Final energy costs and investments in Spain along the 2050 Holistic & Efficient Roadmap

Update to our April 2020 Report to Iberdrola

April 2021

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1. Introduction

In its May 2020 public report, prepared jointly with Iberdrola and titled 2050 Holistic & Efficient Roadmap for a Zero-Emissions EU Energy, AFRY explored the key factors to a successful and efficient decarbonisation of the European energy sector by 2050. The report investigated how the different segments of the energy sector (transport, heat in buildings and industrial processes, and electricity) could be fully decarbonised by 2050, in line with the objectives set by the Paris Agreement in 2016, and with subsequent European Union targets.

The numbers projected in the previous report were built with AFRY's decarbonisation modelling suite, which combines our modelling of the transport, heating and power sectors, and is governed by our 'Total System Cost' model, which ensures that the outputs reflect the least cost solution for the whole energy sector to decarbonise. Although the project looked at the pathway for decarbonisation for the whole of Europe, it had a special focus on Spain and Great Britain, which are the two markets where Iberdrola is most active in Europe.

In this update, AFRY makes further analyses of the decarbonisation pathway constructed with Iberdrola in 2020 and looks specifically at the evolution of final energy costs in Spain in the transport, heat and power sectors along the pathway, in order to show the impact of such a transition on households, businesses and industries. This update also shows an overview of the investments that are needed to reach the zero-carbon objective.

2. Zero-carbon transport sector

Total costs calculated for the transport sector include the recovery of the investments in vehicles, fuel costs for each type of vehicle and yearly maintenance costs. These numbers use AFRY's own view on how vehicles' capex will evolve in the future as well as the evolution of retail fuel costs, which include not only the cost of the fuel itself but also all the system costs that are passed-through to final customers (i.e. taxes, renewable subsidy charges on consumers, investments in charging or fuelling infrastructure, etc.).

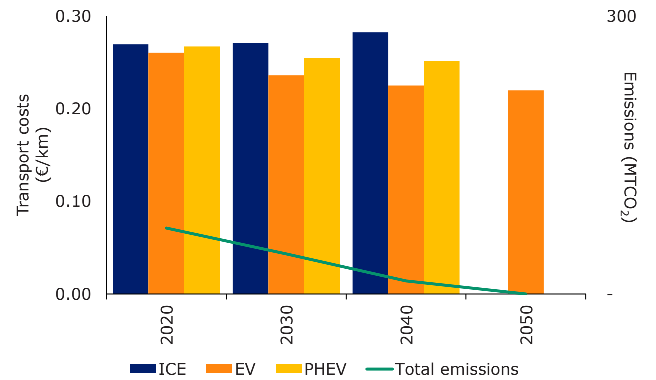
Vehicle types are classified into:

— Internal Combustion Engine (ICE): These are traditional cars fuelled either with gasoline, diesel, gas, LPG or biofuels.
— Plug-in-Hybrid Electric Vehicle (PHEV): These vehicles are fuelled with a mix of electricity and refined products (diesel or gasoline), with the latter keeping a minimum share of driving distance at 40% before 2025, decreasing to 20% until 2035, and 5% after 2035 in AFRY's modelling. The costs of both types of fuels have been taken into account in the calculations.
— Electric Vehicles (EV): These are vehicles fuelled 100% with electricity.
— Fuel-Cell Electric Vehicles (FCEVs): These are vehicles powered by hydrogen.

One of our key assumptions is that, within a same vehicle segment, all cars/trucks/vans travel the same distance as required by the consumers on a yearly basis, regardless of the fuel type used.

Exhibit 2.1 shows total costs, in €/km, of small road passenger vehicles. These are vehicles with an engine size below two litres for internal combustion engines or 90kW for electric engines. These types of vehicles make up most of the road passenger vehicles in Spain. The chart shows that, currently, electric vehicles are comparable to ICE vehicles in terms of total cost per km, but this cost is expected to decrease in the coming decades as the technology advances and the cost of acquiring a new EV decreases.

EXHIBIT 2.1 – TRANSPORT COSTS OF SMALL PASSENGER VEHICLES



Notes: By 2050 restrictions to emissions do not allow for PHEVs of ICE vehicles

The exhibit indeed shows that in the small passenger vehicles segment, total costs are already at similar levels in 2020 among the different types of vehicles (ICE, EV and PHEV), at around €0.27/km.

By 2030, the capex of EV has decreased significantly, mainly due to the decrease in battery prices which makes up for the biggest portion of today's EV costs; that is also the case for PHEV, but to a lesser extent. EV and PHEV also benefit from a decrease in electricity prices during the same period. This combination leads to EV and PHEV being more competitive than ICE small passenger vehicles already by 2030, with EV at a slight advantage. This trend continues towards 2040, with a more pronounced decrease of EV total costs at the level of €0.22/km by 2040 – and remains flat until 2050 when only EV remains in the small passenger segment as emission restrictions do not allow for ICE or PHEV.

Regarding other segments of vehicles, such as trucks, FCEV enter into play by 2040. As the capex of these vehicles decreases, as well as the cost of hydrogen, FCEV trucks are able to compete with EV from 2040 onwards. By 2050 FCEV trucks become more competitive than EV trucks when travelling long distances.

Accordingly, transitioning towards a zero-carbon transport sector does not lead to higher transport costs for passengers and goods, but can indeed be achieved with lower transport costs, as total costs per kilometre travelled associated with EV and PHEV are significantly lower than those of ICE by 2030 – which is mainly due to decreasing final electricity prices.

Exhibit 2.2 shows the average cost of the Spanish fleet and total emissions expected from the whole transport sector. This chart shows how average costs for consumers decrease over time as cheaper alternatives enter the market, and how at the same time total emissions for this sector decrease significantly, reaching zero by 2050.

Exhibit 2.3 shows total investments in the transport sector by decade. The increase in investments is mainly due to growing demand for vehicles and the higher cost of some of the low-emitting alternatives.

EXHIBIT 2.2 – AVERAGE TRANSPORT COSTS IN SPAIN AND TOTAL EMISSIONS FROM THE TRANSPORT SECTOR

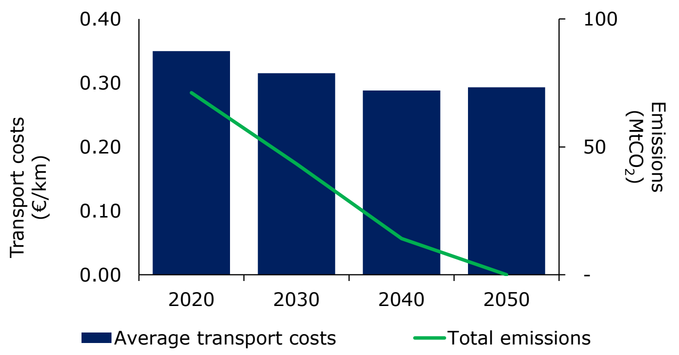
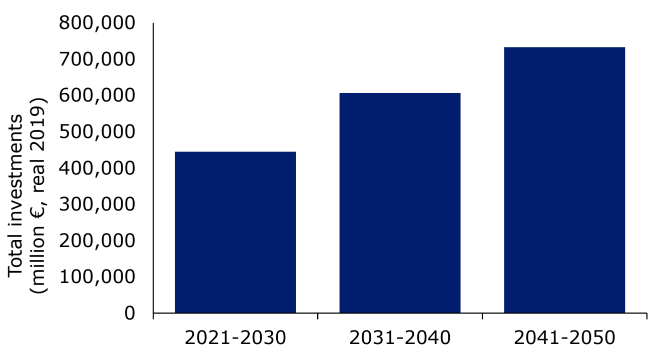


EXHIBIT 2.3 – TOTAL INVESTMENTS IN THE TRANSPORT SECTOR BY DECADE



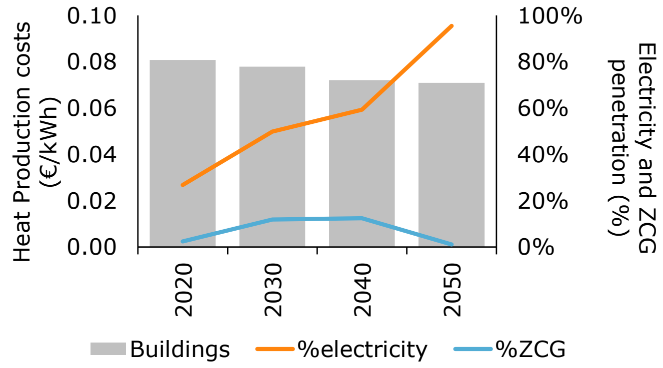
3. Zero-carbon heat sector

In this section AFRY looks at the costs and investments associated with the decarbonisation of the heat sector in Spain along the pathway developed with Iberdrola. Total costs in the heat sector include investment in heat appliances (typically heat pumps or boilers), necessary conversion costs, fuel costs for each type of appliance and yearly maintenance costs. These numbers use AFRY's view on how the capex for appliances will develop in the coming decades as well as the evolution of retail fuel costs, which include not only the cost of the fuel itself but also all of the system costs that are passed-through to the final customers (i.e. taxes, renewable costs, investments in infrastructure, etc.).

As explained in Section 4 of the main report, the heat sector is divided into two main segments:

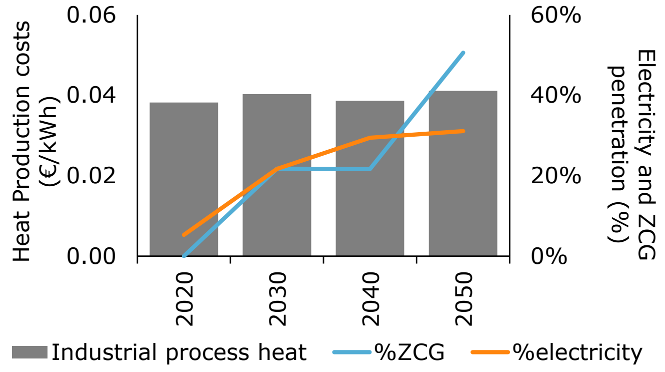
- Buildings segment: This includes the heating of households, commercial buildings, offices, and industrial sites; it can also be referred to as 'space heating'.
- Industrial processes segment: This includes heat used by processes in the industry.

EXHIBIT 3.1 – HEAT PRODUCTION FOR BUILDINGS



Note: ZCG include biogas/biomethane, Hydrogen and CCS.

EXHIBIT 3.2 – HEAT PRODUCTION FOR INDUSTRIAL PROCESS HEAT



Note: ZCG include biogas/biomethane, Hydrogen and CCS.

Exhibit 3.1 and Exhibit 3.2 show total costs in €/kWh of heat produced for both the buildings and industrial processes heat segments. The results shown correspond to the weighted average cost of the different fuels (biomass, electricity, hydrogen, natural gas, coal, oil, biomethane and CCS gas) and appliances (mainly heat pumps and boilers) used in each segment.

In the buildings segment heat production costs decrease from €0.08/kWh of heat in 2020 to €0.07/kWh in 2050. This is driven by the high penetration of air-sourced heat pumps (ASHP) in this segment: in this pathway electricity fuels up to 50% of the heat produced in Spain by 2030, and almost 100% by 2050. This is achieved due to a significant decrease in ASHP capex during the next decade; very high efficiency (up to 400%, i.e. 400kWh of heat produced for 100kWh of electricity consumed) favoured by the mild average climate of Spain; and the decreasing final cost of electricity. In this segment, the use of ASHP allows for a 74% reduction (180TWh) of total fuel consumption between 2020 and 2050.

In the industrial segment, the cost of process heat remains fairly stable, in spite of the growing use of zero-carbon gases (ZCG), which fuel up to 50% of total process heat by 2050, whilst electricity is used to fuel the rest in lower temperature processes (i.e. for process temperatures below 200°C, where ASHP are considered viable in our assumptions). The use of ZCG entails higher costs, as important investments are needed in the production of ZCG (cf. hydrogen, biomethane) and also to accommodate industrial facilities (cf. hydrogen, CCS). However, the absence of CO_2 costs associated with these decarbonised fuels guarantees their competitiveness in the long-term, whilst average process heat costs for industrial users remain at similar levels as in 2020.

Exhibit 3.3 compares the total weighted average cost of heating in Spain (for both buildings and industrial processes segments) from 2020 to 2050, against the total emissions produced by this sector. It shows that by 2050, it is possible to achieve net zero emissions in Spain in the heat sector, and at lower costs than in 2020.

Exhibit 3.4 shows total investments in the heat sector by decade. While the heat demand remains stable in Spain across the pathway (see Section 4 of the main report), investments linked to decarbonisation, such as deployment of decarbonised appliances in the residential and industrial segments, are expected to grow steadily – further consolidating the role of the heat sector as a driver for new business opportunities and employment in Spain.

EXHIBIT 3.3 – AVERAGE HEAT PRODUCTION COSTS IN SPAIN AND TOTAL EMISSIONS FROM THE HEAT SECTOR

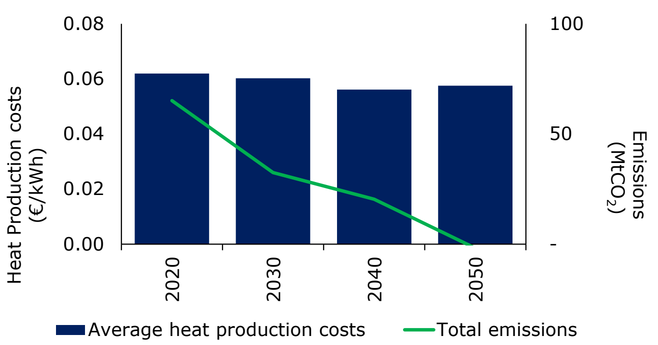
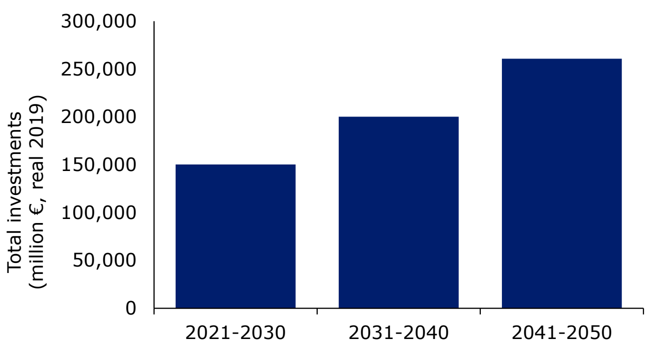


EXHIBIT 3.4 – TOTAL INVESTMENTS IN THE HEAT SECTOR BY DECADE



4. Zero-carbon power sector

In this section AFRY shows and comments on its modelling results regarding the costs associated with the decarbonisation of the power sector in Spain. Costs in the power sector are divided into:

— Generation costs: These include costs directly associated with the Spanish wholesale electricity market, i.e. the pool price and ancillary services prices times the total generation.

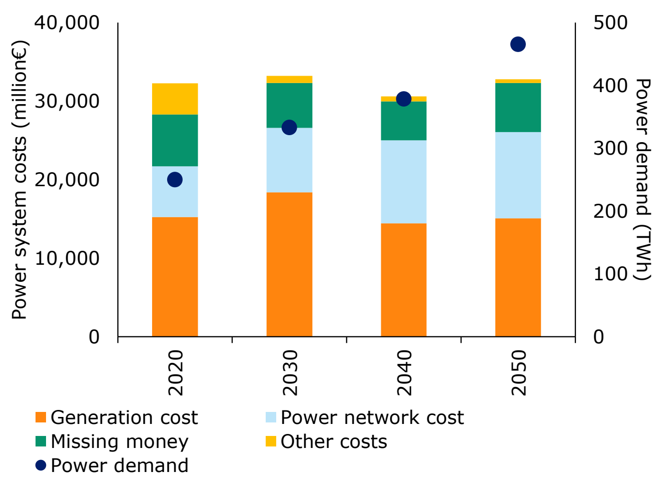
— Power network costs: This is the cost associated with the development of power networks[1] needed to support the general electrification of the energy sector and achieve its full decarbonisation by 2050.

— Missing money: This includes all the costs that are derived from the remuneration of that generation capacity that cannot achieve a reasonable return from the Spanish wholesale electricity market, e.g. subsidised renewable generation as well as firm capacity (mainly CCGTs, including those operating under ZCG) and storage.

— Other costs: These include other costs specific to Spain, such as the repayment of the tariff deficit or the extra-peninsular costs.

Exhibit 4.1 shows the total annual costs of the Spanish power system divided into the different cost categories.

EXHIBIT 4.1 – TOTAL SPANISH POWER SYSTEM COSTS



Despite increasing electricity demand, the total costs of the Spanish power system remain fairly stable as the increase in network costs is compensated by the decrease in payments to existing renewables and the repayment of past deficits:

— Generation costs make up for most of the system costs in Spain, and they evolve in line with power pool prices for this pathway.

— Power network costs see a big increase due to growth of installed renewable capacity and the fast penetration of EV and ASHP – which requires increased system capacity and smart networks to manage these appliances as distributed storage capacity.

— The amount of missing money that must be paid to generation assets remains more or less stable along the pathway. On the one hand, subsidies paid to existing renewable plants decrease, and the amount of subsidies needed for new renewable capacity is not as high since the prices captured in the market by new solar and wind plants remain close to their LCOE. On the other hand, additional payments are needed in order to maintain back-up generation (CCGTs and future addition of CCS) for security of supply matters, as these costs are not recoverable from the market due to their very limited number of running hours.

Exhibit 4.2 shows the totals costs in €/MWh as well as the emissions from the power sector in $MtCO_2$. As shown in Exhibit 4.1 total system costs remain relatively stable, but since total electricity demand increases significantly due to the growing electrification of the economy (resulting from EV and ASHP penetration), final unitary electricity costs for end-users decrease, and shows that achieving net-zero emissions is not only possible but economical for households, businesses and industries.

Exhibit 4.3 represents total investments in the power sector. The chart shows new investments that are carried out for the development of the grid as well as for new generation assets in each decade, in order to reach net-zero emissions. Reaching net-zero emissions will require a huge volume of investments in the power sector, both in preparing the grid for the increase in electrification, as well as the massive deployment of renewables that is needed. Much of the electrification efforts concentrate in the decades 2021-2030 and 2031-2040, especially in the transmission sector, which creates the need for the power grid to carry out most of its investments during these periods. Additionally, most of the renewable development occurs up to 2030, with a slight decrease seen from then to 2050.

Historical investments for the period 2011-2020 have been estimated based on reports prepared by the CNMC, the grid transmission planning document and capex values shown in Royal Decree 413.

EXHIBIT 4.2 – UNITARY POWER SYSTEM COSTS AND EMISSIONS

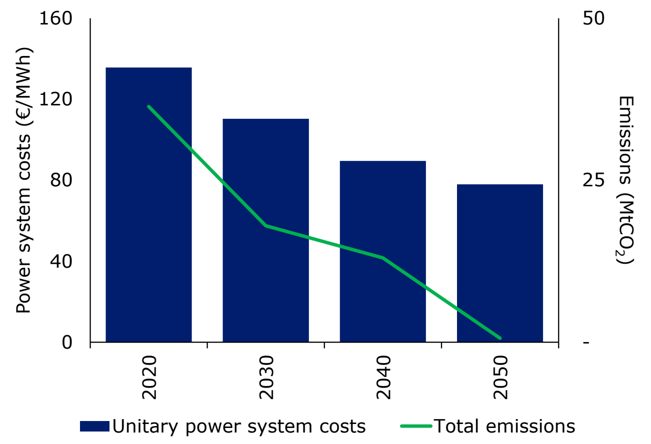
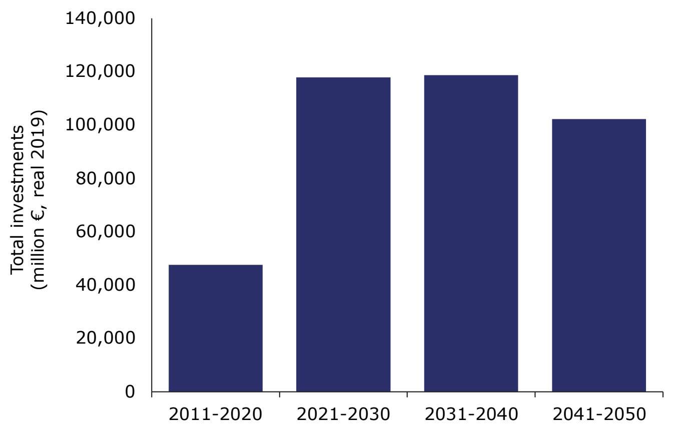


EXHIBIT 4.3 – TOTAL INVESTMENTS IN THE POWER SECTOR BY DECADE



5. Conclusions

The analysis developed in this update shows that the transition towards a zero-carbon energy sector is not only possible but also positive from an economic point of view.

This is especially relevant for individual consumers or businesses, who could see their energy bills reduced. Furthermore, the transition will help to improve industry's competitiveness and create opportunities to protect vulnerable consumers. In particular:

— The increase in the use of electric vehicles, with much lower fuel costs, decreases transport costs for road passengers and businesses;

— A higher electrification and more efficient heating in the residential sector also decrease costs for households, and the growing use of zero-carbon gases in industrial processes allows for decreases in emissions while keeping costs stable; and

— In spite of the increased investments in the power sector needed to achieve a higher electrification, the strong growth in demand and the lower cost of generation result in diminishing final electricity costs for all consumers.

The decarbonisation pathway also corresponds to massive investments in the Spanish energy sector, bringing a range of business opportunities with positive effects in terms of GDP and employment[2], the main benefits being:

— The reduction in costs of renewables for electricity generation due to technology improvements and learning curves allow for reduced electricity prices and CO_2 emissions in the power sector;

— Lower electricity prices, improvements in efficiency and reduced emissions lessen the dependence on fossil fuels in the whole energy sector, and reduce energy costs at the same time;

— There is a deep shift from a low investment and high expenses model of the energy sector to a high investment and low expenses model. This allows for the adjustment of the national payments balance, the reduction of Spain's dependence on energy imports, and new opportunities of economic growth and employment.

[1] The source used for the CAPEX of power networks is the Spanish NECP document.

[2] These effects have not been analysed in this update.

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