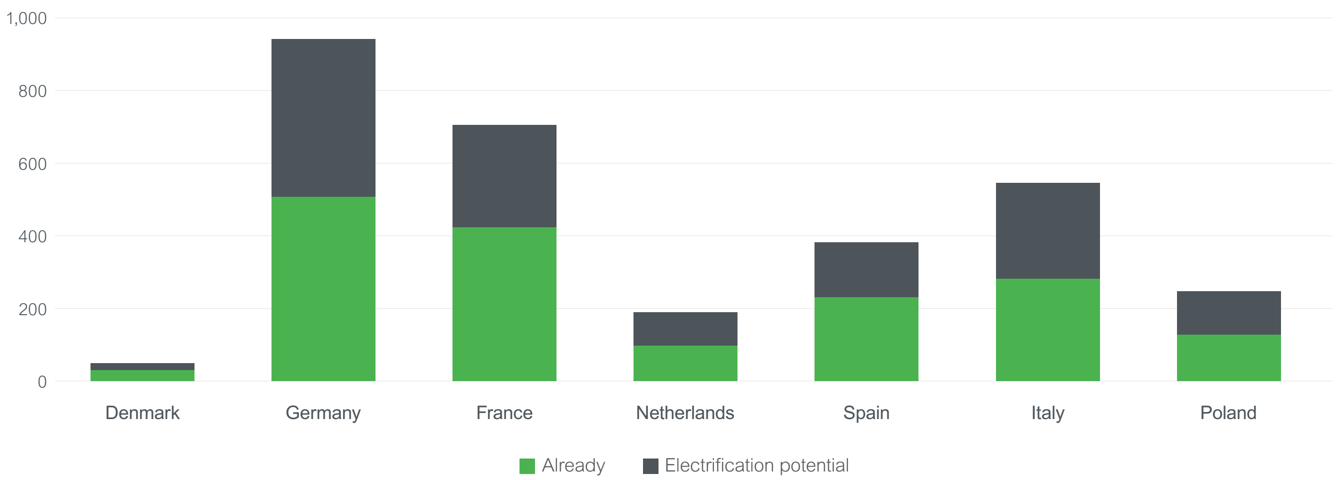
**Figure 9 – Electrification penetration, by sector (% of final energy demand)**




# A 50% electrification mark yields nearly a doubling in electricity demand, mainly in buildings

**Reaching such level of electrification would correspond to 80% growth in electricity demand at the European Union level, or around 2,100 TWh per year**[14] (Figure 10). This increase is lower in France and Spain (around two-thirds), given the already high share of electrification (relative to others), and notably higher in Italy and Poland (nearly doubling).

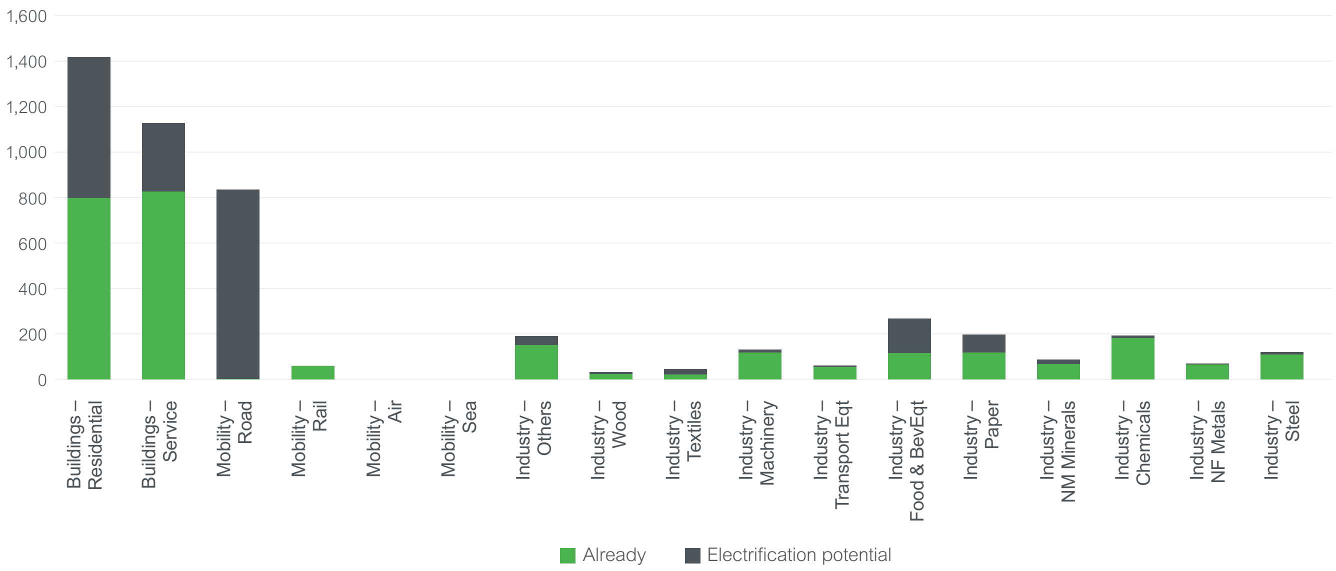
**Figure 10 – Electricity demand increase in volume, by region (TWh/y)**




(14) This is prior to any additional energy efficiency measures that could significantly optimize this growth.

More importantly, around **80% of that increase in demand would come from buildings and road mobility** (i.e., electric vehicles). As 90% of vehicle charging is expected to happen within building premises[15], it is within buildings that the key challenge of infrastructure buildup is thus expected to materialize (Figure 11). There, electricity demand would more than double.

**Figure 11 – Electricity demand increase in volume, by sector (TWh/y)**




A key roadblock to the rapid substitution of fossil fuels within the European Union economy will thus primarily depend on how the distribution infrastructure will be able to cope with such increases in electricity demand[16]. Beyond necessary infrastructure upgrades, the role of "non-wire" alternatives will play a crucial role in smoothing this transition.

In this respect, the rapid and parallel development of distributed generation (rooftop solar) and digital solutions for efficiency and flexibility will therefore be paramount, leading way to a new breed of buildings. The combined development of electrification, digitalization, and distributed generation within buildings could not only help mitigate the impact on infrastructure, but also generate significant positive impacts, with an energy spend reduction of between 10% and 80% across the building stock. Moreover, such upgrades would impact costs of acquisitions by less than 8%, cruising toward 5% or below by 2030, as was discussed in a previous report[17].

(15) BloombergNEF (2022).
(16) It will also and notably depend on the availability of decarbonized power supply, although a detailed review of this is not the object of this study.
(17) Schneider Electric (2022).

# Blockbusters of Electrification

## Opening the way to a radically different future

### Transitioning to become All Electric, All Digital

**Homes of the Future:**

**Decentralized and decarbonized grid.** Self-generation with Rooftop solar panels and backup battery systems.

Homes today

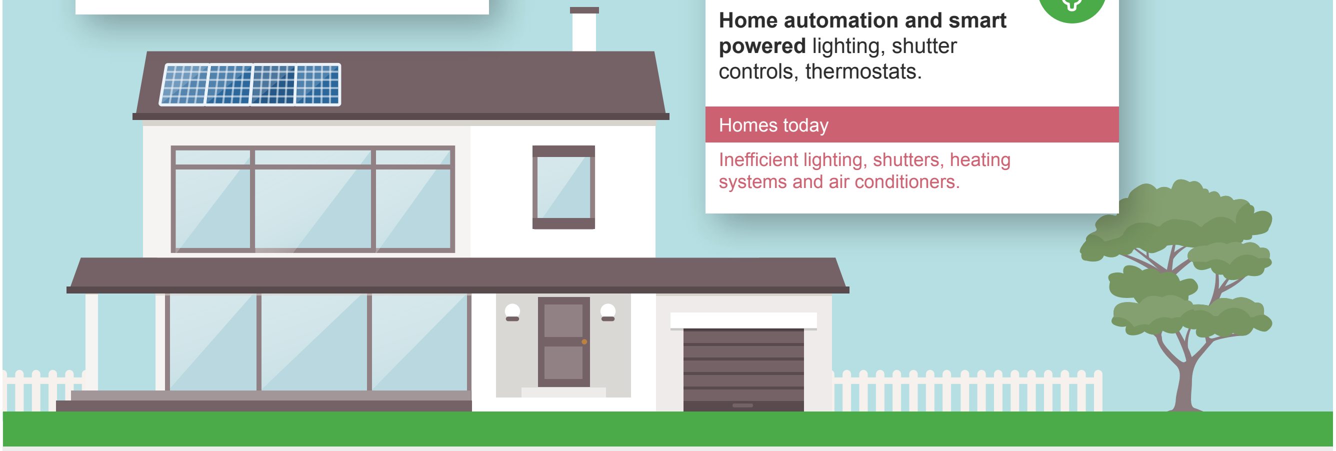
Grid-tied + fossil fuel-based gen sets for backup power. Furnaces and boilers for heating. Gas-powered water heaters, ovens and burners.

**Homes of the Future:**

**Home automation and smart powered** lighting, shutter controls, thermostats.

Homes today

Inefficient lighting, shutters, heating systems and air conditioners.



**Homes of the Future:**

Home Energy Management System coupled with **smart Energy Centers** and smart meters.

Homes today

Manual controls, gas meters, traditional electrical distribution panels.

### Example Home in 2025

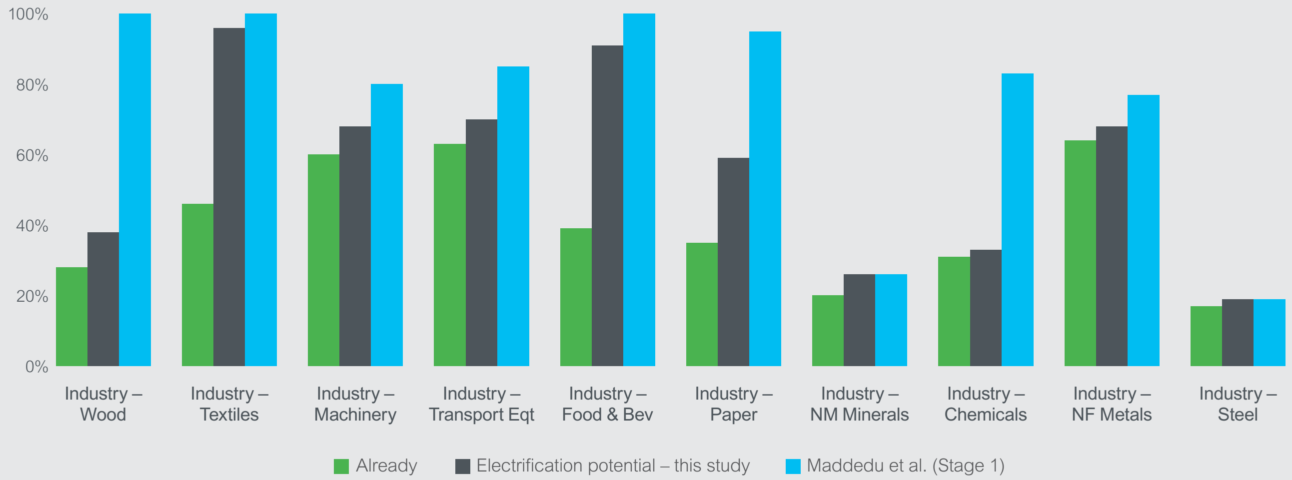
| ÷2 | ÷3 | ÷4-10 |
|---|---|---|
| Total Energy Demand (Joules) | Energy Spend ($USD/y) | Carbon Emissions ($kgCO_2/y$) |

## How this study compares to others

This study was inspired from a significant 2020 academic work[18], which looked at the same topic, albeit with slight differences in the methodological approach.

- The focus of this academic effort was primarily on industry, whereas this study spans across all sectors of economic activity.
- The split of industrial sectors slightly differs across both studies, notably within manufacturing activities[19].
- This academic effort based its evaluation on useful energy demand, while the focus in this study is on final energy demand[20].
- This 2020 research effort splits process energy uses in stages. Stage 1 "includes thermal processes that are common to all industries" and represent an "entry point" for electrification. Stage 2 is a "more technologically advanced phase of electrification" and is thus expected to be "slower and require a more substantial technological upgrade". Stage 3 "explores the maximum achievable electrification potential" and includes "technologies that have higher uncertainties and lower technological maturity". Despite such differences in the approach, we can nevertheless compare the level of electrification reached in Stage 1 within this study with our own estimates for industry.
- The difference in electrification potential remains relatively limited in sectors such as textiles, food and beverage, non-metallic minerals, and steel.
- There are, however, significant variations in modeling for sectors such as wood, paper, non-ferrous metals, and chemicals, and to a lower extent machinery and transport equipment.

**Figure 12 – Comparison with another study, industry only**




The observed differences essentially come from a different set of selected process steps eligible for electrification.

- Wood industry: we have typically not assumed any electrification of biomass-based processes in the industry[21]. As this is technically feasible, the two forecasts are in fact rather consistent (it is the approach which is different).
- Machinery and transport equipment industries: the main difference comes from the electrification potential of metal treatment (foundries, welding, etc.), which we have considered more transformative, hence less relevant in the short term.
- Paper industry: assumptions regarding the electrification potential of chemical pulping but also stock preparation and paper machines differ across both forecasts. As for the wood industry, we have also not accounted for biomass substitution with electricity.
- Non-ferrous metals industry: similar to the metal treatment processes in the machinery and transport equipment industries, our estimates on the potential of electrification are more conservative, given the extent of process redesign required and associated costs of substitution.
- Chemical industry: the main difference between the two forecasts comes from the electrification of steam. Though technically feasible, we discard it from an easiness/attractiveness standpoint in this study.

A key conclusion of this review is that the forecast presented in our report may in fact underestimate the potential of electrification in a number of sectors of activity.

(18) Maddedu et al., 2020.
(19) Note as well that Maddeddu et al. baseline for calculation of the electrification potential in chemicals excludes energy use for feedstock. Hence the baseline share of electricity in the energy mix is higher than what has been presented above. Here, our evaluation has been restated accordingly to provide a comparative baseline.
(20) It is the useful energy demand that is substituted. Final energy must be converted back again as yields (useful energy/final energy) differ from one source of energy to another, which we have taken into consideration in our calculations. See annex for more details. In Figure 12, we compare useful energies (we have restated our figures accordingly to provide a comparable base).
(21) We have also discarded electrification of processes based on derived gases, distributed steam, or other liquids across all sectors of activity.

# 4 Radical improvement toward decarbonization and energy security

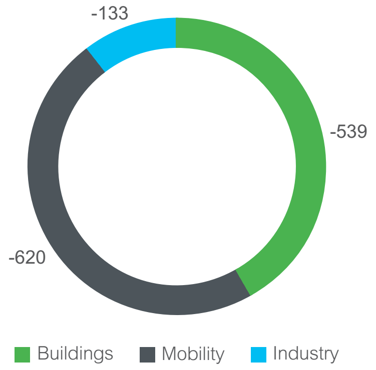
We now look at the impact such levels of electrification would bring about on fossil fuels demand.

## Key to decarbonization

The rapid electrification of the European energy system will have a significant impact on carbon emissions at end-use. By combining the volume of fossil fuels saved with their carbon intensities[22], **we find that 1,300 $MtCO_2$/y could be saved, a figure slightly higher than our rough estimate on what should be achieved to meet the 2030 target set by the European Commission** (Figure 13).

Not surprisingly, these savings also correspond to where electrification happens most rapidly. Buildings and road mobility account for 90% of the total.

**Figure 13 – Over one billion tons saved through electrification (data in $MtCO_2$/y)**

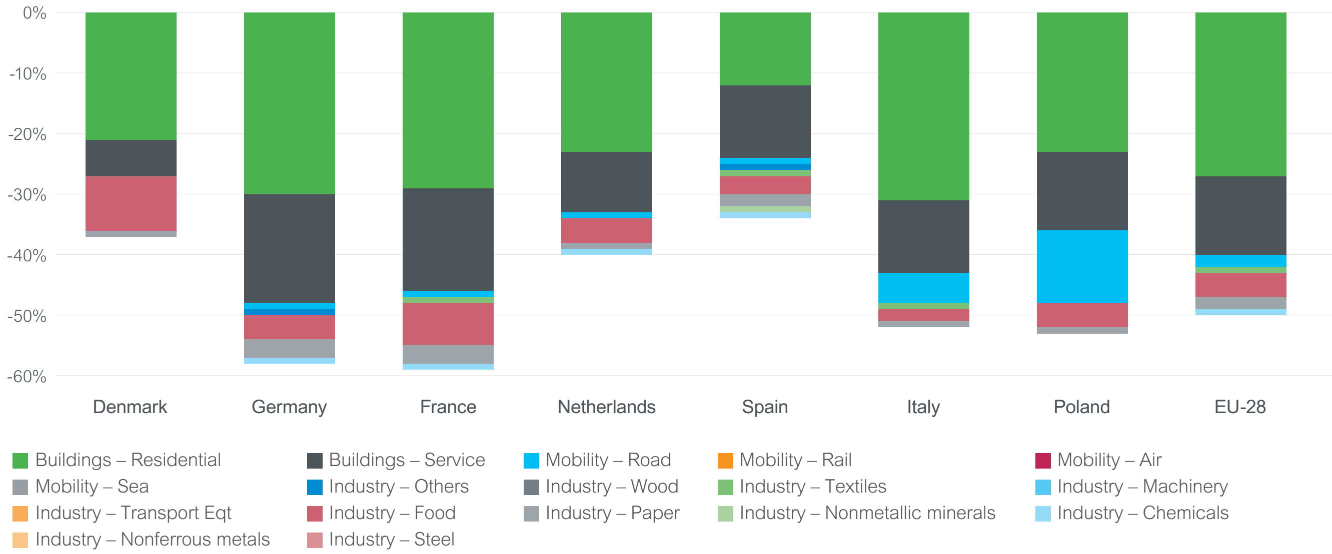



## Key to energy security

Beyond decarbonization, such transformation of the energy system would also bring natural gas and oil supply down by around 50%[23] (Figure 14, Figure 15). The impact on coal would be much more limited, with a reduction in supply of around 5%.

These ratios vary per country. For natural gas, they vary between 30% and 60%. They are lower in Spain, Denmark, and the Netherlands. This is due to the lower share of natural gas supply in buildings relative to other uses.

**Figure 14 – Natural gas supply displacement from electrification**

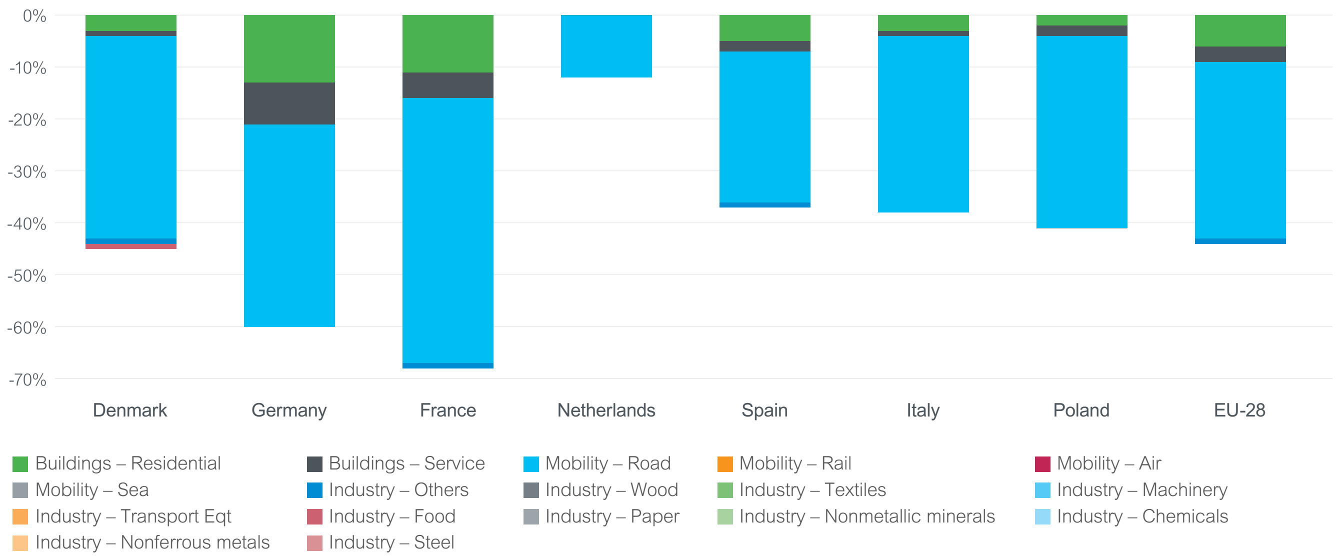



(22) More details available in annex.
(23) 51% for natural gas, 44% for oil. Note that this is a percentage of total energy supply, not only final energy demand. This therefore includes fossil fuels supply for specific non-energy needs (industrial feedstock) as well as power generation. This is the key indicator to look at from the standpoint of energy security.

For oil, they vary between 10% and 70%. The bulk of displacement stems from mobility electrification, as already discussed. The share of oil supply for mobility, however, varies across countries. It is lowest in the Netherlands, due to a high petrochemical refining activity, which explains the lower displacement level.

It is to be noted that, as private mobility switches rapidly to electric vehicles, the actual needs for oil refining will likely decrease, further impacting these levels. Such impacts are, however, not modeled in this study.

**Figure 15 – Oil supply displacement from electrification**




**The substitution of fossil fuels supply in final end-uses (demand) would thus enable to displace around half of natural gas and oil supply (and 5% of coal), a major turnaround in terms of energy security.**

## More is achievable

Further potential is also achievable. The maximum share of fossil fuels supply displaceable by electrifying final end-uses represents around two-thirds of oil and natural gas, but only 13% of coal (Figure 16). Substituting fossil fuels in this area would require, however, more significant process redesigns and/or technological innovations(24).

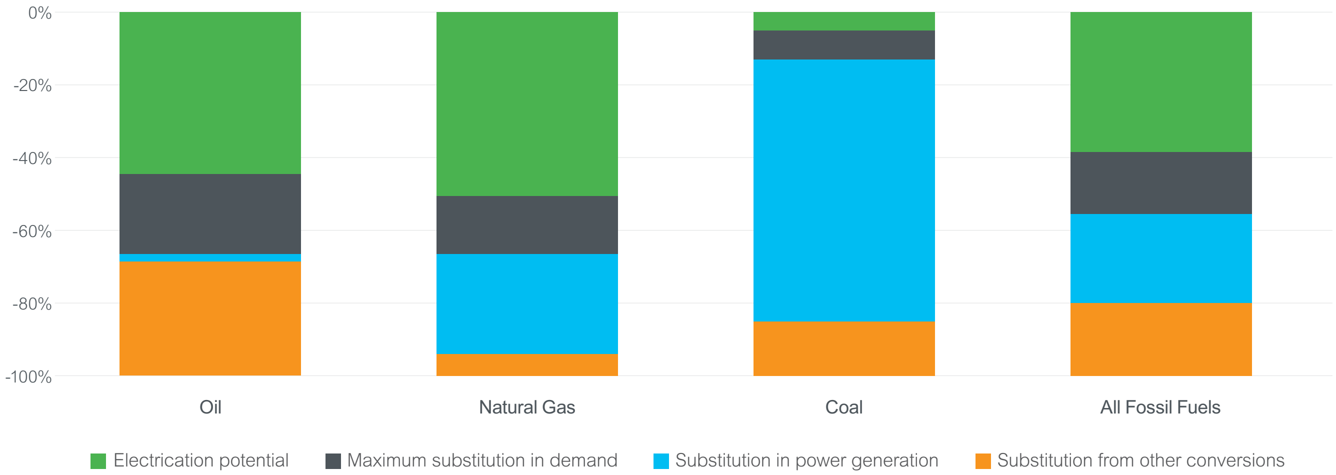
Beyond final end-uses, substituting fossil fuels with alternatives (e.g., renewable, nuclear) in power generation would impact natural gas supply by another 30% and coal supply by up to 70% (but oil by only 2% as it has virtually been displaced already). This is also a key priority as reducing emissions at end-use through electrification supposes that this additional electricity will effectively be zero-carbon, which recent trends suggest is highly practical(25).

Finally, the use of fossil fuels as feedstock (coal or natural gas for steel; natural gas and oil for petrochemicals) represents a final frontier, which accounts for another 30% of oil, 5% of natural gas, and 15% of coal supply.

Three key conclusions emerge:

- There is still potential to further remove fossil fuels from final end-uses (demand). This will notably concern freight transport (in particular trucks, which will likely be more easily accessible as battery development continues to progress) and specific industrial processes (metals treatment, glass melting, petrochemical cracking, steel production, etc.). This potential represents another 20% of total fossil fuels supply (notably oil and natural gas).
- Removing fossil fuels further from power generation goes hand in hand with the decarbonization of the power system, which is still heavily reliant on fossil fuels. This would represent another 25% of fossil fuel supply (with the bulk of it coming from coal).
- Finally, the switch to new feedstock types (e.g., bio-feedstocks or new processes for steel manufacturing) could substitute the remaining 20% of fossil fuels use in the system.

**Figure 16 – Fossil fuels substitution map**




(24) More details available in annex.
(25) New capacities brought online are expected for the most part, and across all scenarios, to be zero-carbon. ©OECD/IEA, 2021; BloombergNEF, 2020.

# 5 Key takeaways

# Key takeaways

Decarbonizing the European Union energy system while ensuring energy security are two faces of the same coin. The detailed analysis of the European system, at the level of each process step within each sector of activity of each country of the European Union, suggests that the share of electricity could move from around 20% today to 50% by simply electrifying what is both technologically feasible and easy or rationale to do, in other words "easy to abate".

**Such "common sense" measures would reduce emissions at end-use by around 1,300 Mt$CO_2$/y, and the supply of natural gas and oil by around 50%, significantly improving the European Union energy security at the same time. A major breakthrough.**

Further efforts would need to be undertaken to go a step further. There remains potential in a number of industrial sectors (particularly manufacturing, paper, and chemicals), and power generation is a key sector to look at (notably for coal, but also for natural gas, as 30% of it is used in power generation). New feedstocks will also be a key route to explore to further remove dependency on oil.

Reaching such penetration of electricity in the energy mix will primarily affect buildings, where demand would double as a result; a key challenge from an infrastructure standpoint. This is where innovative approaches will play a crucial role, combining digital solutions (efficiency, flexibility) and distributed generation to more conventional infrastructure upgrades[26].

## Integrated policy approaches

Such transition will thus require integrated policy approaches to both new constructions as well as retrofits. Figure 17 provides a first order of key actions that could be undertaken for the buildings and mobility sectors. They are based on a broader set of suggestions, published earlier in 2022[27].

**Figure 17 – Key policies**

| Priority | Key policies |
|---|---|
| Electrify heating in buildings with connected heat pumps and smart controls | • Ban new fossil fuel boilers<br>• Promote smart heat pumps<br>• Train installers and leverage the NextGenerationEU (NGEU) fund<br>• Align energy taxation rates |
| Deploy electric vehicles and smart charging | • Prescribe smart functionalities in electric vehicle (EV) charging stations as part of the *Alternative Fuels Infrastructure Regulation* (AFIR) revision<br>• Set targets for smart EV charging by as early as 2025<br>• Increase the EV charging ambition of the *Energy Performance of Buildings Directive* (EPBD)<br>• Channel the Innovation Fund toward the roll-out of smart EV charging at private level |
| Drive energy efficiency in buildings with digital monitoring and control | • Accelerate *Minimum Energy Performance Standards* (MEPS) to renovate non-residential buildings from 2025<br>• Fast track agreement to lower threshold for deploying provisions for Building Management Systems (BMS) in the EPBD<br>• Create an Energy Efficiency accelerator to triple the current installation rate of smart heating controls<br>• Encourage member states to subsidize heating controls<br>• Leverage utility obligation schemes to prioritize deployment of BMS |
| Deploy renewables with rooftop solar and self-consumption | • Make rooftop solar compulsory for service buildings by leveraging the recast of the *Renewable Energy Directive* (RED) and the EPBD<br>• Accelerate networks digitalization with a Smart Readiness Indicator (SRI)<br>• Encourage smart energy tariffication to support storage and solar PV combination |
| Invest in demand-side flexibility sources | • Set a reference of 10% peak demand reduction<br>• Accelerate implementation of the *EU Electricity Market Design*<br>• Make Smart Grid Indicators mandatory as part of the revision of the RED |
| Develop microgrids | • Modify the legislative definition of a renewable energy community<br>• Reform RED II to encourage microgrids<br>• Develop a longer-term strategy |

(26) This will also require keeping the pace of decarbonization of the European power system. Schneider Electric (2022).
(27) Schneider Electric (b)(2022).

# At which pace could this unfold?

As a final conclusion to this paper, one could ask the question of the short-term impact of such measures and their impact thereof on both decarbonization and security targets. **What share of this potential could be reached by 2030?**

We have run three different scenarios[28]:

- A run-rate scenario, assuming a continuation of low rates of deep renovations in buildings and industry and current forecasts of penetration of electric vehicles.
- A policy scenario, assuming a more forceful policy effort on building and industry deep renovations to 2030 (3% per year).
- An ambitious scenario, with even higher rates of renovation (5% per year) and a faster penetration of electric drivetrains in mobility (30% across the fleet by 2030, excluding heavy duty freight).

Figure 18 summarizes these findings.

- At current *run rate*, the levels of displacement of both natural gas and oil would be low (negligible for natural gas), with a level of carbon dioxide savings of around 100 $MtCO_2$/y.
- A more forceful *policy* focus on buildings (and industry) renovations could bring around 10% displacement of natural gas and oil and 275 $MtCO_2$/y of carbon dioxide emissions reduction.
- An *ambitious* effort could bring these levels further down with 15% to 25% displacement of natural gas and oil, and up to 500 $MtCO_2$/y of emissions reduction.

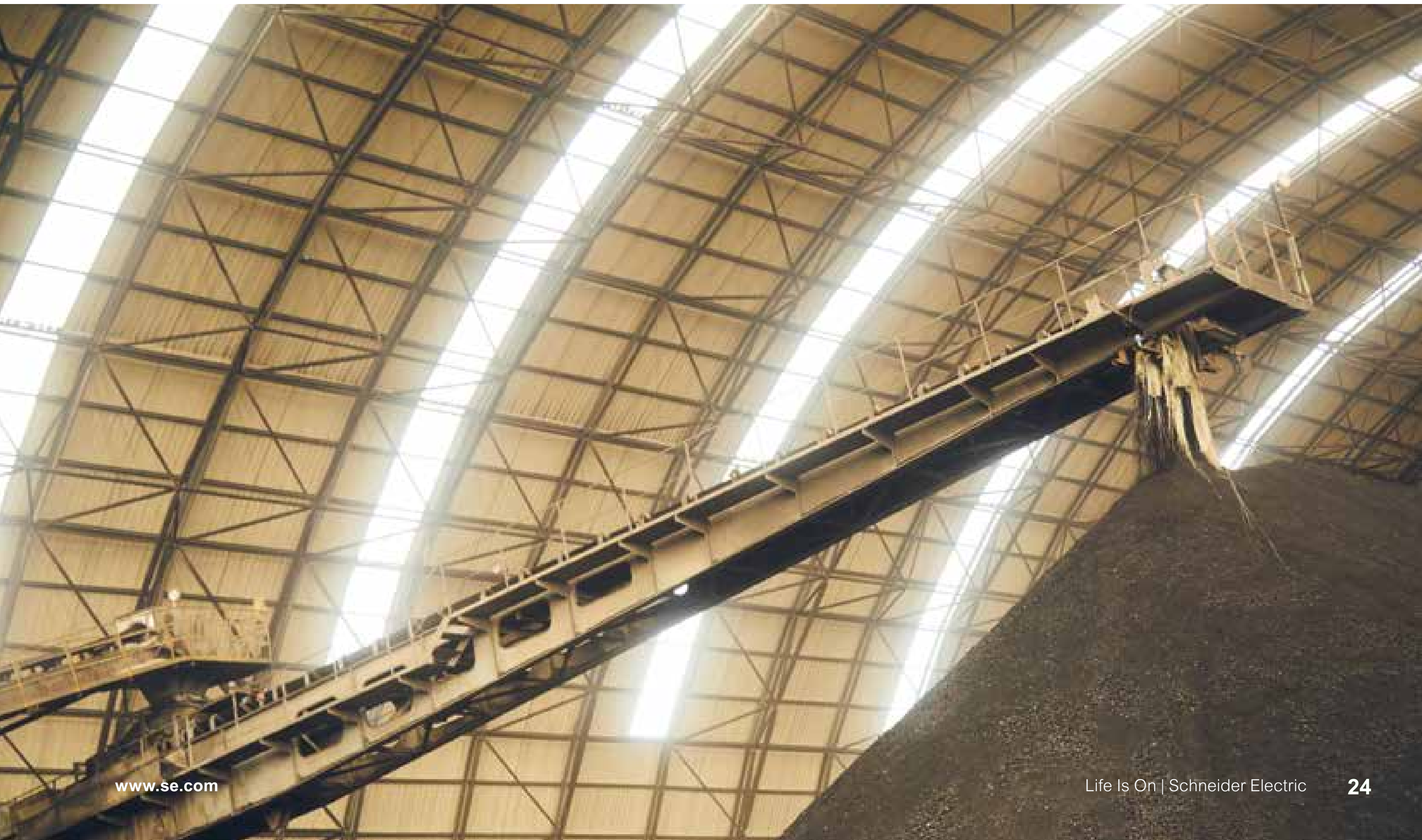
**Figure 18 – Scenarios of change**

| Fossil fuels displacement scenarios | Natural gas | Oil | $CO_2$ saved ($MtCO_2$/y) |
|---|---|---|---|
| Run rate | -0.7 to -1.2% | -5.2 to -5.4% | -100 |
| Policy | -13.0% | -7.3% | -275 |
| Ambitious | -23.2% | -14.2% | -509 |

**Achieving such an ambitious scenario would require renovating around 120 million buildings by 2030 and electrify 95 million vehicles[29]. These are the targets to reach.**

(28) More details available in annex.
(29) In the policy scenario, this would be 70 million buildings and around 60 million vehicles.

# 6 Annex



# Methodology

As presented above, we apply a three-step methodology:

1. Retrieve for each country the detailed energy system per sector of economic activity (17 sectors) and per process step (e.g., automotive: foundries, thermal connections, various drying processes, etc.).
2. Assess the electrification potential of each process step within each industrial sector.
3. Evaluate the corresponding additional electricity demand and fossil fuels displacement, as well as the resulting share of electricity in total energy mix as a result.

## Steps 1 and 2

We retrieve detailed energy mix for each targeted country (Denmark, Germany, France, the Netherlands, Spain, Italy, Poland, and the whole of the European Union – EU28) split per sector of activity (17 sectors), and per process step within each sector, leveraging the work from the Joint Research Center of the European Commission, the “Integrated Database of the European Energy Sector”[30].

We then qualify for each process whether it is “already” electric, or whether it has potential for rapid “electrification”. The selection criteria for rapid “electrification” is based on two qualitative aspects:

- Is the technology widely available? For instance, electric boilers exist and are already mature. The same applies to heat pumps, various forms of resistive heating, infrared or microwave drying systems, electric compressors, and (growingly) battery electric vehicles (BEVs).
- Is the technology easy to substitute? This will vary per sector and depend on a series of factors:
  - How significant is the work required to substitute the energy source? For instance, space heating substitution within buildings is more complicated than adopting an electric cooking stove.
  - What is the impact on the economics of the service delivered? If it comes at an additional cost, it is more likely to take longer to materialize, at least when proper incentives are not in place.

For each criterion, we apply a simple ranking from 1 to 3 to qualify the potential for electrification (Figure 19). We consider rapid electrification is possible when the sum of both criteria is above 5[31].

**Figure 19 – Electrification assessment criteria**

| Rating | Technology maturity | Easiness to substitute |
|---|---|---|
| Rate – 1 | Research and development stage (TRL<6) | Highly complex process redesign |
| Rate – 2 | Deployed technology, but lack of scale or adequate value chains | Workable substitution despite process redesign and/or no clear economic benefit |
| Rate – 3 | Mature technologies, at scale (TRL>8) | Simpler substitution (change of equipment) and/or positive economic benefits |

Figure 20 presents the results of our assessment. “Next step” stands for all process steps that we consider not eligible in this first phase of electrification. Some may score high on the technology availability but poorly on the easiness to substitute (heavy upgrades required). Others may also require technologies to reach maturity.

Also indicated on Figure 20 is the share of energy demand for each sector within each country/region (grey lines), and the split of that energy demand across process steps (the sum of every process step in a sector yielding 100%).

(30) Mantzos et al., 2018.
(31) The technology maturity assessment is based on ©OECD/IEA (b)(2021) as well as Schneider Electric research. The easiness to substitute assessment is based on Schneider Electric research.

**Figure 20 – Assessing the electrification potential per process in 17 sectors and eight regions**

| | | Electrification potential | | Share of energy per process step within each sector (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Process step | Electrification | Technology maturity | Easiness to substitute | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
| Buildings – Residential | Total | | | 33% | 25% | 27% | 21% | 19% | 29% | 32% | 26% |
| Space heating (thermal) | Electrification | 3 | 3 | 64% | 62% | 49% | 54% | 35% | 59% | 65% | 56% |
| Space heating (electric) | Already | already | already | 3% | 4% | 7% | 3% | 6% | 1% | 1% | 5% |
| Water heating (thermal) | Electrification | 3 | 3 | 14% | 13% | 12% | 18% | 18% | 16% | 16% | 14% |
| Water heating (electric) | Already | already | already | 1% | 1% | 5% | 2% | 4% | 1% | 0% | 3% |
| Cooking (thermal) | Electrification | 3 | 3 | 1% | 4% | 5% | 7% | 6% | 8% | 5% | 5% |
| Cooking (electric) | Already | already | already | 5% | 2% | 4% | 1% | 5% | 2% | 4% | 3% |
| Other electric uses | Already | already | already | 12% | 13% | 18% | 14% | 26% | 14% | 8% | 14% |
| Buildings – Service | Total | | | 14% | 16% | 17% | 15% | 13% | 14% | 13% | 14% |
| Space heating (thermal) | Electrification | 3 | 3 | 45% | 48% | 35% | 39% | 25% | 33% | 41% | 39% |
| Space heating (electric) | Already | already | already | 2% | 3% | 13% | 4% | 6% | 9% | 11% | 8% |
| Water heating (thermal) | Electrification | 3 | 3 | 7% | 8% | 5% | 7% | 7% | 7% | 5% | 7% |
| Water heating (electric) | Already | already | already | 2% | 2% | 5% | 4% | 4% | 4% | 4% | 4% |
| Catering (thermal) | Electrification | 3 | 3 | 2% | 7% | 4% | 7% | 7% | 9% | 4% | 6% |
| Catering (electric) | Already | already | already | 8% | 5% | 6% | 5% | 9% | 2% | 6% | 6% |
| Other electric uses | Already | already | already | 34% | 26% | 31% | 33% | 41% | 36% | 28% | 31% |
| Mobility – Road | Total | | | 29% | 25% | 30% | 22% | 34% | 30% | 27% | 28% |
| 2-wheelers | Electrification | 3 | 3 | 1% | 1% | 1% | 2% | 2% | 3% | 1% | 1% |
| Passengers LDV (combustion) | Electrification | 3 | 3 | 56% | 64% | 54% | 56% | 61% | 63% | 56% | 59% |
| Passengers LDV (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Buses (combustion) | Electrification | 3 | 3 | 9% | 3% | 5% | 3% | 4% | 7% | 6% | 5% |
| Buses (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Freight Light Duty (combustion) | Electrification | 3 | 3 | 12% | 5% | 19% | 15% | 8% | 12% | 13% | 12% |
| Freight Light Duty (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Freight Heavy Duty | Next step | 1 | 3 | 22% | 27% | 21% | 24% | 25% | 15% | 24% | 23% |
| Mobility – Rail | Total | | | 1% | 1% | 1% | 0% | 1% | 1% | 1% | 1% |
| All rail | Next step | 3 | 1 | 70% | 26% | 16% | 18% | 26% | 2% | 26% | 30% |
| All rail (electric) | Already | already | already | 30% | 74% | 84% | 82% | 74% | 98% | 74% | 70% |
| Mobility – Air | Total | | | 7% | 4% | 5% | 9% | 7% | 3% | 1% | 5% |
| All domestic air | Next step | 1 | 2 | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Mobility – Sea | Total | | | 1% | 0% | 0% | 1% | 1% | 1% | 0% | 0% |
| All domestic sea | Next step | 1 | 2 | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Industry – Others | Total | | | 3% | 1% | 2% | 3% | 3% | 2% | 2% | 3% |
| Low-enthalpy heat | Electrification | 3 | 2 | 2% | 9% | 3% | 2% | 2% | 2% | 1% | 2% |
| Steam processing | Electrification | 3 | 2 | 14% | 23% | 6% | 12% | 7% | 4% | 16% | 19% |
| Process heating (thermal) | Next step | 2 | 2 | 30% | 14% | 35% | 42% | 41% | 14% | 20% | 29% |
| Process heating (electric) | Already | already | already | 1% | 2% | 1% | 1% | 2% | 3% | 2% | 2% |
| Drying (thermal) | Electrification | 3 | 2 | 1% | 1% | 1% | 1% | 2% | 1% | 2% | 2% |
| Drying (steam) | Electrification | 3 | 2 | 1% | 2% | 1% | 2% | 2% | 5% | 2% | 2% |
| Drying (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Cooling (thermal) | Electrification | 3 | 2 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Cooling (steam) | Electrification | 3 | 2 | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% |
| Cooling (electric) | Already | already | already | 1% | 1% | 1% | 1% | 1% | 2% | 1% | 1% |
| Diesel motors | Electrification | 3 | 3 | 20% | 0% | 22% | 18% | 13% | 1% | 5% | 8% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 30% | 47% | 29% | 20% | 31% | 68% | 50% | 34% |

| Process step | Electrification | Electrification potential: Technology maturity | Electrification potential: Easiness to substitute | Share of energy per process step within each sector (%): Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Industry – Wood | Total | | | 1% | 1% | 0% | 0% | 1% | 0% | 2% | 1% |
| Low-enthalpy heat | Electrification | 3 | 2 | 2% | 2% | 1% | 2% | 2% | 2% | 2% | 2% |
| Steam processing | Electrification | 3 | 2 | 64% | 66% | 52% | 56% | 64% | 7% | 64% | 61% |
| Mechanical processing | Already | already | already | 4% | 2% | 9% | 8% | 3% | 18% | 3% | 5% |
| Drying (thermal) | Electrification | 3 | 2 | 5% | 6% | 14% | 2% | 9% | 6% | 9% | 7% |
| Drying (steam) | Electrification | 3 | 2 | 5% | 5% | 3% | 5% | 4% | 30% | 5% | 6% |
| Drying (electric) | Already | already | already | 0% | 0% | 1% | 1% | 0% | 2% | 0% | 0% |
| Finishing | Already | already | already | 5% | 2% | 10% | 9% | 3% | 20% | 3% | 5% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 15% | 16% | 10% | 17% | 15% | 16% | 14% | 14% |
| Industry – Textiles | Total | | | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% |
| Low enthalpy heat | Electrification | 3 | 2 | 8% | 8% | 8% | 6% | 8% | 8% | 8% | 7% |
| Steam pre-treatment | Electrification | 3 | 2 | 3% | 3% | 3% | 5% | 3% | 3% | 3% | 4% |
| Steam wet processing | Electrification | 3 | 2 | 22% | 26% | 25% | 28% | 25% | 25% | 26% | 26% |
| Drying (thermal) | Electrification | 3 | 2 | 7% | 25% | 25% | 21% | 17% | 23% | 20% | 22% |
| Drying (steam) | Electrification | 3 | 2 | 5% | 5% | 5% | 8% | 5% | 5% | 5% | 5% |
| Drying (electric) | Already | already | already | 6% | 3% | 3% | 3% | 4% | 3% | 4% | 3% |
| Finishing | Already | already | already | 8% | 4% | 4% | 4% | 6% | 4% | 5% | 5% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 40% | 27% | 27% | 24% | 32% | 29% | 30% | 28% |
| Industry – Machinery | Total | | | 2% | 2% | 1% | 1% | 1% | 3% | 1% | 2% |
| Low enthalpy heat | Electrification | 3 | 2 | 3% | 3% | 3% | 3% | 3% | 3% | 2% | 3% |
| Foundries (thermal) | Next step | 2 | 2 | 13% | 0% | 6% | 8% | 9% | 9% | 7% | 6% |
| Foundries (electric) | Already | already | already | 3% | 19% | 11% | 10% | 9% | 11% | 8% | 12% |
| Connection techniques (thermal) | Next step | 2 | 2 | 6% | 7% | 6% | 7% | 7% | 7% | 6% | 6% |
| Connection techniques (electric) | Already | already | already | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| Heat treatment (thermal) | Next step | 2 | 2 | 8% | 25% | 23% | 23% | 24% | 23% | 20% | 21% |
| Heat treatment (electric) | Already | already | already | 15% | 3% | 2% | 4% | 3% | 4% | 2% | 4% |
| Steam processing | Electrification | 3 | 2 | 17% | 10% | 4% | 12% | 15% | 9% | 15% | 11% |
| Finishing | Already | already | already | 6% | 2% | 12% | 7% | 7% | 4% | 6% | 7% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 28% | 28% | 31% | 24% | 21% | 28% | 32% | 28% |
| Industry – Transport Equipment | Total | | | 0% | 1% | 1% | 0% | 1% | 0% | 1% | 1% |
| Low enthalpy heat | Electrification | 3 | 2 | 2% | 3% | 3% | 3% | 3% | 5% | 3% | 3% |
| Foundries (thermal) | Next step | 2 | 2 | 4% | 3% | 6% | 10% | 9% | 0% | 5% | 5% |
| Foundries (electric) | Already | already | already | 5% | 2% | 4% | 0% | 2% | 5% | 1% | 2% |
| Connection techniques (thermal) | Next step | 2 | 2 | 3% | 4% | 4% | 4% | 5% | 0% | 5% | 4% |
| Connection techniques (electric) | Already | already | already | 1% | 2% | 2% | 2% | 1% | 5% | 2% | 2% |
| Heat treatment (thermal) | Next step | 2 | 2 | 15% | 16% | 21% | 32% | 9% | 0% | 19% | 17% |
| Heat treatment (electric) | Already | already | already | 12% | 9% | 11% | 1% | 26% | 19% | 11% | 10% |
| Steam processing | Electrification | 3 | 2 | 29% | 19% | 8% | 7% | 8% | 24% | 12% | 15% |
| Finishing | Already | already | already | 10% | 10% | 17% | 19% | 19% | 15% | 22% | 17% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 20% | 30% | 25% | 21% | 19% | 29% | 20% | 25% |
| Industry – Food & Beverages | Total | | | 4% | 2% | 4% | 5% | 3% | 2% | 3% | 3% |
| Low enthalpy heat | Electrification | 3 | 2 | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| Oven (direct heat)(thermal) | Electrification | 3 | 2 | 3% | 3% | 2% | 3% | 2% | 1% | 4% | 2% |
| Oven (direct heat)(electric) | Already | already | already | 3% | 3% | 4% | 3% | 4% | 4% | 2% | 4% |
| Specific process heat (thermal) | Electrification | 3 | 2 | 4% | 4% | 4% | 4% | 3% | 4% | 4% | 4% |

| Process step | Electrification | Electrification potential: Technology maturity | Electrification potential: Easiness to substitute | Share of energy per process step within each sector (%): Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Specific process heat (electric) | Already | already | already | 1% | 1% | 1% | 1% | 2% | 1% | 1% | 1% |
| Steam processing | Electrification | 3 | 2 | 45% | 50% | 48% | 55% | 43% | 46% | 49% | 48% |
| Drying (thermal) | Electrification | 3 | 2 | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% |
| Drying (steam) | Electrification | 3 | 2 | 4% | 4% | 4% | 4% | 4% | 4% | 5% | 4% |
| Drying (electric) | Already | already | already | 1% | 2% | 1% | 1% | 2% | 2% | 1% | 1% |
| Process cooling and refrigeration (thermal) | Electrification | 3 | 2 | 3% | 2% | 2% | 2% | 2% | 1% | 4% | 2% |
| Process cooling and refrigeration (steam) | Electrification | 3 | 2 | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| Process cooling and refrigeration (electric) | Already | already | already | 4% | 6% | 6% | 6% | 6% | 7% | 4% | 6% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 24% | 19% | 21% | 14% | 26% | 23% | 20% | 21% |
| Industry – Paper | Total | | | 1% | 3% | 2% | 1% | 2% | 2% | 3% | 3% |
| Low enthalpy heat | Electrification | 3 | 2 | 2% | 2% | 3% | 3% | 3% | 3% | 2% | 2% |
| Wood preparation, grinding | Already | already | already | 0% | 0% | 1% | 0% | 0% | 0% | 1% | 1% |
| Pulping (thermal) | Next step | 3 | 1 | 3% | 4% | 11% | 1% | 19% | 2% | 15% | 21% |
| Pulping (electric) | Already | already | already | 4% | 4% | 5% | 0% | 3% | 1% | 6% | 6% |
| Pulp Cleaning | Already | already | already | 1% | 1% | 1% | 0% | 1% | 0% | 1% | 2% |
| Paper: Stock preparation (thermal) | Next step | 2 | 1 | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 1% |
| Paper: Stock preparation (electric) | Already | already | already | 8% | 5% | 3% | 7% | 1% | 5% | 2% | 3% |
| Paper: Paper machine (thermal, steam) | Electrification | 3 | 2 | 48% | 54% | 51% | 53% | 41% | 57% | 53% | 42% |
| Paper: Paper machine (electric) | Already | already | already | 15% | 10% | 6% | 14% | 10% | 10% | 4% | 6% |
| Paper: Product finishing (thermal, steam) | Electrification | 3 | 2 | 6% | 6% | 6% | 6% | 7% | 7% | 6% | 5% |
| Paper: Product finishing (electric) | Already | already | already | 3% | 2% | 1% | 3% | 1% | 2% | 1% | 1% |
| Printing and publishing | Already | already | already | 3% | 2% | 3% | 4% | 3% | 4% | 1% | 2% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 6% | 7% | 8% | 7% | 9% | 7% | 7% | 7% |
| Industry – Nonmetallic minerals | Total | | | 3% | 3% | 2% | 1% | 4% | 4% | 4% | 3% |
| Low enthalpy heat | Electrification | 3 | 2 | 0% | 0% | 0% | 1% | 1% | 0% | 0% | 0% |
| Cement: Grinding, milling of raw material | Already | already | already | 0% | 1% | 2% | 1% | 1% | 1% | 1% | 1% |
| Cement: Pre-heating and pre-calcination (fuel use) | Next step | 2 | 1 | 7% | 10% | 14% | 7% | 8% | 9% | 13% | 11% |
| Cement: Pre-heating and pre-calcination (steam) | Electrification | 3 | 2 | 1% | 1% | 1% | 0% | 1% | 1% | 3% | 1% |
| Cement: Clinker production (kilns) | Next step | 1 | 1 | 9% | 18% | 25% | 12% | 13% | 14% | 27% | 19% |
| Cement: Grinding, packaging | Already | already | already | 0% | 1% | 2% | 1% | 1% | 1% | 1% | 1% |
| Ceramics: Mixing of raw material | Already | already | already | 2% | 1% | 2% | 1% | 3% | 2% | 1% | 2% |
| Ceramics: Drying and sintering of raw material (thermal) | Next step | 2 | 1 | 1% | 4% | 3% | 4% | 9% | 7% | 2% | 5% |
| Ceramics: Drying and sintering of raw material (steam) | Electrification | 3 | 2 | 6% | 1% | 1% | 0% | 1% | 2% | 0% | 1% |
| Ceramics: Drying and sintering of raw material (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Ceramics: Primary production process (thermal kiln) | Next step | 2 | 1 | 47% | 19% | 17% | 15% | 41% | 33% | 10% | 25% |
| Ceramics: Primary production process (electric kiln) | Already | already | already | 2% | 1% | 1% | 1% | 3% | 2% | 1% | 2% |
| Ceramics: Product finishing (thermal furnace) | Next step | 2 | 1 | 4% | 2% | 2% | 2% | 5% | 4% | 1% | 3% |

| Process step | Electrification | Electrification potential | | Share of energy per process step within each sector (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Technology maturity | Easiness to substitute | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
| Ceramics: Product finishing (electric furnace) | Already | already | already | 3% | 1% | 2% | 1% | 3% | 2% | 1% | 2% |
| Glass: Melting tank (thermal) | Next step | 2 | 1 | 8% | 26% | 15% | 39% | 6% | 13% | 25% | 16% |
| Glass: Melting tank (electric) | Already | already | already | 1% | 3% | 4% | 4% | 1% | 2% | 3% | 2% |
| Glass: Forming | Already | already | already | 1% | 2% | 3% | 3% | 0% | 1% | 2% | 2% |
| Glass: Annealing (thermal) | Next step | 2 | 1 | 1% | 2% | 1% | 3% | 0% | 1% | 2% | 1% |
| Glass: Annealing (electric) | Already | already | already | 0% | 1% | 1% | 1% | 0% | 0% | 1% | 1% |
| Glass: Finishing processes | Already | already | already | 1% | 2% | 3% | 3% | 0% | 1% | 2% | 2% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 2% | 2% | 3% | 3% | 4% | 3% | 2% | 3% |
| Industry – Chemicals | Total | | | 1% | 7% | 4% | 15% | 4% | 3% | 4% | 5% |
| Low enthalpy heat | Electrification | 3 | 2 | 4% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| Basic Chemicals: Feedstock (energy used as raw material) | NA | na | na | 0% | 54% | 65% | 66% | 51% | 55% | 60% | 60% |
| Basic Chemicals: Steam processing | Next step | 2 | 1 | 0% | 20% | 13% | 21% | 19% | 15% | 21% | 18% |
| Basic Chemicals: Furnaces (thermal) | Next step | 1 | 1 | 0% | 4% | 3% | 5% | 5% | 3% | 2% | 3% |
| Basic Chemicals: Furnaces (electric) | Already | already | already | 0% | 1% | 1% | 1% | 2% | 1% | 3% | 1% |
| Basic Chemicals: Process cooling (thermal) | Electrification | 3 | 2 | 0% | 2% | 1% | 2% | 2% | 1% | 2% | 2% |
| Basic Chemicals: Process cooling (electric) | Already | already | already | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% |
| Other Chemicals: High enthalpy heat processing (thermal) | Next step | 1 | 1 | 14% | 0% | 1% | 0% | 1% | 1% | 1% | 1% |
| Other Chemicals: High enthalpy heat processing (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Other Chemicals: Furnaces (thermal) | Next step | 2 | 1 | 26% | 3% | 5% | 1% | 6% | 6% | 1% | 3% |
| Other Chemicals: Furnaces (electric) | Already | already | already | 4% | 0% | 1% | 0% | 3% | 3% | 2% | 1% |
| Other Chemicals: Process cooling (thermal) | Electrification | 3 | 2 | 9% | 1% | 1% | 0% | 1% | 1% | 1% | 1% |
| Other Chemicals: Process cooling (electric) | Already | already | already | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Pharma: High enthalpy heat processing (thermal) | Next step | 1 | 1 | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Pharma: High enthalpy heat processing (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Pharma: Furnaces (thermal) | Next step | 1 | 1 | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Pharma: Furnaces (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Pharma: Process cooling (thermal) | Electrification | 3 | 2 | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Pharma: Process cooling (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 36% | 12% | 9% | 4% | 7% | 10% | 5% | 8% |
| Industry – Nonferrous metals | Total | | | 0% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| Low enthalpy heat | Electrification | 3 | 2 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Alumina production: High enthalpy heat | Next step | 2 | 1 | 0% | 7% | 10% | 0% | 14% | 0% | 0% | 8% |
| Alumina production: Refining | Next step | 1 | 1 | 0% | 11% | 7% | 0% | 20% | 0% | 0% | 12% |
| Aluminium electrolysis (smelting) | Already | already | already | 0% | 26% | 47% | 26% | 19% | 0% | 0% | 21% |
| Aluminium processing (cast house, reheating)(thermal) | Next step | 3 | 1 | 0% | 1% | 0% | 1% | 0% | 0% | 0% | 1% |

| Process step | Electrification | Electrification potential: Technology maturity | Electrification potential: Easiness to substitute | Share of energy per process step within each sector (%): Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminium processing (cast house, reheating)(electric) | Already | already | already | 0% | 1% | 5% | 2% | 2% | 0% | 0% | 2% |
| Aluminium finishing (thermal) | Next step | 2 | 1 | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 1% |
| Aluminium finishing (steam) | Electrification | 3 | 2 | 0% | 1% | 1% | 2% | 1% | 0% | 0% | 1% |
| Aluminium finishing (electric) | Already | already | already | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% |
| Secondary aluminium (pre-treatment, remelting)(thermal) | Next step | 2 | 2 | 0% | 0% | 0% | 0% | 0% | 6% | 0% | 1% |
| Secondary aluminium (pre-treatment, remelting)(electric) | Already | already | already | 0% | 1% | 1% | 0% | 0% | 4% | 0% | 1% |
| Sec Aluminium processing (cast house, reheating)(thermal) | Next step | 2 | 2 | 0% | 0% | 0% | 0% | 0% | 11% | 0% | 1% |
| Sec Aluminium processing (cast house, reheating)(electric) | Already | already | already | 0% | 1% | 1% | 0% | 0% | 6% | 0% | 1% |
| Sec Aluminium finishing (thermal) | Next step | 2 | 1 | 0% | 0% | 0% | 0% | 0% | 3% | 0% | 0% |
| Sec Aluminium finishing (steam) | Electrification | 3 | 2 | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 1% |
| Sec Aluminium finishing (electric) | Already | already | already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Other Metals: production (thermal) | Next step | 3 | 1 | 0% | 10% | 0% | 8% | 0% | 20% | 29% | 10% |
| Other Metals: production (electric) | Already | already | already | 0% | 15% | 14% | 31% | 23% | 16% | 22% | 16% |
| Metal processing (cast house, reheating)(thermal) | Next step | 2 | 1 | 0% | 4% | 0% | 7% | 1% | 11% | 10% | 4% |
| Metal processing (cast house, reheating)(electric) | Already | already | already | 0% | 9% | 6% | 11% | 10% | 6% | 17% | 8% |
| Metal finishing (thermal) | Next step | 3 | 1 | 0% | 2% | 1% | 3% | 2% | 4% | 3% | 2% |
| Metal finishing (steam) | Electrification | 3 | 2 | 0% | 4% | 3% | 7% | 4% | 5% | 16% | 5% |
| Metal finishing (electric) | Already | already | already | 0% | 0% | 1% | 1% | 1% | 0% | 1% | 1% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 0% | 3% | 2% | 2% | 2% | 2% | 2% | 3% |
| Industry – Steel | Total | | | 1% | 6% | 4% | 5% | 4% | 4% | 5% | 5% |
| Low enthalpy heat | Electrification | 3 | 2 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Steel: Sinter/Pellet making | Next step | 1 | 1 | 0% | 9% | 6% | 10% | 7% | 5% | 7% | 8% |
| Steel: Blast/Basic oxygen furnace | Next step | 1 | 1 | 0% | 59% | 67% | 71% | 39% | 35% | 57% | 58% |
| Steel: Furnaces, Refining and Rolling (thermal) | Next step | 3 | 1 | 0% | 8% | 5% | 7% | 3% | 6% | 6% | 7% |
| Steel: Furnaces, Refining and Rolling (electric) | Already | already | already | 0% | 5% | 4% | 4% | 7% | 3% | 5% | 4% |
| Steel: Products finishing (thermal) | Next step | 3 | 1 | 0% | 3% | 1% | 2% | 2% | 0% | 1% | 2% |
| Steel: Products finishing (steam) | Electrification | 3 | 2 | 0% | 2% | 1% | 1% | 2% | 3% | 6% | 2% |
| Steel: Products finishing (electric) | Already | already | already | 0% | 2% | 2% | 2% | 3% | 0% | 1% | 1% |
| Electric Arc Steel: Smelters | Next step | 1 | 1 | 38% | 2% | 2% | 0% | 6% | 7% | 2% | 3% |
| Electric Arc Steel: Electric arc | Already | already | already | 12% | 4% | 5% | 0% | 14% | 20% | 7% | 7% |
| Electric Arc Steel: Furnaces, Refining and Rolling (thermal) | Next step | 3 | 1 | 14% | 1% | 1% | 0% | 2% | 7% | 2% | 2% |
| Electric Arc Steel: Furnaces, Refining and Rolling (electric) | Already | already | already | 8% | 1% | 1% | 0% | 6% | 3% | 2% | 1% |
| Electric Arc: Products finishing (thermal) | Next step | 3 | 1 | 9% | 0% | 0% | 0% | 2% | 1% | 1% | 1% |
| Electric Arc: Products finishing (steam) | Electrification | 3 | 2 | 6% | 0% | 0% | 0% | 2% | 4% | 1% | 1% |
| Electric Arc: Products finishing (electric) | Already | already | already | 8% | 0% | 1% | 0% | 2% | 1% | 0% | 1% |
| Other electric uses (machinery, drives, etc.) | Already | already | already | 4% | 3% | 3% | 3% | 3% | 4% | 3% | 3% |

## Step 3

Once the share of energy that can be electrified is clarified, the new energy system balance must be evaluated. This simple set of equations is used:

$$En\ (new) = En\ (historic) - En\ (substituted) + Elec\ (additional)$$

$$Elec\ (additional) = En\ (substituted) \times \frac{(Yield\ (En\ substituted))}{(Yield\ (Elec))}$$

*En (new)* is the new level of final energy demand, *En (historic)* is the current level of final energy demand, *En (substituted)* is the amount of final energy (fossil fuels) displaced by electricity, and *Elec (additional)* is the additional electricity demand from the substitution. *Elec (additional)* is defined as the product of the volume of final energy substituted with the ratio of yields of electric versus conventional (historic) energy solutions. The useful energy displaced is similar, but the corresponding final energy demand will depend on those yields. For instance, a heat pump is three to five times more efficient than a natural gas boiler. While the useful energy (heating unit) is the same, final energy will be three to five times less with a heat pump than with a natural gas boiler as a result.

The following improvements in yields between electric and conventional solutions are applied[32] (Figure 21).

**Figure 21 – Energy conversion yields**

| Efficiency improvement from switch to electrification | % |
|---|---|
| Compression heat pumps and chillers | x3 |
| Electric boilers | +20% |
| Drying systems (infrared or microwave heaters) | +20% |
| Cooking stoves | +20% |
| Motors | x3 |

The shares of electrification can then be retrieved on the base of the new energy demand and new electricity demand (which is the sum of the already existing and additional electricity demand).

## Impact on $CO_2$ emissions

We use these levels of fossil fuel savings to recompute the associated carbon emissions saved. We apply the following carbon intensities to the volumes of fossil fuels displaced (Figure 22).

**Figure 22 – Carbon intensities of various fuels**

| Carbon intensities of various fuels | $ktCO_2/PJ$ |
|---|---|
| Solid fuels | 99.60 |
| Gasoline, Diesel | 69.27 |
| Residual fuel oil | 77.39 |
| Liquid Petroleum Gas (LPG) | 63.06 |
| Other liquids | 71.65 |
| Natural gas | 56.13 |

We focus here on emissions at end-use and do not account for upstream emissions such as those stemming from power generation. Therefore, for these reductions to be net savings implies that the additional electricity demand is zero-carbon. Although this assumption could be put in question, the reality of the last years as well as existing forecasts suggest that the bulk (around 90%) of new capacities deployed (to fuel new demand) are expected to be zero-carbon[33].

(32) Schneider Electric research, Maddedu et al., 2020.
(33) ©OECD/IEA, 2021; BloombergNEF, 2020.

# Final energy demand

Figure 23 provides a view of the initial energy system retrieved from the Joint Research Center of the European Commission. Final energy demand is split across 17 sectors of activity, and specific consumption for oil, natural gas, and coal are also available. Others account for direct electricity use and other resources, mainly biomass and distributed energies (e.g., distributed steam).

Total supply of energy is also indicated at the bottom. The difference between total demand and total supply comes from the consumption of energy resources in the production of electricity and as a feedstock for other conversions (e.g., coke for steel production).

**Figure 23 – 2015 Final energy demand**

| Final Energy demand, 2015, PJ/y | Type | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|
| Buildings – Residential | Total | 178.12 | 2,226.16 | 1,577.61 | 400.14 | 631.53 | 1,360.48 | 788.91 | 11,538.29 |
| Buildings – Residential | – Oil | 10.03 | 490.78 | 268.45 | 1.55 | 125.63 | 99.42 | 24.40 | 1,460.92 |
| Buildings – Residential | – Natural Gas | 25.03 | 826.43 | 426.34 | 285.29 | 126.36 | 711.15 | 132.20 | 4,081.73 |
| Buildings – Residential | – Coal | 0.00 | 25.18 | 1.45 | 0.02 | 4.93 | 0.00 | 260.22 | 388.67 |
| Buildings – Service | Total | 78.25 | 1,412.21 | 963.19 | 277.92 | 436.77 | 650.01 | 326.97 | 6,219.05 |
| Buildings – Service | – Oil | 2.63 | 300.61 | 115.90 | 9.50 | 44.52 | 28.88 | 17.44 | 691.83 |
| Buildings – Service | – Natural Gas | 7.67 | 481.57 | 249.98 | 128.17 | 122.01 | 270.22 | 74.08 | 1,959.59 |
| Buildings – Service | – Coal | 0.00 | 7.70 | 1.70 | 0.04 | 0.00 | 0.00 | 27.11 | 45.07 |
| Mobility – Road | Total | 157.39 | 2,201.22 | 1,752.84 | 414.03 | 1,123.69 | 1,407.52 | 664.95 | 12,308.22 |
| Mobility – Road | – Oil | 147.26 | 2,061.12 | 1,618.78 | 390.60 | 1,068.37 | 1,243.81 | 560.36 | 11,385.58 |
| Mobility – Road | – Natural Gas | 0.08 | 33.50 | 9.22 | 9.75 | 15.03 | 113.80 | 71.65 | 327.96 |
| Mobility – Road | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Rail | Total | 4.80 | 53.92 | 42.91 | 7.41 | 23.72 | 38.32 | 13.60 | 302.79 |
| Mobility – Rail | – Oil | 3.37 | 13.36 | 6.74 | 1.32 | 6.26 | 0.94 | 3.53 | 88.35 |
| Mobility – Rail | – Natural Gas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Rail | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.43 |
| Mobility – Air | Total | 38.98 | 365.95 | 281.15 | 160.65 | 236.25 | 161.77 | 27.95 | 2,148.40 |
| Mobility – Air | – Oil | 38.98 | 365.95 | 281.15 | 160.65 | 236.25 | 161.77 | 27.95 | 2,148.40 |
| Mobility – Air | – Natural Gas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Air | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Sea | Total | 6.23 | 13.36 | 19.82 | 15.88 | 18.64 | 39.02 | 0.09 | 191.34 |
| Mobility – Sea | – Oil | 6.23 | 13.36 | 19.82 | 15.88 | 18.64 | 39.02 | 0.09 | 191.15 |
| Mobility – Sea | – Natural Gas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Sea | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Industry – Others | Total | 14.22 | 125.17 | 92.52 | 47.14 | 108.44 | 84.78 | 52.65 | 1,162.27 |
| Industry – Others | – Oil | 5.81 | 5.56 | 32.26 | 17.01 | 24.55 | 3.41 | 5.00 | 332.80 |
| Industry – Others | – Natural Gas | 1.71 | 34.28 | 26.07 | 12.35 | 44.15 | 11.17 | 7.03 | 216.89 |
| Industry – Others | – Coal | 0.11 | 2.48 | 0.00 | 0.62 | 0.00 | 0.03 | 3.30 | 26.94 |
| Industry – Wood | Total | 2.99 | 75.01 | 25.62 | 2.26 | 18.93 | 18.97 | 37.03 | 331.83 |
| Industry – Wood | – Oil | 0.13 | 0.57 | 1.90 | 0.00 | 0.93 | 0.00 | 0.56 | 8.47 |
| Industry – Wood | – Natural Gas | 0.08 | 5.14 | 2.67 | 0.48 | 0.88 | 1.21 | 1.92 | 20.72 |
| Industry – Wood | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.44 | 1.72 |
| Industry – Textiles | Total | 0.71 | 21.57 | 15.06 | 3.71 | 13.55 | 46.33 | 4.84 | 187.12 |
| Industry – Textiles | – Oil | 0.00 | 0.94 | 0.93 | 0.00 | 1.29 | 3.43 | 0.22 | 10.71 |
| Industry – Textiles | – Natural Gas | 0.23 | 9.85 | 8.32 | 2.34 | 5.88 | 22.58 | 1.51 | 90.04 |
| Industry – Textiles | – Coal | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.42 | 2.66 |
| Industry – Machinery | Total | 9.36 | 214.80 | 78.62 | 20.43 | 39.10 | 140.54 | 31.54 | 772.56 |
| Industry – Machinery | – Oil | 0.79 | 9.95 | 4.68 | 0.18 | 5.15 | 11.66 | 1.88 | 44.03 |
| Industry – Machinery | – Natural Gas | 2.12 | 71.51 | 26.45 | 10.05 | 16.56 | 55.83 | 8.63 | 270.52 |
| Industry – Machinery | – Coal | 0.00 | 0.33 | 0.68 | 0.00 | 0.00 | 0.00 | 2.22 | 4.38 |
| Industry – Transport Eqt | Total | 0.68 | 120.50 | 41.74 | 4.41 | 19.23 | 16.68 | 16.17 | 338.32 |
| Industry – Transport Eqt | – Oil | 0.04 | 1.90 | 0.90 | 0.47 | 1.65 | 0.00 | 0.61 | 16.71 |
| Industry – Transport Eqt | – Natural Gas | 0.23 | 36.49 | 15.42 | 1.94 | 4.41 | 0.00 | 3.86 | 99.12 |
| Industry – Transport Eqt | – Coal | 0.00 | 0.13 | 0.26 | 0.00 | 0.00 | 0.00 | 0.53 | 2.83 |
| Industry – Food & Bev | Total | 24.58 | 204.58 | 212.21 | 86.76 | 95.71 | 113.37 | 77.74 | 1,221.64 |
| Industry – Food & Bev | – Oil | 2.07 | 7.77 | 10.78 | 0.21 | 12.46 | 8.14 | 2.86 | 77.03 |
| Industry – Food & Bev | – Natural Gas | 10.81 | 106.89 | 106.44 | 54.44 | 32.52 | 45.32 | 22.98 | 555.79 |
| Industry – Food & Bev | – Coal | 1.21 | 8.53 | 11.42 | 0.97 | 1.44 | 0.00 | 22.64 | 54.06 |

| Final Energy demand, 2015, PJ/y | Type | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|
| Industry – Paper | Total | 3.14 | 237.49 | 96.71 | 23.47 | 70.39 | 99.33 | 65.65 | 1,397.72 |
| Industry – Paper | – Oil | 0.13 | 2.29 | 2.14 | 0.00 | 3.63 | 2.83 | 1.83 | 30.21 |
| Industry – Paper | – Natural Gas | 1.46 | 87.76 | 40.71 | 12.40 | 24.87 | 25.68 | 7.25 | 297.38 |
| Industry – Paper | – Coal | 0.00 | 14.92 | 0.71 | 0.00 | 0.00 | 0.00 | 10.92 | 44.45 |
| Industry – NM Minerals | Total | 18.30 | 271.49 | 135.89 | 23.51 | 137.03 | 208.11 | 108.01 | 1,416.98 |
| Industry – NM Minerals | – Oil | 7.21 | 17.29 | 28.62 | 0.41 | 53.77 | 70.65 | 1.98 | 280.83 |
| Industry – NM Minerals | – Natural Gas | 4.23 | 104.03 | 61.71 | 17.45 | 53.20 | 79.24 | 40.55 | 534.03 |
| Industry – NM Minerals | – Coal | 2.36 | 54.91 | 10.77 | 1.45 | 0.29 | 5.76 | 24.25 | 184.88 |
| Industry – Chemicals | Total | 5.87 | 1,336.00 | 636.99 | 801.94 | 239.96 | 306.60 | 269.84 | 5,284.04 |
| Industry – Chemicals | – Oil | 0.12 | 54.30 | 9.27 | 2.09 | 5.67 | 11.12 | 3.07 | 125.56 |
| Industry – Chemicals | – Natural Gas | 2.26 | 205.16 | 125.75 | 69.96 | 70.56 | 39.46 | 14.87 | 741.79 |
| Industry – Chemicals | – Coal | 0.30 | 40.77 | 15.11 | 0.00 | 7.38 | 0.03 | 45.75 | 128.09 |
| Industry – NF metals | Total | 0.00 | 96.81 | 39.56 | 10.07 | 44.95 | 26.15 | 18.12 | 404.13 |
| Industry – NF metals | – Oil | 0.00 | 3.12 | 0.47 | 0.00 | 1.99 | 1.28 | 0.25 | 12.60 |
| Industry – NF metals | – Natural Gas | 0.00 | 33.86 | 7.66 | 2.65 | 7.22 | 15.82 | 7.23 | 133.88 |
| Industry – NF metals | – Coal | 0.00 | 1.34 | 0.00 | 0.00 | 1.37 | 0.11 | 0.31 | 13.95 |
| Industry – Steel | Total | 3.54 | 568.30 | 236.02 | 100.68 | 126.57 | 197.45 | 111.47 | 2,100.70 |
| Industry – Steel | – Oil | 0.09 | 7.57 | 1.10 | 0.17 | 2.98 | 3.75 | 0.20 | 36.32 |
| Industry – Steel | – Natural Gas | 1.65 | 186.50 | 67.14 | 30.03 | 38.91 | 58.15 | 33.25 | 647.42 |
| Industry – Steel | – Coal | 0.00 | 192.61 | 79.40 | 42.89 | 23.12 | 17.02 | 8.75 | 520.75 |
| **All sectors – demand** | **Total** | **547.15** | **9,544.54** | **6,248.45** | **2,400.41** | **3,384.45** | **4,915.41** | **2,615.52** | **47,325.41** |
| **All sectors – demand** | **– Oil** | **224.89** | **3,356.42** | **2,403.86** | **600.05** | **1,613.75** | **1,690.11** | **652.22** | **16,941.50** |
| **All sectors – demand** | **– Natural Gas** | **57.56** | **2,222.96** | **1,173.88** | **637.28** | **562.57** | **1,449.63** | **427.01** | **9,976.86** |
| **All sectors – demand** | **– Coal** | **3.99** | **349.15** | **121.49** | **45.99** | **38.52** | **22.96** | **407.86** | **1,418.88** |
| Other Supply – Power generation, conversion feedstocks | Total | 154.80 | 3,610.51 | 4,328.04 | 846.72 | 1,699.18 | 1,623.06 | 1,380.12 | 20,813.79 |
| Other Supply – Power generation, conversion feedstocks | – Oil | 70.01 | 416.36 | 81.80 | 1,816.16 | 1,129.45 | 1,390.34 | 456.89 | 8,562.33 |
| Other Supply – Power generation, conversion feedstocks | – Natural Gas | 61.87 | 504.92 | 293.45 | 584.26 | 464.79 | 865.74 | 149.75 | 5,007.19 |
| Other Supply – Power generation, conversion feedstocks | – Coal | 68.31 | 2,979.99 | 248.06 | 412.16 | 515.71 | 492.06 | 1,612.51 | 9,419.79 |
| **All sectors – total supply (power generation, feedstocks)** | **Total** | **701.95** | **13,155.05** | **10,576.49** | **3,247.14** | **5,083.62** | **6,538.47** | **3,995.64** | **68,139.20** |
| **All sectors – total supply (power generation, feedstocks)** | **– Oil** | **294.89** | **3,772.78** | **2,485.66** | **2,416.21** | **2,743.20** | **3,080.45** | **1,109.11** | **25,503.83** |
| **All sectors – total supply (power generation, feedstocks)** | **– Natural Gas** | **119.42** | **2,727.88** | **1,467.33** | **1,221.55** | **1,027.36** | **2,315.36** | **576.76** | **14,984.04** |
| **All sectors – total supply (power generation, feedstocks)** | **– Coal** | **72.29** | **3,329.14** | **369.55** | **458.15** | **554.23** | **515.02** | **2,020.37** | **10,838.68** |

As the system electrifies, final energy demand evolves accordingly, since electrification brings higher efficiency to the energy system. Figure 24 shows this evolution from current state (“already”) to the newly electrified system (“electrification”).

**Figure 24 – Final energy demand evolution**

| Final Energy demand evolution, PJ/y | Electrification | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|
| Buildings – Residential | Already | 178.12 | 2,226.16 | 1,577.61 | 400.14 | 631.53 | 1,360.48 | 788.91 | 11,538.29 |
| Buildings – Residential | Electrification | 155.87 | 1,373.52 | 1,147.53 | 221.88 | 476.47 | 868.12 | 531.11 | 7,836.29 |
| Buildings – Service | Already | 78.25 | 1,412.21 | 963.19 | 277.92 | 436.77 | 650.01 | 326.97 | 6,219.05 |
| Buildings – Service | Electrification | 72.00 | 931.43 | 734.30 | 195.70 | 340.59 | 476.64 | 253.27 | 4,592.83 |
| Mobility – Road | Already | 157.39 | 2,201.22 | 1,752.84 | 414.03 | 1,123.69 | 1,407.52 | 664.95 | 12,308.22 |
| Mobility – Road | Electrification | 79.74 | 1,185.89 | 893.83 | 212.26 | 583.38 | 639.19 | 345.25 | 6,311.91 |
| Mobility – Rail | Already | 4.80 | 53.92 | 42.91 | 7.41 | 23.72 | 38.32 | 13.60 | 302.79 |
| Mobility – Rail | Electrification | 4.80 | 53.92 | 42.91 | 7.41 | 23.72 | 38.32 | 13.60 | 302.79 |
| Mobility – Air | Already | 38.98 | 365.95 | 281.15 | 160.65 | 236.25 | 161.77 | 27.95 | 2,148.40 |
| Mobility – Air | Electrification | 38.98 | 365.95 | 281.15 | 160.65 | 236.25 | 161.77 | 27.95 | 2,148.40 |
| Mobility – Sea | Already | 6.23 | 13.36 | 19.82 | 15.88 | 18.64 | 39.02 | 0.09 | 191.34 |
| Mobility – Sea | Electrification | 6.23 | 13.36 | 19.82 | 15.88 | 18.64 | 39.02 | 0.09 | 191.34 |
| Industry – Others | Already | 14.22 | 125.17 | 92.52 | 47.14 | 108.44 | 84.78 | 52.65 | 1,162.27 |
| Industry – Others | Electrification | 12.24 | 120.45 | 78.07 | 41.19 | 97.30 | 83.75 | 50.58 | 1,071.11 |
| Industry – Wood | Already | 2.99 | 75.01 | 25.62 | 2.26 | 18.93 | 18.97 | 37.03 | 331.83 |
| Industry – Wood | Electrification | 2.91 | 72.91 | 24.51 | 2.13 | 18.34 | 18.47 | 35.84 | 321.77 |
| Industry – Textiles | Already | 0.71 | 21.57 | 15.06 | 3.71 | 13.55 | 46.33 | 4.84 | 187.12 |
| Industry – Textiles | Electrification | 0.66 | 18.98 | 12.99 | 3.21 | 11.87 | 40.34 | 4.32 | 163.56 |
| Industry – Machinery | Already | 9.36 | 214.80 | 78.62 | 20.43 | 39.10 | 140.54 | 31.54 | 772.56 |
| Industry – Machinery | Electrification | 9.22 | 210.66 | 77.33 | 19.81 | 37.60 | 137.05 | 30.88 | 755.23 |
| Industry – Transport Eqt | Already | 0.68 | 120.50 | 41.74 | 4.41 | 19.23 | 16.68 | 16.17 | 338.32 |
| Industry – Transport Eqt | Electrification | 0.65 | 117.60 | 40.76 | 4.30 | 18.73 | 16.68 | 16.00 | 330.27 |
| Industry – Food & Bev | Already | 24.58 | 204.58 | 212.21 | 86.76 | 95.71 | 113.37 | 77.74 | 1,221.64 |
| Industry – Food & Bev | Electrification | 21.57 | 178.44 | 185.06 | 75.13 | 85.72 | 101.92 | 67.48 | 1,075.98 |
| Industry – Paper | Already | 3.14 | 237.49 | 96.71 | 23.47 | 70.39 | 99.33 | 65.65 | 1,397.72 |
| Industry – Paper | Electrification | 2.81 | 215.87 | 87.56 | 20.89 | 64.36 | 93.25 | 61.60 | 1,320.69 |
| Industry – NM Minerals | Already | 18.30 | 271.49 | 135.89 | 23.51 | 137.03 | 208.11 | 108.01 | 1,416.98 |
| Industry – NM Minerals | Electrification | 18.21 | 268.35 | 134.61 | 23.28 | 134.03 | 204.77 | 107.18 | 1,398.60 |
| Industry – Chemicals | Already | 5.87 | 1,336.00 | 636.99 | 801.94 | 239.96 | 306.60 | 269.84 | 5,284.04 |
| Industry – Chemicals | Electrification | 5.46 | 1,310.44 | 624.85 | 796.37 | 234.13 | 300.78 | 264.87 | 5,203.45 |
| Industry – NF metals | Already | 0.00 | 96.81 | 39.56 | 10.07 | 44.95 | 26.15 | 18.12 | 404.13 |
| Industry – NF metals | Electrification | 0.00 | 95.80 | 39.21 | 9.93 | 44.54 | 25.60 | 18.08 | 400.25 |
| Industry – Steel | Already | 3.54 | 568.30 | 236.02 | 100.68 | 126.57 | 197.45 | 111.47 | 2,100.70 |
| Industry – Steel | Electrification | 3.53 | 565.68 | 235.25 | 100.36 | 125.65 | 195.86 | 110.70 | 2,092.04 |
| **All sectors – demand** | **Already** | **547.15** | **9,544.54** | **6,248.45** | **2,400.41** | **3,384.45** | **4,915.41** | **2,615.52** | **47,325.41** |
| **All sectors – demand** | **Electrification** | **434.89** | **7,099.22** | **4,659.74** | **1,910.39** | **2,551.29** | **3,441.53** | **1,938.80** | **35,516.51** |

# Electricity demand

Electricity demand increases from the electrification of the different processes described above. Figures 25 and 26 indicate the actual evolution in volume (TWh per year) and in percentage (of final energy demand) of electricity demand[34].

**Figure 25 – Evolution of electricity demand**

| Electricity demand (TWh) | Electrification | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|
| Buildings – Residential | Already | 10 | 129 | 152 | 23 | 72 | 66 | 28 | 798 |
| Buildings – Residential | Electrification | 14 | 265 | 226 | 53 | 100 | 155 | 72 | 1,417 |
| Buildings – Service | Already | 10 | 141 | 147 | 36 | 73 | 92 | 45 | 827 |
| Buildings – Service | Electrification | 11 | 228 | 187 | 51 | 93 | 127 | 58 | 1,128 |
| Mobility – Road | Already | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Mobility – Road | Electrification | 11 | 141 | 120 | 28 | 75 | 107 | 44 | 835 |
| Mobility – Rail | Already | 0 | 11 | 10 | 2 | 5 | 10 | 3 | 59 |
| Mobility – Rail | Electrification | 0 | 11 | 10 | 2 | 5 | 10 | 3 | 59 |
| Mobility – Air | Already | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mobility – Air | Electrification | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mobility – Sea | Already | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mobility – Sea | Electrification | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Industry – Others | Already | 2 | 19 | 14 | 5 | 14 | 18 | 9 | 150 |
| Industry – Others | Electrification | 2 | 24 | 17 | 7 | 18 | 18 | 9 | 189 |
| Industry – Wood | Already | 0 | 4 | 2 | 0 | 1 | 3 | 2 | 24 |
| Industry – Wood | Electrification | 0 | 6 | 3 | 0 | 2 | 3 | 3 | 31 |
| Industry – Textiles | Already | 0 | 2 | 2 | 0 | 2 | 5 | 1 | 21 |
| Industry – Textiles | Electrification | 0 | 5 | 4 | 1 | 3 | 11 | 1 | 43 |
| Industry – Machinery | Already | 1 | 33 | 13 | 3 | 5 | 20 | 5 | 118 |
| Industry – Machinery | Electrification | 2 | 36 | 14 | 3 | 6 | 23 | 5 | 131 |
| Industry – Transport Eqt | Already | 0 | 19 | 7 | 1 | 4 | 4 | 3 | 54 |
| Industry – Transport Eqt | Electrification | 0 | 20 | 8 | 1 | 4 | 4 | 3 | 60 |
| Industry – Food & Bev | Already | 2 | 18 | 21 | 6 | 11 | 12 | 6 | 116 |
| Industry – Food & Bev | Electrification | 5 | 45 | 49 | 19 | 21 | 24 | 17 | 266 |
| Industry – Paper | Already | 0 | 21 | 8 | 2 | 6 | 9 | 4 | 117 |
| Industry – Paper | Electrification | 1 | 44 | 17 | 5 | 12 | 15 | 9 | 196 |
| Industry – NM Minerals | Already | 1 | 12 | 8 | 1 | 6 | 9 | 5 | 67 |
| Industry – NM Minerals | Electrification | 1 | 15 | 9 | 1 | 9 | 12 | 5 | 85 |
| Industry – Chemicals | Already | 1 | 53 | 20 | 13 | 10 | 14 | 8 | 181 |
| Industry – Chemicals | Electrification | 1 | 57 | 21 | 13 | 10 | 15 | 9 | 192 |
| Industry – NF metals | Already | 0 | 16 | 9 | 2 | 10 | 2 | 2 | 65 |
| Industry – NF metals | Electrification | 0 | 17 | 9 | 2 | 10 | 3 | 2 | 70 |
| Industry – Steel | Already | 0 | 26 | 10 | 3 | 13 | 17 | 6 | 110 |
| Industry – Steel | Electrification | 0 | 29 | 11 | 3 | 14 | 19 | 7 | 119 |
| **All sectors** | **Already** | **29** | **506** | **422** | **97** | **230** | **282** | **127** | **2,709** |
| **All sectors** | **Electrification** | **49** | **942** | **705** | **189** | **381** | **545** | **247** | **4,820** |

(34) As for the above, "already" corresponds to current situation and "electrification" to the newly electrified system.

**Figure 26 – Electrification penetration in the energy system**

| Share of electricity, per sector | Electrification | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|
| Buildings – Residential | Already | 21% | 21% | 35% | 20% | 41% | 18% | 13% | 25% |
| Buildings – Residential | Electrification | 32% | 69% | 71% | 86% | 76% | 64% | 49% | 65% |
| Buildings – Service | Already | 46% | 36% | 55% | 46% | 60% | 51% | 50% | 48% |
| Buildings – Service | Electrification | 55% | 88% | 92% | 94% | 98% | 96% | 82% | 88% |
| Mobility – Road | Already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Road | Electrification | 49% | 43% | 48% | 48% | 46% | 60% | 46% | 48% |
| Mobility – Rail | Already | 30% | 74% | 84% | 82% | 74% | 98% | 74% | 70% |
| Mobility – Rail | Electrification | 30% | 74% | 84% | 82% | 74% | 98% | 74% | 70% |
| Mobility – Air | Already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Air | Electrification | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Sea | Already | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Sea | Electrification | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Others | Already | 52% | 55% | 54% | 42% | 47% | 74% | 59% | 46% |
| Industry – Others | Electrification | 71% | 71% | 77% | 57% | 65% | 77% | 65% | 64% |
| Industry – Wood | Already | 25% | 22% | 31% | 37% | 22% | 57% | 20% | 26% |
| Industry – Wood | Electrification | 32% | 28% | 47% | 57% | 30% | 64% | 30% | 34% |
| Industry – Textiles | Already | 60% | 38% | 39% | 36% | 46% | 41% | 42% | 40% |
| Industry – Textiles | Electrification | 91% | 87% | 100% | 98% | 99% | 96% | 85% | 95% |
| Industry – Machinery | Already | 55% | 56% | 59% | 50% | 44% | 51% | 52% | 55% |
| Industry – Machinery | Electrification | 59% | 61% | 64% | 61% | 59% | 59% | 59% | 62% |
| Industry – Transport Eqt | Already | 49% | 55% | 60% | 45% | 68% | 76% | 57% | 57% |
| Industry – Transport Eqt | Electrification | 65% | 63% | 68% | 53% | 77% | 76% | 58% | 65% |
| Industry – Food & Bev | Already | 35% | 32% | 35% | 27% | 41% | 39% | 29% | 34% |
| Industry – Food & Bev | Electrification | 91% | 91% | 95% | 89% | 89% | 84% | 90% | 89% |
| Industry – Paper | Already | 41% | 32% | 29% | 37% | 30% | 32% | 23% | 30% |
| Industry – Paper | Electrification | 89% | 73% | 70% | 87% | 66% | 57% | 50% | 53% |
| Industry – NM Minerals | Already | 15% | 16% | 21% | 18% | 15% | 16% | 16% | 17% |
| Industry – NM Minerals | Electrification | 16% | 21% | 25% | 21% | 24% | 22% | 18% | 22% |
| Industry – Chemicals | Already | 45% | 14% | 11% | 6% | 14% | 16% | 11% | 12% |
| Industry – Chemicals | Electrification | 52% | 16% | 12% | 6% | 16% | 18% | 12% | 13% |
| Industry – NF metals | Already | na | 59% | 79% | 73% | 76% | 34% | 42% | 58% |
| Industry – NF metals | Electrification | na | 64% | 84% | 80% | 81% | 43% | 43% | 63% |
| Industry – Steel | Already | 46% | 17% | 16% | 9% | 36% | 32% | 20% | 19% |
| Industry – Steel | Electrification | 47% | 18% | 17% | 11% | 39% | 35% | 23% | 20% |
| **All sectors** | **Already** | **19%** | **19%** | **24%** | **15%** | **24%** | **21%** | **17%** | **21%** |
| **All sectors** | **Electrification** | **40%** | **48%** | **54%** | **36%** | **54%** | **57%** | **46%** | **49%** |

# Fossil fuels displacement

Finally, we can derive from this exercise the actual reduction in supply of fossil fuels. This is provided in volume (Figure 27) and in percentage of total supply of energy (Figure 28).

**Figure 27 – Fossil fuels displacement, in volume**

| Fossil fuels displaced, PJ/y | Type | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|
| Buildings – Residential | Total | -35.06 | -1,342.39 | -696.24 | -286.86 | -256.93 | -810.57 | -416.82 | -5,931.32 |
| Buildings – Residential | – Oil | -10.03 | -490.78 | -268.45 | -1.55 | -125.63 | -99.42 | -24.40 | -1,460.92 |
| Buildings – Residential | – Natural Gas | -25.03 | -826.43 | -426.34 | -285.29 | -126.36 | -711.15 | -132.20 | -4,081.73 |
| Buildings – Residential | – Coal | 0.00 | -25.18 | -1.45 | -0.02 | -4.93 | 0.00 | -260.22 | -388.67 |
| Buildings – Service | Total | -10.30 | -789.88 | -367.57 | -137.71 | -166.53 | -299.10 | -118.63 | -2,696.48 |
| Buildings – Service | – Oil | -2.63 | -300.61 | -115.90 | -9.50 | -44.52 | -28.88 | -17.44 | -691.83 |
| Buildings – Service | – Natural Gas | -7.67 | -481.57 | -249.98 | -128.17 | -122.01 | -270.22 | -74.08 | -1,959.59 |
| Buildings – Service | – Coal | 0.00 | -7.70 | -1.70 | -0.04 | 0.00 | 0.00 | -27.11 | -45.07 |
| Mobility – Road | Total | -116.47 | -1,522.99 | -1,288.51 | -302.66 | -810.48 | -1,152.49 | -479.55 | -8,994.46 |
| Mobility – Road | – Oil | -116.39 | -1,489.49 | -1,279.29 | -292.90 | -795.44 | -1,038.68 | -407.90 | -8,666.50 |
| Mobility – Road | – Natural Gas | -0.08 | -33.50 | -9.22 | -9.75 | -15.03 | -113.80 | -71.65 | -327.96 |
| Mobility – Road | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Rail | Total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Rail | – Oil | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Rail | – Natural Gas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Rail | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Air | Total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Air | – Oil | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Air | – Natural Gas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Air | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Sea | Total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Sea | – Oil | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Sea | – Natural Gas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mobility – Sea | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Industry – Others | Total | -3.38 | -24.30 | -25.54 | -10.12 | -24.25 | -2.80 | -4.56 | -242.59 |
| Industry – Others | – Oil | -2.93 | -4.76 | -21.39 | -8.79 | -14.85 | -1.72 | -2.97 | -185.71 |
| Industry – Others | – Natural Gas | -0.45 | -19.44 | -4.15 | -1.23 | -9.39 | -1.07 | -1.31 | -53.52 |
| Industry – Others | – Coal | 0.00 | -0.10 | 0.00 | -0.11 | 0.00 | -0.01 | -0.27 | -3.36 |
| Industry – Wood | Total | -0.21 | -5.71 | -4.57 | -0.48 | -1.81 | -1.21 | -2.48 | -29.20 |
| Industry – Wood | – Oil | -0.13 | -0.57 | -1.90 | 0.00 | -0.93 | 0.00 | -0.56 | -8.47 |
| Industry – Wood | – Natural Gas | -0.08 | -5.14 | -2.67 | -0.48 | -0.88 | -1.21 | -1.92 | -20.72 |
| Industry – Wood | – Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Industry – Textiles | Total | -0.23 | -11.04 | -9.25 | -2.34 | -7.17 | -26.01 | -2.15 | -103.41 |
| Industry – Textiles | – Oil | 0.00 | -0.94 | -0.93 | 0.00 | -1.29 | -3.43 | -0.22 | -10.71 |
| Industry – Textiles | – Natural Gas | -0.23 | -9.85 | -8.32 | -2.34 | -5.88 | -22.58 | -1.51 | -90.04 |
| Industry – Textiles | – Coal | 0.00 | -0.25 | 0.00 | 0.00 | 0.00 | 0.00 | -0.42 | -2.66 |
| Industry – Machinery | Total | -0.45 | -12.92 | -3.92 | -2.55 | -6.26 | -12.86 | -2.52 | -63.22 |
| Industry – Machinery | – Oil | -0.18 | -2.62 | -0.70 | -0.09 | -3.13 | -7.15 | -0.92 | -19.04 |
| Industry – Machinery | – Natural Gas | -0.27 | -9.96 | -2.54 | -2.47 | -3.13 | -5.71 | -0.21 | -41.03 |
| Industry – Machinery | – Coal | 0.00 | -0.33 | -0.68 | 0.00 | 0.00 | 0.00 | -1.40 | -3.16 |
| Industry – Transport Eqt | Total | -0.12 | -9.84 | -3.66 | -0.37 | -1.79 | 0.00 | -0.25 | -30.04 |
| Industry – Transport Eqt | – Oil | -0.02 | -1.25 | -0.30 | -0.09 | -0.53 | 0.00 | -0.10 | -6.40 |
| Industry – Transport Eqt | – Natural Gas | -0.10 | -8.46 | -3.10 | -0.28 | -1.26 | 0.00 | -0.15 | -21.33 |
| Industry – Transport Eqt | – Coal | 0.00 | -0.13 | -0.26 | 0.00 | 0.00 | 0.00 | 0.00 | -2.30 |
| Industry – Food & Bev | Total | -14.09 | -123.19 | -128.64 | -55.62 | -46.42 | -53.45 | -48.47 | -686.87 |
| Industry – Food & Bev | – Oil | -2.07 | -7.77 | -10.78 | -0.21 | -12.46 | -8.14 | -2.86 | -77.03 |
| Industry – Food & Bev | – Natural Gas | -10.81 | -106.89 | -106.44 | -54.44 | -32.52 | -45.32 | -22.98 | -555.79 |
| Industry – Food & Bev | – Coal | -1.21 | -8.53 | -11.42 | -0.97 | -1.44 | 0.00 | -22.64 | -54.06 |
| Industry – Paper | Total | -1.59 | -104.96 | -43.56 | -12.40 | -28.51 | -28.51 | -20.00 | -370.20 |
| Industry – Paper | – Oil | -0.13 | -2.29 | -2.14 | 0.00 | -3.63 | -2.83 | -1.83 | -30.15 |
| Industry – Paper | – Natural Gas | -1.46 | -87.76 | -40.71 | -12.40 | -24.87 | -25.68 | -7.25 | -296.65 |
| Industry – Paper | – Coal | 0.00 | -14.92 | -0.71 | 0.00 | 0.00 | 0.00 | -10.92 | -43.40 |
| Industry – NM Minerals | Total | -0.37 | -14.31 | -5.66 | -1.00 | -13.90 | -15.52 | -3.60 | -83.76 |
| Industry – NM Minerals | – Oil | -0.15 | -3.96 | -3.49 | -0.21 | -7.46 | -5.92 | -1.66 | -35.94 |
| Industry – NM Minerals | – Natural Gas | -0.02 | -8.48 | -0.86 | -0.68 | -6.16 | -9.58 | -0.97 | -37.04 |
| Industry – NM Minerals | – Coal | -0.20 | -1.88 | -1.31 | -0.11 | -0.29 | -0.03 | -0.97 | -10.78 |

| Fossil fuels displaced, PJ/y | Type | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|
| Industry – Chemicals | Total | -0.61 | -38.34 | -18.21 | -8.35 | -8.75 | -8.73 | -7.45 | -120.88 |
| Industry – Chemicals | – Oil | -0.05 | -2.63 | -0.77 | -0.07 | -0.83 | -1.21 | -0.76 | -9.63 |
| Industry – Chemicals | – Natural Gas | -0.50 | -34.28 | -16.90 | -8.27 | -7.66 | -7.52 | -1.83 | -102.97 |
| Industry – Chemicals | – Coal | -0.06 | -1.43 | -0.54 | 0.00 | -0.26 | 0.00 | -4.87 | -8.28 |
| Industry – NF metals | Total | 0.00 | -5.00 | -1.69 | -0.72 | -2.01 | -2.71 | -0.19 | -19.04 |
| Industry – NF metals | – Oil | 0.00 | -1.12 | -0.06 | 0.00 | -0.39 | -0.60 | -0.05 | -2.99 |
| Industry – NF metals | – Natural Gas | 0.00 | -3.29 | -1.62 | -0.72 | -1.31 | -2.00 | -0.02 | -11.82 |
| Industry – NF metals | – Coal | 0.00 | -0.59 | 0.00 | 0.00 | -0.32 | -0.11 | -0.11 | -4.23 |
| Industry – Steel | Total | -0.04 | -12.37 | -3.53 | -1.47 | -4.45 | -7.41 | -3.68 | -40.48 |
| Industry – Steel | – Oil | 0.00 | -0.34 | -0.30 | -0.03 | -0.16 | -0.22 | -0.11 | -2.18 |
| Industry – Steel | – Natural Gas | -0.04 | -3.92 | -1.01 | -0.32 | -2.42 | -5.40 | -2.35 | -18.65 |
| Industry – Steel | – Coal | 0.00 | -8.11 | -2.22 | -1.12 | -1.87 | -1.79 | -1.22 | -19.65 |
| **All sectors – demand** | **Total** | **-182.92** | **-4,017.24** | **-2,600.55** | **-822.64** | **-1,379.25** | **-2,421.38** | **-1,110.35** | **-19,411.94** |
| **All sectors – demand** | **– Oil** | **-134.70** | **-2,309.14** | **-1,706.40** | **-313.45** | **-1,011.26** | **-1,198.19** | **-461.77** | **-11,207.51** |
| **All sectors – demand** | **– Natural Gas** | **-46.75** | **-1,638.95** | **-873.87** | **-506.83** | **-358.89** | **-1,221.24** | **-318.42** | **-7,618.83** |
| **All sectors – demand** | **– Coal** | **-1.47** | **-69.16** | **-20.28** | **-2.36** | **-9.10** | **-1.95** | **-330.15** | **-585.60** |

**Figure 28 – Fossil fuels displacement, in percentage of total supply**

| Share of Fossil Fuels displaced | Type | Denmark | Germany | France | Netherlands | Spain | Italy | Poland | EU-28 |
|---|---|---|---|---|---|---|---|---|---|
| Buildings – Residential | Oil | -3% | -13% | -11% | 0% | -5% | -3% | -2% | -6% |
| Buildings – Residential | Natural Gas | -21% | -30% | -29% | -23% | -12% | -31% | -23% | -27% |
| Buildings – Residential | Coal | 0% | -1% | 0% | 0% | -1% | 0% | -13% | -4% |
| Buildings – Service | Oil | -1% | -8% | -5% | 0% | -2% | -1% | -2% | -3% |
| Buildings – Service | Natural Gas | -6% | -18% | -17% | -10% | -12% | -12% | -13% | -13% |
| Buildings – Service | Coal | 0% | 0% | 0% | 0% | 0% | 0% | -1% | 0% |
| Mobility – Road | Oil | -39% | -39% | -51% | -12% | -29% | -34% | -37% | -34% |
| Mobility – Road | Natural Gas | 0% | -1% | -1% | -1% | -1% | -5% | -12% | -2% |
| Mobility – Road | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Rail | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Rail | Natural Gas | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Rail | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Air | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Air | Natural Gas | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Air | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Sea | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Sea | Natural Gas | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobility – Sea | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Others | Oil | -1% | 0% | -1% | 0% | -1% | 0% | 0% | -1% |
| Industry – Others | Natural Gas | 0% | -1% | 0% | 0% | -1% | 0% | 0% | 0% |
| Industry – Others | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Wood | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Wood | Natural Gas | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Wood | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Textiles | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Textiles | Natural Gas | 0% | 0% | -1% | 0% | -1% | -1% | 0% | -1% |
| Industry – Textiles | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Machinery | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Machinery | Natural Gas | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Machinery | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Transport Eqt | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Transport Eqt | Natural Gas | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Transport Eqt | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Food | Oil | -1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Food | Natural Gas | -9% | -4% | -7% | -4% | -3% | -2% | -4% | -4% |
| Industry – Food | Coal | -2% | 0% | -3% | 0% | 0% | 0% | -1% | 0% |
| Industry – Paper | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Paper | Natural Gas | -1% | -3% | -3% | -1% | -2% | -1% | -1% | -2% |
| Industry – Paper | Coal | 0% | 0% | 0% | 0% | 0% | 0% | -1% | 0% |
| Industry – Nonmetallic minerals | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Nonmetallic minerals | Natural Gas | 0% | 0% | 0% | 0% | -1% | 0% | 0% | 0% |
| Industry – Nonmetallic minerals | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Chemicals | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Chemicals | Natural Gas | 0% | -1% | -1% | -1% | -1% | 0% | 0% | -1% |
| Industry – Chemicals | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Nonferrous metals | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Nonferrous metals | Natural Gas | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Nonferrous metals | Coal | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Steel | Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Steel | Natural Gas | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Industry – Steel | Coal | 0% | 0% | -1% | 0% | 0% | 0% | 0% | 0% |
| **All sectors** | **Oil** | **-46%** | **-61%** | **-69%** | **-13%** | **-37%** | **-39%** | **-42%** | **-44%** |
| **All sectors** | **Natural Gas** | **-39%** | **-60%** | **-60%** | **-41%** | **-35%** | **-53%** | **-55%** | **-51%** |
| **All sectors** | **Coal** | **-2%** | **-2%** | **-5%** | **-1%** | **-2%** | **0%** | **-16%** | **-5%** |

# 2030 forecast

We can evaluate the potential realization of this potential over time based on current rates of renovation and electric mobility adoption. We project this for 2030.

## Buildings

The building stock in the European Union represents today around 260 million buildings (approximately 85% for residential) and 25 billion square meters[35] (approximately 75% for residential). Renovation and electrification of these existing buildings is thus the prime target. For the sake of this exercise, we choose to discard the impact of new constructions (around 0.5% per year) and demolitions (around 0.2% per year), and their impact on total stock evolution[36].

Current rates of renovations are dependent on the actual definition of renovations. The European Union Commission uses the "Major Renovation Equivalent", which varies between 0.08% and 1.75% per year, a rate defined from renovations that apply to more than 25% of the building surface or cost more than 25% of the value of the building. BPIE and the European Policy Center use the "Deep Renovation" rate, which ranges around 0.2% per year and accounts for renovations that provide more than 60% energy savings. Finally, Enerdata (2016) provides a perspective on the sale of heat pumps, with sales ranging between 0.1% and 3% across countries of the European Union[37].

Here, we will assume a natural rate of 0.2% per year, which we consider more consistent with the extent of actual renovations needed. From this rate, we can evaluate the total substitution happening by 2030[38]. We do this by multiplying the total stock renovated by 2030 with the total potential for natural gas and oil displacement[39] (Figure 28). We also look at different rates of renovations, assuming a more forceful policy mechanism from 2022 onward, driving renovation rates to 3% per year[40], and a theoretical 5% renovation rate (Figure 29).

**Figure 29 – Scenarios of change, buildings**

| Fossil fuels displacement in Buildings | Natural gas | Oil | $CO_2$ saved ($MtCO_2/y$) |
|---|---|---|---|
| 0.2% renovation rate | -0.6 to -1% | -0.1 to -0.3% | negligible |
| 3% renovation rate | -10.8% | -2.3% | -145 |
| 5% renovation rate | -19.3% | -4.0% | -259 |

## Mobility

BloombergNEF estimated the penetration of electric (and hybrid solutions) in the mobility fleet of the European Union to 2030[41]. The forecasts are 20% penetration of the passenger fleet, 40% of the bus fleet, and 10% of the light commercial vehicle fleet, by 2030. We discard 2-wheelers as they represent a negligible volume of oil demand.

We use these penetration levels to evaluate the share of oil displaced as a result, with a similar methodology as the one used for buildings. Beyond the BloombergNEF forecast, we also compute a more aggressive penetration of 30% of the fleet by 2030 across all vehicle types (outside of heavy duty freight) (Figure 30).

**Figure 30 – Scenarios of change, mobility**

| Fossil fuels displacement in Mobility | Oil | $CO_2$ saved ($MtCO_2/y$) |
|---|---|---|
| BloombergNEF forecast | -5.1% | -93 |
| 30% penetration rate | -10.2% | -186 |

(35) BPIE, 2011; EU Commission, n.d. Data from BPIE is 10 years old, but was cross-checked with more recent resources from the European Union Commission (2015-2017).
(36) Our study is based on 2015 data and hence is a few years old. However, more recent statistics are not available.
(37) BPIE, 2021; EPC, 2021; Enerdata, 2016; EU Commission, 2021.
(38) We provide a range depending on whether this substitution begins in 2015 or from 2022 onward. Arguably, they have begun to occur (particularly for heat pumps), but not necessarily at a rate consistent with "major renovation equivalent" or "deep renovation" rates. Additionally, for the sake of simplicity, we assume the rate of penetration is similar across the stock.
(39) Given the limited use of coal, we neglect it in the calculation.
(40) BPIE, 2021.
(41) BloombergNEF, 2022. With regards to hybrid solutions, we also include them in the forecast for the sake of simplicity, since they represent overall a minor share of total.

## Industry

Buildings and mobility account for over 97% of the total potential of oil displacement, and 85% of natural gas displacement. Thus, there remains an opportunity for electrification in industry that would need to be assessed. We assume similar renovation rates as for buildings (Figure 31).

**Figure 31 – Scenarios of change, industry**

| Fossil fuels displacement in Industry | Natural gas | $CO_2$ saved ($MtCO_2/y$) |
|---|---|---|
| 0.2% renovation rate | -0.1 to -0.2% | negligible |
| 3% renovation rate | -2.2% | -36 |
| 5% renovation rate | -4.0% | -64 |

## Total

We can consolidate the results above in three scenarios (Figure 18):

- Run rate: estimated levels of fossil fuels displacements with current trends (e.g. natural rates of renovations for buildings and industry and BloombergNEF forecasts for electric vehicles).
- Policy: 3% renovation rates on buildings and industry and current BloombergNEF forecasts on mobility.
- Ambitious: 5% renovation rates and a 30% penetration of electric vehicles in the fleet by 2030, from additional policy measures.

**Figure 18 – Scenarios of change**

| Fossil fuels displacement scenarios | Natural gas | Oil | $CO_2$ saved ($MtCO_2/y$) |
|---|---|---|---|
| Run rate | -0.7 to -1.2% | -5.2 to -5.4% | -100 |
| Policy | -13.0% | -7.3% | -275 |
| Ambitious | -23.2% | -14.2% | -509 |

By recomputing the partially electrified system using the same methodology as discussed above, we get a share of electricity that rises to around 25% in the policy scenario, and 30% in the ambitious scenario. This is obviously prior to any other measures such as energy efficiency or the GDP impact on the energy system (penetration of electric appliances, distribution of economic activity, development of the digital economy and new electric uses, etc.), hence does not constitute an actual forecast, but more a thought experiment to provide an order of magnitude of what could potentially be achieved by 2030.

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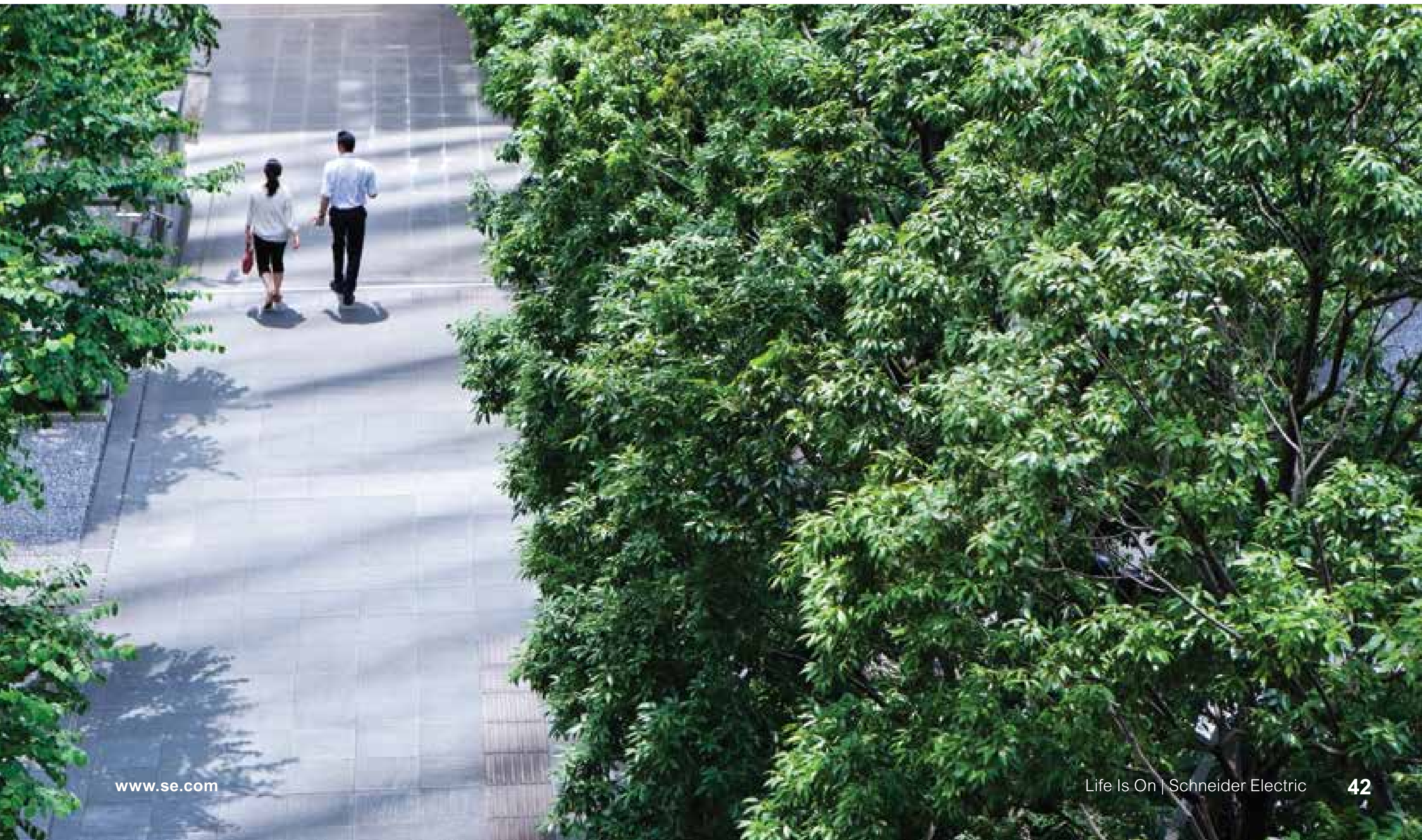

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