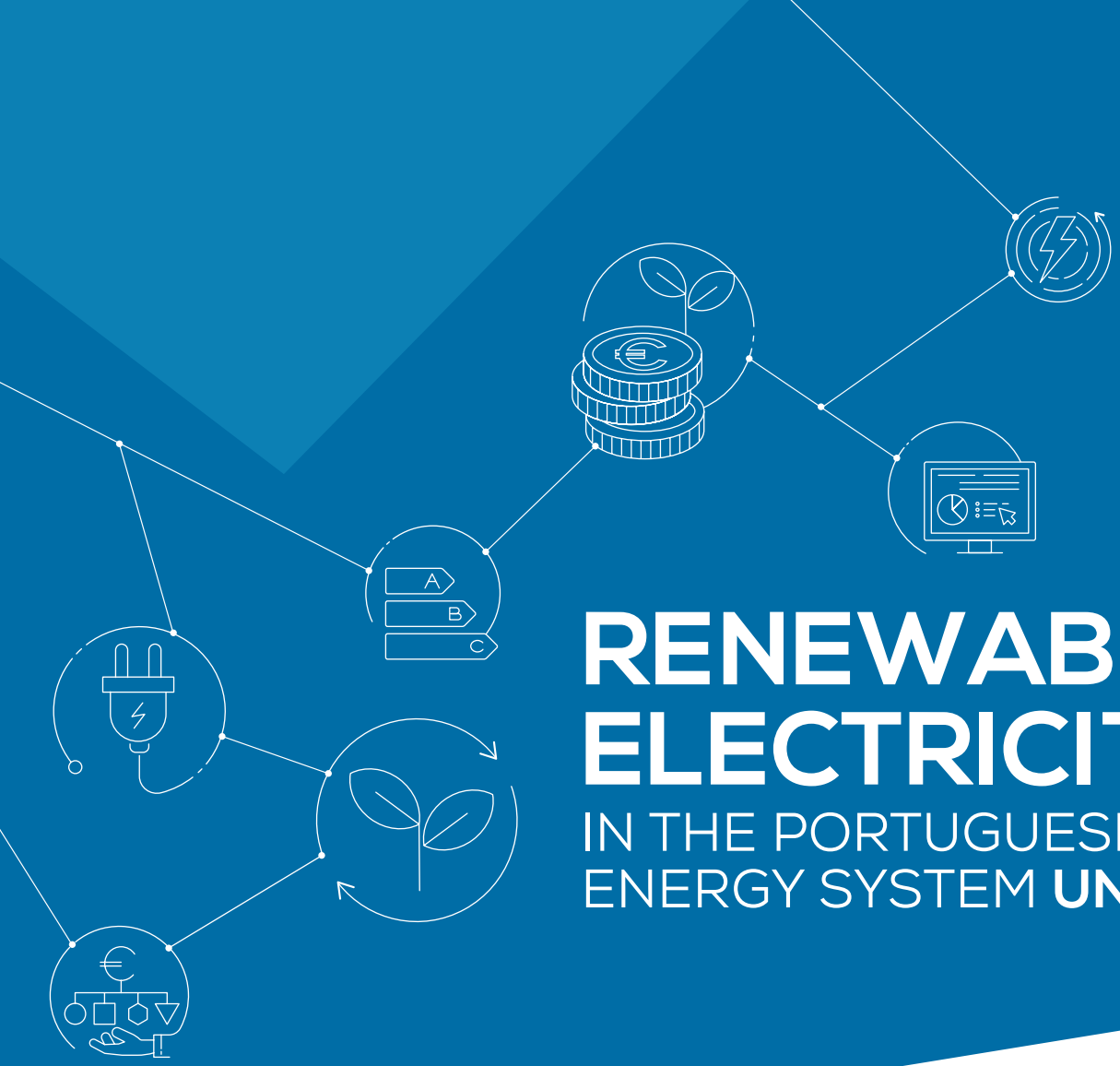
30 YEARS APREN



RENEWABLE ELECTRICITY

IN THE PORTUGUESE ENERGY SYSTEM **UNTIL 2050**

CENSE center for environmental and sustainability research

FCT FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA

APREN Associação de Energias Renováveis

TECHNICAL SHEET

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Renewable Electricity in the Portuguese Energy System until 2050

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CHALLENGES TO DECARBONISE UNTIL 2050

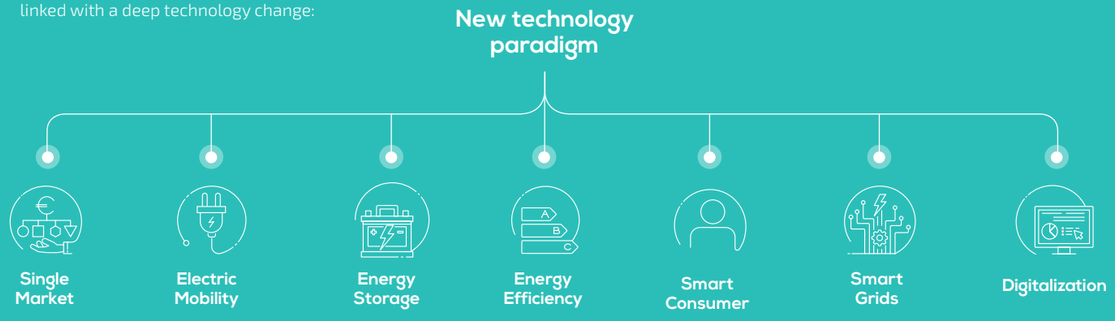
Until 2050
throughout the effort of all Member States, the EU aims to achieve a degree of decarbonisation between 80 and 95% over 1990 levels.

Portugal
is committed to achieve greenhouse gas emissions neutrality by the end of the first half of this century.

Transition
to a low-carbon, highly energy-efficient economy is an imperative goal for Europe.

Participation
active participation of society as a whole, involving citizens, businesses and academia.

Besides, the energy sector is in a paradigm shift that foresees a disruption linked with a deep technology change:



The broad lines of action are:

- Inform, empower and sensitize policy-makers, industry and citizens.
- Establish regulatory frameworks that fits the paradigm shift.
- Define strategies and plans that can promote stability and encourage cost-effective technologies' development.

THE ROLE OF **RENEWABLE ELECTRICITY**

Electrification
The electrification of the transport sector, industrial processes and heating and cooling is essential to achieve carbon neutrality.

Renewable technologies
are the most cost-effective vector for the decarbonisation of the electric power sector.

Renewable technologies
complemented by storage solutions and active demand response, promote security of supply and reduce energy dependence on fossil fuels.

The incorporation of more renewable technologies
into the system boosts research, development and innovation, as well as academia's cooperation with industry.

Leadership in competence and technology,
is still the key to a sustainable economy and for job creation.

Questions

1. What is the trajectory and the optimal technology profile for the electricity sector to ensure a low carbon economy?
2. What are the costs and benefits of the transition to a electricity system with more renewable penetration?
3. What is the impact of this transition in the energy sector and in the Portuguese economy?

To answer these questions a study was developed by CENSE – Center for Sustainability and Environmental Research, from the Faculty of Sciences and Technology of the New University of Lisbon, requested by APREN, which defines cost-effective trajectories for the transition of the electric power sector until 2050.

Decarbonisation scenarios were developed from 2015 to 2050, through a holistic approach of the Portuguese energy system, supported by an energy optimization model that includes: primary energy supply; the generation of electricity; the final energy consumption in industry, households, services, agriculture, forestry & fisheries and transport.

The main results are shown in this document. For more information please consult the complete report at **www.apren.pt.**

Scenarios 2050

CONSERVATIVE RES-E

Absence of specific targets for reducing GHG (Greenhouse Gases) emissions from the energy sector. Renewable electricity increases up to 60% of the production mix.

MITIGATION -60%

Reduction of GHG emissions from the energy sector up to -60% in 2050/1990.
The renewable penetration's increase is limited by the resource potential.

MITIGATION -75%

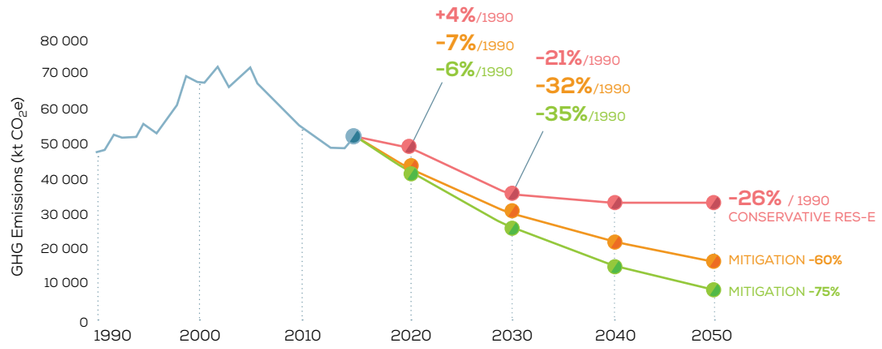
Reduction of GHG emissions from the energy sector up to -75% in 2050/1990[1].
The renewable penetration's increase is limited by the resource potential.

1. middle target of -60% in 2040/1990.

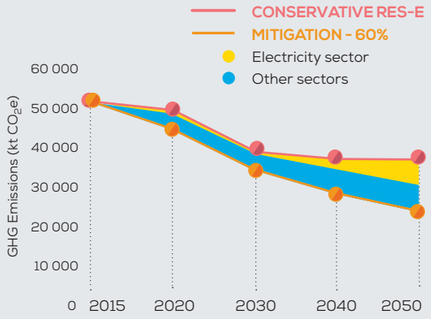
RENEWABLE ELECTRICITY FOR THE **DECARBONISATION OF THE PORTUGUESE ENERGY SYSTEM**

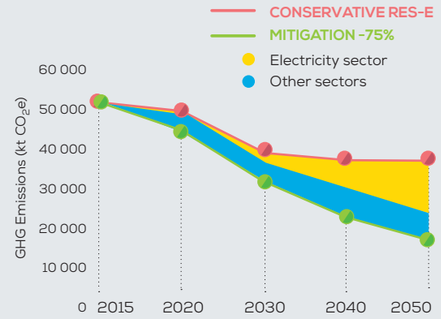
The emissions trajectory of the Portuguese energy system (including emissions from industrial processes) shows that without any specific GHG mitigation target for a renewable electricity ceiling of 60%, a reduction of -21% is achieved in 2030 and of -26% in 2050 compared to 1990, well below the mitigation trend necessary to achieve the objectives to which Portugal is committed.

GHG Emissions Trajectory of the Portuguese Energy System



Decarbonisation of the Portuguese Energy System – Sectors Contribution



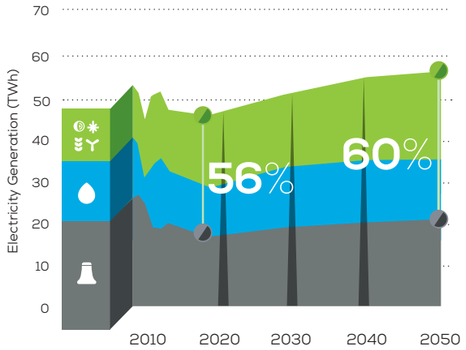


More than 1/3 of the effort to reduce GHG emissions will come from the electricity sector.

ELECTRICITY **GENERATION**

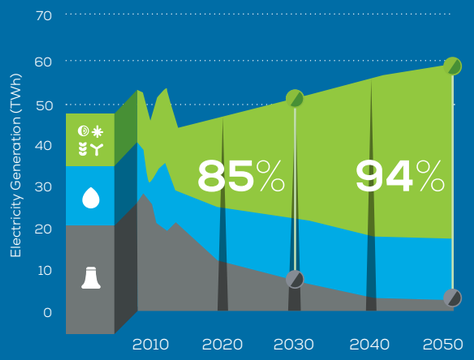
To achieve the required decarbonisation levels, the contribution of renewable electricity should be 85% by 2030 and 94% by 2050 (without including cogeneration). This contribution shows the important role of renewable electricity.

Conservative RES-E

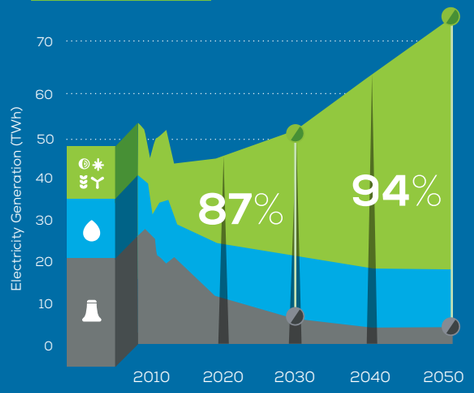


For ambitious decarbonisation levels, the share of renewable electricity reaches 94% in 2050.

Mitigation -60%



Mitigation -75%



Other renewables · Hydro · Fossil

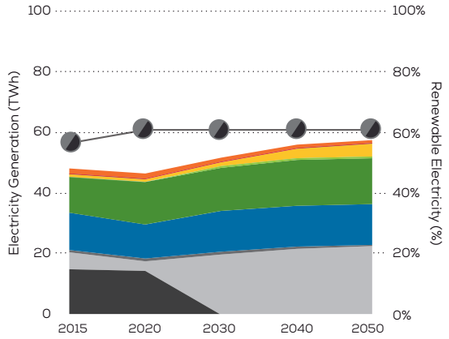
ELECTRICITY GENERATION **BY TECHNOLOGY**

Onshore wind could account for around 39% of the electricity generated in 2050 in the Mitigation scenarios.

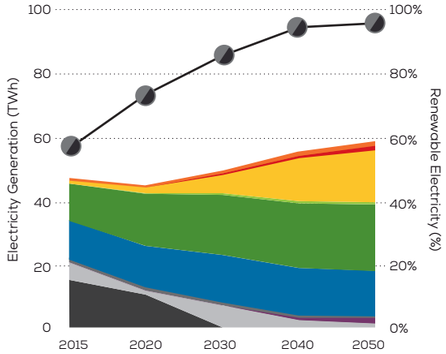
Solar PV will increase from the current share of 2% of the electricity production **to about 12 % to 14 % in 2030. In 2050, it could reach 30% of the production.**

In the Mitigation -75% scenario, where a significant increase in electricity demand takes place, offshore wind becomes cost-effective. In both decarbonisation scenarios, it is necessary to use emerging technologies that can ensure availability of supply in situations of renewable resources scarcity. In this exercise, Natural Gas with CCS (Carbon Capture and Sequestration) turned out cost-effective. However, this solution may be replaced by other large-scale storage technologies such as batteries and/or hydroelectric pumping.

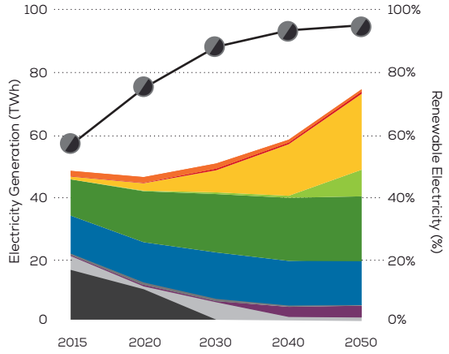
Conservative RES-E



Mitigation -60%



Mitigation -75%



Biomass · Geothermal · Solar · Wind Offshore · Wind Onshore · Hydro · Fuel · Natural Gas CSS · Natural Gas · Coal · RES-E (right axis)

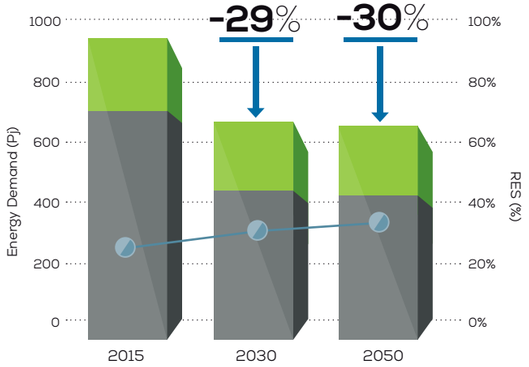
In 2050, Solar PV will represent 30% of the Portuguese electricity mix, while Wind will reach 39%.

PRIMARY ENERGY VS. RENEWABLE ENERGY

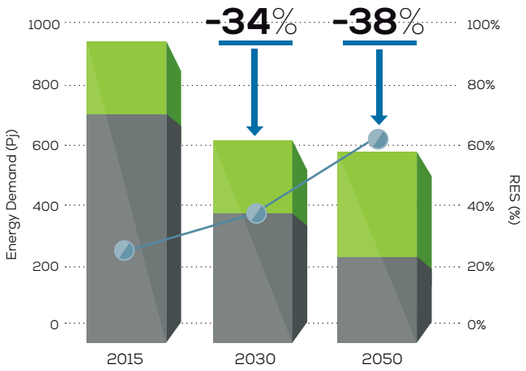
Primary energy consumption denotes a clear reduction in all 3 scenarios. In the Conservative RES-E scenario, the reduction is due to the implementation of more efficient technologies with higher potential for energy efficiency. In the Mitigation scenarios -60% and -75%, the reduction is more significant, due to a greater share of the electricity demand in several end-use technologies, generally more efficient than former fossil fuels based technologies.

The mitigation scenarios ensure a reduction in primary energy consumption of 38%, when compared to the current consumption. This is due, among other factors, to the larger share of high efficient end-use electric technologies.

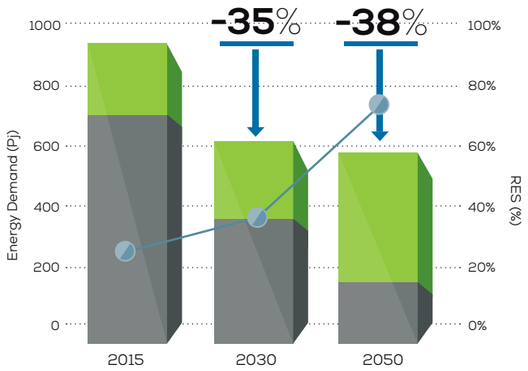
Conservative RES-E



Mitigation -60%



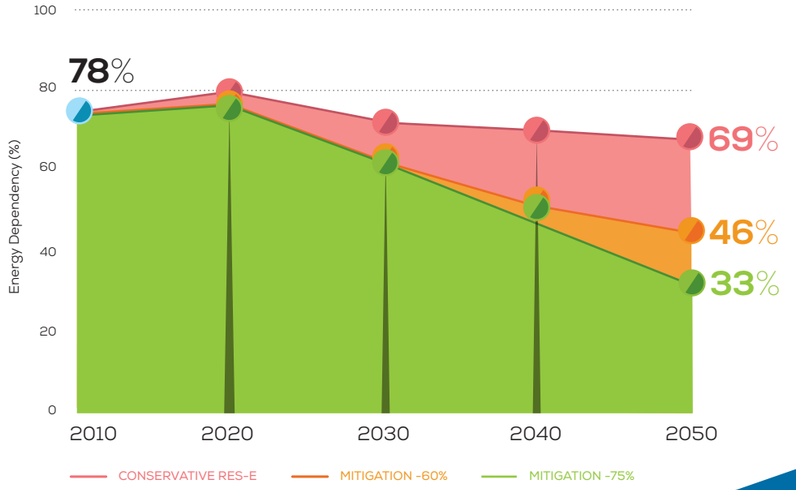
Mitigation -75%



X% = reduction in relation to 2015 · % Renewables · Fossil · Renewables

PORTUGUESE ENERGY DEPENDENCY

In the Conservative RES-E scenario, there is a slight reduction in the Portuguese energy dependency, from the current 78% to 69% in 2050. **In the scenarios of greater decarbonisation** ambition, the incorporation of higher values of renewable electricity, **could decrease the energy dependency, respectively, to 46% and 33%.**



The country's external energy dependence could decrease to 33% in the Mitigation -75% scenario, less than half the current value.

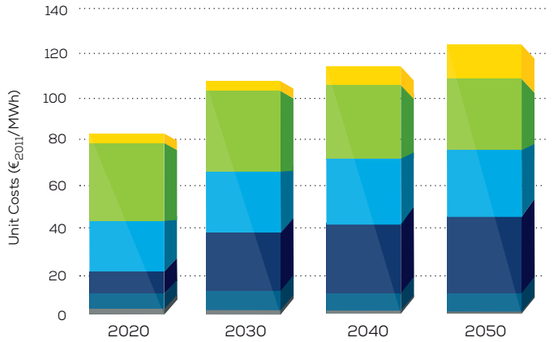
UNIT COSTS OF THE **ELECTRICITY SYSTEM**

The unit costs of the electricity system (electric power sector + transport and distribution (T&D) networks) **show a clear reduction in the mitigation scenarios where RES have a higher share.**

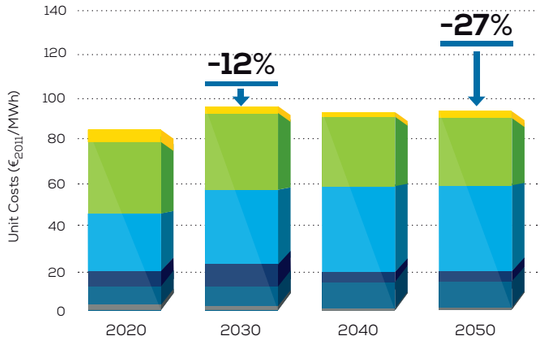
Regardless of the scenario or year, a production profile with a larger share of renewable energy leads to lower unit costs, between 22 and 27% depending on the mitigation scenarios. This is mainly due to the costs of fossil fuels, namely natural gas, and CO_2 permits, which account for more than 30% of the total cost by 2050 in the Conservative scenario.

The scenarios of GHG mitigation present unit costs lower than the Conservative scenario by more than 20%.

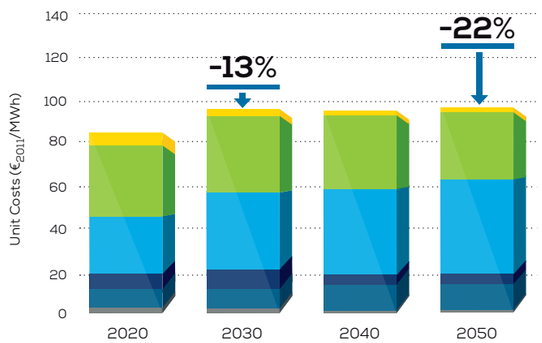
Conservative RES-E



Mitigation -60%



Mitigation -75%

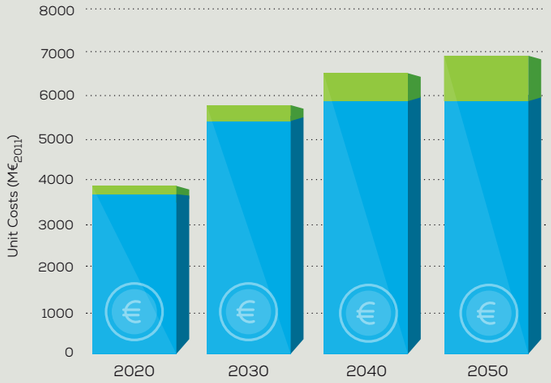


O&M - Variable | O&M Fixed | Networks | CAPEX | Networks | CO_2

X% = reduction in relation to the unit cost of the same year of the Conservative RES-E scenario

SAVINGS WITH **EMISSION PERMITS**

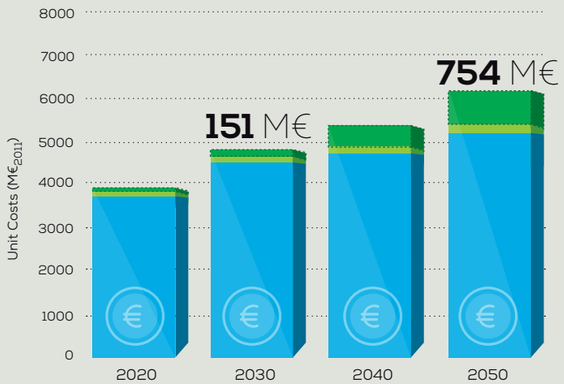
Conservative RES-E



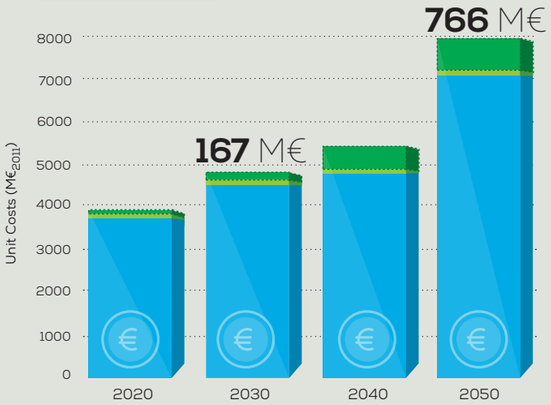
The savings due to the reduction in the purchase of emission permits may represent an annual average value of 370 M€ in the period between 2030 and 2050, and could reach more than 750 M€ in 2050.

Significant savings on CO_2 permits are expected in the mitigation scenarios and could reach 750 million € in 2050.

Mitigation -60%



Mitigation -75%



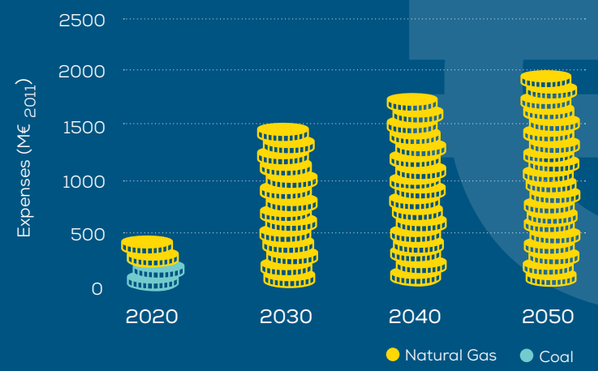
Other Costs | CO_2 Costs | Avoided costs with CO_2 permits in relation to the same year of the Conservative RES-E scenario.

ENERGY BILL OF THE **ELECTRICITY SECTOR**

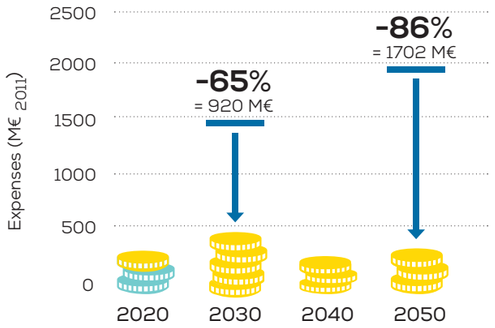
Energy savings in the electric power sector may reach annual values of more than € 1 billion in the mitigation scenarios, when compared to the Conservative RES-E scenario. **These savings are equivalent to 28% of the current Portuguese energy import balance**, and translates into a very positive impact on the Portuguese trade balance.

The decrease in the country's energy bill, in the mitigation scenarios, may exceed 1 000 M €, from 2030 onwards.

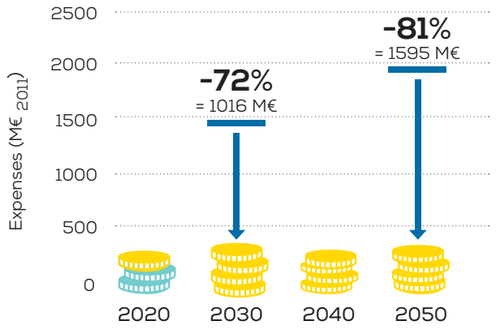
Conservative RES-E



Mitigation -60%



Mitigation -75%

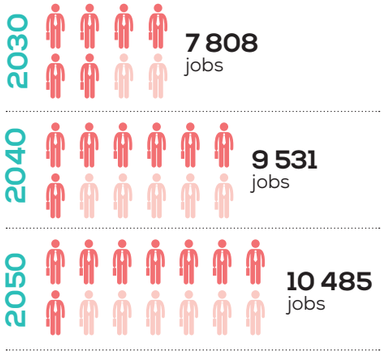


Natural Gas Coal X% in relation to the expenses of the same year of the Conservative RES-E scenario

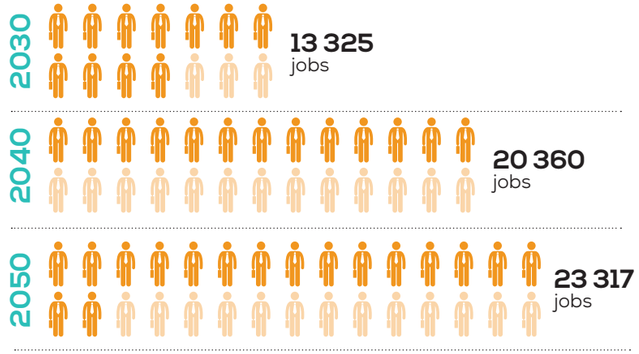
JOB **CREATION**

The scenarios with more renewable electricity are those that create more jobs. In 2050 the jobs created due an increase of renewable electricity are more than the double of jobs created in the Conservative RES-E scenario.

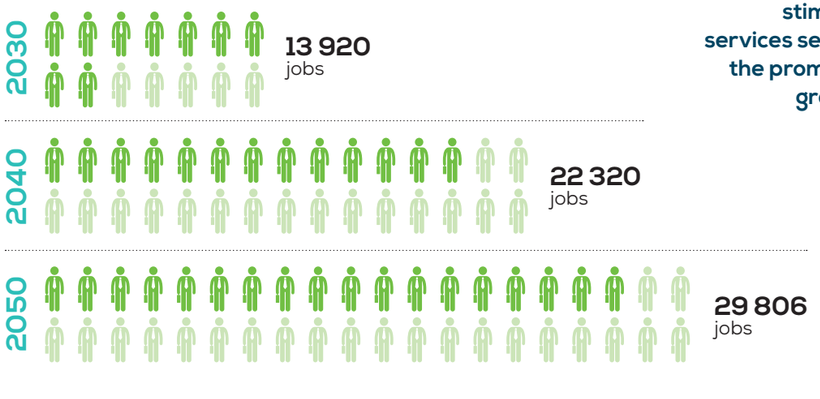
Conservative RES-E



Mitigation -60%



Mitigation -75%



The mitigation scenarios stimulate the industry and services sectors and R&D through the promotion of more jobs and greater competitiveness.

1 000 direct jobs in the O&M phase 1 000 direct jobs in the manufacture, construction and installation phases

CONCLUSIONS

- Using renewables to generate electricity (RES-E) is the most cost-effective way to decarbonise the Portuguese economy;
- Renewables play a dominant role in the generation of electricity (85% in 2030 and 90% in 2050 in the decarbonisation scenarios), with emphasis on hydropower, onshore wind and solar PV. In the 2050's horizon offshore wind reveals as a cost-effective solution in the scenarios of greater decarbonisation.
- In the scenarios of greater decarbonisation, offshore wind is cost effective in 2050;
- The most ambitious decarbonisation targets promote the electrification of final consumption, supported by RES-E technologies, since they are the most cost-effective for the energy system;
- High RES-E Mitigation scenarios have more benefits than the Conservative RES-E scenario, from an economic point of view, due to lower unit cost of electricity generation and from an environmental point of view, because of very significant GHG reductions, as well as from social point of view for creating more direct jobs and improving regional development.

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CENSE

CENSE – Center for Environmental and Sustainability Research – is devoted to the promotion of interdisciplinary research in environmental sciences and engineering, focusing in the interaction between human and ecological systems, to promote sustainable development. It is the research branch of a wider organization including researchers, students and staff from the Environmental Sciences and Engineering Department of the Faculty of Sciences and Technology of the New University of Lisbon, plus a number of affiliated organizations (teaching and research, business and public organizations). CENSE develops its activities through the promotion of research projects, outreach initiatives, training programs, collaboration with private and public organizations, dissemination of results and science-policy dialogues.

30 YEARS APREN

APREN

APREN - Portuguese Renewable Energy Association is a non-profit association, founded in October of 1988 with the mission of coordinate, represent and defend the common interests of its Associates in the promotion of renewable energies. APREN's Associates are companies holding power plants for electricity production from renewable sources under special regime, as well as, any individual or collective person interested in the development of renewable energy sources in Portugal. By the end of 2017, APREN represented around 93 % of the total installed capacity of electricity production from renewable sources.

APREN - Portuguese Renewable Energy Association
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