MASTER IN THE ELECTRIC POWER INDUSTRY

Final Thesis Project

ELECTRICITY DEMAND FORECAST 2030

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Executive Summary

Electricity demand is a critical concern in the EU, driven by recent crises and events. To reduce reliance on third-party countries for oil and gas, the EU plans to promote electrification, transitioning from gas/oil-powered systems to electric alternatives like electric vehicles and heat pumps. To counteract this, the EU must prioritize energy efficiency and distributed generation.

After analyzing several drivers, it became clear that the main drivers impacting electricity demand going forward are:

- Electrification
- Energy Efficiency
- Distributed Generation
- New Electricity Connections

After using a top-down approach to estimate electricity demand for the key drivers, some key takeaways can be extracted:

- Electrification has the highest impact in electricity demand increase.
- Only under a low electrification scenario and high distributed energy and energy efficiency scenario, both demand reduction drivers are available to fully counteract electrification impact.

Depending on the scenarios, electricity demand increase with respect to 2021 demand could be 4% in a scenario in which electrification is not as high as expected (e.g. could be for example due to a electrification of heavy duty with other technologies as Hydrogen) combined with a high penetration of distributed energy and energy efficiency. Or increase by 20% causing issues to energy system in a scenario of high electrification combined with a low penetration of energy efficiency and distributed energy solutions.

As discussed in further steps, a complimentary analysis for peak demand, grid impact, and stability analysis would be key to understand the full impact of the drivers in electricity system.

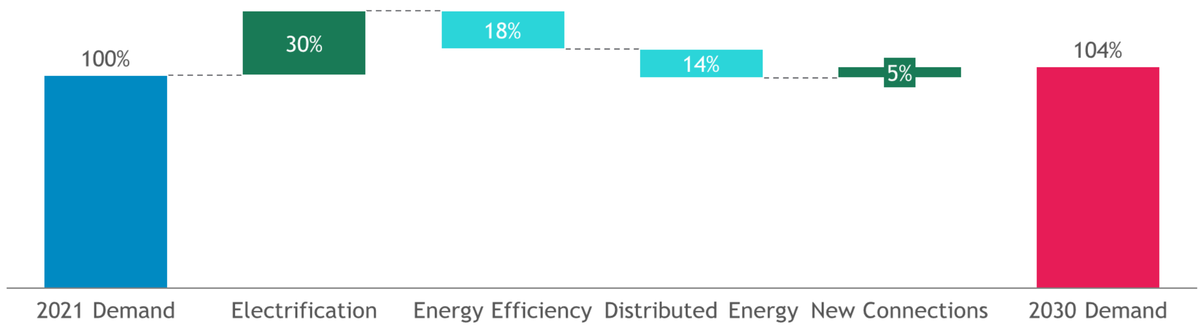

Figure 1 Impact of drivers in electricity demand -Lowest Scenario [1]

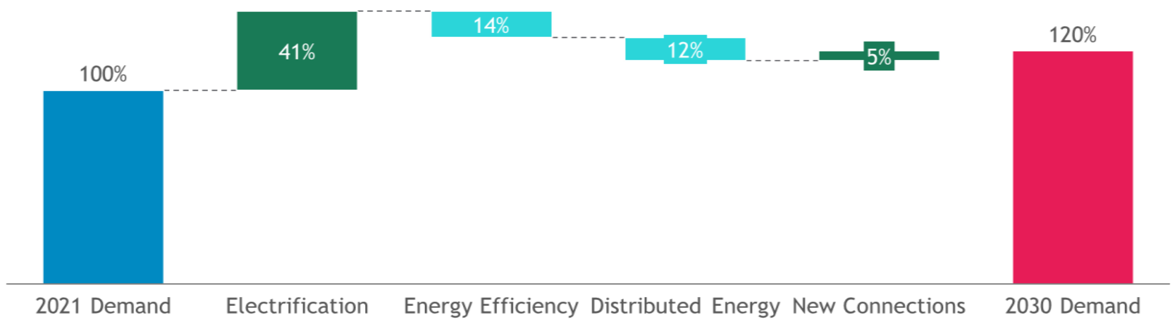

Figure 2 Impact of drivers in electricity demand -Highest Scenario [1]

Results from this thesis are in line with other industry estimates:

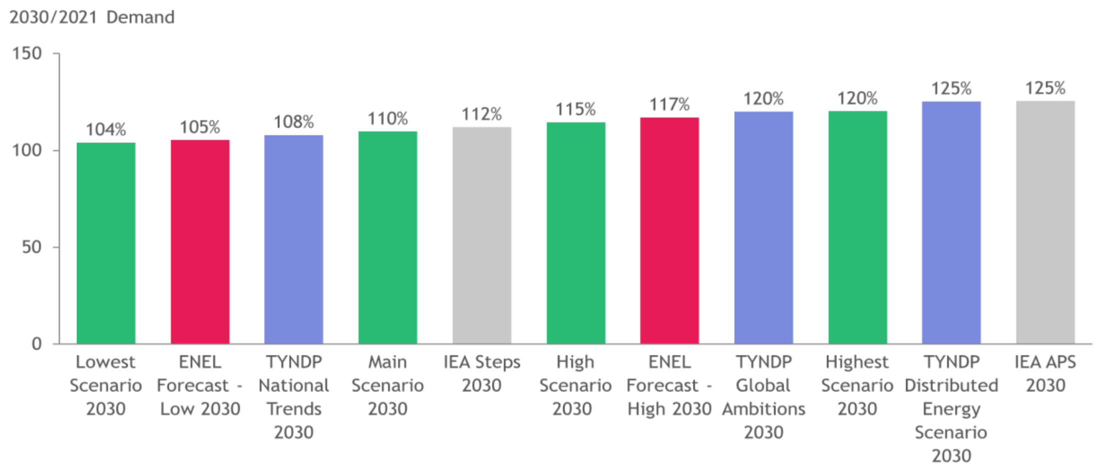

Figure 3 Electricity Demand Increase by 2030 vs 2021 demand [1]

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Introduction

Motivation and Current Status

Electricity demand has become in the recent years a key topic in the European Union, several event and crisis that occurred recently (such as the EU energy crisis, following Russian invasion of Ukraine) have made energy demand one of the main priorities of the European union. The European Union has proposed a series of measures under the REPowerEU communication, where the aim is to drastically reduce gas dependence from third party countries.

The European Union is mainly dependent on third countries for oil and gas, the key option for the European Union to reduce dependence from third countries relies on electrification. Electrification consists in transitioning something that previously was gas/oil powered to electricity. There are several things that could be electrified, some examples are: Internal combustion engine cars transitioning to electric vehicles, Gas fired water heating and space cooling transitioning to heat pumps…

Some of the key targets stablished by this REPowerEU communication for 2030 are:

- **Renewable gases**
  - **Hydrogen:** 20 million tons of renewable hydrogen produced or imported
  - **Biomethane:** 35 bcm of production
- **Home electrification:**
  - **Energy efficiency measures:** Measures saving 48 bcm.
  - **Heat pump:** 30 million installed, saving 35 bcm.
- **Power sector electrification**
  - **Wind and solar:** 480 GW of wind and 420 GW of solar (including distributed), saving 170 bcm (80GW extra under REPowerEU)
- **Industry (Energy-intensive) electrification**
  - Front load innovation fund and extent the scope to carbon contracts for difference and renewable hydrogen uptake

Now that it is agreed that the solution for the European Union to reduce energy dependence lies in electrification, there is one major concern that the European Union needs to take into consideration, and this is that if all the gas demand transitions to electricity, the current power system would not be available to supply that amount of energy.

In order to ensure that electrification of demand will not be a thread for the electricity sector, there are two technologies that need to counteract the effect of the increase of demand due to electrification:

- Energy Efficiency: Consists in the increase in the efficiency of the different appliances or devices, or in other words, being available to produce the same output with a lower amount of electricity due to increases in performance efficiency.
- Distributed Generation: Generation of electricity behind-the-meter, from the perspective of the grid it would be equivalent to a reduction in demand.

It is key to understand what will be the impact of the mentioned parameters (electrification, distributed generation and energy efficiency) in final electricity demand to understand if the electricity sector will be available to handle the demand.

The main objective of this thesis will be to assess what will be the impact the main divers with potential to influence demand by 2030. Scenarios will be used with different levels of penetration by technology, to ensure that a comprehensive view of what the outcomes depending on the scenarios for each of the technologies (e.g. what would be demand if penetration of distributed generation and energy efficiency is low, but high penetration of electrification: Highest possible 2030 demand scenario).

Final results will enable to see what additional energy will be needed by 2030 in order to avoid scarcity in the electricity sector. Additionally, it will give a perspective on what degree will affect each of the technologies in demand, and whether current targets will be sufficient to ensure a reasonable increase in electricity demand.

Electricity demand & forecasting in the past

In the last years electricity demand has experienced some changes in trends. Electricity demand grew at a 0.3% annually since 2015 to 2019, however in 2019 there was a strong decrease in demand of ~4% due to the covid crisis, as industries and companies were forced to stop due to lockdown. Following covid crisis, there was a strong recovery to previous levels in 2021 as covid restrictions were eliminated.

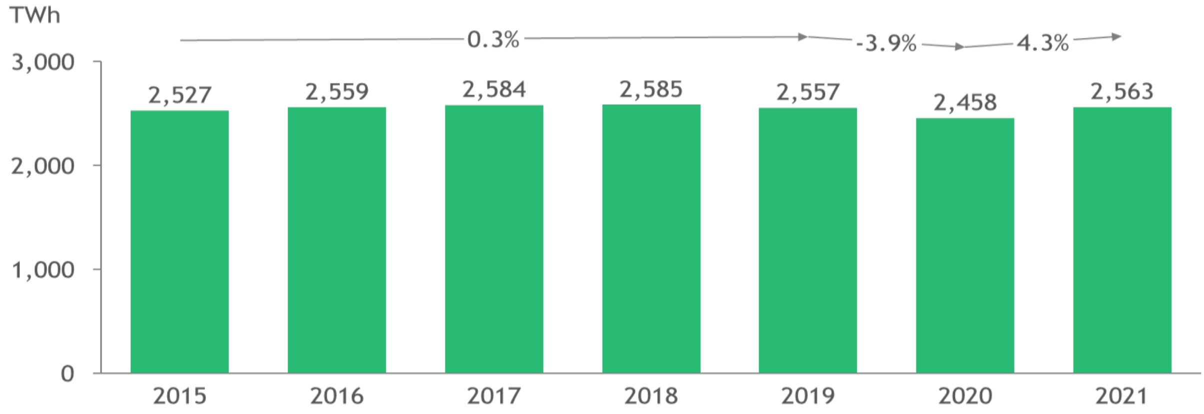

Figure 4 Electricity for EU27 countries [2]

Now looking into the breakdown of electricity demand by end-use, industrial use is the predominant use of electricity, but closely followed by Residential and commercial buildings. Breaking down electricity by use case it can be seen how residential demand has increased due to work from home after covid crisis.

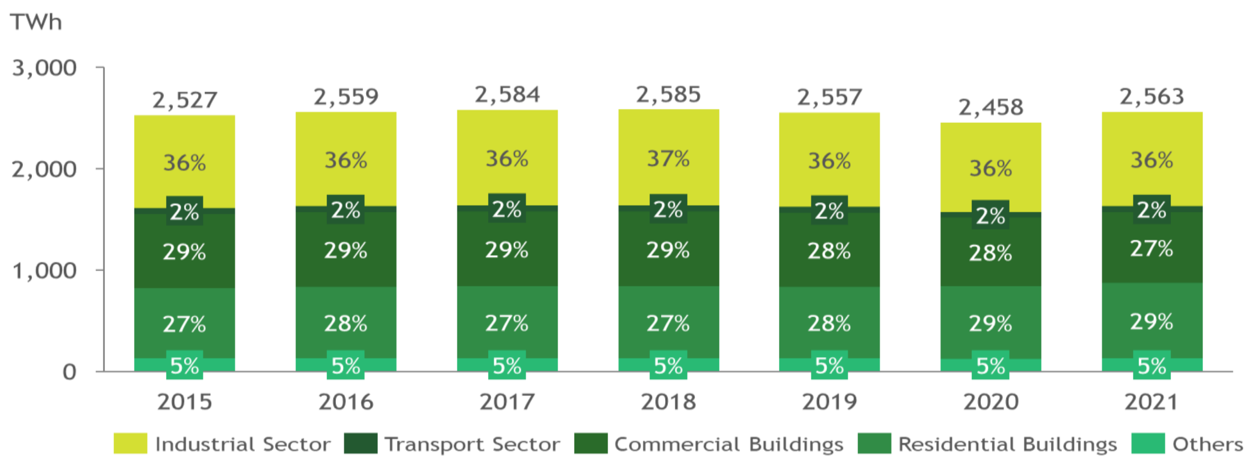

Figure 5 Electricity for EU27 countries breakdown [2]

In the past, electricity consumption and gross domestic product (GDP) were closely linked, with a high correlation making GDP an accurate predictor of electricity consumption. However, in recent years, a decoupling effect has emerged, driven primarily by improvements in energy efficiency and the rise of distributed generation. This decoupling has broken the traditional reliance on GDP as the sole forecast for electricity consumption, creating a need for a new approach to estimating future demand.

Modern modeling efforts now prioritize examining the individual impacts of various drivers on electricity demand, a focus exemplified in this thesis. One notable example of such modeling is the Ten-year network development plan by the European institution ACER. This plan holds significant importance as it shapes the network expansion strategies aimed at meeting future electricity demand. Utilizing diverse scenarios, this model estimates future demand segmented by different factors, effectively assessing the influence of major drivers and trends within each segment. The utilization of such modeling techniques offers a higher level of granularity in the output, enabling the isolation and testing of various components of electricity demand separately.

By adopting this detailed approach to modeling, researchers and policymakers can gain comprehensive insights into the intricate dynamics of electricity demand. This improved understanding facilitates better decision-making and strategic planning, ensuring that the electricity infrastructure is adequately prepared to meet the evolving energy landscape. The ability to analyze the individual contributions of energy efficiency measures, distributed generation, technological advancements, and other factors empowers stakeholders to implement targeted and effective policies, ultimately driving the transition towards a more sustainable and resilient energy future in the European Union.

Methodology used

To assess the impact of various elements on electricity demand, a systematic approach will be used, ensuring a comprehensive understanding of the main drivers behind. This multi-step process will involve the following:

1. **Top-Down Approach for Individual Demands:** The first step consists in utilizing a top-down approach to calculate the individual demands for all segments, categories, and scenarios. By carefully considering each element and its specific characteristics, a detailed breakdown of electricity demand will be derived. This comprehensive analysis allows for a holistic view of the contributing factors that influence demand across different sectors and regions.

2. **Quantifying the Impact of Incremental Demand:** The next stage focuses on quantifying the impact of incremental demand on electricity consumption. To achieve this, the electricity demand in 2030 will be compared to the baseline electricity demand in 2021. By examining the difference between these two points, we can isolate and analyze the specific drivers that contribute to the additional electricity demand over the intervening period.

3. **Aggregating Incremental Demands from All Drivers**: Building on the previous step, the impacts of incremental demands resulting from various drivers will be combined. This involves accounting for the additional electricity demand driven by energy efficiency measures, distributed generation adoption, technological advancements, and any other significant influencing factors. By starting from the 2021 baseline demand and factoring in the incremental contributions, an estimate of the electricity demand in 2030 will be derived

Annual electricity demand by technology

It would be hard to estimate final electricity demand by technology without breaking down the "problem" into smaller pieces that are easy to estimate. As an example, trying to directly estimate annual consumption for electric water heaters for residential buildings might seem as an impossible task at first. By using a bottom up approach and breaking down the sizing into smaller pieces, it is possible to derive the number using easily available data (e.g. number of residential buildings, average consumption of an electric water heater…) and combined with regulation targets, or industry forecast it is possible to add penetration rates and derive the total electricity consumption by segment.

A very similar approach will be used for all components, but for the sake of simplicity only few examples will be presented in this thesis. (All other driver trees are available on demand)

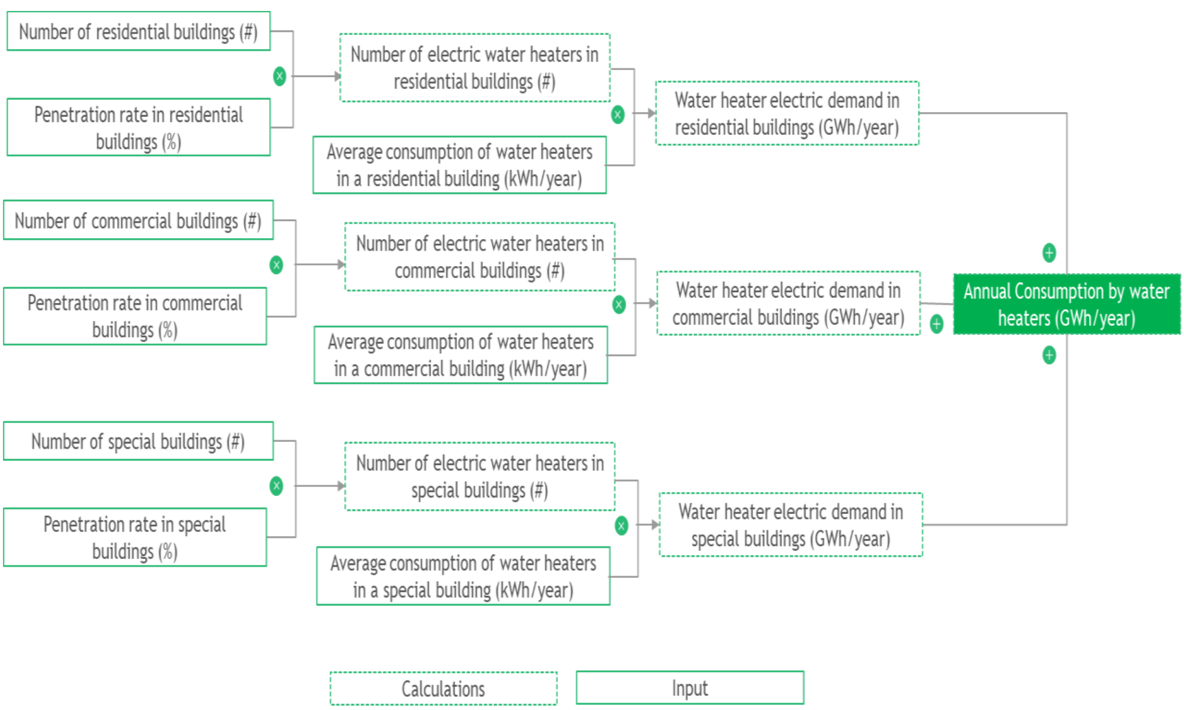

Figure 6 Driver tree for electric water heater calculation [1]

In contrast to the previous approach, the evaluation of energy efficiency will focus on estimating electricity savings rather than forecasting consumption. This targeted analysis allows for a comprehensive assessment of the impact of different energy efficiency technologies. By calculating average savings achieved through their adoption, the influence of these measures on electricity consumption patterns can be accurately quantified.

The analysis will employ the following driver tree, beginning with known data points such as the number of residential buildings and the average savings achieved with LED technology. For other factors, such as the penetration of LED technology, projections will be made based on forecasting methods and other estimates. This approach allows for a comprehensive examination of the impact of different drivers on electricity demand,

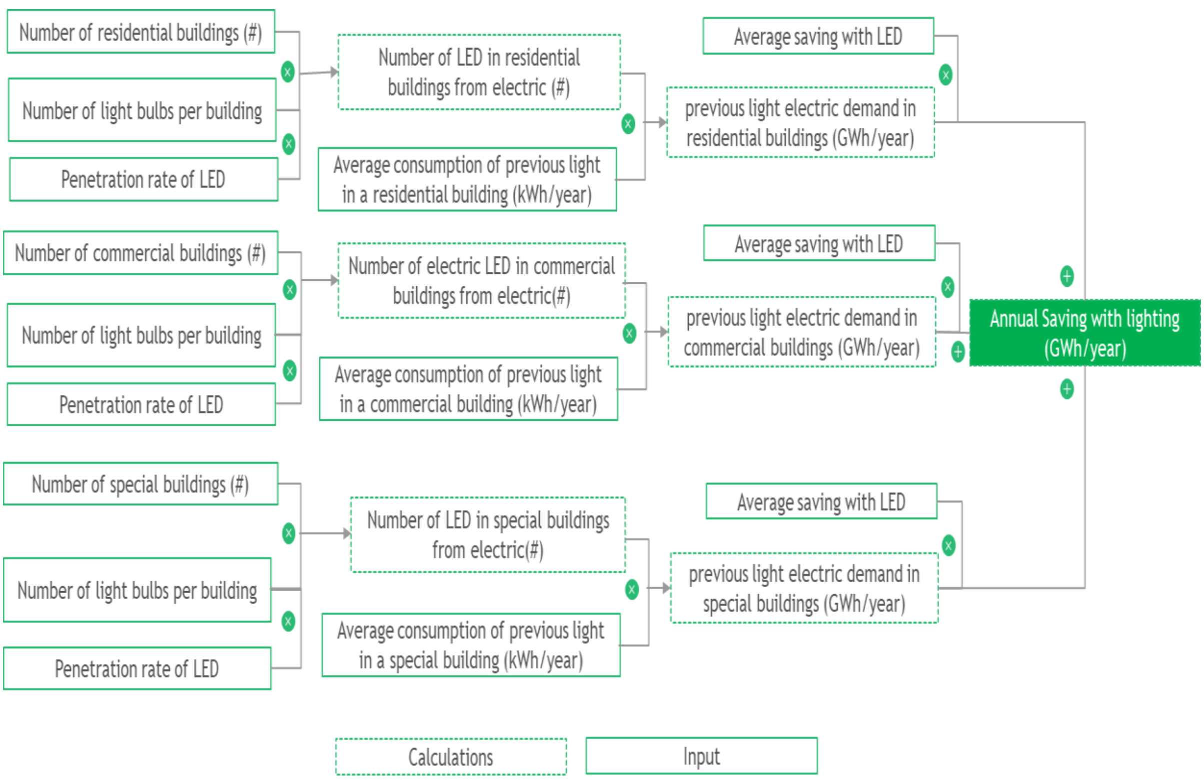

Figure 7 Driver tree for lighting energy efficiency [1]

Main driver definition

As it was mentioned previously the key for this thesis will be to decide which are the main drivers that will have an impact in electricity demand. It would not be neither pragmatic, nor feasible to estimate all of the drivers that will have an impact in electricity demand, as they could be endless. After some modeling, testing and research 4 key drivers were selected as the key drivers that will drive electricity demand changes in the future.

One of the key rules that this thesis will refer is the 80/20 rule (also known as pareto principle). This rule states that 80% of the causes are explained by 20% of the causes. In other words, it is possible to explain ~80% of changes in electricity demand changes just by using the 4 selected drivers, after these 4 key drivers at least an extra 10 drivers would be needed to explain the next 10% of changes in demand. Accepting this trade off in practicality and hability to explain demand, 4 key drivers will be used.

As introduced before, key drivers are:

- Electrification
- Energy Efficiency
- Distributed Generation
- New Electricity Connections

The above drivers could be segmented into two categories:

- **Demand Increasing Drivers:** Drivers that will contribute to an increase in demand by 2030
    - Electrification
    - New Connections
- **Demand Decreasing Drivers:** Drivers that will contribute to a decrease in demand by 2030.
    - Distributed Energy
    - Energy Efficiency

Driver Deep-Dive

1. Electrification Driver

1.1 Introduction

Electrification is one of the key drivers in electricity demand growth. Electrification consists in the shift from a non-electric source of energy to electricity at the final consumption point. One of the key benefits from electricity is that it is a clean source of electricity at the consumption point, which does not mean that it has to be a clean source of energy. To give an illustrative example, there could be a country where all vehicles are electric vehicles, but that country is generating electricity 80% from coal, therefore for that country the electrification of the car park would not traduce in a reduction of the number of emissions.

With the energy price crisis following the Russian invasion of Ukraine, electrification is one of the main priorities for Europe, given that the fastest way to reduce gas/oil consumption is to switch away from those fuels to electricity. It might be true that for the production of electricity European countries are still using gas/oil, but with the recent developments in the energy system transitioning towards a renewable led electricity generation, electrification could help both: reducing fossil fuel dependency from third party countries and reducing CO2 emissions.

It is crucial to size the electricity demand that will result from the electrification process in the future to ensure that the electricity system is available to provide the necessary energy and without causing issues in the grid. Two main points need to be assessed to ensure viability of the electrification process in Europe:

- **Energy terms:** The system needs to be available to provide the electricity from the new "devices" that are replacing other energy sources.
- **Network/Generation Capacity:** The system needs to be available to provide the necessary instant power and the grid needs to be prepared to supply the necessary instant power. (As a further step)

Using electric vehicles (EVs) as an example, it becomes evident that the energy system must be adequately prepared to handle the increased demand for charging all the new electric vehicles. However, the challenge extends beyond mere energy supply; it also involves addressing the issue of timing. Even if there is enough energy available, the grid may not be equipped to handle the simultaneous charging of all vehicles. The scenario of everyone deciding to charge their EVs at the same time could overload the grid, leading to potential power supply shortages and disruptions.

Defining the scope of technologies for electrification is just as critical as the concept of electrification itself. For each study segment, specific technologies need to be carefully considered:

- **Transportation Sector:** the focus will be on light transport vehicles, as other solutions such as hydrogen or biofuels might be better suited for heavy transportation.
- **Building Sector**: which already boasts high levels of electrification, the main emphasis will be on technologies related to heating, ventilation, and air conditioning (HVAC) and water heating.
- **Industrial Sector:** the primary focus will be on technologies related to machines drives, HVAC systems, and process heating.

Within each of the segment it is also important to segment by technologies or subgroups, to be available to fully capture the impact of all of the technologies and subsegments. As an example: transportation will be divided by weight and by purpose, this way it becomes easier to understand the different contributions of the subsegments to the total electricity demand

Electrification Impact in 2030 demand

Total electrification demand would have an impact in total demand of up to 1 extra TWh by 2030 according to the most optimistic scenario. Impact in demand of transport, Buildings and Industry will be equivalent, with buildings being the sector with the highest growth in the period.

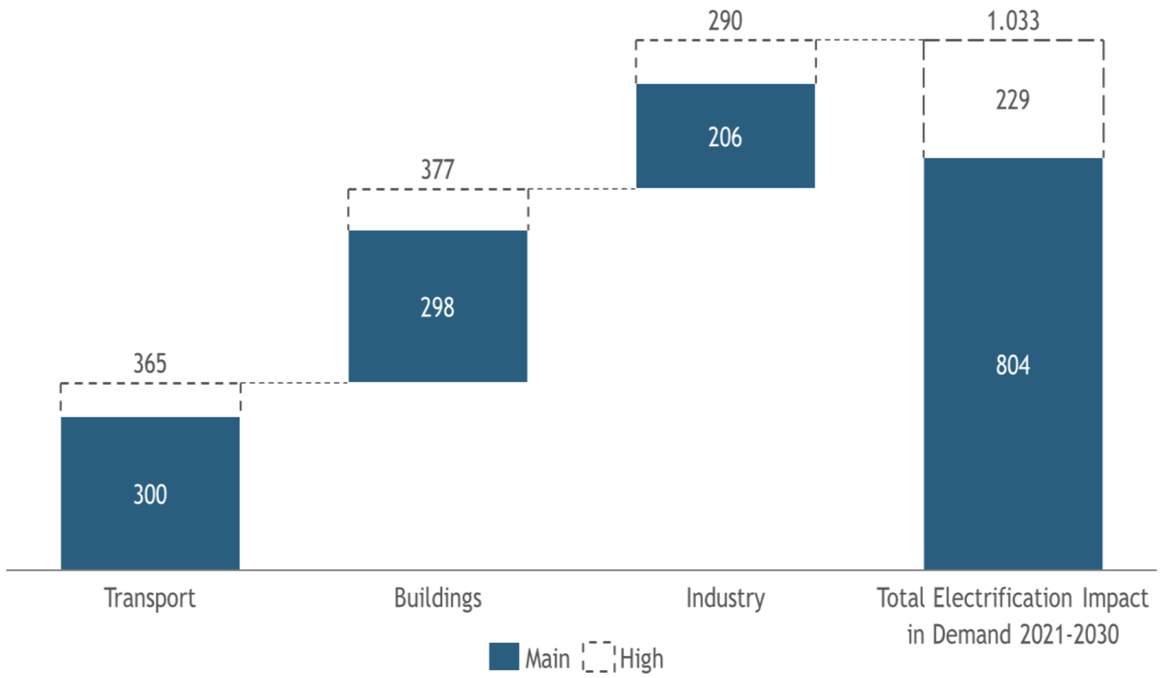

Figure 8 Electrification impact in 2030 demand [1]

Transport electrification will be driven by a faster growth in the commercial vehicles sector, but with light duty vehicles closely following. On the other side, when talking about building electrification, residential buildings will have most of the growth in terms of electrification, this can be explained with a higher penetration in general in commercial buildings compared with residential buildings that have still lower penetration (Specially in heating). In terms of technologies within buildings, heat pumps will be responsible of almost all increase in demand.

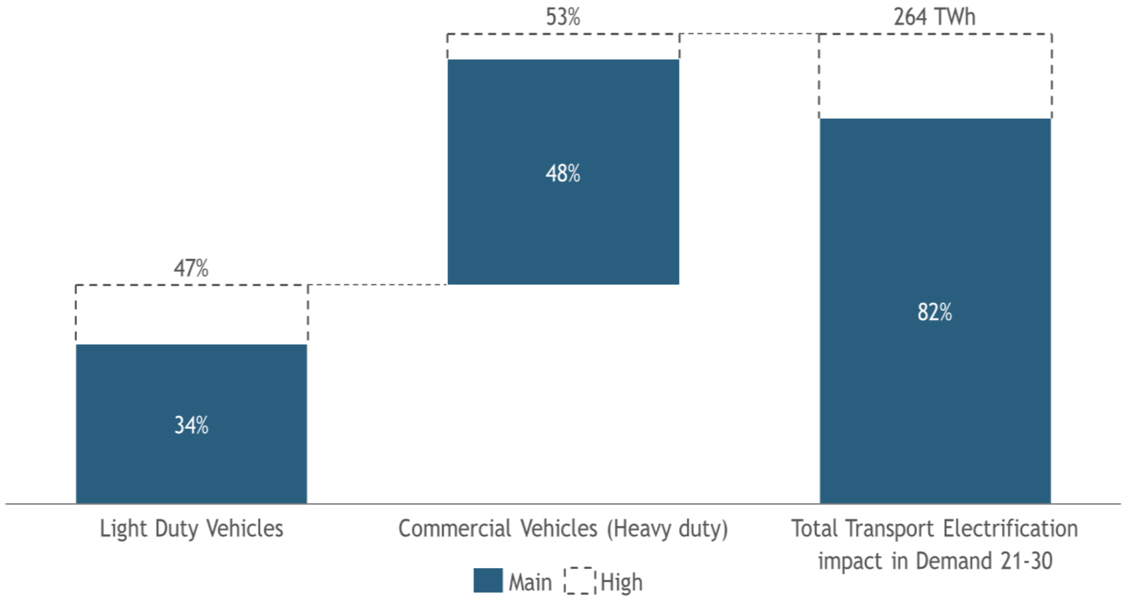

Figure 9 Transport electrification impact in demand breakdown [1]

Figure 10 Building Electrification impact in demand breakdown [1]

1.2 Transport Electrification

Introduction

One of the key drivers of electricity demand within electrification. The main focus of this section would be light transportation, since even though there might be a small share of heavy transportation, there are other solutions that could fit best as for example hydrogen and biofuels.

- **Heavy transportation** will most likely not be electrified given that there are other more viable solutions. The main feasibility problem for this subsegment would be the required size of the battery in order to maintain current specifications (e.g. range, power). On the other side, hydrogen or biofuels could be stored in approximately the same space as the previous fuel. Below, some examples of heavy transportation that would not make sense to electrify:
  - **Airplanes:** There could be some short-haul airplanes and smaller airplanes that could be electrified, given that for the range and speed (Currently not available to reach jet speeds with electricity). Long-haul planes would not be electrified since the battery would be to large to fit on the airplane and the speed would be reduced significantly, increasing fight times. The alternative here would be to use Biofuels or if properly developed, hydrogen powered airplanes.
  - **Marine:** The issue here is very similar to the airplane case; the necessary battery size and the charging time would not make it cost effective to electrify marine transport. It would make sense to either use hydrogen or biofuels for this category.

- **Light transportation** is the key subsector that electrification should target, given the typical ranges and power that current light vehicles have, it is feasible to replace old internal combustion engines (ICE) with new electric power train including necessary battery to offer similar ranges.

For the scope of this analysis the categories within light transportation will be:

1. Light-duty passenger cars and vans
2. Commercial light duty trucks
3. Transit buses
4. Others: Including all other vehicles

The driver tree below illustrates what was the approach used to calculate electricity demand from the 4 categories above. In order to keep this paper short, as the driver tree for all 4 segments is the same only the driver tree for light-duty vehicles will be shown.

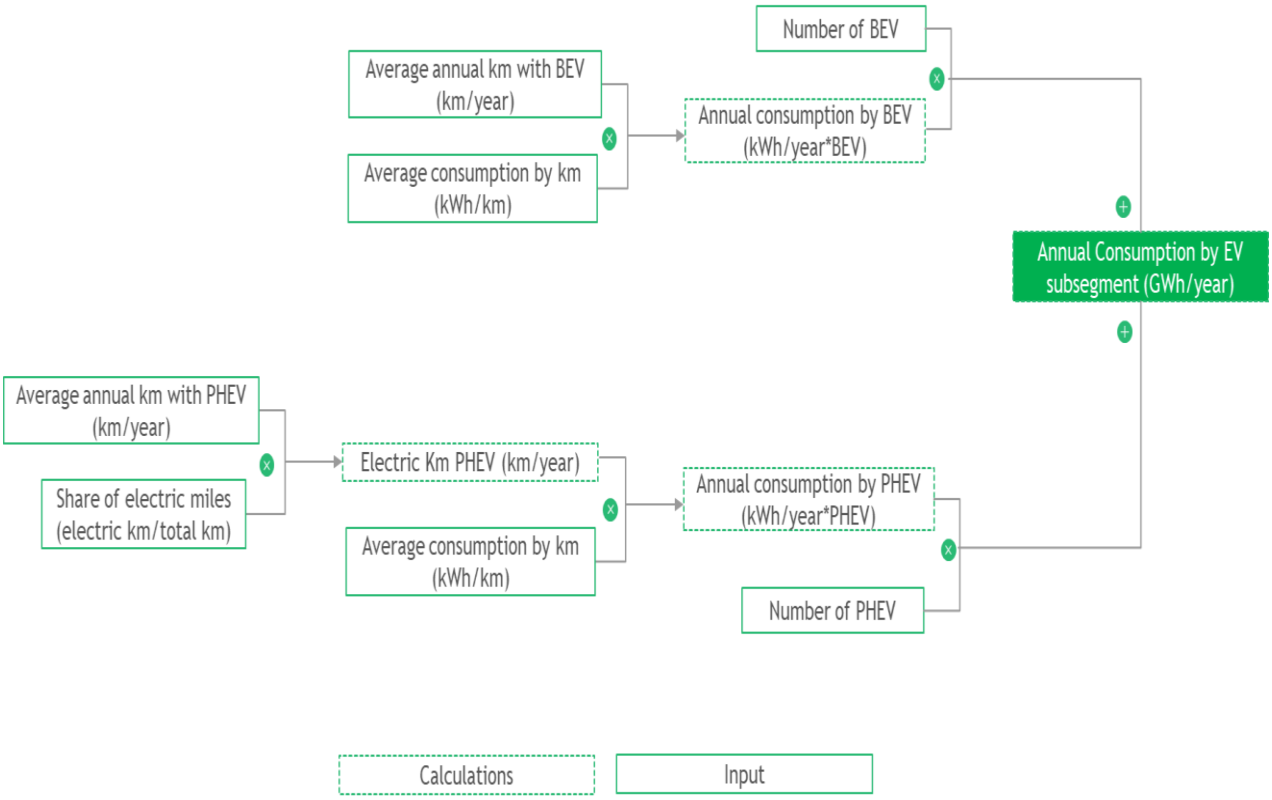

Figure 11 EV Electricity demand consumption driver tree [1]

Demand Forecast

Currently electric vehicles deployment is at an early stage. However, the market is expected to skyrocket in the following years.

There are 3 key drivers for electric vehicles development:

- **Regulation:** European regulation is pointing towards a massive deployment of EVs. At a country level, most cities award with benefits to EV owners (e.g. free parking, reduced tax…)
- **Total cost of Ownership:** Referred to the total cost of owning an electric vehicle. Takes into account the initial cost of the vehicle, maintenance, and specially the total cost of fuel during the lifetime of the car. TCO outlook is very favorable, and it is now cheaper to own an EV than to own an internal combustion engine car, however current energy prices is having a negative impact in TCO for EVs (But also gas prices are up for internal combustion engine cars). Energy prices are expected to recover in the medium term, bringing back down the TCO for EVs
- **Charging infrastructure:** One of the main fears when thinking about electric vehicles is how, where and for how long to charge your electric vehicle. It is worth separating the 3 points.
    - **How:** In Europe the market outlook seems to indicate that traditional wired charging will be the way to charge electric vehicles. There are other technologies that are being tested or used as wireless charging or battery swap (Common in China)
    - **Where:** Range anxiety is one of the biggest fears for EV owners, however with EV charging the refueling paradigm has changed. With ICE drivers needed to go to a fuel station to refuel their car, with EVs drivers can charge everywhere without needing to specifically drive somewhere to charge (e.g. at a super market, at work, at home)
    - **For how long:** It is key to have an appropriate distribution of speed within the different locations. For example, at home/work it does not make sense to

have a fast charged since you will be sleeping/working for several hours, but having fast /High power charging at road fuel stations is critical to ensure EV owners can make longer drivers without wasting time charging.

In Europe we currently have around 4M electric vehicles (1.8M Plug-in-Hybrid (PHEV) and 2.2M Battery-electric (BEV) cars). This number driven by the 3 drivers presented before, will skyrocket to 90M-110M (depending on the scenario) by 2030.

An average car in Europe drives ~11.000km per year, however it is important to take into consideration that even though battery electric cars will travel 100% using electricity PHEV will only travel ~40% of those km using electricity. The average electricity consumption is near to 0.2kWh/km but this number will slowly decrease as market matures and EVs become more efficient.

Light vehicles electricity demand is estimated at ~9TWh, which compared to total electricity demand is negligible, however according to the high scenario it could grow to 176 TWh by 2030 which will represent ~6% of current EU electricity demand. Results from the model are in line with the ones forecasted by IEA.

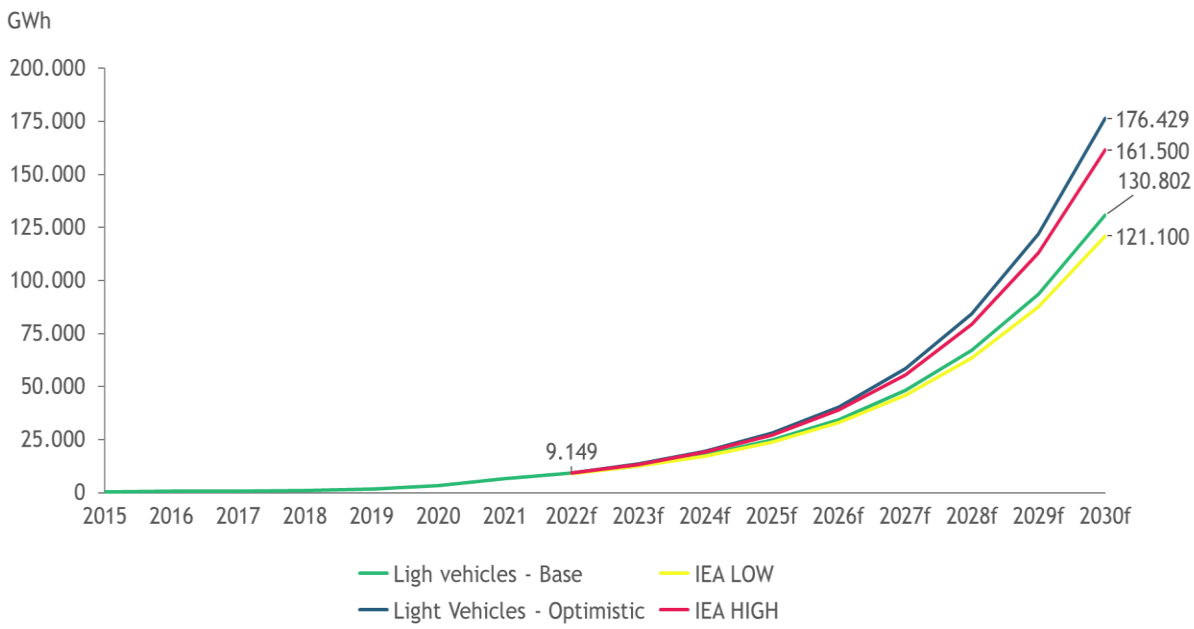

Figure 12 Light duty vehicles electricity demand forecast [1,4]

Heavy-duty vehicles car park for Europe is estimated to be ~11.5k vehicles (including trucks and buses). This number could grow up to 2.23M vehicles by 2030 according to the high development scenario. The number of km driven annually by these types of vehicles is much higher with an average 120.000km per year and the consumption per km is also higher with 1.15kWh/km. Regardless to the fact the fact that the number of light vehicles is much higher, driven by an average consumption and a higher km per year, total energy consumption is expected to be comparable to light vehicles by 2030. Growing from just 2.4TWh in 2022 to close to 196TWh according to the high scenario.

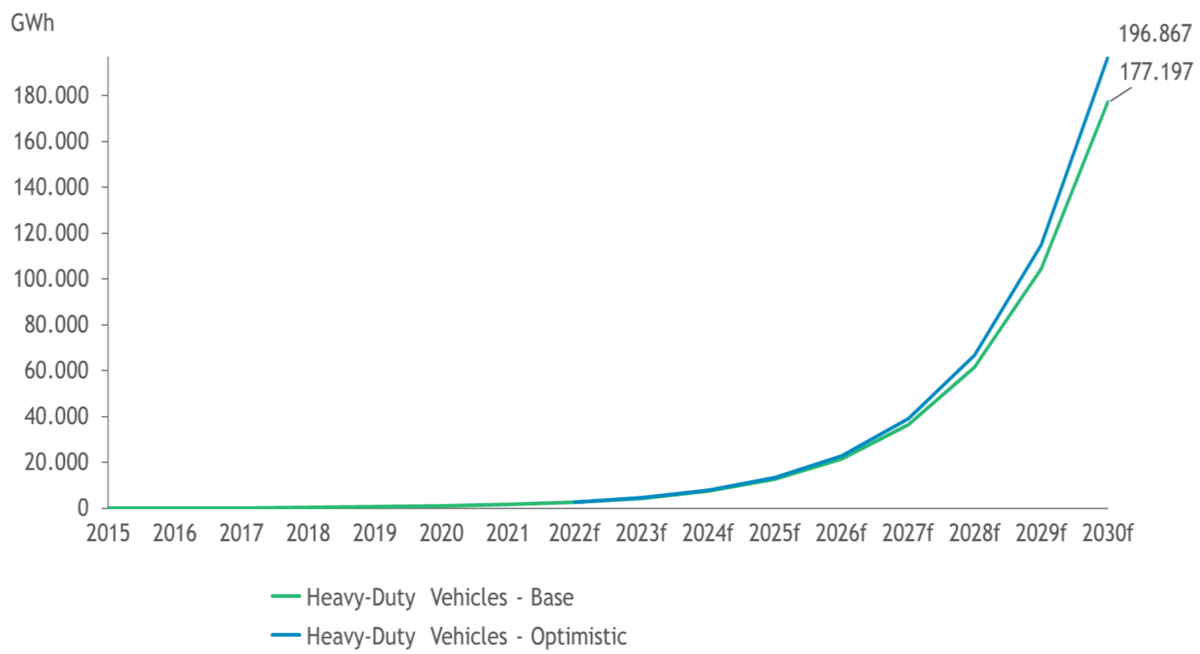

Figure 13 Heavy Duty vehicles electricity demand [1]

Total electricity demand coming from EVs will be in the range of 373GWh and 308GWh depending on the scenario considered. This would mean that electricity demand from electric vehicles by 2030 could potentially be ~14% of current total European electricity demand.

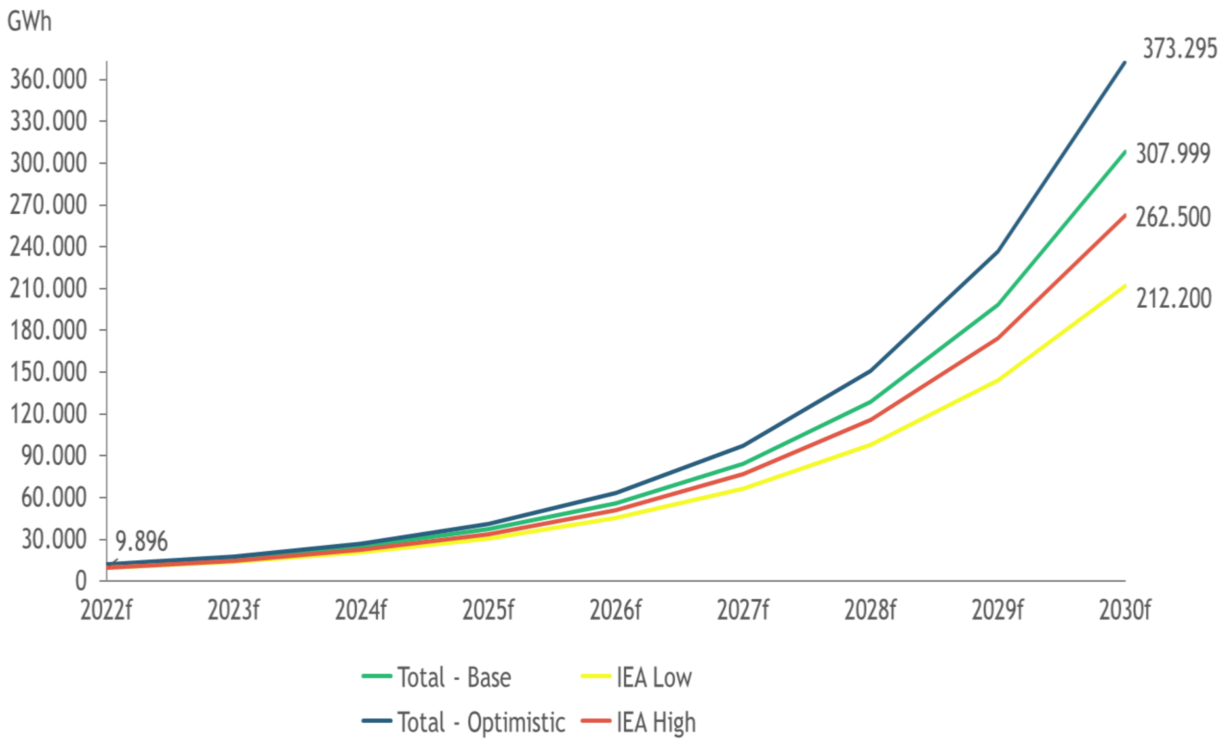

Figure 14 Total electric vehicles electricity demand [1,4]

Other forecasts as IEA are underestimating heavy duty transport electrification but are still in the same orders of magnitudes as the model presented in this thesis.

1.2 Building Electrification

Building sector is already very electrified with most of appliances being electric such as: refrigerators, washing machine and much more. The focus and the technologies with more potential for electrification, are heating, cooling and ventilation (HVAC) and others.

For simplicity all buildings will be categorized under 3 main groups:

- **Residential buildings:** All residential buildings including multi-familiar houses and single-family houses.
- **Commercial buildings:** Includes all type of commercial buildings with similar characteristics such as: Public buildings, malls, hotels, hospitals…
- **Special buildings:** All other buildings that require a special treatment due to their special characteristics such as: Airports, military basements…

In order to define a scope of technologies that will be studied in this thesis, the following technologies will be analyzed using the same driver tree shown below:

1. Space heating & cooling (Mainly heat pumps)
2. Water heating
3. Others: All other technologies that could affect building electrification

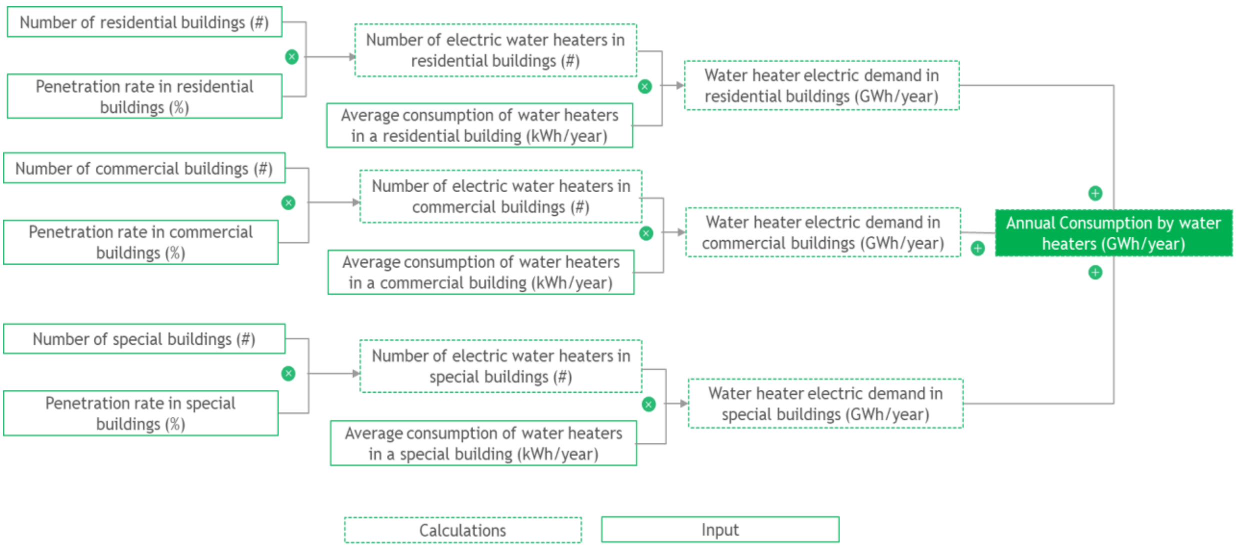

Figure 15 Water heating demand driver tree [1]

Water Heating

Introduction

Water heaters are one of the most energy consuming devices that a home can have (Behind space cooling/heating). There are two main predominant water heater devices at homes:

- **Instant heaters:** Are the ones that have a continuous flow of water, and the water is heated instantaneously as it goes through the heater. These types of heaters require very high-power ratings ~20kW for a normal device, and consume a lot of energy.
- **Storage water heaters:** The typical water heater where the water is stored in the device and it is progressively heated, using much less energy and with a much smaller rated power (~2kW). One of the main advantages of this devices is that newest devices come with smart features, that adapt to typical water demand to have the water ready just when it is needed and avoid wasting energy.

Demand Forecast

Penetration of electric water heaters is expected to grow from ~36% in 2015 to close to 57% by 2030 according to the high scenario. This increase in penetration will be mainly driven by a massive switch from gas water heaters.

Electricity demand for residential buildings is ~72TWh by 2021 but it is expected to grow up to 111TWh by 2030 according to the high scenario.

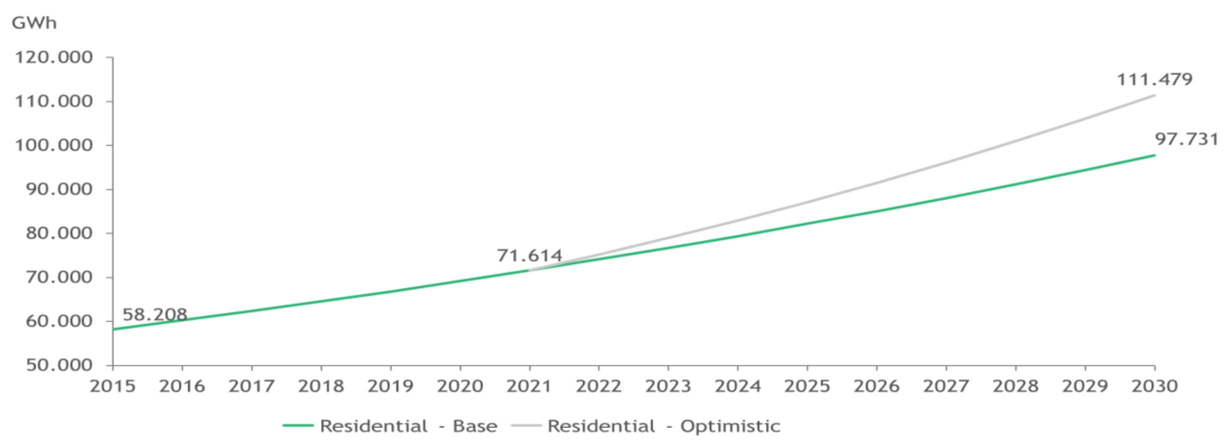

Figure 16 Water heating residential demand [1]

Commercial and special buildings demand will grow at a lower rate due to 2 main reasons:

- Already electrified most of the heaters that are feasible to be electrified.
- Sometimes it is more efficient to have a central gas boiler.

Electricity demand from commercial and special buildings will grow from ~44TWh in 2021 to around 62TWh by 2030 according to the high scenario.

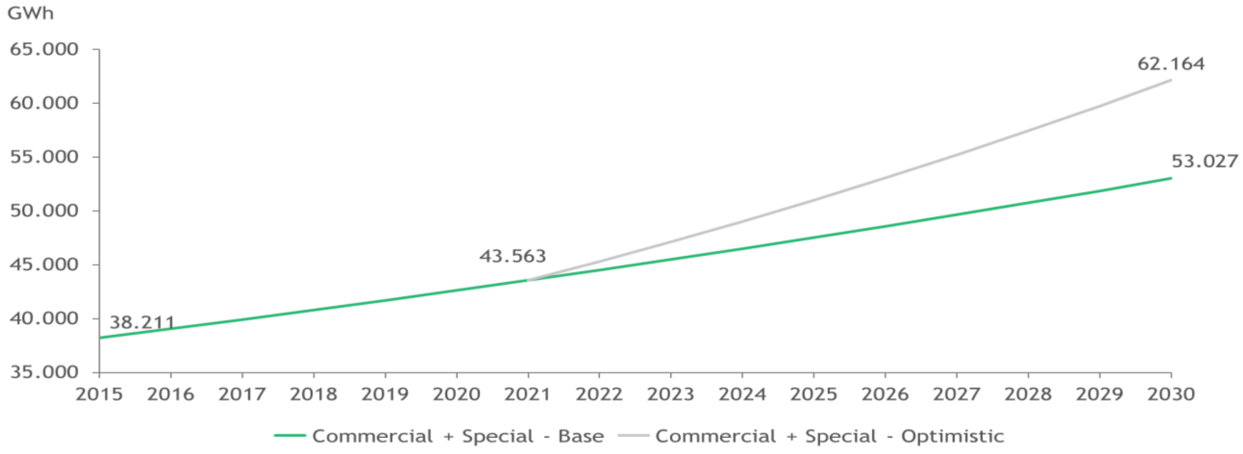

Figure 17 Water heating commercial and special buildings demand [1]

Total water heating demand will grow from 115TWh in 2021 to as high as 173TWh by 2030, slightly higher than the TYNDP22 high estimate for the same parameter.

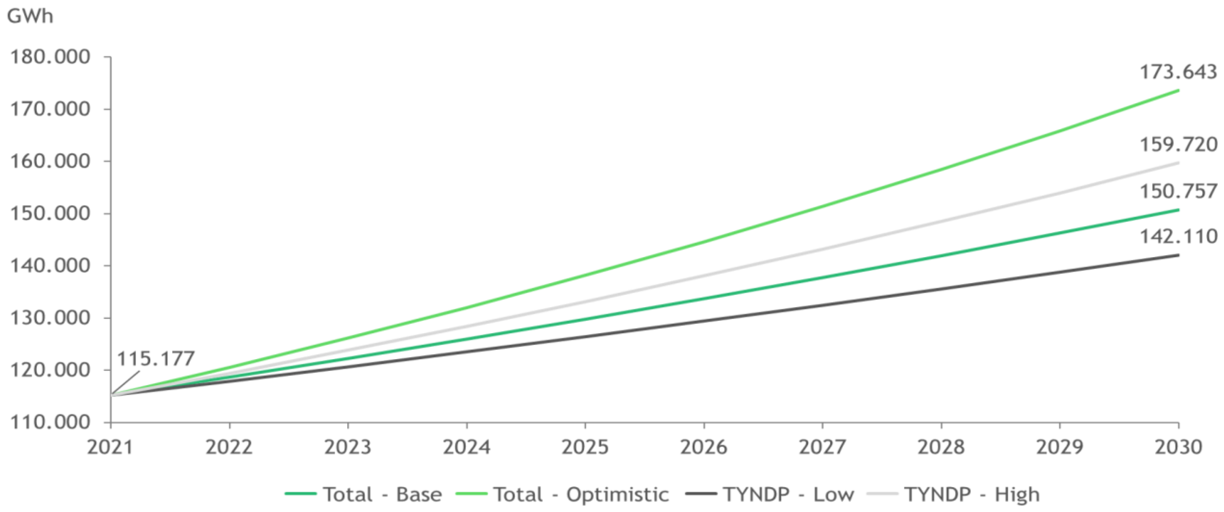

Figure 18 Water heating total demand [1,3]

Heat Pumps

Introduction

Heat pumps is one of the key technologies that will drive European electricity demand until 2030. It is a key technology for electrification, given that it cannot only inject cold air into a building (as a regular air conditioning would), it can also inject heat, making it the perfect replacement for gas/oil fueled heaters.

There are many types of technologies or types of heat-pumps:

- Air source: Exchanges heat with outside air
- Water source: Exchanges heat with a water source (e.g. a lake)
- Ground/Geothermal Source: Exchanges heat with a geothermal source

The most common type is the Air source heat pump, given it can be installed almost everywhere regardless of if there is a lake or a geothermal source near.

The EU has stablished as a target for 2030 in REPowerEU to have +60M heat pumps installed in Europe. For the modeling purpose, that was the target that was used for 2030.

Demand Forecast

Penetration of heat pumps is expected to increase until 2030 from current ~8% to around 37% in Europe. This will translate in around ~80M heat pumps by 2030 (Residential + Commercial + Special) according to the high penetration scenario.

Electricity consumption by residential heat pumps is expected to grow ~x5 from 2021 to 2030, growing from ~45TWh in 2021 to close to 230TWh by 2030.

On the other hand, commercial and special buildings electricity demand, even though they will account for a much lower number of heat pumps, due to a much higher electricity consumption per device, they will account for a significant amount of electricity demand by 2030. Electricity demand will grow from ~27TWh by 2021 to close to 141TWh by 2030 according to the most optimistic scenario.

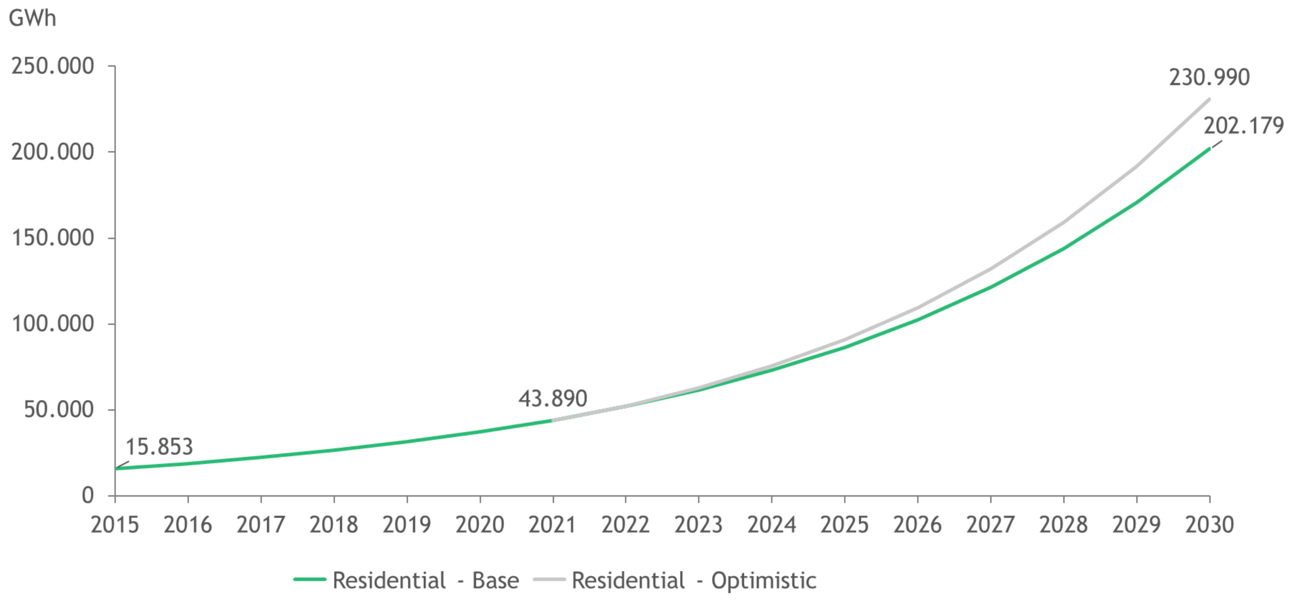

Figure 19 Residential Heat pump Electrification Demand [1]

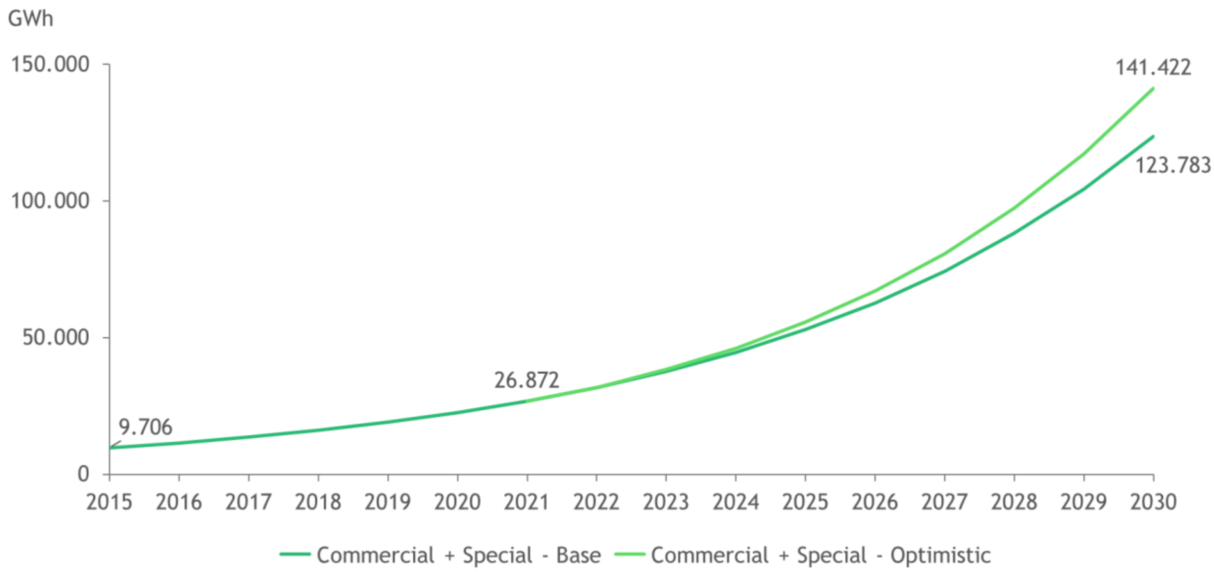

Figure 20 Commercial + Special heat pump electrification demand [1]

Total heat pump demand will grow from 70TWh in 2021 to around 372TWh according to the most optimistic scenario. This will mean that heat pump demand will account a similar demand by 2030 than electric vehicles will.

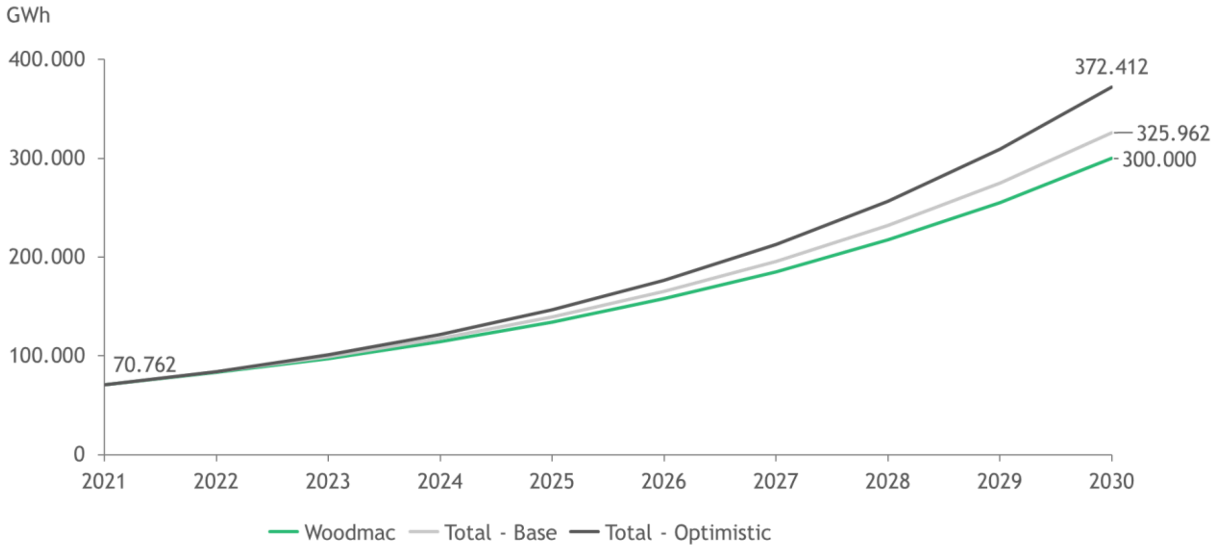

Figure 21 Total Heat-pumps Electrification demand [1,5]

Others

Introduction

Under this category fall all the other electrification technologies such as cooking, induction stoves… these technologies will not have a huge impact in total demand, so they will be grouped under the umbrella of “Others”

Demand Forecast

Electricity demand from “Others” will have different growth rates for commercial and industrial than for residential. Penetration and electricity consumption will grow faster in the second group (residential) given that there are more technologies.

For the commercial and special buildings there are two main drivers:

1. Commercial and special clients, energy bills will represent a much higher share of their total costs, being incentivized to electrify their consumption if this will help them save energy.
2. Regulation will push harder for commercial and special clients to electrify, given that with the higher size and consuming devices for commercial and special buildings, electrification would have a higher impact in gas demand.

Demand will grow from ~59TWh in 2021 to up to 74TWh by 2030, representing a small increase with respect to 2015 values.

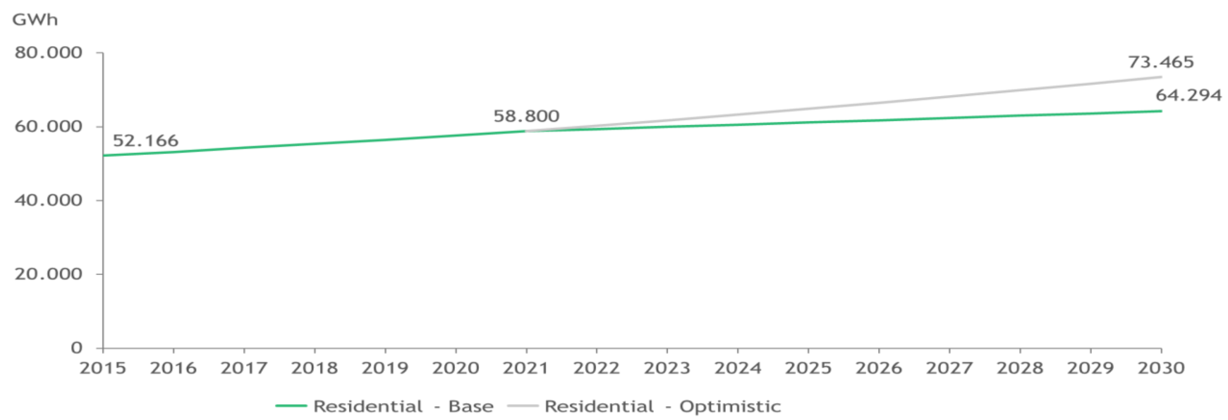

Figure 22 Residential electrification – Others [1]

On the other hand, commercial and special will grow at a lower rate compared with residential, growing from 18TWh in 2021 to close to 21TWh in 2030.

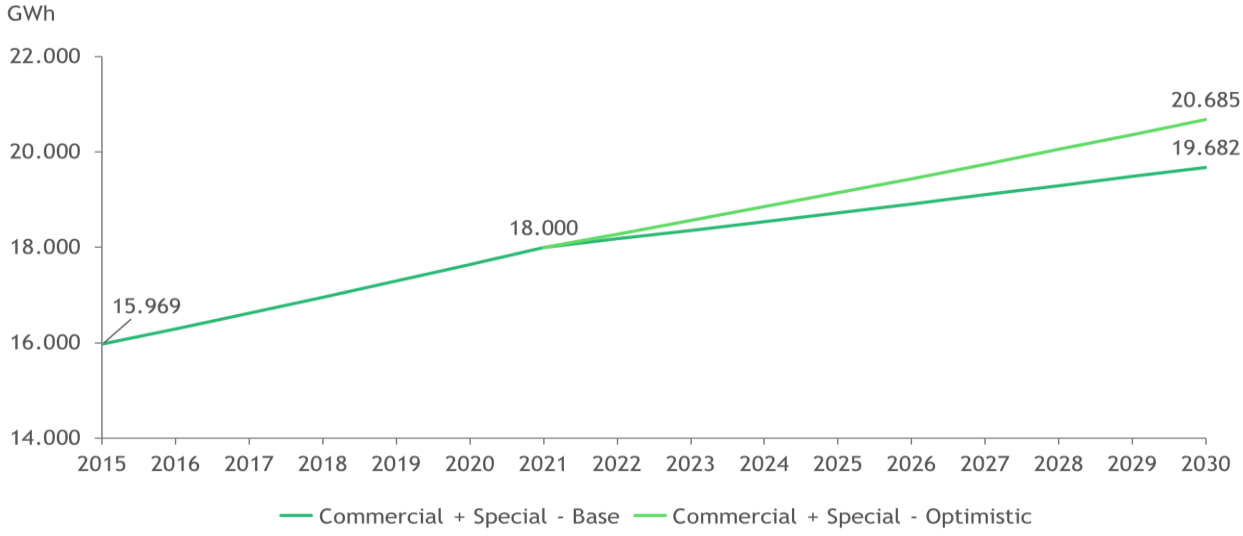

Figure 23 Commercial and industrial electrification-Others [1]

The total electrification demand from "others" group, will grow from ~77TWh in 2021 to close to 94TWh by 2030

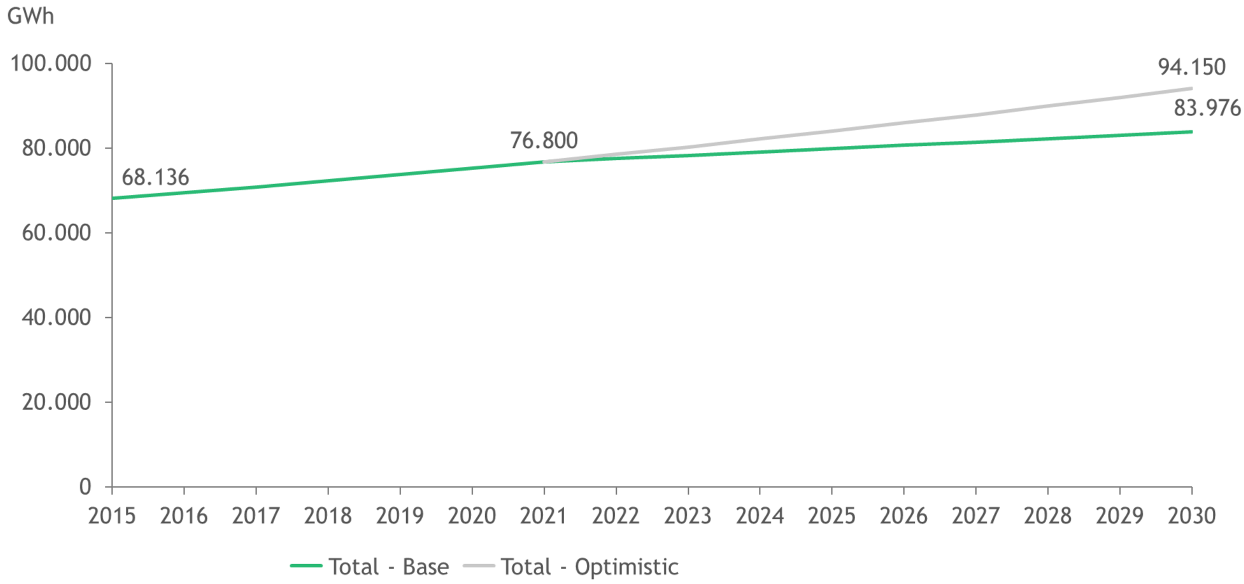

Figure 24 Total Electrification Demand – Others [1]

1.3 Industrial Electrification

Industrial sector is probably the most complicated to analyze, given that there are plenty of solutions that could be electrified. However, if happens as it happened with the transport sector, there are certain technologies that would not be cost effective to electrify, since it would be much cheaper to use green hydrogen or biofuels to replace current fuel. To give an example, in steelmaking they are currently using hydrogen as a fuel, so if decarbonization is targeted it would make sense to use green hydrogen to replace current grey/blue hydrogen. Other applications such as refining, where it would not make sense given the high amount of energy necessary, it would require installing an electrical installation with a huge size. Industrial energy consumption or measures could be divided into two main categories:

- **Manufacturing building:** Solutions are similar to building solutions, and are in the line of heating and cooling of the manufacturing building.
- **Process specific solutions:** For this category, technologies that are still not electrified is because it would make no economic sense to do such thing. As an example, machine drives are already electrified because it is economically beneficial, whereas petroleum refining is not electrified because it would make sense to switch to biofuels/green hydrogen rather than electrifying.

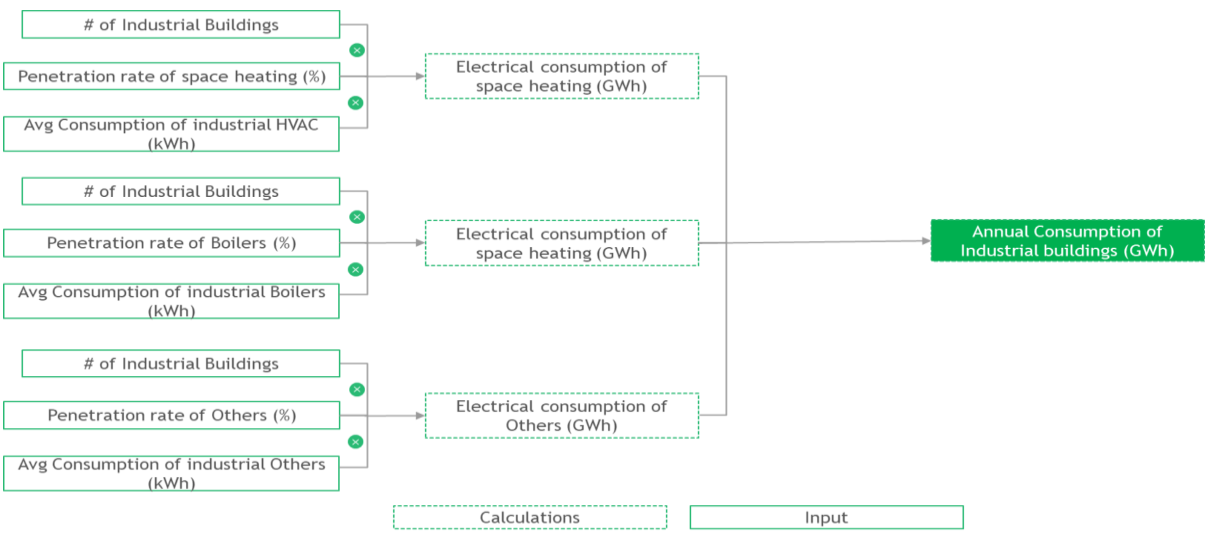

Figure 25 Industrial electrification driver tree [1]

1.4 Electrification Demand

Transport

Transport electrification demand will grow from around 4.2TWh annually in 2020 to up to 261 TWh according to the most optimistic scenario, and mainly driven by a strong growth in commercial vehicles, that will outpace light duty passenger cars, although this second segment will remain the biggest segment.

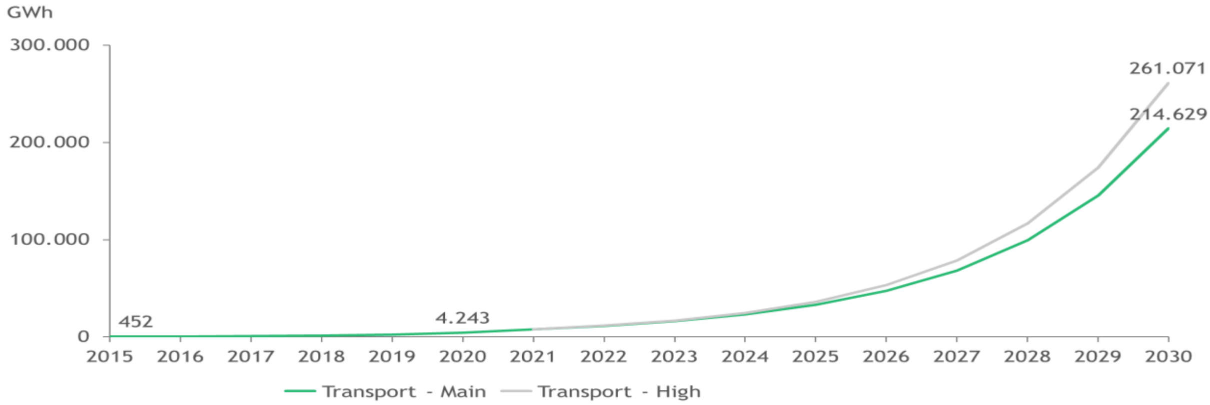

Figure 26 Total Electrification Demand – Transport [1]

Buildings

Building electrification demand will grow from 391TWh in 2020 to up to 728 TWh in 2030 according to the highest scenario, mainly driven by the commercial sector. Heat pumps are responsible for most of the growth in demand, they will replace existing gas boilers, and even with new high temperature heat pumps they could be used for space heating.

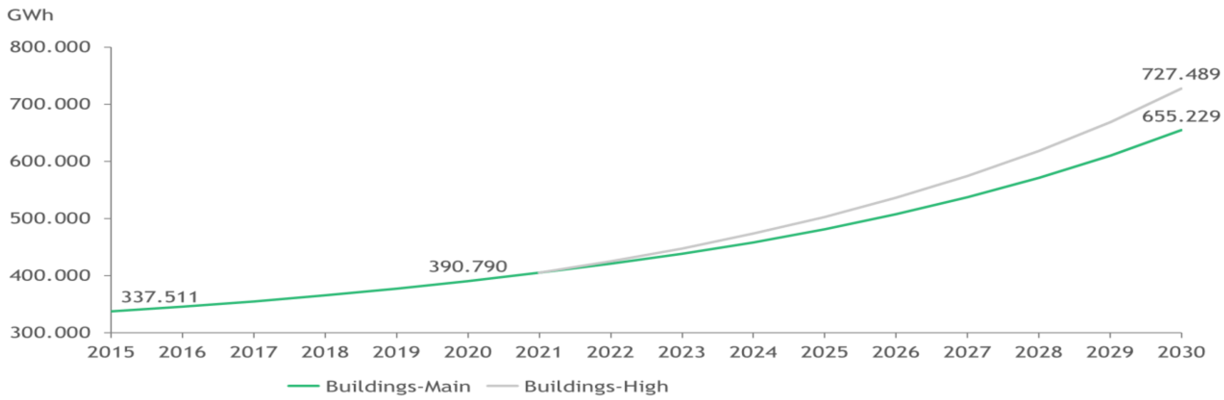

Figure 27 Total Electrification Demand – Buildings [1]

Industry

Industrial electrification electricity demand will increase from 882TWh in 2020 to around 1200TWh according to the most optimistic scenario. Most of this demand increase will come due to improvements in technologies that will enable electrification of processes that were not possible to electrify before with existing technologies (e.g. high temperature HP)

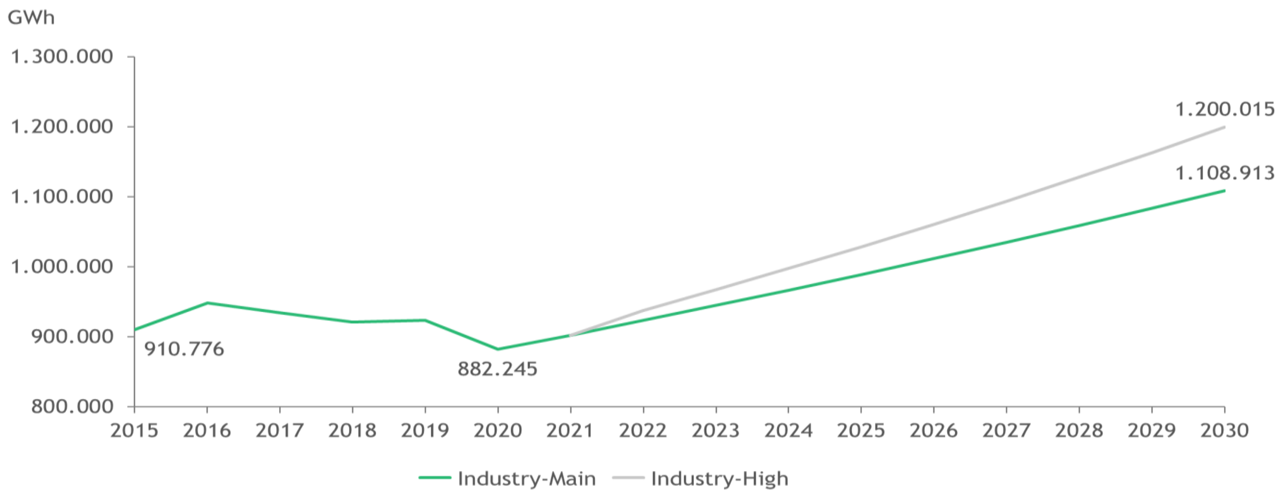

Figure 28 Total Electrifiation Demand – Industry [1]

Total Electrification Demand

Total Electrification demand will from 1277 TWh in 2020 to up to 2189 TWh mainly driven by a transport sector that will grow at a 44% CAGR during the period.

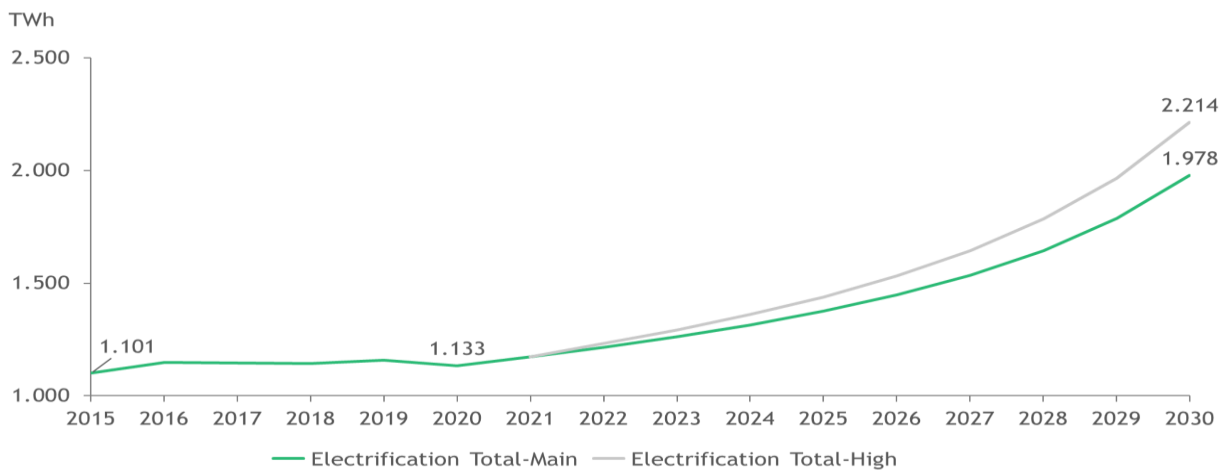

Figure 29 Total Electrification Demand [1]

2. Energy Efficiency

2.1 Introduction

Energy Efficiency has been the main responsible of the decoupling of electricity demand with GDP. Previously electricity demand was closely linked to GDP, in fact growth in GDP was a good estimate for the growth in electricity demand. Introduction of Energy efficiency has decoupled these two parameters. In developing economies, where there are not many energy efficiency measurements implemented, electricity demand could be easily forecasted with GDP.

It is always complicated to estimate what the effect of energy efficiency would have in total energy consumption given that energy demand is changing due to several factors. The approach to be followed on this analysis will be to estimate the savings that could be achieved by the smallest unit of study (one buildings, one factory…) and then use a bottom-up approach to estimate total energy consumption.

2.2 Study Segments

To avoid overlapping with electrification (Many shared technologies) , it is important to clearly state the differences between the two categories:

- Electrification consists in the change of a non-electrical device with an electrical device e.g. substituting a gas powered heater, with a heat pump.
- For our analysis, Energy Efficiency consists in substituting a previously electrical device for another electrical device with identical/similar characteristics but with a lower electricity input.

In order to provide a detailed analysis of the topic, demand will be distributed across 3 sectors:

- **Buildings:** Probably the sector with the highest expected potential in terms of energy efficiency. Main focus in HVAC, Lighting and insulations as key technologies

- **Industrial**: As for electrification, two main lines of action: Manufacturing building and process specific solutions
- **Transport**: Mainly in line of car sharing and public transport, not worth including in the analysis given that EV is already covered with electrification

Buildings

Buildings segment is probably the segment with the highest potential in terms of energy efficiency. In Europe most building and houses are using some old inefficient appliances, lighting, and HVAC. New developments in technologies allow to reduce energy consumption significantly.

As it happened with Electrification, even though there are plenty of subsegments within building category, for the sake of simplicity all subsegments will be grouped under the following groups:

- Residential buildings: All residential buildings including multi-familiar houses and single-family houses.
- Commercial buildings: Includes all type of commercial buildings with similar characteristics such as: Public buildings, malls, hotels, hospitals…
- Special buildings: All other buildings that require a special treatment due to their special characteristics such as: Airports, military basements…

All building categories share some common key technologies that should be analyzed to understand how energy efficiency could impact energy demand in the future.

Key technologies that are key to explain Energy Efficiency developments are:

1. HVAC: Replacing old electrical heating and cooling systems with newest, more efficient technologies. It is important to understand that this segment is not considering changes from a gas or other fuel to electricity since this will be covered in electrification.

2. Lighting: replacing regular light bulbs with LED technology could achieve a significant reduction in energy consumption in buildings
3. Insulation: increasing insulation levels to avoid heat exchange with the exterior
4. Monitoring and Smart management: Reducing energy consumption by monitoring and optimizing energy usage: e.g. light sensors to turn on light only when people detected, room temperature optimization…
5. Others: all other technologies that do not fall under previous categories will be considered here e.g. sub-metering

Industrial

For industrial segments two main type of energy efficiency measurements will be used:

- Manufacturing building: All the measures that will help reduce consumption from the general needs of the manufacturing building. technologies are similar to the building sector for this category: Lighting, heating, heat production…
- Process specific solutions: These type of solutions depends completely in the process, so it would not be possible to define and analyze all of them. To give an example, efficiency solutions for a refining company would not be applicable to a car manufacturing company. In order to calculate the potential energy savings, the total consumption from processes will be calculated and a percentage of savings will be estimated.

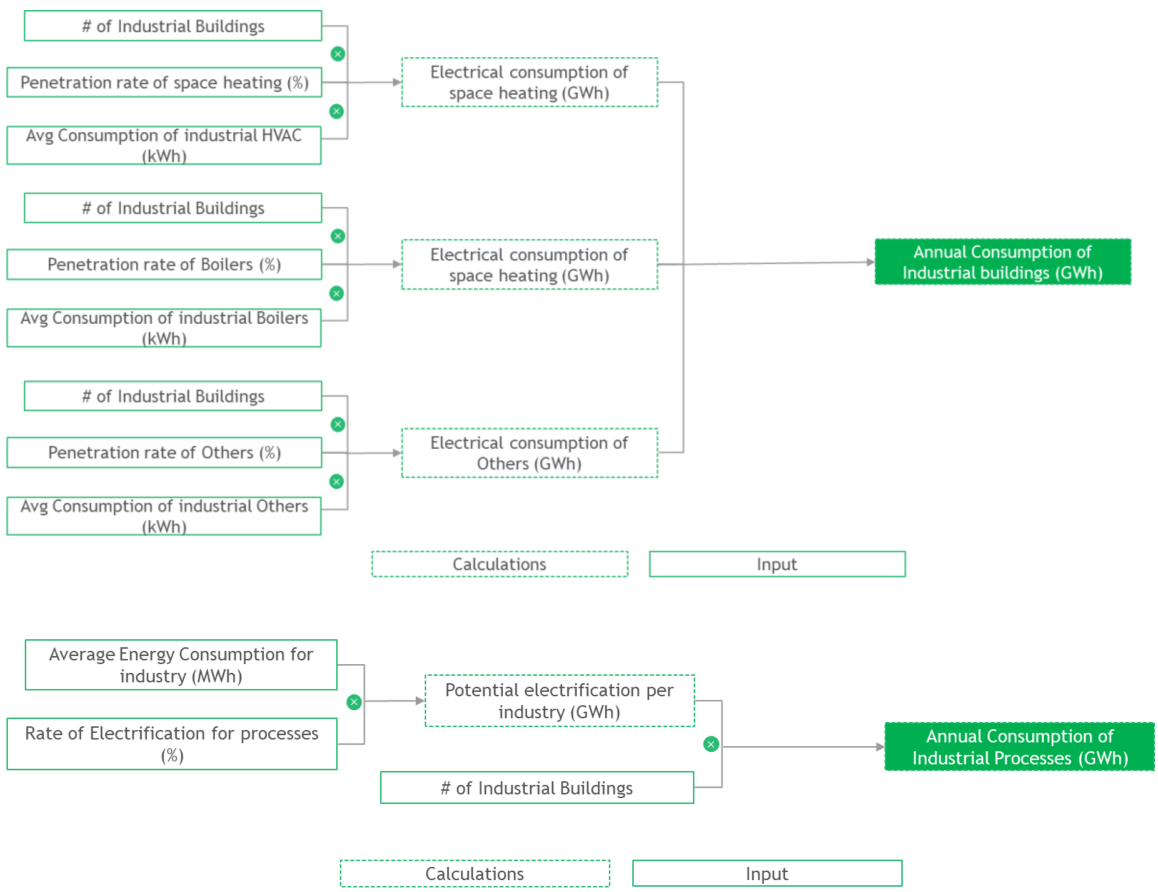

Figure 30 Driver tree for industrial energy efficiency [1]

2.3 Energy efficiency Impact in demand

Energy efficiency will have an impact in demand of up to 411TWh by 2030, meaning that without energy efficiency electricity would be 411TWh higher. Energy efficiency is key to archive all the electrification and decarbonization targets without increasing total electricity demand drastically.

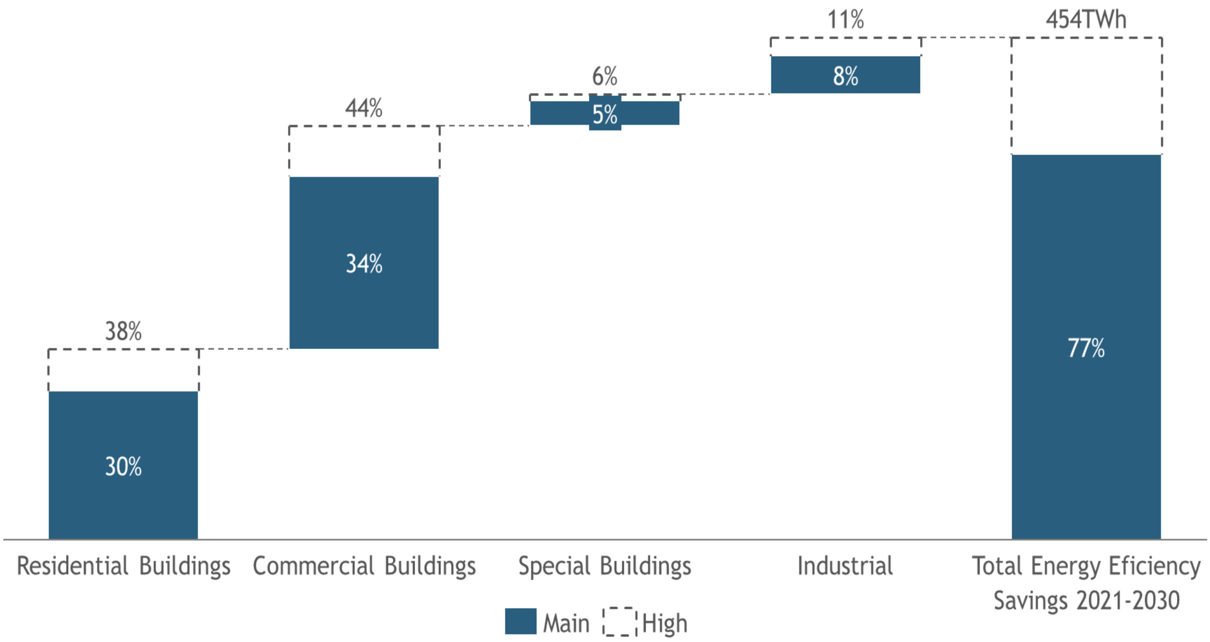

Figure 31 Energy Efficiency impact in demand breakdown 1 [1]

Breaking down impact in demand, buildings will have a much higher impact in 2030 demand, this can be mainly explained mainly due to a current status of buildings with very low efficiency measures and in most cases with old appliances and equipment. On the other hand, the industrial sector even though represents a significant share of total energy is in general in better shape in terms of energy efficiency, as processes and manufacturing buildings are carefully designed to maximize efficiency. This could also be explained with the share of costs that electricity represents in both segments, while for industries energy costs represent one of the greatest cost and it is closely monitored and optimized, for buildings it typically only represents a small share of total expenditure, making it less relevant to monitor for owners.

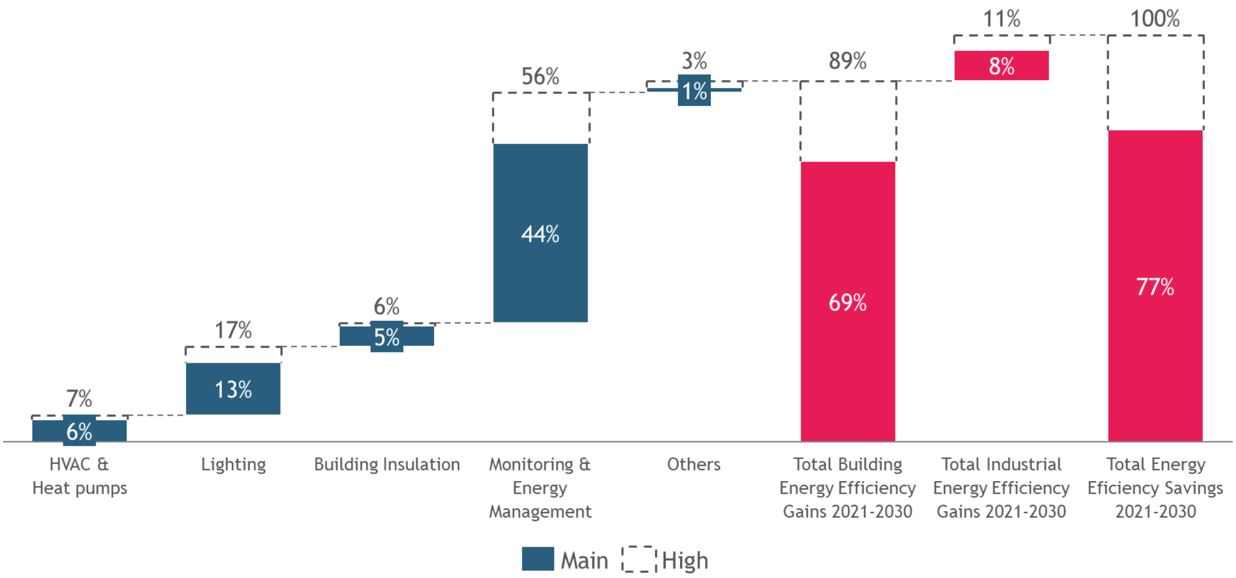

Figure 32 Energy Efficiency impact in demand breakdown 2 [1]

By making a different cut in the energy efficiency impact, it can be seen how energy management represents the technology that will have the most impact in demand. Smart demand management will be present in most buildings and will help reduce energy consumption in addition to integrate distributed generation.

HVAC demand

Introduction

HVAC energy efficiency will be mostly defined by a replacement of traditional HVAC with efficient heat pumps. It is very important to mention that heat pumps will not be double counted in energy efficiency and in electrification, the main difference is that on electrification we are considering a heat pump replacing a previously gas fired water heater, while on this case would be the heat pumps that will be substituting previously electric HVAC (Share of total heat pumps). While heat pumps will be one of the main drivers of electrification demand, it will not have such importance in energy efficiency, because from all the new heat pumps only a share will be replacing previously electric HVAC and furthermore, increase in efficiency will be in the range of ~20% with respect with traditional systems.

Demand forecast

HVAC energy efficiency demand is expected to save up to 37.2 TWh of energy by 2030 growing from just ¬6TWh today.

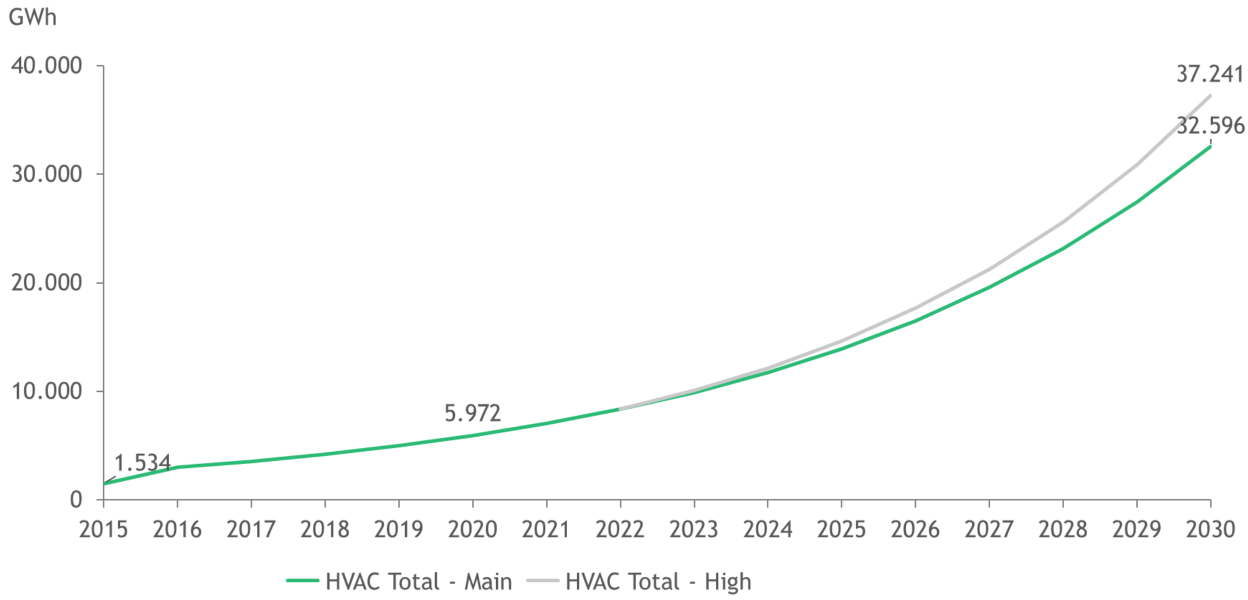

Figure 33 HVAC Energy efficiency savings in total demand [1]

Energy management systems and Smart Homes

Introduction

Under this bucket there are a series of technologies that will enable to consume electricity in a more efficient way. Some of the main solutions under this umbrella are:

- Smart home/buildings devices:
  - Smart thermostats
  - Smart Plugs
  - Smart appliances
- Energy Management
  - Sub metering
  - Real time consumption monitoring
  - Consumption reduction during peak time

The examples mentioned above are only few examples within the energy management umbrella, what all of them have in common is that they have the objective to identify and analyze trends in consumption and suggest or act to efficiently reduce electricity consumption.

EMS & Smart Home demand

Energy savings from EMS and Smart home demand will amount to up to 322TWh by 2030, growing from just 56TWh in 2020. Such a steep increase is mainly driven by two main factors:

- Increase in penetration: the main reason for such a high increase is a low penetration of smart/energy management devices currently, and a very high penetration expected going forward. As energy management is crucial for electric vehicle charging and for distributed generation management, penetration will grow exponentially as electric vehicles and distributed generation will.

- Technology development: another reason supporting rise in demand savings would be the development and launch of new technologies that will enable to save more energy

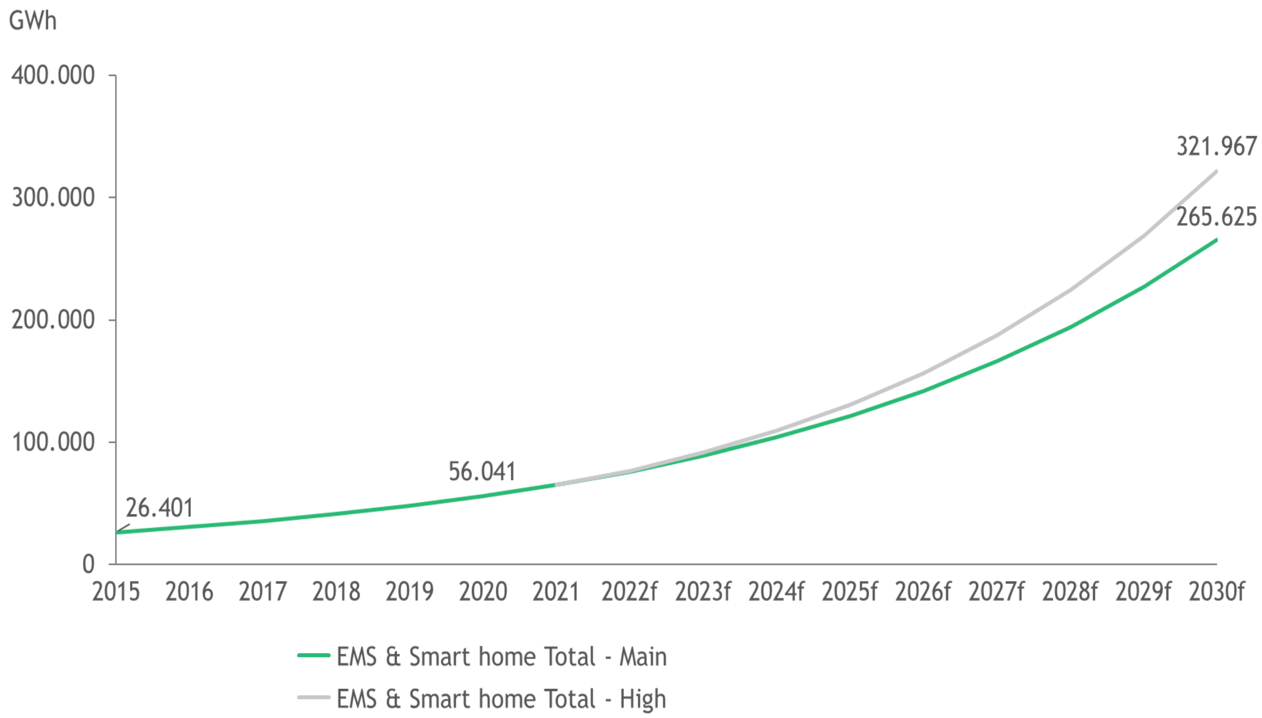

Figure 34 EMS & Smart home savings in demand [1]

Lighting

Introduction

Energy efficiency from lighting will mainly come from substituting traditional light bulbs with high efficiency LED. These types of lights can consume around 75% less electricity compared with a traditional light bulb with the same output. Lighting energy efficiency is one of the easiest and cheapest way of saving electricity, a LED light can be bought at around 10€ (at residential level, at commercial level prices will be lower driven by a reduction in price for high volumes). Additionally, it generally does not require any sort of retrofit or adaptation so it can be easily done by everyone.

Smart home could also support lighting energy efficiency, as smart lights that can be controlled with the smart-home systems (e.g. Google Home, Apple home or Amazon Alexa) are LED lights. The penetration of smart home devices will then also boost lighting efficiency penetration.

Lighting Energy Efficiency Savings

Savings in total demand due to increases in efficiency from lighting is expected to amount up to 216 TWh by 2030. This number might seem relevant compared with other technologies, the main difference is that penetration of LED is already in an advanced phase, so increase in demand is no so significant.

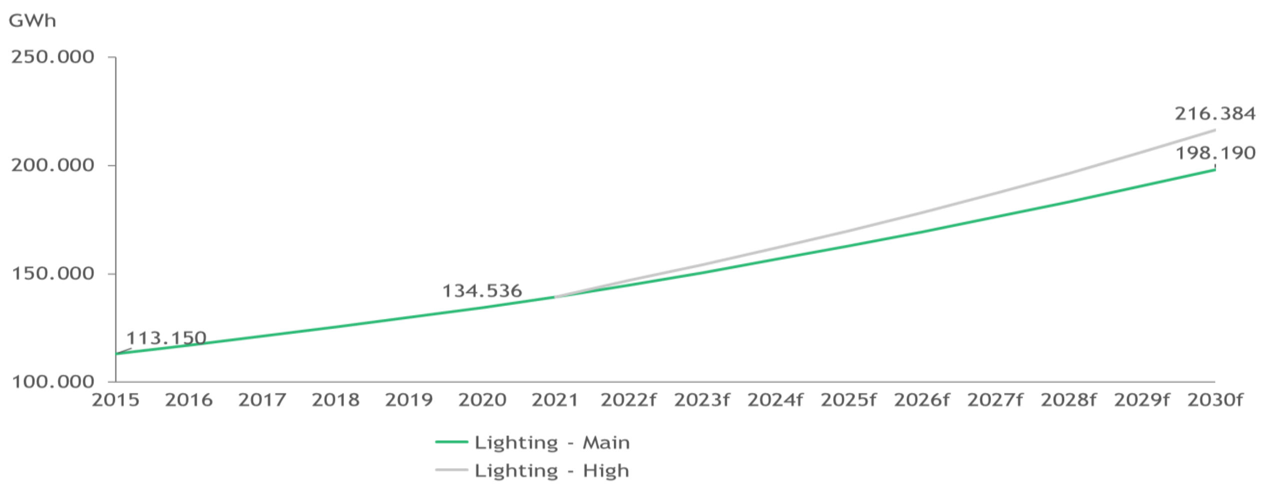

Figure 35 Efficient Lighting demand savings [1]

Insulation

Introduction

Insulation could be considered as an indirect way of saving electricity, as impact is not direct in electricity. Rather than this impact is achieved by a saving in heating and cooling electricity demand. When a building is retrofitted and insulation is improved, it requires less energy to maintain it cool/warm as the heat exchange with exterior is reduced.

In this case it is important to mention that even though insulation will help reduce energy consumption for heating/cooling due to a more efficient heat exchange with exterior not all heating/cooling is done with electricity as it is also done with gas

Building Insulation demand savings

Building retrofit and insulation will amount a total saving of ~44TWh of electricity by 2030 growing from ~15TWh in 2020.

There are two main drivers behind the increase in the savings.

- Penetration: Buildings are starting to perform retrofits to comply with EU regulation
- Increase in the share of heating/cooling done with electricity, as insulation reduced only the energy consumed for heating and cooling so the higher the share of electric heating/cooling the higher the electricity to be saved.

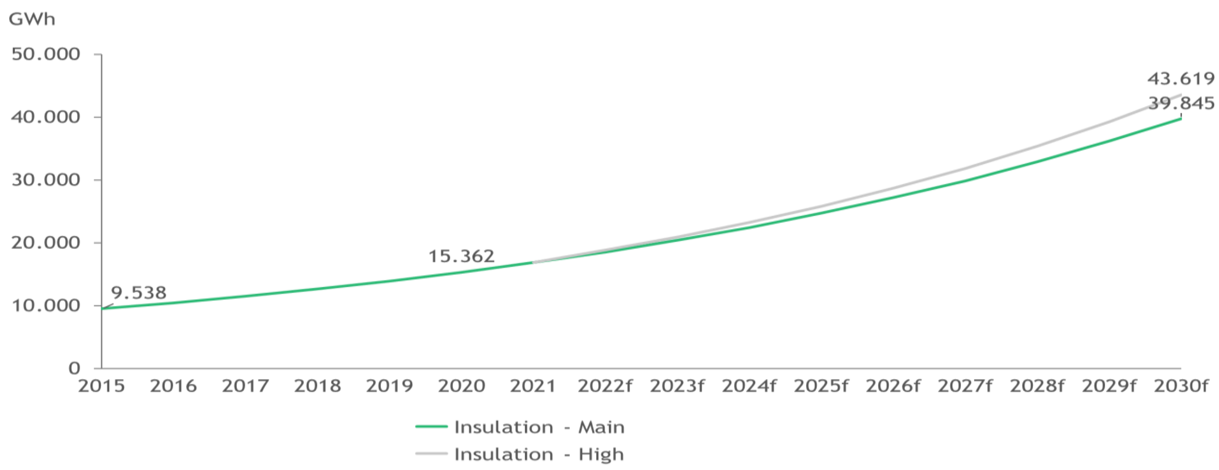

Figure 36 Building envelope retrofit saving in demand [1]

Industrial Energy Efficiency

Introduction

As It was mentioned before, industrial energy efficiency can be divided into two main blocks:

- Process Specific Energy efficiency: Savings due to a direct optimization of the industrial process (Shown here)
- Manufacturing Building: Savings in manufacturing building were already considered in the building sector.

Industry sector consumes a significant share of the total electricity, so with just a minor increase in energy efficiency it will result in a major electricity saving overall. Industrial processes are typically designed to minimize electricity consumption, as it represents an important share of total expenditure of the manufacturing company. Furthermore, typically electricity consumption is closely monitored in order to minimize electricity bills. Due to all the factors mentioned before, electricity savings in the industrial sector will not be as aggressive as it would be without those factors.

Industrial energy efficiency impact in demand

Energy savings from industrial energy efficiency are expected to amount around 103 TWh by 2030 almost doubling compared with 2020.

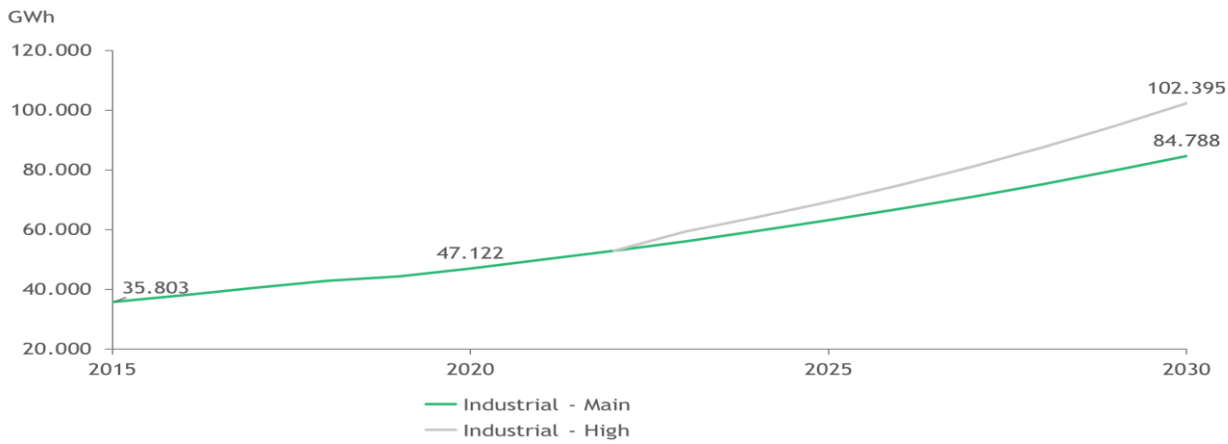

Figure 37 Energy Efficiency in Industry impact in total demand [1]

3. Distributed Generation

3.1 Introduction

Distributed generation together with energy efficiency will be one of the key technologies that will support electrification efforts without a drastic increase in final demand. It is important to start by defining what is considered as distributed generation. Distributed generation is defined as all the behind the meter generation. There can be several technologies that can go under this filter, some examples are:

- Solar PV
- Micro-wind turbine
- Micro-gas turbine
- Combined heat and generation (CHG)

Even though there are several technologies, after some analysis and preliminary results it became clear that the main technology that drive most of the distributed generation capacity in Europe would be solar PV. There might be other countries such as USA where there might be some other technologies with higher relevance, but as mentioned before, in Europe only Solar PV will be taken into consideration.

Recently following the Russian invasion of Ukraine, the EU launched a series of measurements and targets. One of the points on this document was the creation of the EU solar strategy, with the following main objectives:

1. **Promoting PV deployment:** With the objective of adding an Additional 19TWh in the first year of implementation compared with fit for 55 and 58TWh by 2025 doubling fit for 55 projections and an additional 26B€ of investment by 2027 on top of fit for 55.
2. **Simpler permitting procedure:** Limit to a maximum of 3 months the permitting for rooftop solar

3. **Skilled workforce:** Targeting to double solar PV jobs by 2030 from 357.000 jobs in 2020.
4. **European solar PV industry alliance:** De-risked financing to private investment via the EU investment bank and other public institutions and creating Innovation fund and recovery, resilience and cohesion policy funds to boost solar development.

One of the most important initiatives for this thesis, would be the creation of the European solar rooftops' initiative, with the following objectives:

- Installations of rooftop solar mandatory:
    - All new public and commercial buildings >250m2 by 2026 and existing buildings by 2027
    - All new residential buildings by 2029
- At least one renewable based energy community in every municipality with more than 10.000 inhabitants
- Member states should ensure that payback periods are shorter than 10 years.

In addition to this regulatory support, Costs of PV systems are reducing across Europe, making solar PV a competitive technology. Previously self-consumption with solar PV was not economically viable without a set of incentives. This has changed drastically in the recent years with a decrease of the cost of solar PV systems and behind-the-meter storage, making self-consumption economically viable even without government incentives.

There are two main drivers of this cost decrease:

1. **Economies of scale:** Mass production and automatization of processes
2. **Module efficiency:** Increases generated energy with the same module.

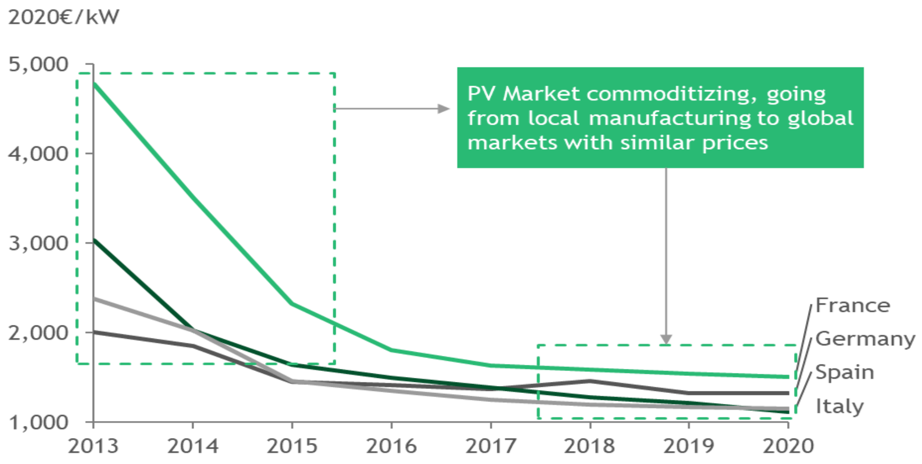

Figure 38 Cost Decrease of modules (TFM MII)

3.2 Distributed Generation Impact in demand

Distributed Generation's rise in residential and commercial buildings is predicted to impact final demand significantly, potentially up to 273TWh. This shift towards decentralized energy solutions is expected to revolutionize the energy sector and promote sustainability.

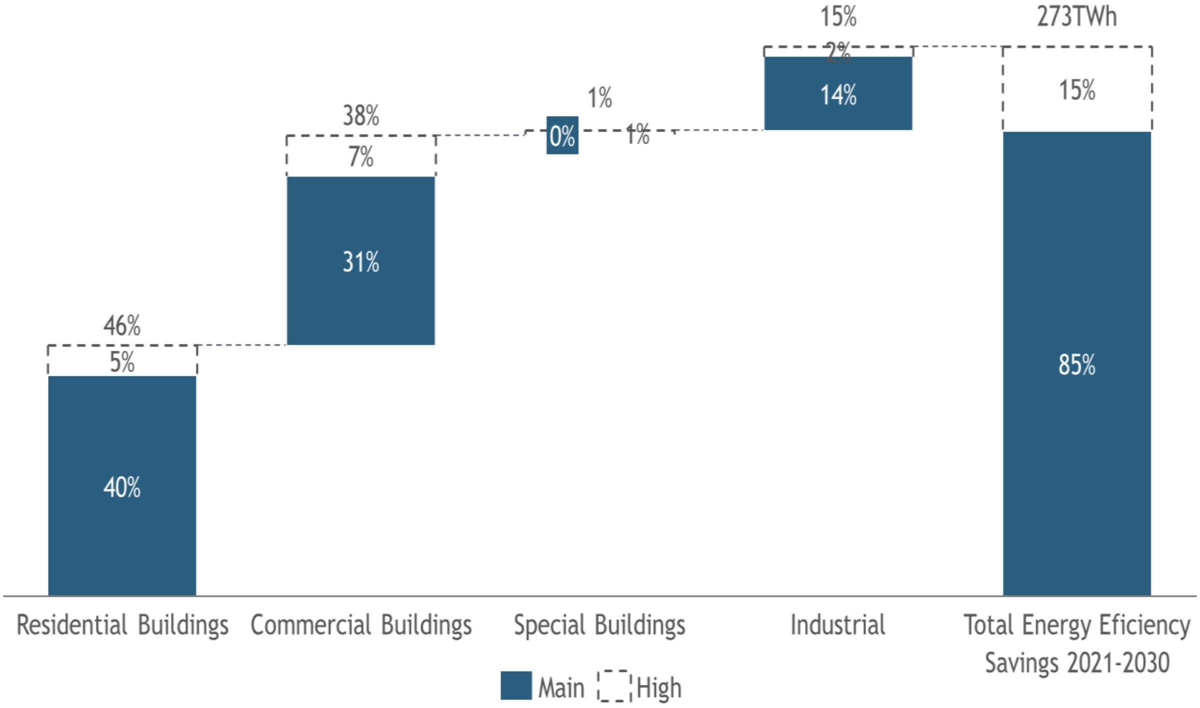

Figure 39 Total energy savings potential breakdown [1]

As highlighted in the introduction, the motivation for buildings to install solar panels revolves around three primary factors. Firstly, regulatory mandates may demand the incorporation of solar panels in particular building types or during renovation processes. Secondly, the increasingly favorable economic viability of solar photovoltaic (PV) technology has captivated building owners, presenting an interesting investment project for them. Lastly, the prevailing economic conditions have rendered solar PV a financially good option for numerous construction projects, , these reasons drive the widespread adoption of solar panels in buildings, contributing to a greener and more sustainable future.

Installed Distributed solar capacity.

For the sake of simplicity, customer segments will be grouped in 2 main groups:

- Residential Buildings: Small scale rooftop solar PV systems with an average capacity of 3.5kW.
- Commercial + Special + Industrial Buildings: Most complex solution ranging from 10kW SME buildings to up to 1MW for certain Industrial buildings.

One last additional consideration before jumping into results would be that not all the energy produced by the solar panels will be self-consumed by the buildings, as it is not possible to perfectly match solar generation and demand, therefore there will be a share of energy that will be injected into the grid. No further consideration needs to be taken into account as this energy injected in the distribution grid will be consumed by nearby loads, having the same impact in total electricity demand.

On the Residential side installed capacity could grow up to 160 GW by 2030 growing from just 35 GW installed in 2021

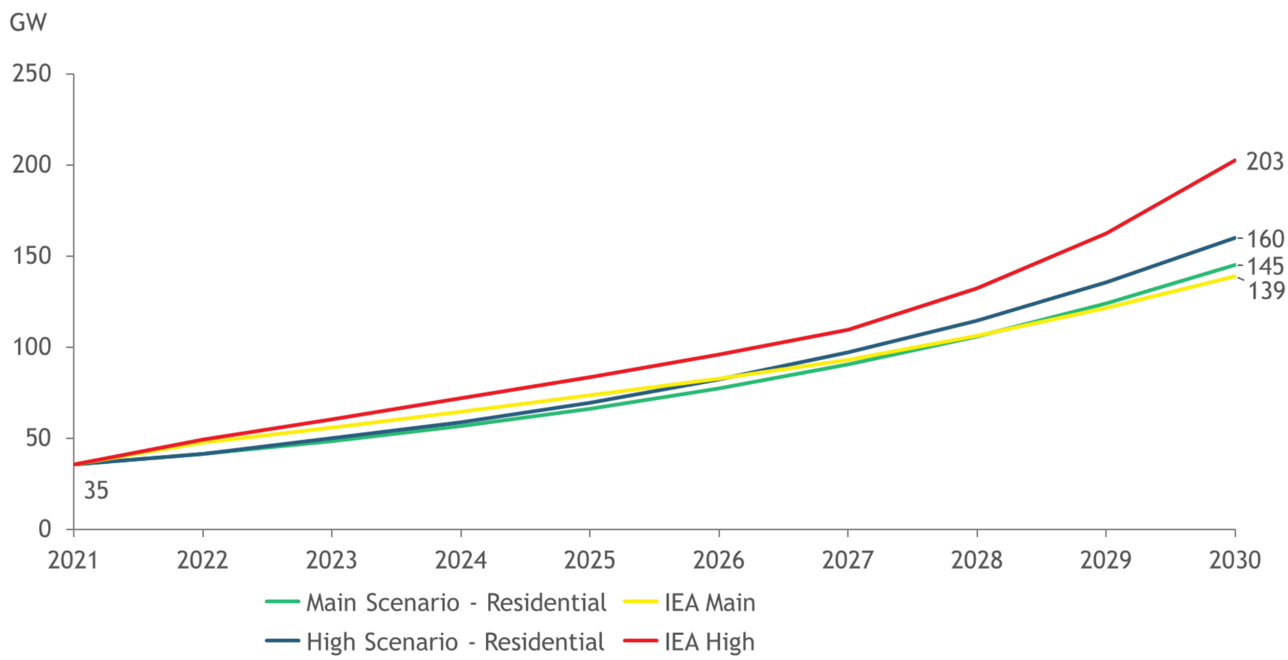

Figure 40 Distributed Solar Installed Capacity -Residential [1,20]

On the commercial, special and industrial side, installed capacity is expected to grow to up to 234 TWh by 2030 growing from close to 100 TWh in 2022

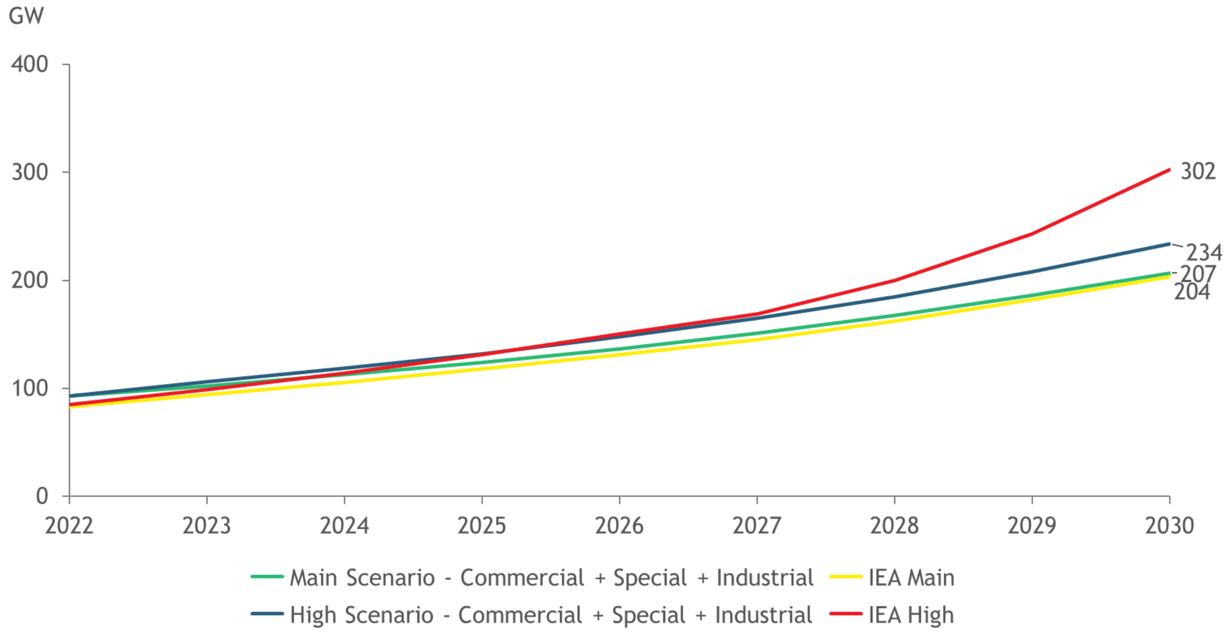

Figure 41 Distributed Solar Installed Capacity -Commercial+Industrial [1,20]

3.3 Energy demand forecast

In this case demand will be segmented again by 4 study segments.

For the residential segment, electricity generated by the solar panels by 2030 could amount 160TWh of energy, growing from 41TWh in 2022

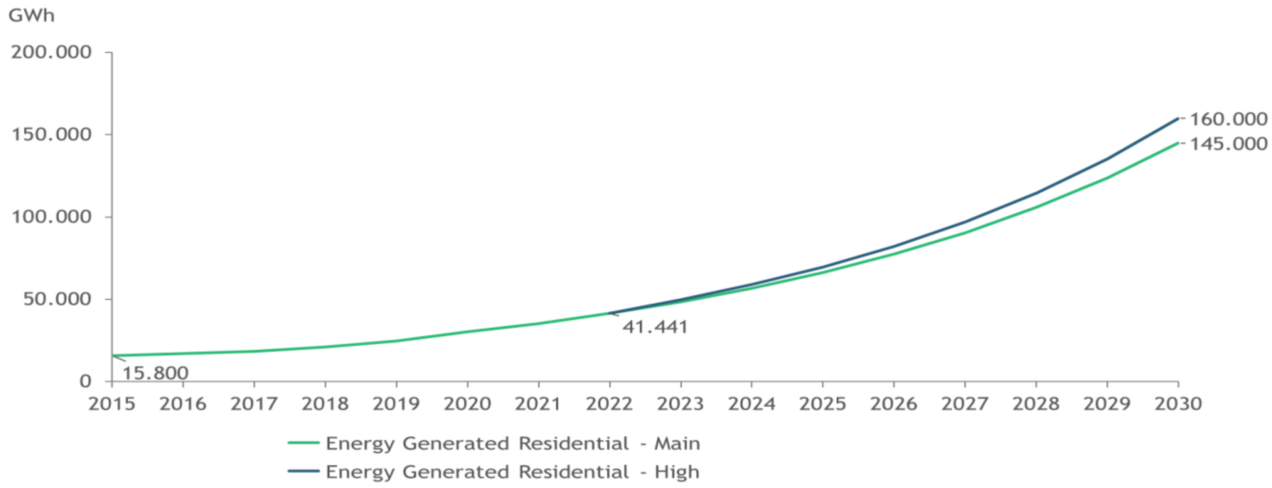

Figure 42 Electricity generated by residential solar panels [1]

For the commercial segment, electricity generated is expected to amount 175TWh by 2030 growing from 76TWh in 2022.

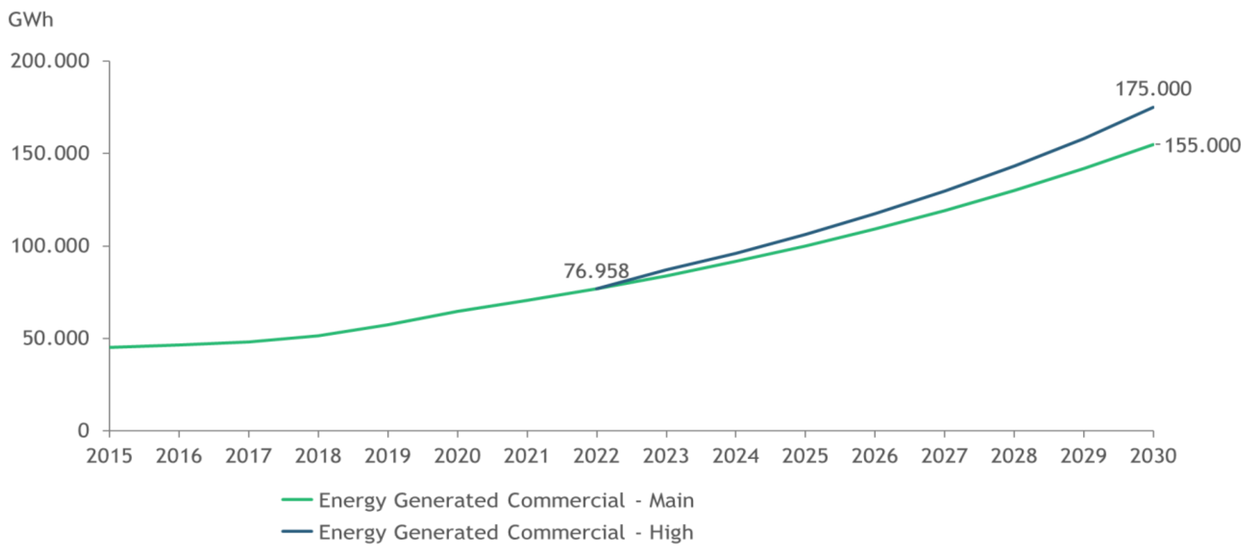

Figure 43 Electricity generated by commercial solar panels [1]

For the special segment, electricity generated by solar panels will amount 9TWh of energy, growing from ~7TWh in 2022.

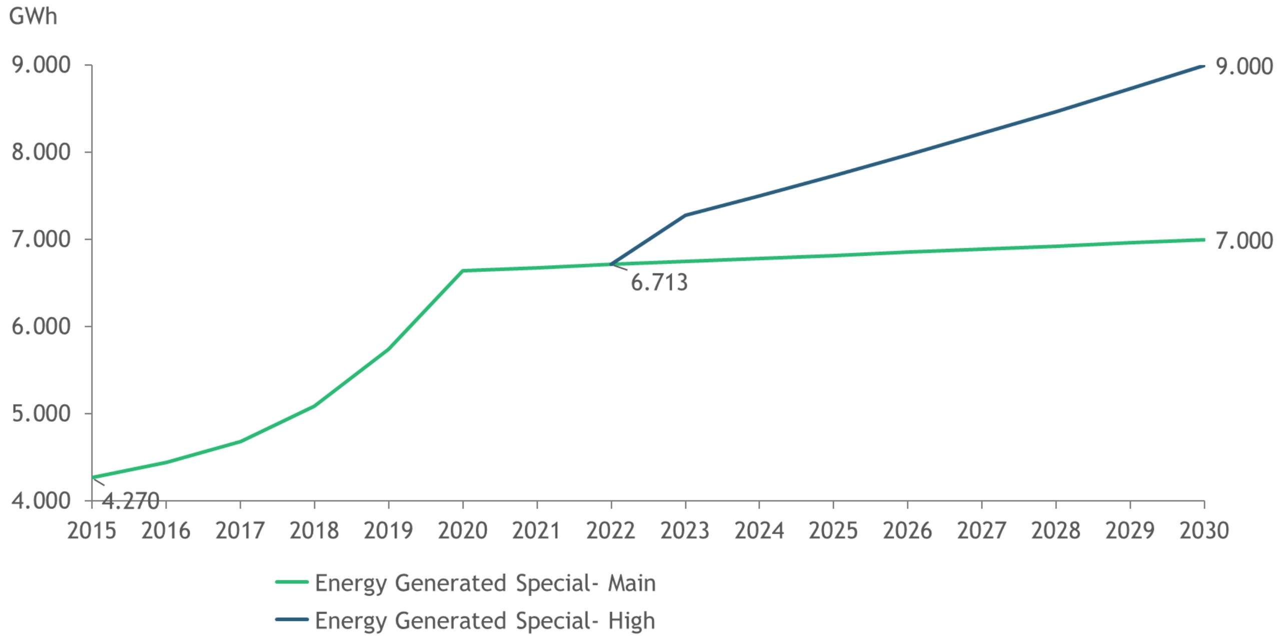

Figure 44 Electricity Generated by solar panels in special buildings [1]

In the industrial segment, electricity generated by panels is expected to amount 50TWh of electricity by 2030 growing from 8TWh in 2021

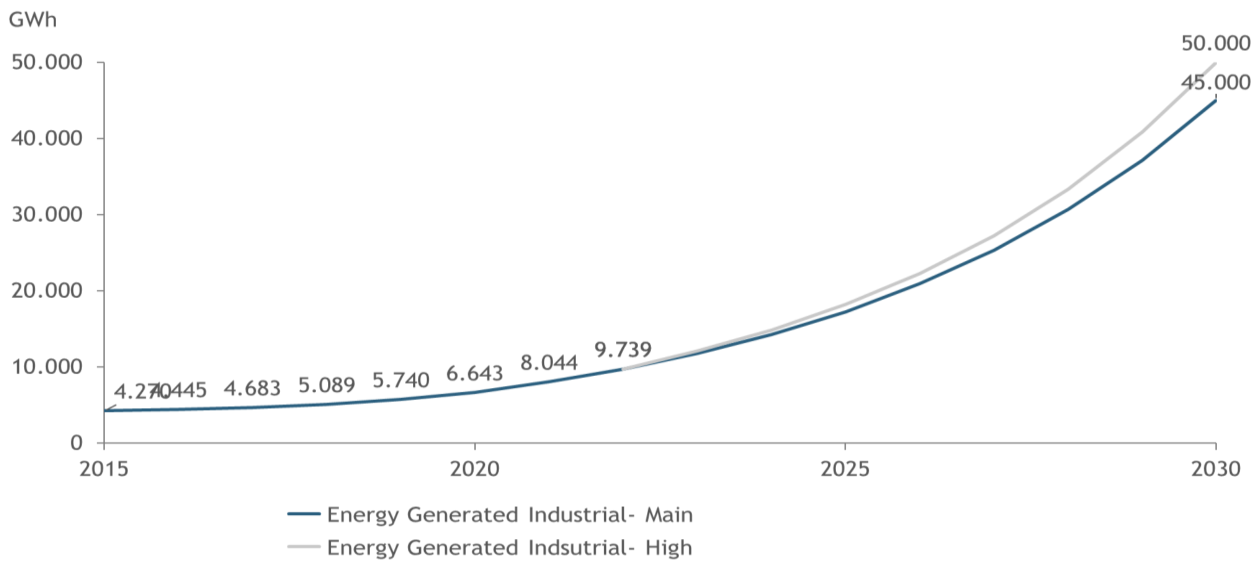

Figure 45 Electricity generated by Industry solar panels [1]

4. New Connections

4.1 Introduction

In addition to all the different technologies that will have an impact in electricity demand, there is another factor to take into consideration: new connections to the grid. Europe is still in expansion, and population is still growing. This chapter will model the electricity demand from new houses and buildings that will be created in the following years, increasing overall electricity demand.

According to Eurostat: "The EU population is projected to increase from 446.7 million in 2022 and peak at 453.3 million in 2026 (+1.5 %)". This increase in total population will also increase total electricity demand.

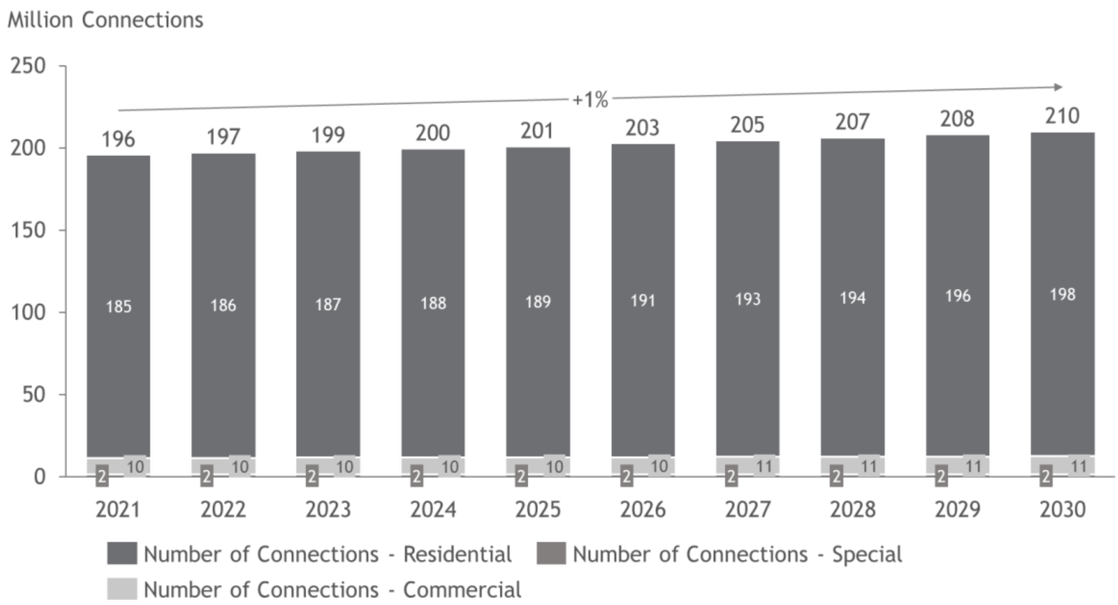

Figure 46 Number of connections [1]

Looking directly into electricity connections it can be seen how connections are expected to grow at a 1% CAGR, growing to 210 million connections by 2030. In this case only one scenario will be considered, as it would not be efficient to play with different scenarios on the European population, as it is not a variable that is expected to experience a high variability.

4.2 Electricity demand and impact in final demand

New connections will have an impact in 2030 demand of around 131TWh mainly driven by new connections in the residential and commercial buildings.

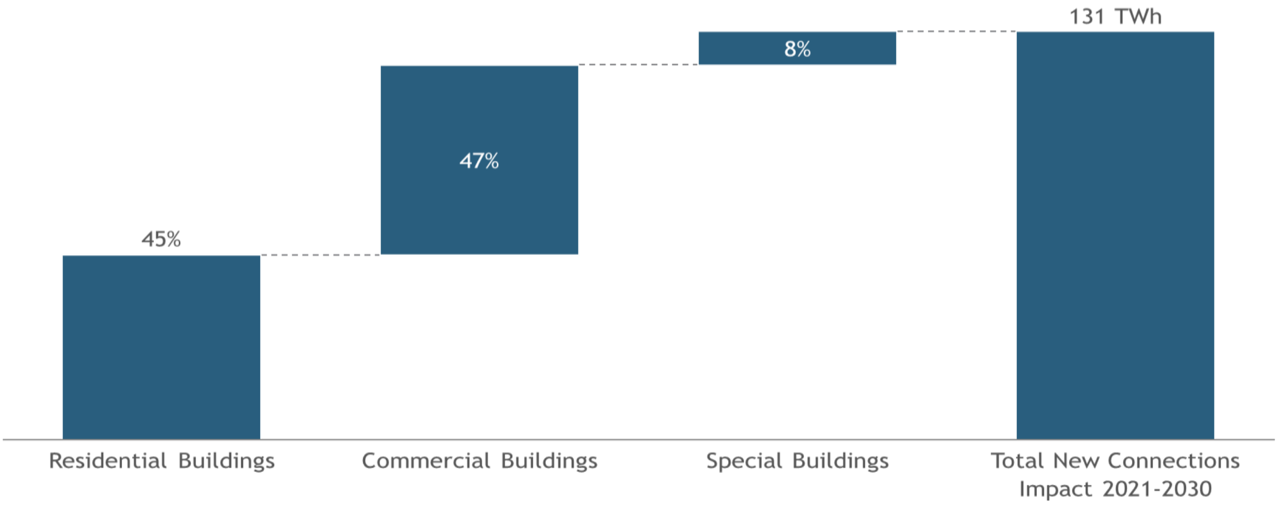

Figure 47 Impact in final demand of new connections [1]

In terms of total demand, electricity demand from 3 segments will grow due to new connections up to 1,717 TWh by 2030 from 1,586 TWh by 2021

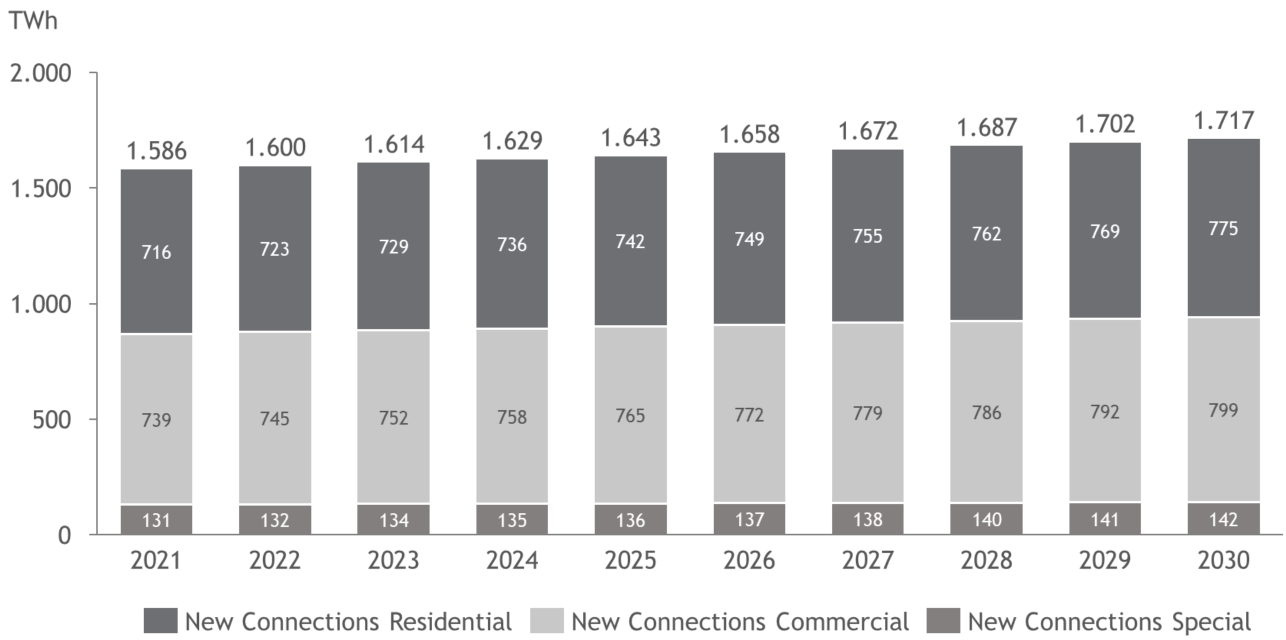

Figure 48 Total Electricity Demand by Segment [1]

Impact in Final Electricity Demand

Introduction

In this chapter impact of drivers in final electricity demand will be presented. In order to provide a realistic view of what the future electricity demand will look like in the future, a set of combination of scenarios will be presented:

- **Lowest Possible Demand:** Minimum value of demand by 2030 a combination of the low scenario for electrification and new connections, and high scenario for distributed energy and energy efficiency
- **Low Scenario All:** Using low scenarios for all drivers, this would be the case if EU does not reach current targets and ambitions by 2030 (neither in electrification or Energy efficiency/ Distributed Generation
- **High Scenario All**: Using high scenarios for all drivers, this would be the case where EU pushes to reach all targets or even rises some of the current ambitions.
- **Highest Possible Demand:** Maximum value of demand by 2030, a combination of high electrification and high number of new connections with low energy efficiency gains and low penetration of distributed generation

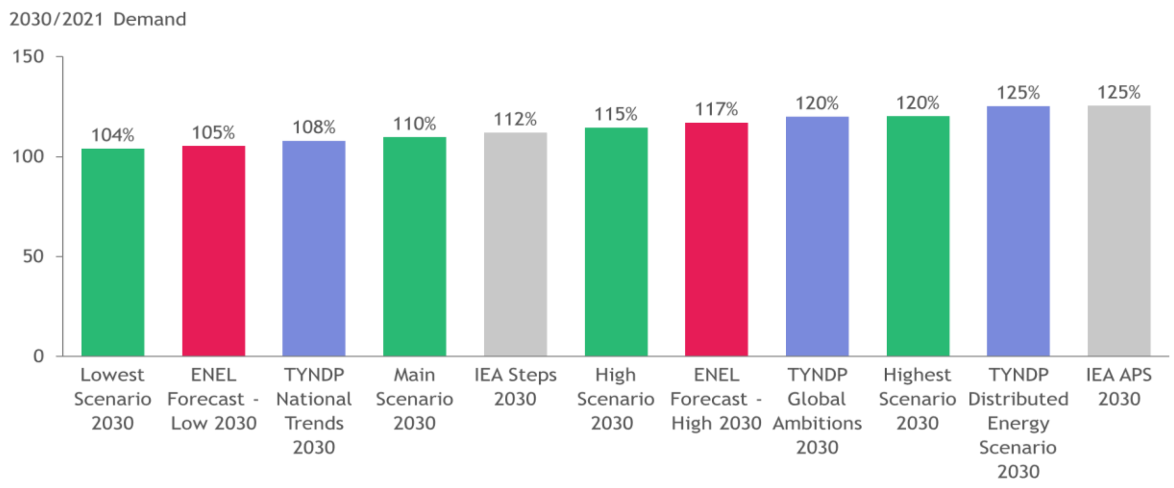

Figure 49 2030 compared with 2021 demand [1,3,7,8]

Increases in electricity demand from this thesis are in line with other industry forecasts.

Lowest Electricity Demand Scenario

Lowest electricity demand scenario represents the lowest expected electricity demand by 2030, which according to the model represents a 4% increase with respect to 2021 demand.

This scenario would correspond to the case where the EU stays below stated ambitions and targets for electrification, possible causes:

- Heat pumps Rollout is slower than expected.
- EV penetration slows down.
- Bottlenecks in manufacturing of equipment (e.g. battery raw materials shortage)
- Rollout of other technologies (e.g. Hydrogen and Biofuels)

This low penetration of electrification combined with a high implementation of energy efficiency measures and high penetration of distributed solar systems. In this case, Energy efficiency together with distributed energy would be available to cancel out impact of electrification, so electricity system would not “notice” the increase of demand caused by electrification.

This would be the optimal scenario from the grid/system point of view, in order to also meet emission targets and reduce dependence in third countries, it would require for some other technology to become predominant for heavier transports (e.g. hydrogen or biofuels),

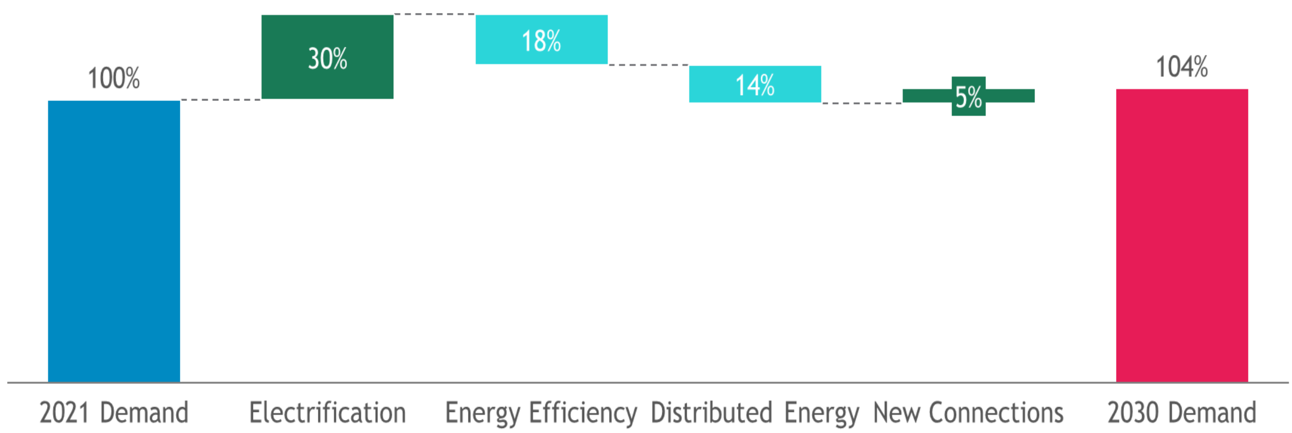

Figure 50 Lowest electricity demand scenario output [1]

All Low Scenario Electricity Demand

The all-low scenario would be a combination of all the low scenarios for the different drivers. It would translate in a 10% increase in electricity demand with respect to 2021 demand.

This scenario would correspond to the case in which electrification has a relatively low penetration (As introduced in last scenario) but also combined with a lower than expected penetration of other demand-reducing drivers (Energy Efficiency and Distributed Energy). It could be the case if there are issues in manufacturing value chains, that constraint planned growth in electrification and other drivers. There are two main situations that could lead to this situation:

- Chip Shortage leading to bottlenecks in EV, Inverters or Smart devices manufacturing.
- Lack of qualified workforce for installations/maintenance

From an energy system point of view this scenario would be neutral, as a lower electrification is also combined with low penetration of distributed energy and EE.

In this case electrification would represent ~86% of increases in electricity demand, with new connections representing remaining 14%. On the other side, on demand reducing drivers, the low scenario has a very similar impact of both energy efficiency and distributed energy drivers, with energy efficiency having a slightly higher impact.

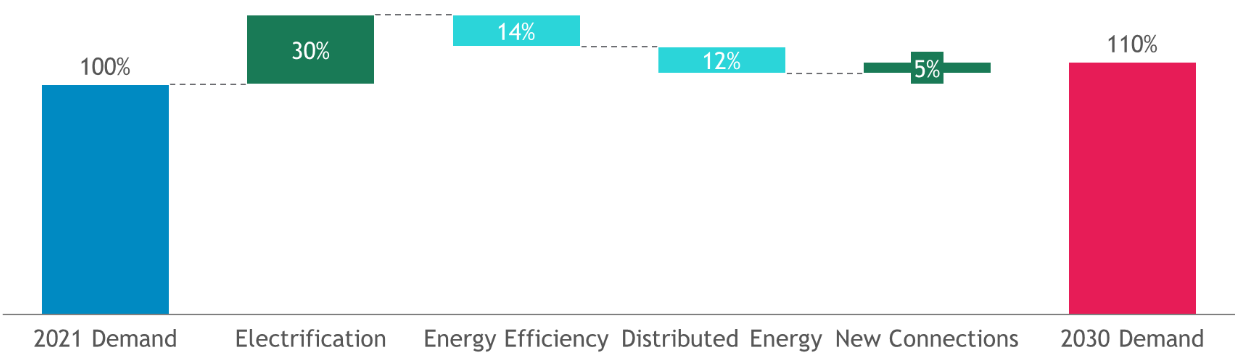

Figure 51 Lowest electricity demand scenario output [1]

All High Electricity Demand

All high electricity demand scenario would correspond to the scenario in which all the main drivers meet or are above of stablished targets. In this scenarios, 2030 electricity demand would increase by 15% compared with 2021 electricity demand. Main driver for this increase would be massive 41% additional demand by electrification.

High levels of rollout in energy efficiency and distributed energy would not be enough to counteract demand increase caused by a massive electrification penetration, mainly driven by heat pump rollout and transport electrification.

This scenario would correspond to the scenario in which there are no constraints or bottlenecks in manufacturing or qualified workforce required to install, maintain and operate required heat pump, charging points, solar panels…

There are some key drivers that would lead to this scenario:

- Heavy road transport electrification: Battery electric vehicles preferred vs other alternative solutions such as hydrogen.
- Innovations in heat pumps: Such as high temperature heat pump that is already being commercialized by Vattenfall and could help electrify gas fired elements.
- Favorable business case for customers: total cost of ownership, and business case of energy efficiency and distributed energy solutions favorable for end customers

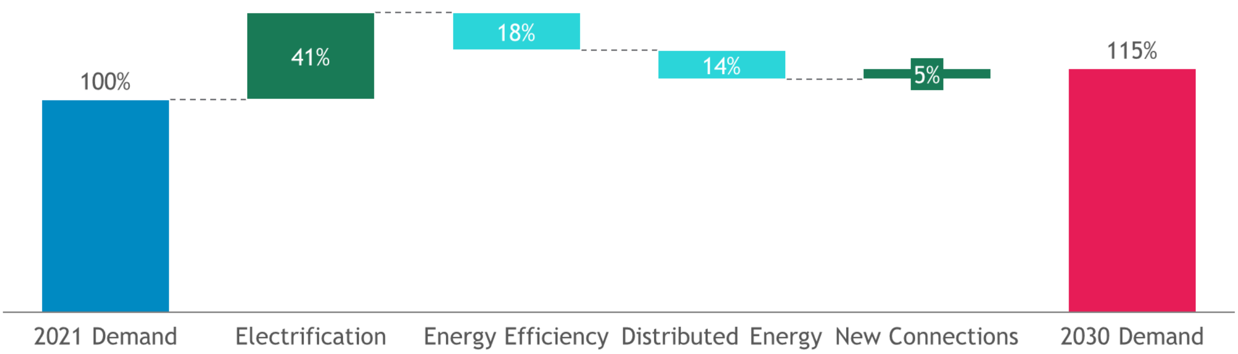

Figure 52 All high scenario electricity demand scenario output [1]

Highest Electricity Demand

Highest electricity demand would correspond to the scenario in which electricity demand increase would be higher, with a 20% increase in electricity demand by 2030 compared with 2021 demand.

Highest electricity demand would be a result of a high electrification (Due to the reasons introduced in the previous scenario) combined with a low penetration of distributed energy and energy efficiency. This scenario could be caused by a shortage in manufacturing materials for distributed energy as for example:

- Shortage in silicon for solar panels development
- Low Electricity prices improving electrification business case but reducing it for distributed energy and energy efficiency.

This scenario would be the worst scenario from the system point of view. A 20% increase in electricity demand would require introducing a higher generation capacity to be available to cover 20% increase in demand. Furthermore, such a high increase in electrification without a reduction with reduction drivers could also be a problem in terms of the grid, the grid might need to be upgraded in some points to cover such a high increase in demand. In order to reduce impact, there would need to be a strong incentive for demand to use electricity demand when better for the grid via time of use tariffs.

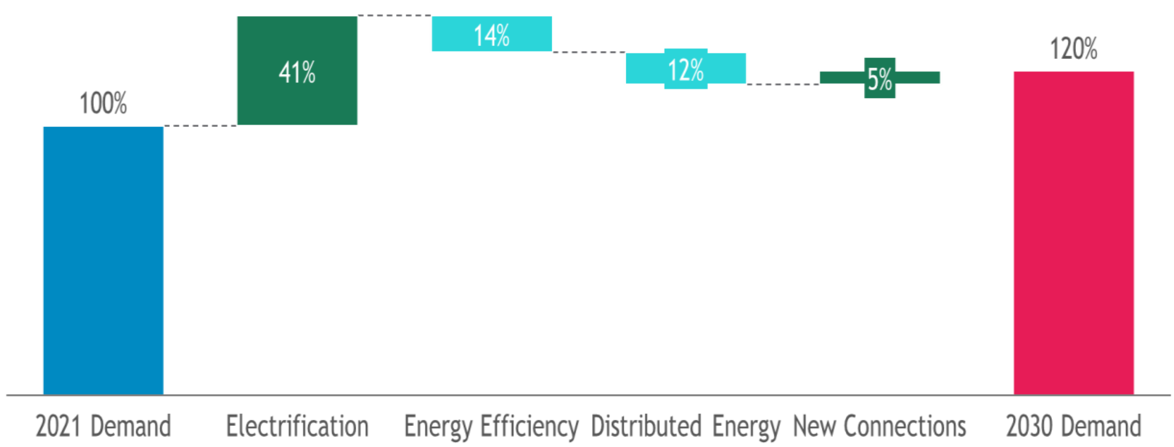

Figure 53 Highest electricity demand scenario electricity demand scenario output [1]

Conclusions

It is clear that European electricity demand will increase driven by a large impact of electrification of transport, buildings and industries. However, impact in total demand will be dependent on penetration of energy efficiency and distributed energy. Europe should push towards a large and fast penetration of both technologies in order to reduce impact in total demand by 2030.

The European Union (EU) can promote energy efficiency and distributed solar adoption through a combination of financial incentives, supportive regulations, public awareness campaigns, energy performance certificates, green public procurement, and favorable financing mechanisms. Additionally, investing in research and innovation, fostering collaborations and partnerships, and implementing net metering and feed-in tariff policies can drive widespread adoption. By adopting these strategies, the EU ensure that boost in electrification can be achieved without it becoming a thread to the electricity system,

While a 5% increase in electricity demand by 2030 (Corresponding to a high penetration of EE and DER) may not be an issue within the existing electricity system, it is necessary to consider the potential challenges that could arise in the future. If there is a substantial rise in electrification, coupled with low energy efficiency and limited adoption of Distributed Energy sources, the electricity demand could surge by up to 20% (Corresponding to a low penetration of EE and DER). Such a scenario would undoubtedly pose significant challenges to the current electricity system's feasibility and reliability.

In the event of this high increase in electricity demand, it becomes crucial for the European Union (EU) to take proactive measures to ensure the feasibility and sustainability of the electricity system. Strategic actions may need to be implemented to enhance energy efficiency, promote the widespread adoption of Distributed Energy sources, and invest in modern grid infrastructure to handle the escalating demands.

Further Steps

There are several additional steps that will be proposed below in order to comprehensively evaluate the potential impact of emerging trends on the European electricity system by the year 2030. This thesis primarily focused on assessing the electricity demand impact, but it is imperative to undertake three further analyses to gain a comprehensive understanding of the overall consequences of key drivers in the future:

- **Peak Power Needs Analysis:** To gain insights into the changing peak demand by 2030, it is essential to conduct a detailed analysis. For instance, the electricity generation from distributed solar sources may not match with the peak charging periods of electric vehicles (EVs), creating the need to assess into the implications and potential solutions for such disparities.
- **Grid Analysis:** An in-depth analysis is warranted to comprehend the implications of the main drivers on the electricity grid. This analysis will investigate the effects of innovative technologies, such as vehicle-to-grid integration and distributed solar energy injection into the grid and explore the potential challenges and opportunities they may present.
- **Stability Analysis:** A comprehensive technical assessment is vital to ensure the stability of the energy system. This analysis will identify the necessary measures that need to be integrated into the grid to guarantee a reliable electricity supply. For example, the installation of energy storage solutions such as batteries and the development of flexibility markets may be instrumental in achieving grid stability.

By conducting these three additional analyses, a holistic view of the impact of new trends on the European electricity system by 2030 will be obtained, allowing for more informed decision-making and strategic planning in the face of a rapidly evolving energy landscape.

Further questions inquiries

If there is any additional suggestion/question, please contact me at my email:

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