TECHNICAL REPORT

TOWARDS A CARBON NEUTRAL ECONOMY HOW IS PORTUGAL GOING TO CREATE EMPLOYMENT AND GROW?

TÉCNICO LISBOA

BCSD RESPONSIBLE BALANCE Business Council for Sustainable Development

MEET2030

BUSINESS, CLIMATE CHANGE AND ECONOMIC GROWTH

MEET 2030 imagine the future

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INTRODUCTION

1. INTRODUCTION

European and international policies demand a reduction in CO_2 emissions, so it is necessary for companies to think strategically about this subject, in such a way as to be able to position themselves competitively in the market in the medium and long term. In other words, it is necessary for companies to identify in what way this framework will affect their business, and which innovative processes it would be possible to develop so that the companies manage to maintain and increase their competitiveness in the future.

MEET 2030 is a project developed by BCSD Portugal in partnership with Instituto Superior Técnico from Universidade de Lisboa. It will contribute to the implementation of the Paris Agreement, which wants to obtain a low carbon economy in the second half of this century. MEET 2030 challenges BCSD Portugal affiliates to imagine the future – the project will transport companies into the unknown and propose opportunities for growth for Portuguese companies on the horizon of 2030.

The objectives of MEET 2030 were:

- To create scenarios for Portugal in 2030, in the context of the fourth industrial revolution taking into account national, European and worldwide compromises in orderto reach a low carbon economy, the challenges of the various economic sectors and the research which has been led by associates of the BCSD
- To identify potential new sectors of economic activity, innovation in products and processes and the competitive advantage necessary to enable companies to maintain sustainable growth in the long term
- To identify solutions with higher added value and contribute to a policy action, which permits us to define strategic priorities on a national and international level
- Two scenarios were developed for the Portuguese economy, with an additional variation in one of the two scenarios, resulting on 2+1 scenarios.

The focal issue of the scenarios was the Future of the Portuguese Economy...

> ... in the context of the fourth industrial revolution and the relationship between energy efficiency and economic growth ...
> ... taking into account the national and European commitment to achieving carbon neutrality.

The time horizon was 2030, but "with an eye on" the 2030-2050 period (i.e. we also considered changes that might occur beyond 2030).

"In a low carbon economy, how will Portugal be able to create jobs and grow?" is, for MEET 2030, the key background question anchoring the process.

The 2 scenarios were based on 25 structural variables[1] defined and evaluated by the participants in the workshops carried out. MEET 2030 made use of a participatory approach for scenario development. In MEET 2030, the stakeholders were the BCSD Portugal affiliates, but also, public entities such as the Portuguese Environment Agency (APA) and the Secretary of State for Industry. The whole process of MEET 2030 was centred around four workshops with the stakeholders and additional interactions with these, for developing scenarios for Portugal for 2030. Scenario development was combined with a modelling approach to explore the consequences of the different scenarios in economic, energy and climate change terms.

The participants in the workshops and meetings covered

1. Many Scenario planning exercises are developed using a much lower number of structural variables, for example, the "HybCO_2: Hybrid approaches to evaluate the economic, environmental and technological impact of long-term low carbon scenarios", the "World Energy Scenarios: Composing energy futures to 2050, WEC (World Energy Council)", and the "Germany 2064: The World of Our Children, A.T. Kearney".

a broad array of sectors, such as Airports, Food and Agriculture, Water, Food and Beverage, Automotive, Banking and Insurance, Construction, Energy, Forest, Waste Management, Industry and Retail, Infrastructures, Chemical, Services, Telecommunications and Transport. Developing scenarios with such a diverse range of structural variables (25) and with such a diverse array of participants was a challenging exercise, and the methodological option of including such a high number of structural variables was made to include the richness of the outcomes from participants.

This report presents the results from the project. MEET 2030 will result in scenarios for Portugal, but it is also a testament to an innovative process, which combines participatory scenario development with modelling and with the innovative concept of exergy and its link to GDP growth. In this sense, the outcomes of the project are the scenarios and the process itself.

The main outputs achieved were:

- The process of developing scenarios, combining a new economic model where exergy efficiency is key, with a participatory process for identifying uncertainties, quantifying variables and identifying technologies and policies that could lead to these scenarios;
- Having companies to think about the fourth industrial revolution, carbon neutrality and exergy efficiency, namely in terms of how the future might look like, what technologies, business models and policies could help companies to move forward. This was achieved throughout the workshops and the challenges provided;
- A list of uncertainties on the development of Portugal through to 2030;
- Two possible scenarios for Portugal for 2030;
- Recommendations or orientation guidelines for companies;
- Recommendations or orientations for policies to contribute to carbon neutrality, energy efficiency and economic growth.

This report is structured as follows. First, the report presents the vision adopted in MEET 2030 (Chapter 2), the relationship between economic growth and energy efficiency, analysing the energy history of Portugal in the last 100 years. Second, the report presents the processes followed within the project (Chapter 3), which was a scenario planning exercise involving four workshops with BCSD Portugal member associates spaced out in time with periods of desk research and systemisation of information between workshops. The resulting scenarios are presented in Chapter 4. The quantitative aspects were derived, in a participative manner, from the narratives of the scenarios, which in turn, were derived from the workshops held with the participating companies. Besides the narratives that frame the scenarios, particular aspects are explored in more detail given their GDP impact. These are labour, capital investment and total factor productivity (calculated based on aggregate energy efficiency).

2.

THE VISION OF MEET 2030

2. THE VISION OF MEET 2030

This Chapter presents the main concepts of MEET 2030. The hallmark of this project is the opportunity to leverage energy efficiency, understood broadly, as a means of creating economic growth. To increase energy efficiency, MEET 2030 takes its cue from the fourth industrial revolution. Increasing energy efficiency is commonly taken as a tool for decreasing GHG emissions from fossil fuels, but MEET 2030 also focuses on GHG emissions not associated to fossil fuels.

2.1. GHG EMISSIONS AND ENERGY EFFICIENCY

The focus of MEET 2030 is on the transition established by the Paris Agreement towards a low carbon or carbon neutral economy in the second half of the century. **The economy's contribution to greenhouse gas emissions comprises three components** (Figure 1).

Figure 1. The three components of GHG emissions

$$CO_{2,eq} = \underbrace{\frac{CO_{2,fossil}}{Energy} \cdot \frac{Energy}{GDP} \cdot GDP}_{\text{Emissions from fossil fuels}} + \underbrace{CO_{2,biogenic}}_{\text{Carbon cycle}} + \underbrace{CO_{2,eq,other\ gases}}_{\text{Methane, nitrous oxide, etc.}}$$

These three components are:

- **Emissions of carbon dioxide from the burning of fossil fuels** (oil, coal and natural gas).
- **Flows of carbon dioxide related to natural cycles that can be either emissions or sinks.** This comprises the burning of biomass or the loss of organic material from the soil, but also have the opposite: carbon dioxide taken out of the atmosphere through photosynthesis and retained as forest biomass or organic material in the soil. It is the only term in the equation that can be positive or negative. Moreover, all the forecasts in the Paris climate agreement consider that we will probably not manage to eliminate greenhouse gas emissions and therefore countries will need to compensate GHG emissions through carbon sinks ("negative emissions"), namely through biological processes.
- **Emissions of other greenhouse gases** such as methane, which come mostly from waste management and ruminants, or nitrous oxide, which comes mostly from the application of nitrogen fertilizers in agriculture and manure. It is usual to convert non carbon dioxide emissions to their equivalent in carbon dioxide, or $CO_{2\ eq}$.

Regarding carbon dioxide emissions derived from fossil fuels, we can further divide this term in three factors (Figure 1). The first concerns changing the quantity of carbon dioxide emitted by the energy system. When moving towards renewable energies, the so called "decarbonisation of the energy system", one is able to provide energy to the economy with fewer carbon dioxide emissions. Second, there is the improvement on energy efficiency, in the broadest sense understood as the energy intensity of GDP. Finally, there is the reduction of GDP itself. MEET 2030 focuses on these three terms, playing a special attention to the second: how can energy efficiency be increased (thereby reducing energy intensity) while at the same time encouraging economic growth (increasing GDP).

The three objectives, on which MEET 2030 will focus (linked with Figure 1), leveraging the opportunities offered by the 4th Industrial Revolution, are:

- increasing energy efficiency (reducing Energy/GDP),
- promoting biological carbon sequestration ($CO_{2,\ biogenic}$),
- reducing emissions of other greenhouse gases ($CO_{2\ eq,\ other\ gases}$).

Regarding massive digitalisation, the hallmark of the 4th Industrial Revolution, MEET 2030 aims mostly to look at how it can be used to increase energy efficiency, but also at how it can be used to encourage carbon sequestration through more efficient practices in forestry and agriculture, as well as to reduce methane and nitrogen oxide emissions.

An important feature of MEET 2030 is its broad ranging vision: it starts with climate but also seeks the maximum level of synergy with other areas and policies. On the one hand, climate change is not the only environmental and sustainability problem that humanity faces. On the other hand, by **creating synergies between climate policies and other policies**, one can achieve a much greater support and strength in order to move forward. One such synergy is the promotion of economic growth. The remaining synergies are:

- investment in natural capital: the ecosystems to be created/improved can promote biodiversity and ecosystem services;
- circular economy:
  - retaining carbon within the human system
  - reduced disposal of waste at landfills;
- climate mitigation (non-carbon) and adaptation;
- common agricultural policy:
  - carbon sequestration
  - land use changes
  - increased efficiency in agriculture and forestry.

Investment in natural capital, in particular that associated with carbon sequestration, can be done by promoting, in the right ways, the expansion and productivity of forests, or the sequestration of carbon in soil by increasing organic matter (and thereby fertility). By doing this, one has the opportunity to create higher quality and more extensive ecosystems, which will help to promote biodiversity and ecosystem services.

The more society manages to keep carbon circulating, or retain it – for example, by using wood in construction – the more society will be following a circular economy approach, keeping resources circulating within the human system, as opposed to constantly extracting them from nature and sending them to destinations that impact nature all around us.
There are synergies with climate change mitigation (beyond greenhouse gas emissions) and adaptation to climate changes. For example, the creation of green areas or forests in urban areas not only sequesters carbon (mitigation) but also reduces the average temperature of cities (adaptation). Finally, there are synergies with the Common Agricultural Policy (CAP), the most significant European Union policy in budget terms (38%), given that issues relating to methane, nitrogen oxide, woodland, soils etc. are interlinked with the activities covered by the CAP.

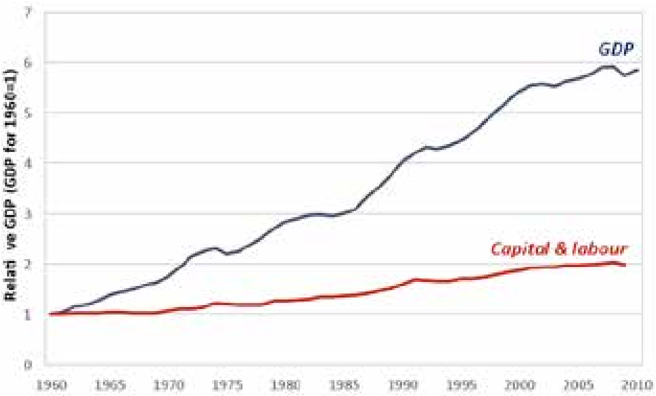
2.2. THE ROLE OF ENERGY EFFICIENCY IN THE GROWTH OF ECONOMIES

We now focus on of the link between energy efficiency and economic growth in Portugal over the last fifty years.
Figure 2 presents the evolution of GDP with the starting year 1960 as a base (i.e. GDP for 1960=1). The annual growth rate was initially very fast, around 5-6%, then fell to around 3% and over the last 15 years was stagnant at around 0.5%.

Figure 2. Gross Domestic Product for the Portuguese economy (1960-2010) [Source: AMECO]

In order to encourage economic growth, one must understand what causes it. Economists believe that there are two key factors, the so-called primary factors of production, which enable economic value to be generated: labour (for example, measured by the number of hours worked by people) and capital (understood as the services provided by the set of factories, machines, road infrastructure and vehicles, amongst others). The contribution of each of these two factors to GDP is taken proportional to what each receives from GDP. Roughly speaking, on average and across the world, 1/3 of the income generated by GDP is paid to capital (in the form of interest, rents and dividends) and 2/3 to labour (in the form of wages). Thus, it is natural to think that the contribution to GDP of capital is 1/3 and that of labour is 2/3. Figure 3 presents this estimate, using for each year, the contributions of 1/3×capital + 2/3×labour. The result obtained is that capital and labour cannot explain economic growth by themselves, a fact originally discovered by Nobel-prize winning economist Robert Solow, in the 1950s, for the USA.

Figure 3. Contribution of capital and labour for Gross Domestic Product for the Portuguese economy (1960-2010) [Source: AMECO]

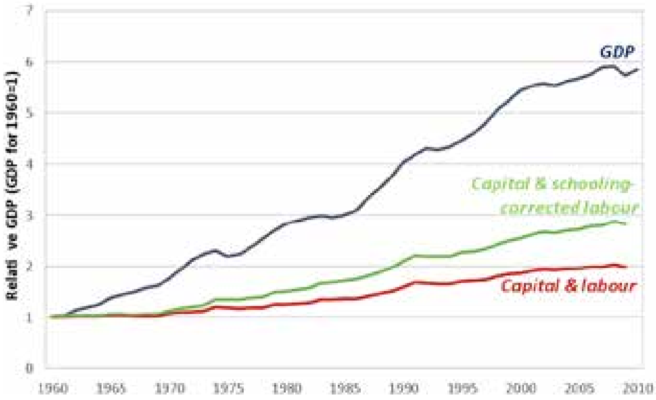


Over the last 50 years, Portuguese GDP increased 6 times, but the contribution from the increases in capital and in labour (mostly in capital, since the number of hours worked in Portugal 50 years ago was less than today's, but not significantly less) in this same period would only have led the economy to double its size. If the Portuguese economy had only grown due to the accumulation of capital and labour, today we would have a GDP equal to that of 1970, i.e., we would be living with the material resources that we had in 1970.

The huge difference that we see between GDP and the contribution from capital and labour is the unexplained part of economic growth, which was originally named the Solow Residual (residual because it is the difference between actual GDP growth and the growth that would be expected due to the accumulation of capital and labour) or growth in *total factor productivity.*

In an attempt to solve this puzzle, economists have looked at a wide range of factors. One such factors is the level of education of the labour force. Although the number of hours worked in Portugal nowadays is only marginally higher than those worked in 1960, the hours worked today come from a much more skilled workforce. Figure 4 presents the contribution to GDP of capital and labour corrected according to years of schooling. With this correction, the Solow Residual is smaller but most of GDP growth still remains to be explained.

Figure 4. Estimated contribution to GDP from the combination of capital and schooling-corrected labour (1960-2010) [Source: AMECO; Feenstra et al. (2015)]



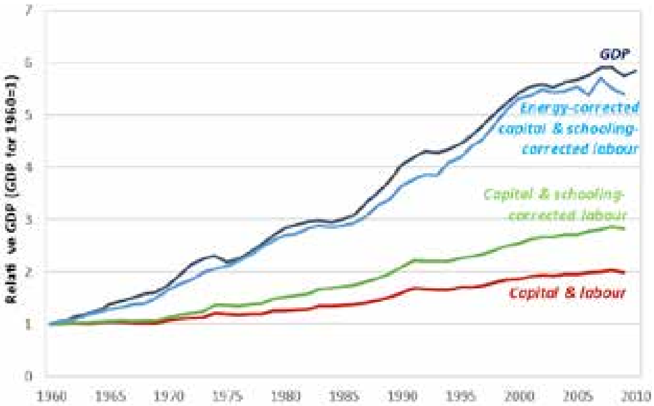
MEET 2030 is based on the hypothesis first proposed fifteen years ago by Robert Ayres and Benjamin Warr that the use of energy (adequately measured) can explain the increase in total factor productivity.

Humanity's great era of economic growth began in England in the 18th century and it was based on the intensive use of energy from fossil fuels. Energy was not the only cause, but it was clearly an essential and fundamental cause of economic growth. This is because machines enable workers to become more productive and energy is what makes machines work. 300 years ago, in England, to work the land, a farmer used one horse that pulled a plough. Nowadays, a farmer in England uses a 100 horsepower tractor to pull a much bigger plough. The farmer controls the power of 100 horses and so does 100 times more and produces 100 times more than one farmer did 300 years ago. So, today, one farmer can produce food for 100 people and only 1% of the English population is involved in agriculture while the other 99% are free to do other things.

This increase in work productivity, which is key to economic growth, and the prosperity that it brings with it, necessarily requires the use of energy, which requires machines. Machines play a fundamental role because they provide energy for societies to control and do things. A computer requires energy, a tractor requires energy, humans need to eat, and humans need light. Absolutely nothing happens in the universe without energy. And the way for people to be more productive is to control more energy through machines, which then allow people to do more than they are able to do on their own.

Santos *et al.* (2016) have been able to formalise this intuition, under what we can call the concept of "energy corrected capital", and empirically measure it, using econometric tools. So, we adjust the capital in Figure 3 and Figure 4 to take into account the fact that machines today can control much more energy than they were able to in the past. This corrected measure of capital takes into account the fact that a farmer with a 100 horsepower tractor is 100 times more productive than a farmer with a horse, but, currently this tractor only costs 10 times more than a horse. Figure 5 shows that with energy corrected capital and schooling corrected labour, the Solow Residual disappears, i.e., **energy corrected capital explains the increase in total factor productivity.** The monetary value of machines, such as tractors, does not express their contribution in terms of productivity. So we understand why conventional economic statistics do not capture the causes of economic growth, while a measure based on energy succeeds in doing so.

Figure 5. Estimated contribution to GDP from the combination of energy-corrected capital and schooling-corrected labour inputs to production (1960-2010) [Source: AMECO; Feenstra et al. (2015); Serrenho et al. (2016)]



Thus, **the ability that capital has of providing energy to do useful things and to make society more productive explains the entire growth of GDP**. However, it is important to bear in mind that having machines succeeding in controlling more energy is not enough to provide economic growth. New business models, management innovations, logistic systems, etc., are also required (the development block of Kander *et al.*, 2014). What we are saying is that the increase in **energy efficiency is a necessary condition for economic growth**.

The most obvious example, widely studied in the economic history literature, is the use of electricity in the 2nd Industrial Revolution. By being able to have electricity at any location in the factory, we were also able to have machines ("machine tools"), from small to large ones (power drills, soldering machines, etc.), anywhere in the factory. And so we achieved the great innovation of the 2nd Industrial Revolution: mass production with the use of machine tools. However, what produced a huge leap in total factor productivity was an energy revolution: electricity, which enabled each worker in a factory to control more energy, to have by his side the power drill, the soldering machine anywhere in the factory. This, coupled with the necessary management innovation, was what allowed factories to be radically reorganized and to produce a gigantic leap in total factor productivity.

2.3. WHAT IS USEFUL EXERGY?

We have seen that the concept of useful exergy is key in our understanding of the role of energy in economic growth. Let us now disentangle its meaning.

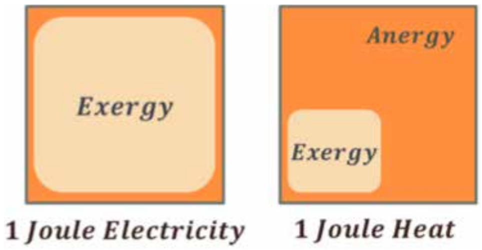
Let us begin with the concept of exergy. The following phrase might look familiar to many us:

*Light bulbs **consume** energy.*

In the strict sense of the term, this sentence is not correct. Lavoisier enunciated in the 18th century the law of physics which states that "in nature, nothing is created, nothing is lost, and everything is transformed". In particular, **energy is not created and is not lost, it is only transformed.** Strictly speaking, a lightbulb does not consume energy, it transforms electrical energy into light and heat. The energy of this light and heat is the same as that of the electricity, but with the light and heat one can do much less than with the electricity. **Exergy expresses the ability of energy to do things**. Technically, the electricity that entered the bulb had a higher exergy than the light and heat that came out (Figure 6), so the correct statement in fact is:

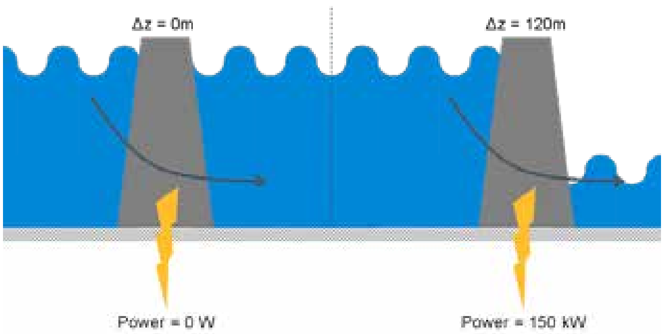
*Light bulbs consume **exergy.***

Figure 6. Illustrative example of the concept of exergy for electricity and heat



Let us consider another example: a dam with a full reservoir, in two different situations, in which the water in the reservoir has the same energy (Figure 7). In the first situation, the level of the water downstream is the same as the level upstream. In this case, nothing is done with the energy of the water; in particular, no electricity is produced. In the second situation, the water downstream is at a lower level, and electricity can be produced because there is a natural tendency for water to flow from one side to the other.

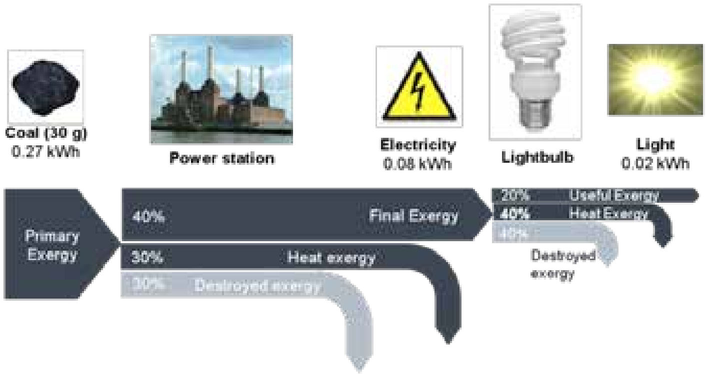
Figure 7. Illustrative example of the thermodynamic concept of exergy



In the first situation, the water is in equilibrium and so nothing happens; the exergy of the water in the reservoir is zero. In the second situation, the water is in disequilibrium, and we can take advantage of this disequilibrium to produce electricity; the exergy of the water in the reservoir is non-zero.

We turn now from the concept of exergy to that of useful exergy, associated with the definitions of primary, final and useful stages in the chain of energy transformation in society (Figure 8).

Figure 8. Illustrative example of exergy flows in the economy



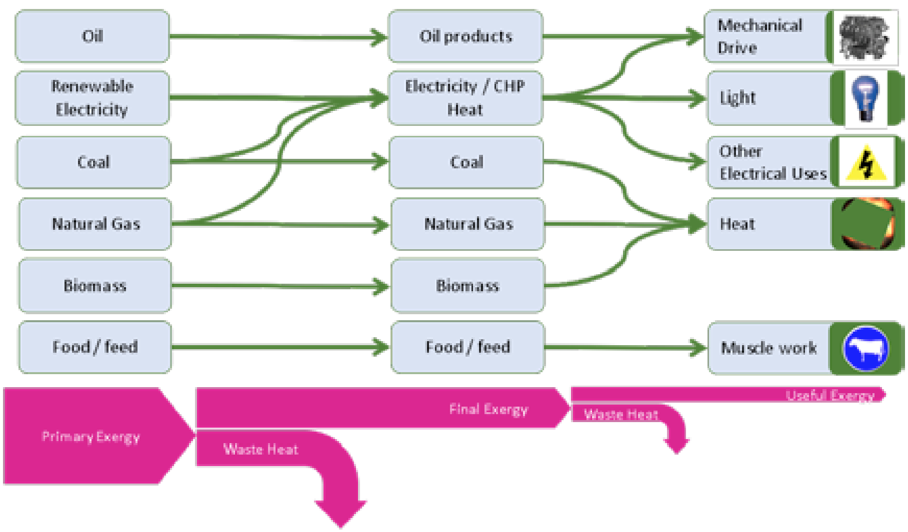
Primary exergy is, for example, the coal under the ground. It is called primary because it has not yet been subjected to any form of human intervention. This coal is extracted and used in a thermoelectric power station, where it is transformed into electricity. Electricity is final exergy, which is sold by a utility in the energy sector. Final exergy is the commercialised form of energy. The electricity enters a lightbulb and is transformed into light. This is the stage that we call useful and it is the one that we are interested in, because what creates economic value is the light that comes out of the light bulb, not the electricity that goes into it. To understand the relationship between energy and economic growth, one needs to look at the useful stage and not only at the primary and final stages, the ones commonly considered.

Whenever energy is transformed, exergy is always destroyed (e.g., the transformation of electricity into light and heat in a lightbulb). Exergy can only be destroyed, but never created[2]. Thus, in the conversions described above, from primary to final exergy, or from final to useful, the efficiency is always less than 100%.

Primary exergy can be divided into oil, hydroelectricity and other renewable sources, coal, natural gas, biomass for energy use; food for humans and feed for working animals (see Figure 9). Final exergy can be divided into categories, also called energy vectors, essentially the same categories as for primary exergy, with the exception of electricity (now all of it, both from renewable and non-renewable sources) and oil products (e.g., gasoline). Useful exergy categories are: mechanical drive (MD) (the work done by stationary motors, such as electrical motors in a factory or a dish washing machine, and by mobile motors such as vehicles, trains and aeroplanes), light, other electrical uses (OE) (computers and all information technology hardware), heat,

and muscle work (the latter was important 50 years ago but has lost relevance to mechanical drive in recent decades and it is not considered for calculations).

Figure 9. Categories of primary exergy (left), final exergy (centre), and useful exergy (right)



2.4. EXERGY AND THE ECONOMY IN PORTUGAL

Let us look at the components of final and useful exergy in the Portuguese economy. Figure 10 presents presents the evolution in the composition of final exergy in Portugal over the last 150 years. Before the first industrial revolution, the energy vectors were essentially food for people and feed for working animals, and firewood for heating and cooking in homes and for small manufacturing activities.

With the first industrial revolution (1st IR), coal usage starts to increase, linked to the use of the steam engine and other uses of heat. The percentage used for feeding people and animals falls steadily.

In the middle of the 20th century, the second industrial revolution (2nd IR) started in Portugal with the arrival of electricity, in particular for electrical motors, and of oil derivatives, such as petrol and diesel for internal combustion engines. From the middle of the 20th century up to today, there has been a steady increase in the percentage of electricity and oil derivatives, and the arrival, though at a smaller scale, of natural gas.

In the 70s, 80s and 90s, the third industrial revolution (3rd IR) starts, involving the revolution triggered by the personal computer and the internet. In contrast to the 1st IR, clearly marked by the start of coal usage, and the 2nd IR, clearly marked by the use of electricity and products derived from oil derivatives, the 3rd IR didn't have an impact in terms of the energy system (although it did have a large impact on our lives).

2. A consequence of the Second Law of Thermodynamics, which states that entropy can only be created and not destroyed (although it can be transferred from one system to another).

Figure 10. Composition of final exergy [Source: Serrenho et al. (2016)]

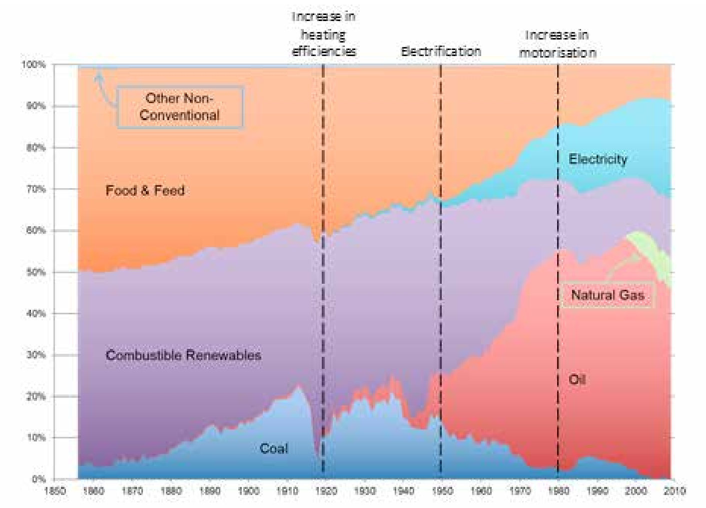


Figure 11. Composition of useful exergy [Source: Serrenho et al. (2016)]

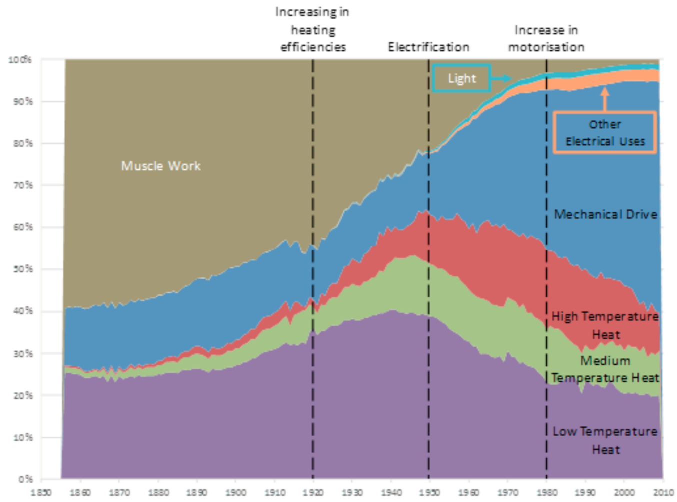


Figure 11 presents the evolution of the categories of useful exergy. These categories are especially important because it is through useful exergy that we can succeed in explaining economic growth. 150 years ago, in an agriculture and forestry based economy, the most important category was muscle work (people and working animals), and this gradually decreases over time; the uses of heat (divided into three levels: low, medium and high temperature) increase with the advent of the 1st IR (coal is used for thermal purposes and for mechanical work such as steam engines in locomotives and factories). When we reach the middle of the 20th century, the 2nd IR arrives, with electric motors and internal combustion engines (passenger cars, lorries etc.) and the concomitant increase in mechanical work, mainly related to the use of electrical motors in factories. Later, we glimpse some signs, but small, of the 3rd IR, since other uses of electricity increase but not significantly.

Let us look now at aggregate exergy efficiency in the Portuguese economy, measured as our ability to convert final exergy (petrol, diesel, electricity etc.) into useful exergy (mechanical work, heat, light): in other words, our capacity to use energy resources to create economic value. For this, we will consider two graphs – final exergy and useful exergy in Portugal over 150 years – where useful exergy is lower than final exergy because the conversion efficiency is necessarily less than 100% (Figure 12).

Figure 12. Final and useful exergy consumption [Source: Serrenho et al. (2016)]

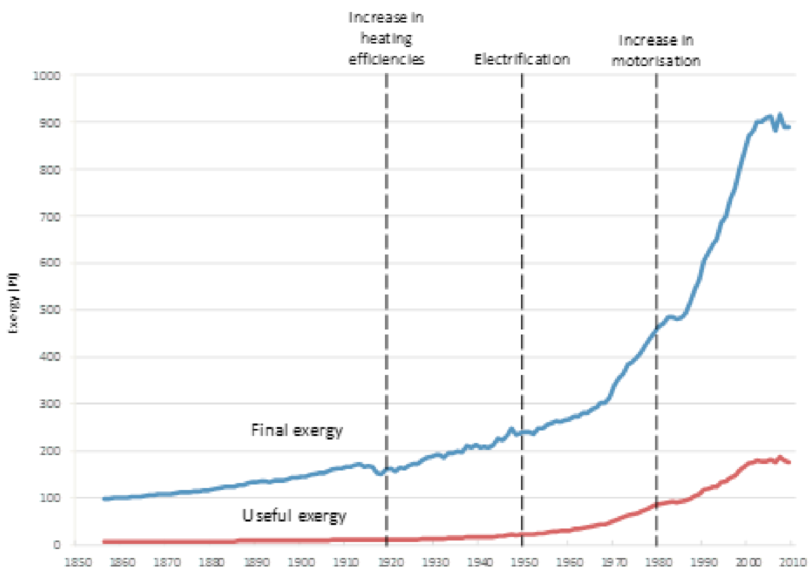
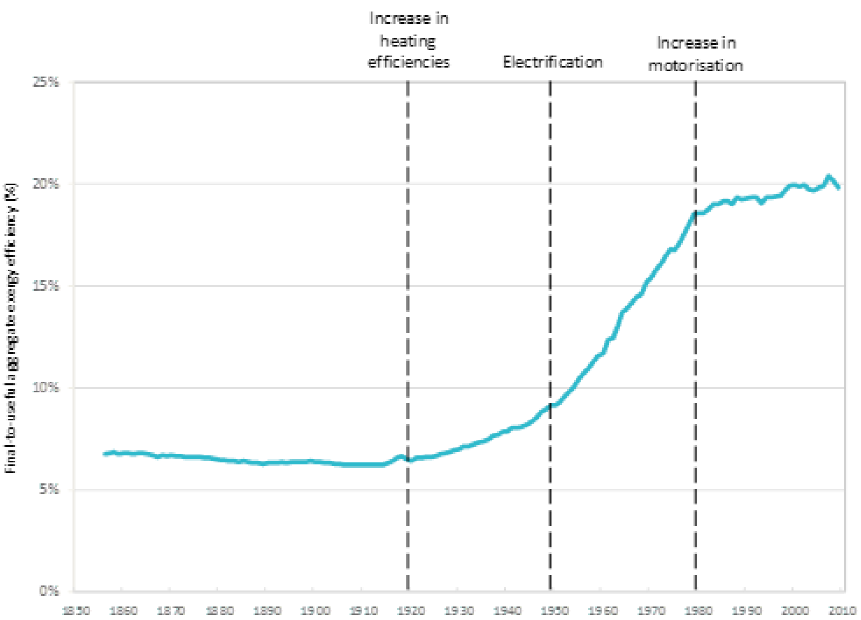


Figure 13 presents the ratio between useful and final exergy, the aggregate exergy efficiency, which can vary between 0% and 100%.

Figure 13. Final-to-useful aggregate exergy efficiency 1856-2009 [Source: Serrenho et al. (2016)]



In the beginning, the curve is stagnant, around 7%. In the 1st IR, with the arrival of steam and the use of coal for high temperature uses, we see a small increase in efficiency. The only time in 150 years that energy efficiency increases significantly is between 1950 and 1980 with a huge jump from 7% to 20%, mainly due to the introduction of electrification, associated with stationary motors, in particular electrical machines used in factories. From 1980 to now, we see a slow increase, because even though electrical machines have efficiencies between 70% and 90% and are still increasing their share, the efficiencies of the diesel and gasoline internal combustion engines are between 10% to 12% and are increasing their share even faster. Also, heat uses with higher efficiencies than internal combustion engines (for temperatures higher than 200ºC) have been decreasing their shares. Current average efficiencies of heat, mechanical drive, light and other electrical uses are shown in Table 1.

Table 1. Current final-to-useful efficiencies for Heat and Mechanical Drive end-uses [Source: Serrenho et al. (2016)]

Heat uses							
HTH (>500ºC)	**MTH (500-120ºC)**	**LTH1 (120-90ºC)**	**LTH2 (90-50ºC)**		**LTH2 (90-50ºC)**		**LTH3(<50ºC)**
46%	26%	19%	14%		14%		9%
Mechanical Drive uses							
Gasoline / LPG	**Diesel**	**Aviation**	**Navigation**	**Diesel-Electric**	**NG vehicles**	**SMD (electric)**	**SMD (other carriers)**
10%	12%	27-31%	39%	25%	8%	85-88%	38-40%
Other electrical uses				**Light**			
11-7%				14-16%			

Summing up, there have been three distinct periods: stagnation, a major increase due to the 2nd IR and electricity, and, once again, stagnation.

We now look at intensities, the energy required per unit of GDP, considering both final exergy (the stage usually considered) and useful exergy (Figure 14). Along these 150 years the final exergy/GDP ratio falls and in particular falls very quickly during the 2nd IR and later stagnates, while the useful exergy/GDP ratio stays relatively constant (note that the ratio of these two curves is the aggregate efficiency in Figure 13).

Figure 14. Final and useful exergy intensities (Portugal, 1856-2009)
[Source: Serrenho et al. (2016)]

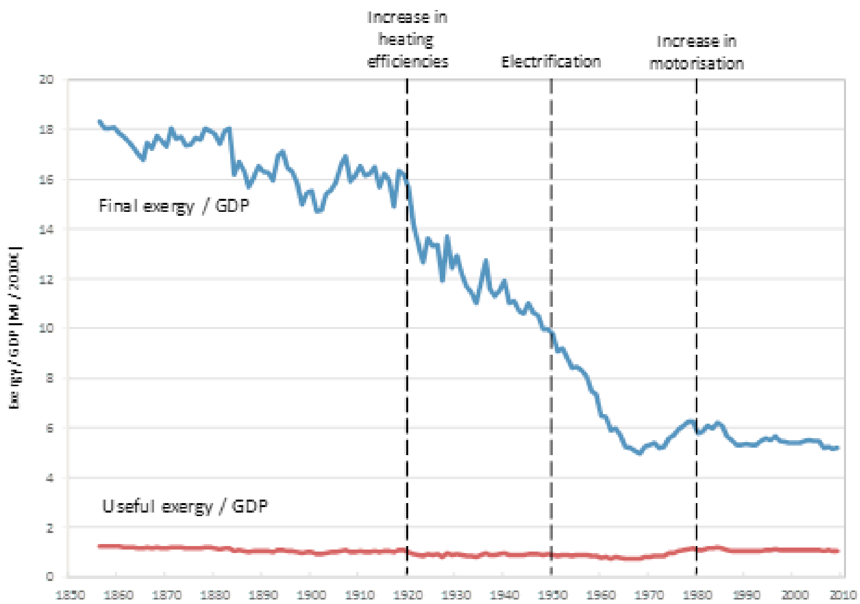
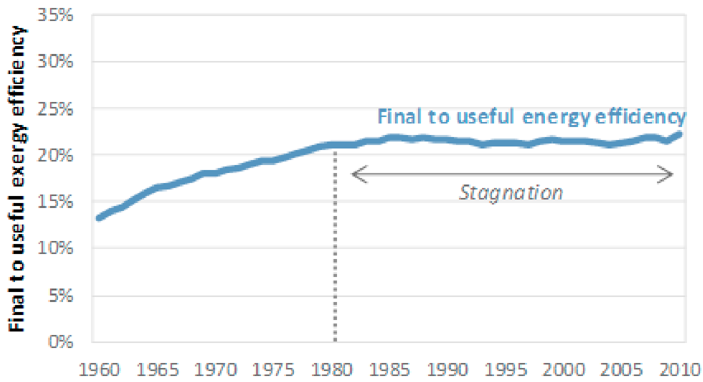


Figure 15. Final-to-useful aggregate exergy efficiency in Portugal, 1960-2010
[Source: Serrenho et at. (2016)]

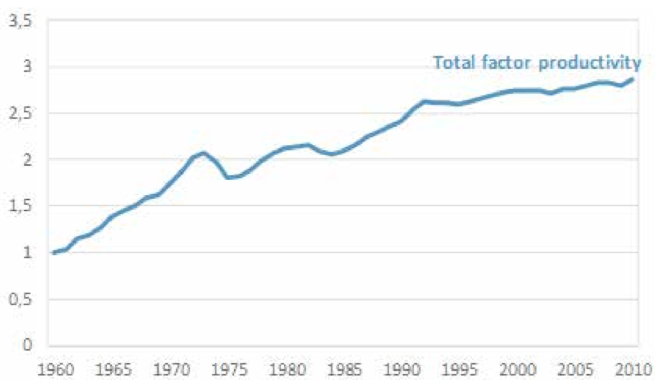


We can see the impact in particular when we look at total factor productivity (Figure 16), with the same pattern of first growth and then stagnation.

So, **150 years ago we needed 1MJ of useful exergy per unit (1€ in 2010 prices) of GDP and today, 150 years later, we continue to need 1MJ of useful exergy per 1€ of GDP.** 150 years ago, we needed 1MJ of useful exergy to produce 1€ of potatoes and wheat, while today we need 1MJ to produce 1€ of an economy which comprises education, health, retail and a little agriculture and industry. Note that, although this ratio has been constant up to now, this does not mean that we cannot change it in the future, if different policies from those used in the past are applied.

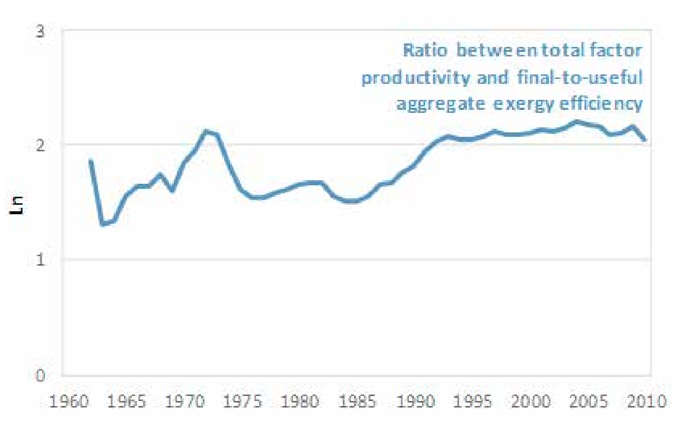
Let us now focus on the evolution of final-to-useful aggregate exergy efficiency in the last 50 years. **It grew strongly from 1960 to 1980 and was stagnant from 1980 to 2010** (Figure 15).

Figure 16. Total factor productivity (1960 = 1)
[Source: AMECO]



Taking the ratio of total factor productivity (Figure 16) to aggregate exergy efficiency (Figure 15), we see that it is roughly constant (Figure 17), i.e., **exergy efficiency is closely linked to total factor productivity and economic growth.**

Figure 17. Ratio (in logarithms) between total factor productivity and final-to-useful aggregate exergy efficiency [Source: Serrenho et al. (2016); AMECO]



2.5. THE FOUR INDUSTRIAL REVOLUTIONS

We have been using the following nomenclature: the 1st industrial revolution (IR) associated with the steam engine; the 2nd IR based on electricity and the internal combustion engine; and the 3rd IR based on computing, personal computers, the microprocessor, and the internet; and the 4th IR, which we are living through today, with the massification of information to a level that did not exist in the 3rd IR and with the "link" of information technologies and communication to the physical world.

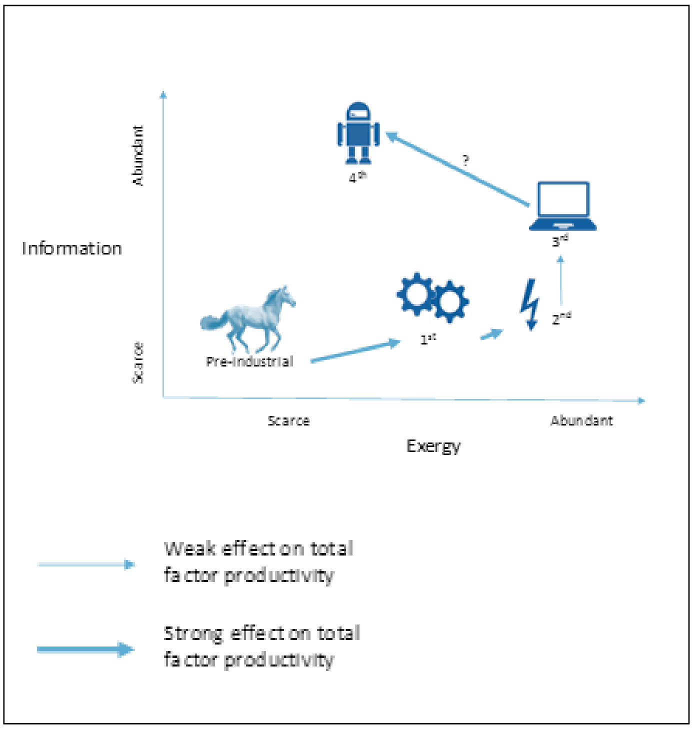
In the 3rd IR, information technologies revolutionised our lives in terms of communication and information management: smartphones, internet, streaming, videos, airline ticket management, etc.

The 4th IR can be seen as the moment when information technologies connect to the physical world. Beginning with the so-called internet of things, which refers to having all physical equipment – fridge, smartphone, car, etc. – with built-in sensors and processors that can communicate with each other. In other words, **information technologies that are much more apt to collect information from the physical world, have the ability to manage and process massive quantities of information** – called big data – and, using this information, build and use algorithms, ***machine learning* and artificial intelligence**, which generate actions to be carried out in the real world. These actions could be robots to be used in industry, forestry, agriculture, or other kinds of automation in all systems with which we work and interact.

Both the 3rd and the 4th IRs are characterised by the huge quantity and volume of information (although much larger in the 4th). **What marks out the 4th and which is extremely important for us is that its technologies are strongly linked to the physical world**, whereas, in the 3rd, they essentially worked in immaterial worlds which brought many benefits.

Figure 18 presents a schematic diagram of the role of energy and information in the industrial revolutions.

Figure 18. Schematic diagram of the role of energy and information in the industrial revolutions



We have two axes, one of which is energy (scarce or abundant) and the other is information (scarce or abundant):

- Before the industrial revolution, we had little of either: our human activity had little energy and information.
- In the 1st IR, with the arrival of coal, a new energy source and a sudden energy transition, we advanced strongly along the energy axis and we increased a little along the information axis (at this time, science developed, Newton's theory of mechanics appeared and engineering advanced).
- In the 2nd IR, another energy source appears (oil and later natural gas). Thus, energy became even more abundant and information continued to slowly grow.
- In the 3rd IR, we do not see a major increase in energy; as we have already pointed out, the 3rd IR is something that does not register on the energy graphs – and we do not see it because the 3rd IR was about information and not about action in the physical world.
- And now, in the 4th IR, the challenge facing us – and which arises from environmental constraints – is that we have to make an energy transition (which did not exist in the 3rd IR) in a direction which is quite the opposite of the previous two IRs.

The energy transition that we now need is more difficult to obtain, because the energy transitions of the past had to do with moving from disperse energy sources (wind, water and sun), to concentrated energy sources (coal, oil, natural gas). This time, we must do the opposite: **we have to return to the disperse energy sources.** And how are we going to turn back in terms of energy without turning back the prosperity of humanity? **Digital and information technologies are precisely the tools that can provide society with the capability to manage this energy transition.** With information technologies, societies can control energy in a much more precise manner: controlling wind farms; controlling photovoltaic panels; controlling an electrical network into which are being fed intermittent sources of energy and from which it is necessary to store the electrical energy in car batteries.

The other element in Figure 18 is total factor productivity growth. The thicker arrows in this figure indicate that there were major increases in total factor productivity (TFP) associated with increases in energy efficiency. In the 3rd IR, the increase in total factor productivity was zero. This is a known problem, called "secular stagnation", where, over the last 40 years, the developed economies have had some economic growth but total factor productivity growth has been close to zero, i.e. all growth has been at the cost of increasing working hours and investment in capital.

The opportunity that MEET 2030 explores is to shift from the 3rd to the 4th Industrial Revolution by significantly increasing total factor productivity. MEET 2030 aims exploring to achieve this through the use of information technologies and the creation of new business models associated to the energy transition.

Let us now explore what can be the main characteristics of a sustainable fourth industrial revolution, along five main axes: capital, labour, exergy, information, institutions[3].
Examining these five axes, we can begin to put forward ideas which could be the building blocks for new business models.

Regarding information, examples are the massive gathering of data, massive transport and storage of data, and massive processing of data.

Regarding capital, the important key element of the fourth industrial revolution cannot be – given what we are seeking of it – the massive use of energy, as was the case with the steam engine and the internal combustion engine in the 1st and 2nd IRs. It must be achieved with a more efficient use of capital, which is we can call "matching capacity to use"– e.g. ***Airbnb***, Uber are examples of a **sharing economy, in which someone has capital that is not being used but then puts it to use.** By sharing it, we earn a return on it and we make our capital more efficient. This is only possible due to information technologies. Another example is ***additive manufacturing***, known colloquially as 3D printing, which can be used not only for customization of products for the final consumer but, more importantly, by creating customised machines for particular uses, and hence more efficient machines.

3. Institutions understood in a broad sense: public policies, social capital, cultural practices, work contracts and the legal system.

Regarding exergy, the fundamental concept is to harness exergy which today is being wasted and add value, instead of using more exergy in our economies. How can this be done?

- **Reuse waste flows** – the logic of the circular economy. We have to bear in mind that another big advantage of the concept of exergy is that it also allows us to measure flows of mass. In other words, when a flow of mass has value, this means that it is not in equilibrium with the environment, and, therefore, its exergy is not zero. So, we can harness waste flows. For example, in a power plant, instead of having the heat generated produce only electricity, it can be used for other purposes, such as a system of cogeneration.

- **Maintain carbon levels in the system**, which is another way of talking about carbon sequestration, using the logic of the circular economy.

- Finally, **extend the value chain, which progressively moves from the sale of goods to the sale of services.** When a company is selling goods, it is in its interest to maximise the flow of mass and energy. But when a company is selling a service, it is in its interest to producing the service as cheaply as possible, and hence to minimise flows of mass and energy. For example, selling mobility instead of fuel – if we sell mobility, we are interested in saving fuel, whereas if we sell fuel, we are interested in selling more fuel. Another example is selling nutrition instead of food: to have a retailer who knows what is inside our refrigerators, knows what we are eating. The retailer, given a profile that we have chosen to "be an environmentally friendly consumer" or "be a consumer with a certain type of diet", optimises what it sells with a view to satisfying the needs that we have set out, and once again it is interested in ensuring the nutritional service rather than selling food. This example is also important in pointing out that, as well as the opportunities related to these new concepts, there are also multiple ethical and legal problems that have to be fully discussed. Another example, very well known in the energy sector, are ESCOs (*energy service companies*), where a company sells thermal comfort, or sells illumination, so that it is in its interest to save energy.

Regarding labour, throughout all the IRs, there has been a concern about unemployment. If one farmer today produces food for everyone, 200 years ago what people thought was that, among 100 farmers, the other 99 would become unemployed. This did not happen because new business models were created, new jobs, but also the arrival of education for the many of an increasingly long duration. **It is critical to train the work force to take advantage of new business opportunities.** If not, we will have massive unemployment, and therefore serious problems, and trace a path into the future that it is not at all what we want.

Finally, regarding institutions, they need to be reorganised: legislation, rules, practices, in order to accommodate these new business models, such as has happened in the past. For example, the fact that the government took charge of and made education mandatory, was a highly important institutional change that took place in our societies over the last 200 years.

3.
MEET2030: THE PROCESS

3. MEET2030: THE PROCESS

3.1. SCENARIO DEVELOPMENT

This section described some of the basic concepts used for scenario development in MEET2030.

Foresight is "a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at present-day decisions and mobilizing joint actions" (EC JRC-IPTS, 2005). Scenario Planning is a foresight approach widely used in decision-making processes, helping designing and implementing policies and programmes (Rhisiart, Störmer *et al*. 2016) and also in the development of strategies within the companies and organisations. Scenarios allow the creation of alternative pictures of the future, pointing out crucial uncertainties with impact on the (strategic) decisions (Postma and Liebl 2005). Scenarios should be a group effort (Meinert 2004) and the input from several experts and stakeholders adds value and robustness to the scenarios developed.

Scenario Planning allows governments, institutions and companies to learn about plausible futures by identifying and understanding past and present features and the potential impacts of the forces that impair the organisations.

Building scenarios involves three (generic) main steps:

- Step 1: Define a focal issue and a time horizon: setting the focal issue (often represented by a question) and the time horizon is crucial to obtain specific and stakeholder-oriented scenarios;
- Step 2: Identify driving forces and uncertainties: it is critical to recognise the variables that are relevant to the defined focal issue and that may cause changes; these drivers can be, for instance, economic, environmental, political, social and technological. It is particularly important to define the uncertainties, which when resolved have impact on the focal issue (Goodwin 2014) and are the "raw material" for defining the scenario structures and building scenarios;
- Step 3: Write scenario narratives: the narratives are the stories that explain how drivers relate to each other and the consequences of that interaction.

The steps above can be detailed. For example, the Extreme-World Method, adapted in MEET 2030, is described in Goodwin and Wright (2004) as including the following steps: (1) identify the issue of concern and the horizon year which will be captured in the scenarios; (2) identify predetermined trends that have some degree of impact on the issue of concern; (3) identify critical uncertainties, which when resolved (one way or the other) have some degree of impact on the issue of concern; (4) identify the degree to which the trends and resolved uncertainties have a negative or positive impact on the issue of concern; (5) create extreme worlds by putting all positively resolved uncertainties in one scenario and all negatively resolved uncertainties in another scenario; (6) add the predetermined trends to both scenarios; (7) check for internal coherence. Could the trends and resolved uncertainties coexist in a plausible future scenario? (8) Add in the actions of individuals and/or organisations who will be impacted by the future described in a scenario identifying which actions would they take/have taken to satisfy their own interests.

Regarding the definition of the issue of concern (i.e., focal issue) and the horizon year (i.e., the time horizon) – which is the first main step in building scenarios, for MEET 2030, as mentioned, we have considered:

Focal Issue: the Future of the Portuguese Economy...

... in the context of the fourth industrial revolution and the relationship between energy efficiency and economic growth ...
... taking into account the national and European commitment to achieving carbon neutrality.

The time horizon is 2030, but "with an eye on" the 2030-2050 period (i.e., considering also changes that might occur

beyond 2030). "In a carbon neutral economy, how will Portugal be able to create jobs and grow?" is, for us, the key background question anchoring the process.
Both the focal issue and the time horizon were review by participants in the first workshop, as described in the following section.

The identification of uncertainties (step 2 of scenario building) was carried out by participants through workshops. The development of scenario narratives based on the uncertainties (step 3 of scenario building) was carried out by the research team and discussed and validated by participants through workshops. Scenarios were developed by "creating extreme worlds" by putting all positively resolved uncertainties in one scenario and all negatively resolved uncertainties in another scenario. In MEET, an option was made to:

- Include a wide range of uncertainties when building the scenarios,
- Develop two scenarios, based on the positive and negative resolutions ("configurations") of the uncertainties identified.

The more common way of creating scenarios is by cross referencing two major uncertainties. By using this very simple methodology (the intuitive-logics approach) it is feasible to develop a higher number of scenarios, usually four possible scenarios. This approach has advantages in terms of execution and discussion but a very limited number of uncertainties is analysed in depth. At the same time, a lot of the richness of the interrelationship between a broader range of uncertainties is lost. Looking into literature examples of scenario building similar to MEET 2030 in terms of the focal issue, on-going relevance, or historical relevance (see Table 2 for a summary and the Appendix 7.1 for a detailed analysis of cases) one can see that the more variables used, the lower the number of scenarios, usually two. Projects such as the one from Shell and Siemens have defined only two scenarios using a large number of variables (30 and 76 variables, respectively). In the MEET 2030 project, in order to retain the richness of the data obtained by the diversity of participants, we have looked for a scenario approach that allows for the consideration of a broader range of uncertainties, also providing a reference for their combination. This approach was, as mentioned before, the Extreme World Method (Goodwin 2014). In this sense, the starting 115 potential uncertainties formed the basis for selecting, developing and adapting the methodology for scenario planning in order to allow keeping track of a process with such strong engagement from participants and maintaining its multi-variable and multi dimensional richness.

The following section described in detail the approach of MEET 2030 for scenario building.

Table 2. Summary of characteristics from scenario building exercises

Project (a)	Year	Number of structural variables	Number of scenarios
MEET 2030	2017	**25**	**2+1**
HybCO$_2$: Hybrid approaches to evaluate the economic, environmental and technological impact of long-term low carbon scenarios – the Portuguese case	2011	**4+10**	**2**
Future Energy Scenarios, National Grid	2017	**2**	**4**
New Lens Scenarios, Shell	2013	**30**	**2**
Horizons 2020, Siemens	2004	**76**	**2**
World Energy Scenarios : Composing energy futures to 2050, WEC (World Energy Council)	2013	**5**	**2**
Germany 2064: The World of Our Children, A.T. Kearney	2015	**6**	**2**
The future of mobility: Scenarios for China in 2030, RAND Corporation	2015	**24 descriptors**	**2 + 1**
Where Do We Go from Here? The Future of English Higher Education, Jeroen Huisman, Harry de Boer and Paulo Charles Pimentel Bótas (Higher Education Quarterly)	2012	**21**	**2**
Electricity Scenarios for New Zealand 2005–2050, Office of the Parliamentary Commissioner for the Environment	2005	**9**	**2**
Two scenarios for carbon capture and storage in Vietnam, Minh Ha-Duong, Hoang Anh Nguyen Trinh	2016	**6**	**2**

(a) The projects were selected either due to their similarity to Meet 2030 focal issue (e.g., HybCO$_2$), their on-going relevance (e.g., Future Energy Scenarios, National Grid) or their historical relevance (e.g. New Lens Scenarios, Shell; Pictures of the Future, Horizons 2020, Siemens). We also tried to select a geographically and thematic diverse list of cases, while allowing for some focus on energy and climate topics, and to explore cases that were referred during MEET 2030 discussions.

3.2 OVERVIEW OF THE MEET 2030 PROCESS

Figure 19 presents a general overview of the MEET 2030 process. MEET 2030 included four workshops with BCSD Portugal member associates. The last workshop held, the 4th Workshop, occurred on the 26th of September. The workshops have been spaced out in time, both because of the analysis and research work conducted between workshops, such as desk research and systemisation of information, and because the project foresaw some additional tasks, challenging companies to perform research work and provide feedback between workshops. An overview of all the different stages can be found in Table 3.

Figure 19. The MEET 2030 process

Table 3. Overview of the MEET 2030 stages

STAGE	AIM	EXPECTED OUTCOMES
1st Workshop	Present the project and the MEET2030 process. Present the basic concepts of MEET 2030: • The role of energy efficiency in economic growth, • 4th Industrial revolution, • Explore examples of new products, services, concepts and business models	
1st Challenge	Identify possible normative options aligned with the 4th industrial revolution and energy efficiency For two of the normative options, identify three potential key uncertainties with two possible configurations for these uncertainties Identify evidence for each configuration	A list of technologies for the 4th Industrial Revolution contributing to the increase in energy efficiency and carbon neutrality A list of potential uncertainties that can affect the Portuguese economy in terms of economic growth, energy efficiency improvement and carbon neutrality for 2030

Table 3. Overview of the MEET2030 stages (Cont.)

STAGE	AIM	EXPECTED OUTCOMES
2nd Workshop	Review and select a list of uncertainties from the list of potential uncertainties Pilot the 2nd Challenge	A shortened list of uncertainties Revision of the 2nd Challenge script
2nd Challenge	Obtain a list of new technologies specific to participating businesses that can improve businesses energy efficiency or reduce GHG emissions	Examples of technologies from the *List of Inspirational Technologies* for the participant businesses
Team analysis	Develop a first proposal of scenarios Develop a conceptual model for quantifying aspects from the scenarios	Scenarios for the future of the Portuguese economy bearing in mind the focal issue of MEET 2030 Conceptual model linking the uncertainties to variables such as GDP, energy consumption and GHG emissions
3rd Workshop	Review the uncertainties, defined/validate quantitative assumptions	Two (reviewed) scenarios for the Portuguese economy for 2030, including GHG emissions from the scenarios
3rd Challenge	Identify technologies, business models and policies that can help companies to position themselves in the Iberian Lynx scenario	A list of technologies, business models and policies. A storyline linking a few of these
4th Workshop	Discuss how to further reduce GHG emissions from the scenarios	Adjustments in the scenarios with lower GHG emissions

The first workshop was an introductory workshop, for sharing ambitions, and an introduction to the innovative approach of MEET 2030: Briefly, this workshop included:

- an overview of the project and its vision;
- discuss the focal issue and the time horizon for MEET 2030
- a presentation and discussion on the role of energy efficiency in economic growth;
- a presentation and discussion about the characteristics and challenges of the 4th Industrial Revolution;
- a group exercise, consisting of a structural brainwriting of products, services, concepts, business models and jobs aligned with the projects vision;
- a presentation and discussion about the key operational concepts for scenario building.

At the end of the 1st Workshop, the **1st Challenge** was launched for participating companies to reply to before the 2nd Workshop. Companies were asked to:

- Identify possible normative options (e.g. strategies, strategic responses, actions, portfolio options, capability options, internal factors of competitiveness, visions) aligned with the 4th Industrial Revolution and reflecting the energy efficiency – economic growth relation (three for their own industry and three for the Portuguese economy as a whole);
- Pick one normative option for their industry and one normative option for the Portuguese economy. For each one of them, generate three potential key uncertainties affecting those normative options. For each uncertainty, generate two plausible, contrasted and challenging configurations;
- Identify evidence / (deep/explicative) causes for each configuration of the uncertainties.

20 companies participated in this 1st Challenge and a list of 85 normative options were obtained (for further details on this list, see Section 7.2.2 in the Appendix 7.2) as well as a list of 115 potential uncertainties and their configurations (for further details on this list, see Section 7.2.3 in the Appendix 7.2). In other words, there was a wealth of variables which could plausibly evolve in different directions.

The results from the 1st Challenge were analysed by the research team. This analysis included a revision of the normative options obtained in the challenge. Duplicates were eliminated and similar options were merged together. The final list was complemented with a literature review using the state of the art international reports and the team's knowledge. The final list – The "list of inspirational technologies", was organised around five themes, with a total of 20 types of technologies and provided to participants on the 2nd Workshop. This list is presented in Section 7.2.2 in the Appendix 7.2 from this report.

The list of potential uncertainties was also reviewed. The revision included an analysis of some of the uncertainties and merging similar uncertainties. Out of this analysis, 86 potential uncertainties were obtained. This list is presented in Section 7.2.3 in the Appendix 7.2 from this report. The 86 potential uncertainties were then classified into two different typologies that were developed during the analysis. One of these typologies (Typology A) organised the 86 uncertainties into 12 themes.

Table 4 identifies these 12 themes and presents the number of uncertainties per each of these themes. This typology – Typology A, allows for a better overview of the themes covered by the uncertainties, which is relevant to help identifying if some aspects were left out of the analysis or if there is redundancy. Climate Change and Energy supply had the highest number of uncertainties defined.

Table 4. Number of potential uncertainties per theme from the 1st Challenge

Themes	Number of uncertainties	
	From the 86 uncertainties	From the original (115) list
Energy supply	12	23
Energy efficiency in buildings	4	6
Mobility and transport	10	10
IoT, connectivity and digitalisation	6	8
AI, robotics	4	7
Circular economy	7	9
Industry	8	9
Climate change	17	20
Employment	3	4
Economy	7	8
Geopolitics	5	6
National politics	3	4

A second typology – Typology B - was also developed during the analysis. This typology divides the uncertainties in 6 themes (see Table 5). Typology B is more policy oriented and it is expected to play a more relevant role in latter stages of the project. From this typology, we can see that most of the uncertainties were related with regulation and policy (how these will evolve and if they will be effective) and economy and finance (costs of technologies and funding availability). Availability of knowledge (research and technology) received only one uncertainty.

Table 5. Number of uncertainties per themes of Typology B (columns) and A (lines)

Typology B	Technology	Knowledge/ human and social capital	Environment	Cooperation and behaviour (industry/ societal)	Regulation/ policy	Economy & Financing
Total	**20**	**1**	**4**	**30**	**29**	**31**
Energy supply	9				5	9
Energy efficiency in buildings				2	2	2
IoT, connectivity, digitalisation	1			3	3	1
Mobility and transport	3		2	3		2
AI, Robotics	2			4		1
Circular economy / wastes			4	4	1	
Industry			2	1	3	3
Climate change	2			4	7	7
Employment	3				1	
Economy		1		1	1	5
Geopolitics				6	1	
National politics				2	2	

Both lists obtained (the List of Inspirational Technologies and the list of potential uncertainties) served as a base for the 2nd workshop.

The **2nd Workshop** had the aim to:

- Review and select a list of uncertainties from the list of potential uncertainties,
- Pilot the 2nd Challenge.

This workshop included the following activities:

- A revision of the results from the previous workshop, the 1st challenge and the team analysis of the previous results,
- Group exercises with the aim of (1) validating and modifying the potential uncertainties, (2) prioritising these uncertainties and (3) piloting the 2nd Challenge,
- Sharing the results from the group exercises and
- Presenting preliminary conclusions

The first group exercise aimed at validating and revising the potential uncertainties, ensuring that in each theme from Typology A, all relevant uncertainties were included and redundant uncertainties were merged or eliminated. For this exercise the 86 uncertainties organised in the 12 themes (Typology A) were presented to participants. The uncertainties and their configurations were discussed and validated by participants. Of the 86 potential uncertainties, 58 resulted from participants' discussions, resulting from merging and eliminating some of the initial potential uncertainties and developing three new ones. The resulting list of potential uncertainties is presented in Table 26 in the Appendix 7.3 from this report.

In the second and third group exercises, participants were then asked to evaluate the new 58 potential uncertainties, based on:

- Their perceived impact on the future of the Portuguese Economy and
- Their perceived level of uncertainty.

Two votings, one for each criterion above, were obtained per participant.

The final group exercise consisted in asking participants to respond to a group of questions on a specific industry sector.

These questions were a preliminary version of the questions from the 2nd Challenge and the aim of this exercise was to understand if the language and format of the questions were clear.

After this workshop, results were analysed in order to:

- Select a group of uncertainties based on the votes from participants and critically review these in the light of the focal issue of MEET 2030;
- Develop a conceptual model linking the reduced list of uncertainties and GDP, exergy consumption and GHG emissions
- Develop a first proposal of scenarios and scenarios narratives based on the configurations from the reduced list of uncertainties
- Develop a first estimation of the some of the uncertainties in order to obtain a first estimate for GDP, exergy consumption and GHG emissions for each scenario, eliciting all the assumptions behind these estimations

For the first aim of this analysis, the results from participants' evaluations were analysed. At this point, we used the results from the collective intelligence exercises performed in the 2nd workshop, in order to better characterise the features of the potential uncertainties.

Up until here, it was more accurate to speak of *potential* uncertainties because they were variables that had some characteristics that could transform them into critical uncertainties. However, after a collective process of applying critical thought to those potential critical uncertainties and evaluating the impact of each one on the future of the Portuguese economy, along with their level of uncertainty, we were able to determine which were, for the Meet 2030 participants, the actual critical uncertainties for the future of the Portuguese economy.

The evaluation of the level of uncertainty of a variable is based on the idea that, in a given moment, we have information ("future-oriented evidence") that supports different developments for that variable that are contrasting, plausible and strategic.

After analysing the voting, the uncertainties with high level of uncertainty and high level of relevance (uncertainties appearing in the top right quadrant on the graph in Figure 81 in the Appendix 7.3 from this report) were selected. Of all of the 58 uncertainties that went into voting, 16 have clearly gained relevance because they were assessed as having relatively high level of uncertainty and relatively high level of impact on the future of the Portuguese Economy.

After identifying these 16 uncertainties we developed a conceptual model linking these variables to GDP, energy efficiency and GHG emissions. This model is described in more detail in the Section 3.3 and in the in the Appendix 7.6 from this report. The model links total factor productivity (and thus, uncertainties related with energy efficiency, electrification, automation, digitalisation), labour, capital investment to GDP, energy efficiency and GHG emissions, based on the vision of MEET 2030 described in Chapter 2 from this report.

In order to better cover the different topics and to closely link the qualitative and quantitative parts of the scenarios (especially to link the uncertainties with the evolution of the GDP and energy use), the research team added nine additional uncertainties to the scenario structure. These uncertainties focused on energy supply (2), mobility and transport (2), employment (3) and climate change (2). These were:

- Strength of EU regulation and incentives inducing renewable energy production;
- European electric grid integration;
- Electrical vehicle (EV&H2) deployment rates;
- Electric grid ability to integrate electric vehicles;
- Impacts of automation and digitalisation on unemployment rates;
- Impacts of automation and digitalisation on the type of employment;
- Adaptability of the educational system to the future industries and market needs;
- Availability of technologies for climate mitigation and adaptation;
- Policy on climate change.

As mentioned, these nine variables are particularly important for the links between the scenario structure, the scenario narratives and the scenario quantification.

As a result, 25 uncertainties (presented in Table 28 in the Appendix 7.4 from this report) are used as components of the scenario structure. The scenario structure, when we have only two uncertainties, is made up of these two uncertainties. In MEET 2030, the scenario structure is a more complex, multi-dimensional one. Two scenarios were developed based on the configurations of the uncertainties.

It is important to stress that scenarios are not only a structure made of uncertainties' configurations, just as our bodies are not just skeletons. They are also made up of "flesh": scenarios are narratives/stories. And they also need to be treated as a brand. However, the 25 uncertainties that constitute our scenarios structure are already a result of collective vision of how our future may unfold. They constitute one of the outputs of this project.

During this period of analysis, between the second and the third workshops:

- **A second challenge was launched** to the participants. This challenge consisted on the identification of the technologies, products and services, and key outputs of the businesses (see the questions provided to participants in the Appendix 7.4);
- Intermediary results from MEET 2030 were presented to the general public in the **Seminar "Energy, climate and economic growth: business opportunities in Portugal"** specially organised for MEET 2030. This seminar was held on the 29th of May in Lisbon and included talks from CDP, European Commission and OECD;
- **Meetings with the Portuguese Environment Agency (APA), the Portuguese State Secretariat for Industry and ADENE** to further present the project, collect their comments on the project and on the preliminary results, and engage these institutions for feedback on future results from the project.

In the **third workshop**, participants were presented with the two scenario narratives, quantitative assumptions the MEET 2030 team derived from these narratives. The scenario narratives and the assumptions behind the quantification of variables in the scenarios were discussed during the workshop. Following this workshop, comments on the scenario quantitative assumptions were also requested from the institutional partners (namely, from APA and ADENE). The results coming from the 3rd Workshop and from the feedback from the institutions consulted were analysed. Two reviewed scenarios resulted from this analysis, including quantified variables such as energy efficiency, employment rates, hours worked per person, electrification rates, electricity mix, capital investment, GDP and GHG emissions for each scenario. A preliminary list of policy and business implications was derived from the scenarios.

During this period, results obtained for GDP, useful exergy and GHG emissions from the scenarios were discussed with:

- The Advisory Committee,
- The Steering Committee and
- ADENE and the Ministry of the Environment.

A **3rd Challenge** was launched, asking the Steering committee companies to place themselves within the more optimistic scenario and to identify which technologies, business models and policies could help them to position themselves in this scenario. 10 responses were obtained. The respondents were then asked to present their work at the 4th Workshop. The questions that composed the 3rd Challenge are presented in the Appendix 7.7.

In the **4th workshop,** held on the 26th of September, a discussion was generated around how to reduce GHG emissions from the scenarios, which technologies, business models and policies would be required by the scenarios.

An overview of the main results obtained by the different stages of MEET 2030 is presented in Table 6. This Table also presents the number of participants in each stage.

Table 6. Engagement and main outcomes of the stages from MEET 2030

STAGE	NUMBER OF PARTICIPANTS	MAIN OUTCOME
1st Workshop	**60 participants**	-
1st Challenge	20 companies participated on the challenge	A list of 85 normative options potentially aligned with the 4th industrial revolution and energy efficiency A list of 115 potential uncertainties for the future of the Portuguese economy
Analysis of the 1st Challenge	-	The *List of Inspirational Technologies* – comprising 20 types of technologies (from the 85 initial ones, complemented with a desk research and expert knowledge) The list of 115 potential uncertainties was reduced to 86 (eliminating duplicates, merging similar uncertainties). List was organised around 12 themes for the 2nd Workshop
2nd Workshop	**40 Participants**	**Revisions of the 85 potential uncertainties** **16 uncertainties selected as the most relevant from the list of 86 potential uncertainties**
2nd Challenge	16 companies participated in the challenge	A sub-list of the Inspirational Technologies specific, from which each participant business, found relevant for businesses in order for them to improve their energy efficiency and contribute to a neutral carbon footprint
Analysis of 2nd Workshop and 2nd Challenge	-	Conceptual model linking the uncertainties to GDP, energy consumption and GHG emissions 9 additional uncertainties added A total of 25 uncertainties selected as the backbone of scenarios 2 scenarios were derived from the uncertainty configurations Initial quantification of some of the structural variables behind the uncertainties
3rd Workshop	**40 Participants**	**Reviewed narratives for the 2 scenarios** **Quantitative assumptions for the modelling of the scenarios**
Analysis of the results from the 3rd Workshop	-	2 reviewed scenarios GHG emissions resulting from each scenario
3rd Challenge	10 companies participated in the challenge	A list of technologies, business models and policies
4th Workshop	**30 participants**	**Options for reducing GHG emissions in one of the scenarios**

3.3 FROM THE UNCERTAINTIES TO THE SCENARIOS

The scenarios were developed based on the two plausible configurations from each of the 25 uncertainties identified and discussed during the workshops. The uncertainties selected are the ones presented in Figure 20 (further details in the Appendix 7.3). The scenario narratives developed are a collective creation based on input from the workshops' participants and the answers to the challenges given by the companies involved. It is also the result of further analyses by the research team of all gathered information and inputs throughout the project.

Figure 20. The 25 uncertainties used for the scenarios

1. Market preparedness for industry synergies	2. Sectoral & Cross-sectoral cooperation in climate protection	3. Stability of international geopolitical and demographic context	4. The political future of the EU	5. EU economic growth capacity
6. Capacity of the banking system to support economic development	7. Financial stability of the Portuguese economy	8. Investment capacity in the Portuguese economy	9. Portugal's capacity to attract and retain talents	10. European electric grid integration
11. Strength of EU regulation and incentives inducing renewable energy prodution	12. Capacity to develop a digitalisation policy sustained in a strong commitment from the industry	13. Effectiveness of more ambitious regulation on energy efficiency in buildings	14. Adaptability of the educational system to the future industries and market needs	15. Policy on climate change (ambition)
16. Allowing/ promoting geological CCS, CCU and use of CO_2	17. Alignment between Government's policies anda companies' needs to address new societal challenges	18. Effectiveness of national policies on retirement, health, justice, education	19. Stability of climate change policies worldwide: actors, programs and priorities	20. Impacts of automation and digitalisation on unemployment rates
21. Impacts of automation and digitalisation on the type of employment	22. Availability of technologies for climate mitigation and adaptation	23. Electrical vehicle (EV&H_2) deployment rates	24. Electric grid ability to integrate electrical vehicles	25. Pace of adoption of energy efficiency technologies and measures and microgeneration

These uncertainties formed the backbone of the scenarios. **A conceptual model was developed linking the uncertainties to GDP, exergy efficiency and GHG emissions** (variables derived from MEET 2030's focal issue).

To link the uncertainties developed by participants to GDP, exergy efficiency and GHG emissions (i.e., to the focal issue), t**he uncertainties were grouped in six groups: uncertainties related with capital and capital investments, uncertainties related with employment, uncertainties related with energy efficiency, uncertainties related with the shares of final energy used, uncertainties directly related with GHG emissions and primary to final energy efficiency, and uncertainties related with cross-cutting geopolitical issues.**

Table 7 presents the relationship between the 25 uncertainties (and their configurations) and the new groups developed for the conceptual model.

Table 7. New groups of uncertainties defined in the workshops

Group	Uncertainties[a]
Capital stock	5, 6, 7, 8[b]
Human labour	9, 14, 17, 18, 20[b], 21
Useful exergy shares	2, 12, 23[b], 24
Final-to-useful exergy efficiency	1, 10, 13[b], 25
GHG Emissions	10, 11, 15, 16, 19, 22, 25
Cross-cutting geopolitical issues	3, 4

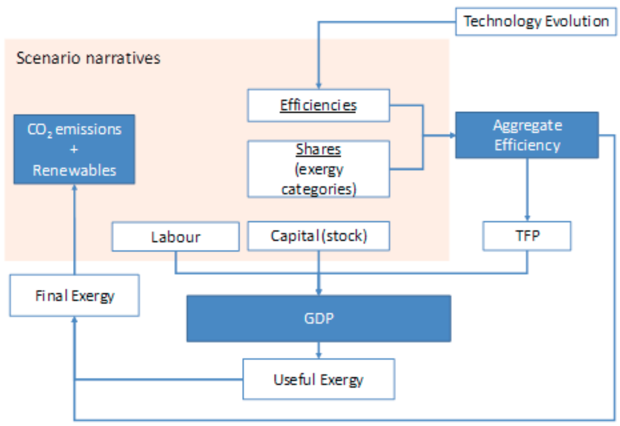
Notes to the Table:
(a) The numbers refer to the uncertainties' numbers in Figure 21;
(b) Uncertainties quantified.

In order to link these groups to the focal issue, intermediary variables were defined. These were:

- *Stock of capital*, variable which allows to link economic uncertainties on investment capacity to GDP evolution;
- *Unemployment rates*, providing a link from the uncertainties to human labour;
- *Number of engaged individuals,* providing a link from the uncertainties to human labour;
- *Annual average number of hours worked per engaged individual,* providing a link from the uncertainties to human labour;
- *Human labour inputs to economic production,* providing a link between the uncertainties on employment and GDP evolution;
- *Useful exergy shares*, providing a link between the uncertainties and the aggregate (economy wide) exergy efficiency;
- *Final-to-useful exergy efficiency*, also providing a link between the uncertainties and the aggregate exergy efficiency;
- *Fraction of renewable resources in the electricity production*, necessary for estimating the GHG emissions from each scenario.

The conceptual model used is presented in Figure 21. The variables Unemployment rates, Annual average number of hours worked per engaged individual, useful exergy shares, final-to-useful exergy efficiencies, Fraction of renewable resources in the electricity production qualitatively defined in each scenario (based on the configurations of the uncertainties) were quantified based on discussions held on the workshops (3rd Workshop) and peer reviewed specialised reports and scientific papers. Consistency with the uncertainty configurations was ensured. Based on these quantifications, it was possible to estimate the stock of capital, the number of engaged individuals, human labour inputs to economic production and TFP. These variables allow estimating GDP, exergy efficiency and CO_2 emissions - variables directly linked to the focal issue. These will be discussed on the 4th Workshop. Each of the variables is described below.

Figure 21. Schematic representation of the scenario-making process



Capital stock available to be used in economic production, for a given period, depends on capital assets available to be used in production in the previous period, plus new investment in capital assets for the same period, minus capital asset depreciation for the same period (see Section 7.6 from this report). The consumption of fixed capital (CFC) was assumed to remain equal to 5.4% of the available capital stock, which corresponds to the average value for Portugal in the last decades.

Human labour inputs to economic production are measured as total hours worked by all engaged individuals in the economy. This depends on: 1) working age population; 2) labour participation rate; 3) unemployment rate; 4) average annual hours worked by each engaged individual in the economy. 1) and 2) are equal in both scenarios. For 1), working age population (i.e., population between the ages of 15 and 64 years old), the central scenario from INE was used, leading to a population of approximately 6 million individuals by 2030. For 2), labour participation rate, values were assumed constant and equal to 77% for the period 2017-2030, approximately the average of the most recent years.

Useful exergy shares are the fractions of each energy carrier[4] used in the economy. These depend on the energy needs of the economy (which include behaviours and habits of society) and fuel substitution that can also lead to the improvement of final-to-useful efficiencies (e.g. a share growth of electric motors use which efficiency is around 85%).

Final-to-useful efficiencies represent the efficiency of conversion of final exergy into useful exergy. The final-to-useful efficiencies are mostly controlled by technology evolution and replacement of capital.

In terms of exergy shares and efficiencies, this report uses the nomenclature presented in Table 8.

Table 8. Exergy end-use categories

CATEGORY	CUB-CATEGORY
Heat uses (HT)	High Temperature Heat (HTH), above 500ºC; Medium Temperature Heat (MTH), between 500ºC and 120ºC; Low Temperature Heat 1 (LTH1), between 120ºC and 90ºC; Low Temperature Heat 2 (LTH2), between 90ºC and 50ºC; and, Low Temperature Heat 3 (LTH3), below 50ºC
Stationary Mechanical Drive (MD)	Stationary motors, including all electricity MD end-uses (except for Diesel-electric and electric vehicles).
Mobile Mechanical Drive (MD)	MW1 for Aviation, MW2 for gasoline/LPG, MW3 for Diesel engines, Navigation, Diesel-electric, including diesel-electric trains, electric and hybrid vehicles and subways NG for Natural Gas vehicles' motors
Other Electrical Uses (OE)	-
Light Uses	-

4. This report uses the typology for energy carriers as the IEA (IEA 2016): coal, oil, combustible renewables (such as wood), natural gas, electricity, co-generation heat and solar photovoltaic.

Based on the useful exergy shares and final-to-useful efficiencies per energy carrier, aggregate exergy efficiency was estimated. Aggregate final-to-useful exergy efficiency represents the efficiency of the overall economy. Total factor productivity (TFP) is projected for the period 2017-2030 by using the observed historical relationship between TFP and the final-to-useful aggregate exergy efficiency shown in Figure 13.

GDP is obtained as an aggregate production function of TFP, as well as capital and labour inputs to production. Useful exergy consumption is obtained through the stable long-run useful exergy intensity empirically verified for the Portuguese economy (Figure 14), i.e., useful exergy intensity is assumed to maintain its stability, at approximately 1 MJ of useful exergy per 1 € of GDP. From the aggregate useful exergy projections computed from projected GDP and assuming constant useful exergy intensity, projections for final exergy can be obtained, dividing useful exergy by final-to-useful efficiency per end use.

GHG emissions were obtained as a result from all the assumptions taken for each scenario, related to useful and final exergy consumption, as well as choices taken on resources consumption (primary exergy level) for Electricity production resulting from the assumptions. Values were estimated based on IPCC (2006) emission factors as followed by APA (Agência Portuguesa do Ambiente) and in the NIR (National Inventory Report for Portugal). The context of MEET 2030 fits in the IPCC's Energy category. GHG emissions estimated are all related to energy production and transformation (i.e., combustion of fossil fuels, including for transport, mechanical drive and heat production). According to the NIR for Portugal, the Energy category from IPCC corresponds to approximately 70% of total Portuguese GHG emissions. The "Energy sector" as referred to in the present report refers only to the energy sector (industries for energy production) and not IPCC's Energy category.

The next chapter (Chapter 4) presents the resulting scenarios.

4.
TWO SCENARIOS FOR PORTUGAL 2030

4. TWO SCENARIOS FOR PORTUGAL 2030

The two scenarios developed were: *The Ostrich and The Iberian Lynx* (Figure 22). Both names were chosen as metaphors for what is described in each of the scenarios.

Figure 22. The two Meet 2030 scenarios

The name *The Ostrich* was chosen based on the general public perception of ostriches, namely the myth that states that ostriches bury their heads in the sand. It is a metaphor of an evolution where Portugal evolved separately from a world transformed by new technological, environmental and energy trends. The Ostrich represents a scenario of stagnation, dissociated from the evolution occurring abroad.

The Iberian Lynx name was chosen as a symbol for the potential that cooperation can have in several contexts. The recovery of the Iberian Lynx is the result of a program that followed a multidisciplinary approach between national, regional and international organisations. As such, in the Iberian Lynx scenario we see signs of recovery based on a strong cooperation between agents and between Portugal and other countries. Furthermore, the Iberian Lynx name is also intended to be a metaphor based on the naming of the very strong economic development of the Four Asian Tigers that, between the 60s and the 90s, "anticipated" the subsequent Chinese boom. The expression was applied to Taiwan, Singapore, Hong-Kong and South Korea. This scenario name represents an image based on the rapid growth and transformation story of these Asian tigers, assuming that, under this scenario, Portugal will be one of the big positive surprises of the world economy, accomplishing sustained growth rates. This does not mean that all news are positive in this scenario: the very positive economic growth rates led to strong challenges in terms of GHG emissions.

4.1. THE OSTRICH SCENARIO

Imagine we are in 2030, looking back at the past...

> ***During the last decade and in a difficult external context, Portugal was not able to transform its economy and align itself with the opportunities arising from the 4th Industrial Revolution. Collectively, we failed to spot the key changes in our strategic environment. Economic instability and stagnation continued, leading to recurrent social crises and emergencies, sometimes not well coordinated actions and measures. This process even led a foreign finance minister to compare Portugal to an Ostrich, stating that "instead of fleeing in a straight line, they ran around in circles like those fairground carousels."***
>
> ***The Portuguese economy became even more peripheral, unable to attract talents and investments.***

The scenario considers more instable international geopolitical and demographic contexts, in terms of political issues, ageing population, migrations, and an increasing global distrust. To what concerns the EU, additional member state exists may occur.

In the following sub-sections, the scenario is described in more detail in terms of the capital stock (4.1.1), employment (4.1.2), energy use (4.1.3 and 4.1.4), economic growth (4.1.5) and GHG emissions (4.1.6).

4.1.1. Capital Investment

In terms of capital investment, there is **great instability and a deepening of the peripheral nature of the Portuguese economy.** There is a stagnation/ retraction of EU economy, a recurrent instability of the Portuguese economy and a lower investment capacity. The banking system is not capable of adequately supporting economic development. The result is **a decrease in the stock of capital for Portugal**. Table 8 summarises the main characteristics of the Ostrich scenario in terms of capital investment.

Table 8. Capital investment in the Ostrich scenario

	CONFIGURATIONS
EU economic growth capacity	Stagnation/ retraction
Capacity of the banking system to support economic development	Banking system is not able to adequately support economic development
Financial stability of the Portuguese economy	Recurrent instability
Investment capacity in the Portuguese economy	Constant (c)
Stock of capital (a) (b)	Decreases 0.8%/year (reaching the levels of 2003 in 2030)

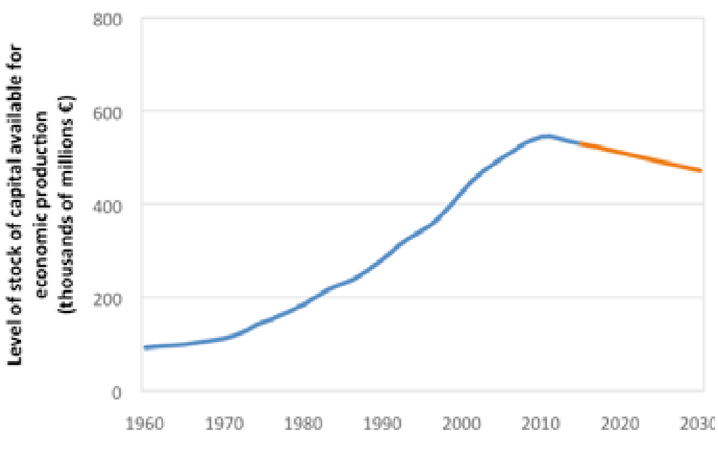
Notes to the table: Variable (a) was defined by the research team in order to link the uncertainties to GDP evolution. All configurations were defined and discussed with the workshops' participants. Exception was for (b), were values are a consequence from the remaining variables' configurations. These were discussed with participants. (c) It is assumed that investment in climate mitigation technologies are included within this value.

Investment in capital (gross fixed capital formation - GFCF), can be measured as a percentage of the previous year's GDP (i.e., a fixed saving rate). Investment in capital assets over the past 50 years has fluctuated between 15% and 27% of previous year GDP, with an average of approximately 21% (Figure 23). In the Ostrich, from 2017 to 2030, GFCF equals its current value, the lowest value for the last 50 years – 15% of the previous year's GDP.

Figure 23. Investment in capital. Projections for the Ostrich scenario [Source of historical data: AMECO]

To estimate the stock of capital, besides the investment in capital, the consumption of capital (CFC) is required. CFC can most naturally be expressed as a percentage of the available capital stock. Historically, consumption of fixed capital is bounded between 4% and 7% of the level of capital stock, and has been roughly constant in the last decades, with an average value of 5.4%. CFC was assumed to remain equal to its historical average value. Based on GFCF and CFC, the capital available for economic production is projected to decrease 0.8%/year reaching the levels of 2003 in 2030 (Figure 24).

Figure 24. Capital stock. Projections for the Ostrich scenario [Source of historical data: AMECO]



4.1.2. Labour

Regulations and policies are weak and ineffective, with low cooperation between agents (National and European wide). At the national level, there is the maintenance of a diffuse digitalisation strategy and dispersion of resources with no effective cooperation between agents. No ability to align technological development and investments on science, technology and innovation with the great challenges of society. These lead to an incapacity of Portugal to attract and retain talents. This scenario also considers that the educational system is unable to adapt to industry's new requirements and that there are no new effective policies on retirement, health, justice and education. The result is the **maintenance of unemployment rates at 11.1%, with less individuals working or actively searching for a job** (lower number of engaged individuals in the economy). **The number of hours worked per individual remains the same as in 2016.** Table9 summarises the main aspects of labour considered in the Ostrich scenario.

Table 9. Labour in the Ostrich scenario

	CONFIGURATIONS
Alignment between Government's policies and companies' needs to address new societal challenges [a]	No alignment between Government's policies and companies' needs to address new societal challenges, namely talent attraction and retention
Effectiveness of national policies on retirement, health, justice, education [a]	No new effective policies
Adaptability of the educational system to the future industries and market needs [b]	Educational system is unable to adapt to industry's new requirements
Impacts of automation and digitalisation on unemployment rates [b]	Unemployment rates maintain at 2014 values

Table 9. Labour in the Ostrich scenario (Cont.)

	CONFIGURATIONS
Impacts of automation and digitalisation on the type of employment [b]	Automation contribute to maintaining current level of unemployment and to a higher social unrest
Unemployment rates [c]	Constant, 11.1% of the total labour force
Portugal's capacity to attract and retain talents [a]	Portugal is not able to compete to create a pool of talents
Labour force [d]	Decreases to 4 million individuals by 2030
Average annual hours worked per employed individual [c]	Unchanged trend
Human labour inputs to economic production [d]	Decrease to 7625 million hours by 2030

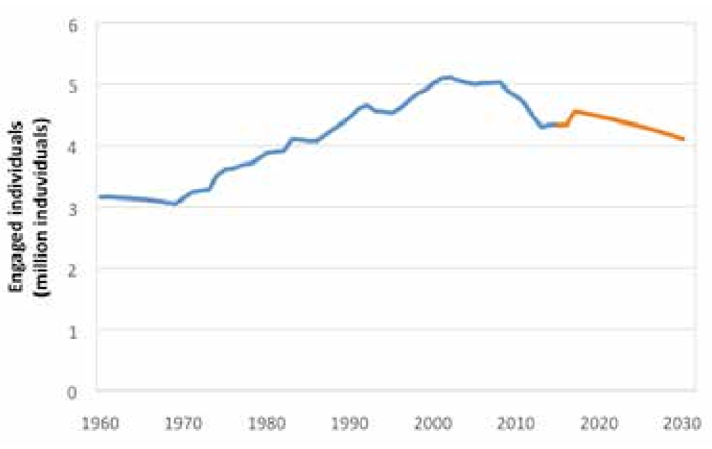
See notes for Table 8.

Historically, unemployment has varied between 4% and 16% of the labour force (obtained from the European Commission's annual macroeconomic database - AMECO), over the past decades, with an average of 8% (Figure 25). Based on the discussions held on the 3rd Workshop, for the Ostrich **the unemployment rate projected for 2017-2030 is constant, at 11.1%** of the labour force.

Figure 25. Unemployment rate for the Ostrich scenario, projections for 2017-2030
[Source of historical data: AMECO; INE]

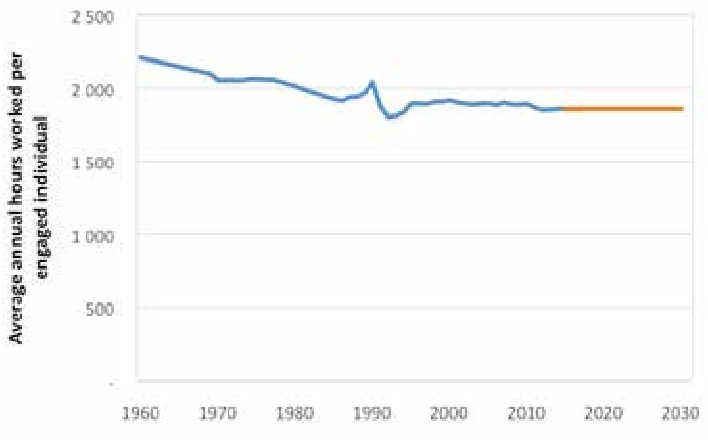
The number of engaged individuals in the economy, i.e., the number of individuals working or actively searching for jobs, is obtained by subtracting the unemployed individuals (in Figure 26) from the total labour force. Historically, the number of engaged individuals has varied between approximately 3 million and 5 million, with an average around 4 million (Figure 26).

Figure 26. Engaged individuals in the Ostrich scenario for 2017-2030
[Source of historical data: Feenstra et al. (2015)]



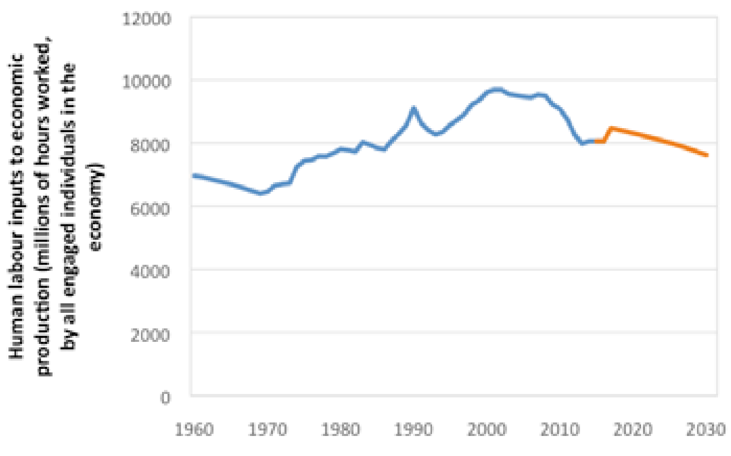
The annual average number of hours worked per employed individual fluctuates around 2000 hours per year, and shows a decreasing trend throughout the last 50 years (Figure 27). For the Ostrich, **the average annual hours worked per employed individual remain unchanged** (approximately 1850 h/year, around 38 h/week per average individual).

Figure 27. Average annual hours worked per engaged individual for the Ostrich scenario, for 2017-2030
[Source of historical data: Feenstra et al. (2015)]



Total human labour inputs to production are obtained by multiplying the average annual hours worked per employed individual by the total number of employed individuals in the economy (Figure 27). For the Ostrich, **total hours worked by all employed individuals in the economy decreases to 7625 million hours by 2030** (Figure 28), **explained by both, unemployment rates at 11.1% and the decrease in the number of individuals working or actively searching for a job,** assuming the central scenario for the population evolution by INE.

Figure 28. Human labour inputs to economic production for 2017-2030 for the Ostrich scenario
[Source of historical data: AMECO; Feenstra et al. (2015); INE]



4.1.3. Final to Useful Exergy Efficiencies and Useful Exergy Shares

Overview

The Ostrich is a conservative scenario in terms of energy options. Table 10 summarises the main characteristics of this scenario.

Table 10. Main variables and configurations for exergy use by category in the Ostrich

	CONFIGURATIONS
Market preparedness for industry synergies [(a)]	Market does not work together to close the loop
Capacity to develop a digitalisation policy sustained in a strong commitment from the industry, looking into taking Portugal to the leadership on digitalisation and connectivity [(a)]	Maintain a diffused national digitalisation strategy and dispersion of resources with no effective cooperation between agents
Useful exergy shares (exergy by end use category) [(c)]	Unchanged trend except for some heat and for mechanical drive uses from Oil products (i.e., HTH, MTH, LTH3, MW2, MW3 and navigation). For these, the scenario considers the maintenance of the average observed in the most recent years (between 2009-2014)
Electrical vehicles circulating by 2030 (EV and H_2) [(b)]	Slow adoption – aproximatelly 6% of vehicles circulating by 2030
Electric grid ability to integrate electrical vehicles [(b)]	Slow and limited
Final-to-useful exergy efficiencies [(c)]	Technology specific final-to-useful efficiencies are constant [Although, aggregated exergy efficiency has marginal increases]

Table 10. Main variables and configurations for exergy use by category in the Ostrich (Cont.)

	CONFIGURATIONS
Energy efficiency in buildings (LTH3) [(a)]	Useful exergy decreases between 0.6 and 1p.p. by 2030 (improved efficiency)
Pace of adoption of energy efficiency technologies and measures and microgeneration [(a)]	Scarce adoption of energy efficiency technologies and measures

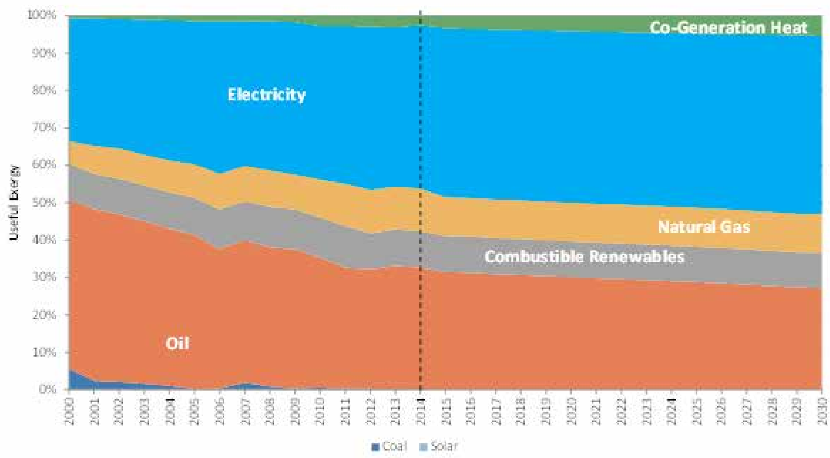
See Table 8 for further notes.

In this scenario, there is a low level of cooperation and low social capital in terms of cooperation and behaviour of the different players. Market players do not work together to close the loop for a circular economy (industry synergies). **Regulations and policies are weak and ineffective, with low cooperation between agents** (National and European wide). There are little results concerning more ambitious regulations for energy efficiency in buildings.

Final-to-useful efficiencies (technology specific) r**emain fairly constant until 2030.** This includes the scarce adoption of energy efficiency technologies and measures. The final-to-useful efficiencies are mostly linked to the evolution of technology and the replacement of capital. Although final-to-useful energy efficiencies of each equipment remain constant, the economy's overall energy efficiency may still vary as this is also dependent on which energy carrier-end use is used more (i.e., the fraction of each energy carrier in the economy or the useful exergy shares), which can vary.

In the Ostrich, **the trends of useful exergy shares from 2000 to 2014 will maintain up to 2030** for all pairs **except for Oil-heat** (HTH, MTH, LTH3), **mechanical work** (Gasoline, Diesel, Navigation) and **electricity and co-generation heat** (Figure 29). For **oil heat and mechanical work**, useful exergy shares evolve at a rate equal to the one observed in the most recent years, i.e., **decreases circa 6%.** For **electricity and co-generation heat** the estimations were developed separately from other energy carriers. General end-use shares for the whole economy were applied rather than sector specific shares, i.e., the same shares were applied to electricity consumed in industry and residential/commercial sectors (see Appendix 8.6 for details). This resulted in **increases of 3%** in electricity share. Even though, in the Ostrich there is a slow adoption of electrical vehicles and the slow and limited ability of the electric grid network to integrate electric vehicles.

Figure 29 Useful exergy shares per energy carrier 2000-2030 for the Ostrich scenario



Comparing useful (Figure 29) and final exergy shares (Figure 30), the most noticeable difference is that Electricity is the energy carrier with the highest share of useful exergy, while Oil is the carrier with the highest share of final exergy. This is explained by the different efficiencies of the machines that use each carrier.

Figure 30. Final exergy shares per energy carrier 2000-2030 in the Ostrich scenario

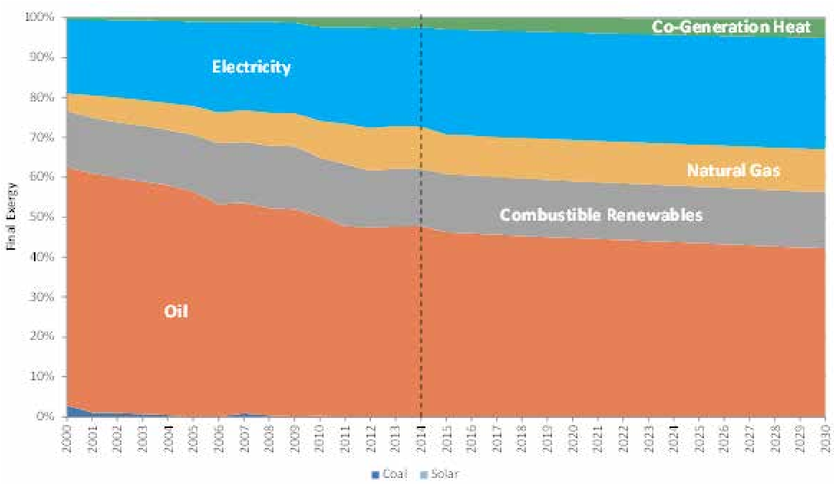


Table 11 shows the energy carriers with the highest final exergy consumption per sector in 2030. The five sectors considered are: Energy; Industry; Transports; Residential/ Commercial (Services) and Agriculture/ Fishing. In the table are presented the energy carriers with consumption shares higher than 3% of Portugal's final consumption. Having the highest shares means that changes in the consumption of these energy carriers lead to higher impacts on exergy projections, since changes on their consumption patterns correspond to modifications in the largest consumption shares.

Final exergy shares

Considering Portugal's total consumption, **the sectors with higher shares of final exergy consumption** (and consequently with the highest influence on exergy projections) **are the Residential/ Commercial (Services) and the Industry.** Nevertheless, **if the Residential and Commercial (Services) sectors were to be disaggregated, the Transport sector would have the second highest share of consumption.**

Table 11. Most significant final energy carriers consumed by sector in 2030

SECTORS	FINAL ENERGY CARRIER	END USE
Industry	Combustible Renewables	Heat (LTH1)
	Electricity	Mechanical Drive (Stationary)
Transportation	Oil Products	Mechanical Drive (MW2 and MW3)
Residential/ Commercial	Electricity	Mechanical Drive (Stationary), OE, Heat (LTH2)
	Combustible Renewables	Heat (LTH3)
	Oil Products	Heat (LTH3)
Agriculture/ Fishing	Oil Products	Mechanical Drive (MW3)

Acronyms: MTH - Medium Temperature Heat (120º-500ºC); LTH1 - Low Temperature Heat 90º-120ºC; LTH2 – Low Temperature Heat 60-90ºC; LTH3 - Low Temperature Heat <60ºC; MW2 - Gasoline/LPG Engines; MW3 - Diesel Engines; OE – Other Electrical uses.
Note to the table: (a) the value refers to the Energy sector's own uses.

In the Energy sector, final exergy is mostly consumed as fuel oil and LPG in refineries. Both the IEA (2016) data and the variables introduced by participants in the workshops do not take into account recent changes in the sector, namely the tendency for oil refineries' to substitute fuel oil by natural gas, something already implemented by oil refineries in Portugal. Nevertheless, the weight of fuel oil consumption within the energy sector is not significant to have an impact on the estimations provided by MEET2030.

Industry's most consumed energy carrier is Combustible Renewables. In this case, the Paper, Pulp & Print industry is the highest final exergy consumer in this sector, and it is projected to continue to be so in 2030. It uses combustible renewables, e.g. black liquor, for heat processes (LTH1). Industry's second most consumed energy carrier is Electricity, mostly in Paper, Pulp & Print, Food & Tobacco, Chemical & Petrochemical, Iron & Steel and Machinery.

Within these industries, the main Electricity uses vary from Heat (HTH in Iron and Steel, LTH1 in Paper, LTH2/LTH3 in Food), to MD (Stationary in general), and OE (Electrochemical uses in Chemical). Even though LTH1 uses using natural gas do not figure in the table, these are the third highest final consumers in Industry, with a projected share close to 2%.

Residential/Commercial sector highest consumption is stationary MD from Electricity, including uses such as washing and dishwashing machines, air conditioners and refrigerators. Also, other electrical uses category is considered to increase until 2030 due to the growing use of electronic appliances such as computers, smartphones, printers etc.

Transportation and Agriculture/Fishing have their higher final consumption associated to Oil products (diesel and gasoline) for mechanical drive mobile uses (e.g. road vehicles and tractors) as expected. The slow penetration of electrical vehicles contributes to this scenario.

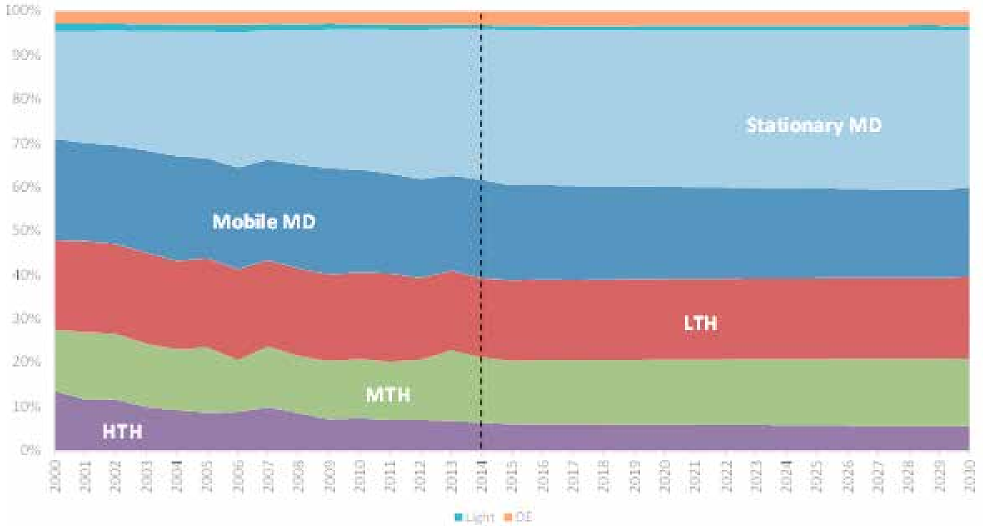
A summary table with useful and final shares as well as the considered efficiencies per sector, energy carrier and end-use is presented in Appendix 7.5.1. Shares presented in this Appendix were estimated relatively to Portugal's total useful exergy consumption and not per sector, while the figures presented below show the calculated useful exergy consumption shares per sector. Shares higher than 3%, in 2030, are highlighted.

It is important to note that a decrease in the share of an energy carrier does not necessarily imply a decrease in absolute value. However, in the case of Oil – Gasoline and Diesel vehicles - the decrease of approximately 6% in Oil's final exergy share corresponds effectively to a decrease in consumption of approx. 25 PJ (~15%) for Diesel uses and 6 PJ (~12%) for Gasoline ones.

Useful exergy shares

In terms of useful exergy, Figure 31 presents the evolution for Portugal, disaggregated by end-uses. The remaining figures from this section present the useful exergy evolution for each sector: energy, industry, transport, residential/commercial and agriculture and fishing.

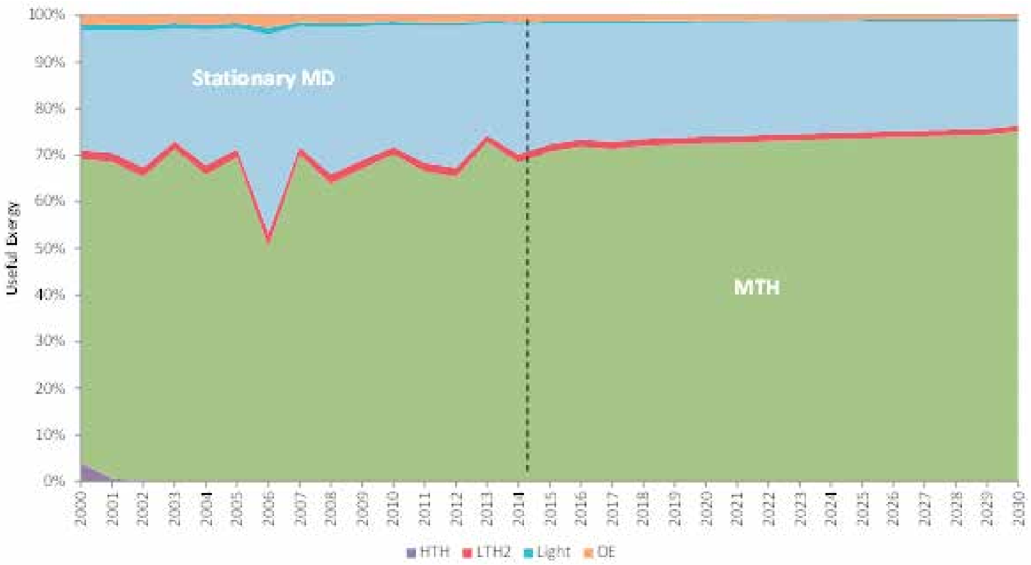
Figure 31. Portugal useful exergy shares per end-use 2000-2030 for the Ostrich scenario



Acronyms: MD – Mechanical Drive; LTH – Low Temperature Heat (<120ºC); MTH – Medium Temperature Heat (500-120ºC); HTH – High Temperature Heat (>500ºC); OE – Other Electrical uses.

The highest shares in the Energy sector (Figure 32) are MTH and Stationary MD. In this sector, and to produce Electricity, higher temperatures are used (category HTH), however, when looking to useful exergy consumption, one is considering the sector's own use of energy/consumption. For this reason, the absolute values of this consumption represent less than 9% of total final exergy and 10.6% of total useful, which means that the consumption for MTH uses is in fact residual consumption used mostly to help during Electricity production processes (e.g. preheating).

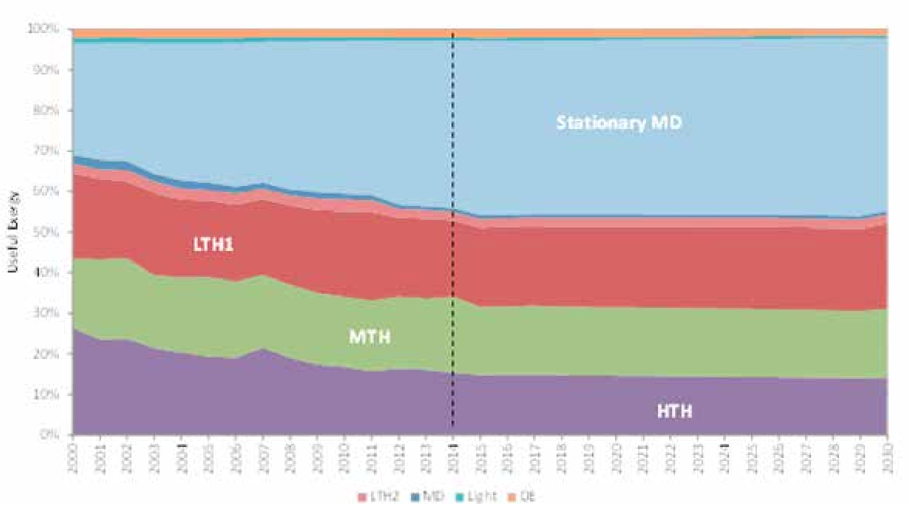
Figure 32. Useful exergy shares in Energy 2000-2030 for the Ostrich scenario



Acronyms: MD – Mechanical Drive; LTH2 – Low Temperature Heat 60-90ºC; MTH – Medium Temperature Heat (500-120ºC); HTH – High Temperature Heat (>500ºC) ; OE – Other Electrical uses.

In the Industry sector, processes use mainly high temperatures and, for that, HTH, MTH and LTH1 have the highest shares associated (Figure 33), while stationary mechanical drive motors have the highest share, since most industries function in their production lines with stationary motors. For the Ostrich, as mentioned before, projections follow past trends which may be observed in the figure. This shows the conservative mind-set for Ostrich projections' scenario; where trends do not change much from the past years and, therefore, do not evolve to a much more energy efficient society.

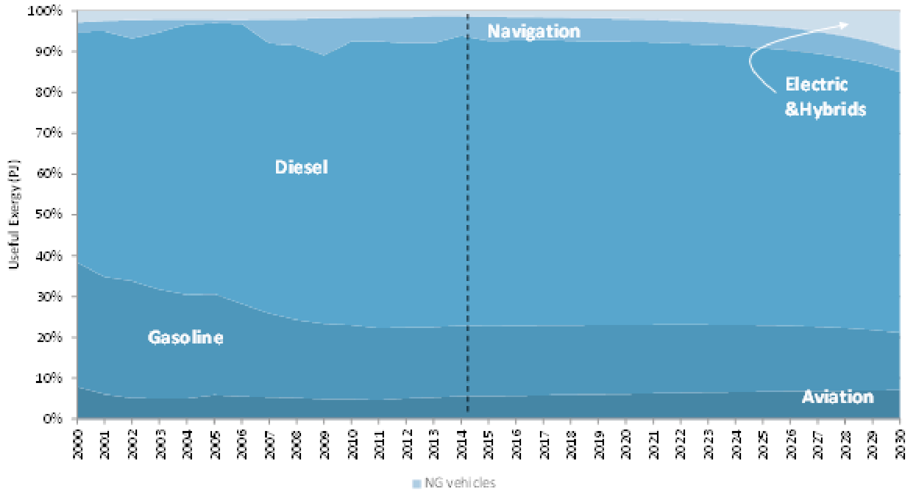
Figure 33. Useful exergy shares in Industry 2000-2030 for the Ostrich scenario



Acronyms: MD – Mechanical Drive; LTH2 – Low Temperature Heat 60-90ºC; LTH1 – Low Temperature Heat 90-120ºC; MTH – Medium Temperature Heat (500-120ºC); HTH – High Temperature Heat (>500ºC); OE – Other Electrical uses.

As might be expected, in Transports (Figure 34), engines fuelled by Diesel and Gasoline have the highest shares, followed by Aviation and Navigation. Shares' projections follow average from recent past years, showing a relative stabilization until 2030. Nevertheless, **Electric & Hybrid vehicles have an increase in projections growing to be around 9.4 % of Transports useful exergy by 2030.**

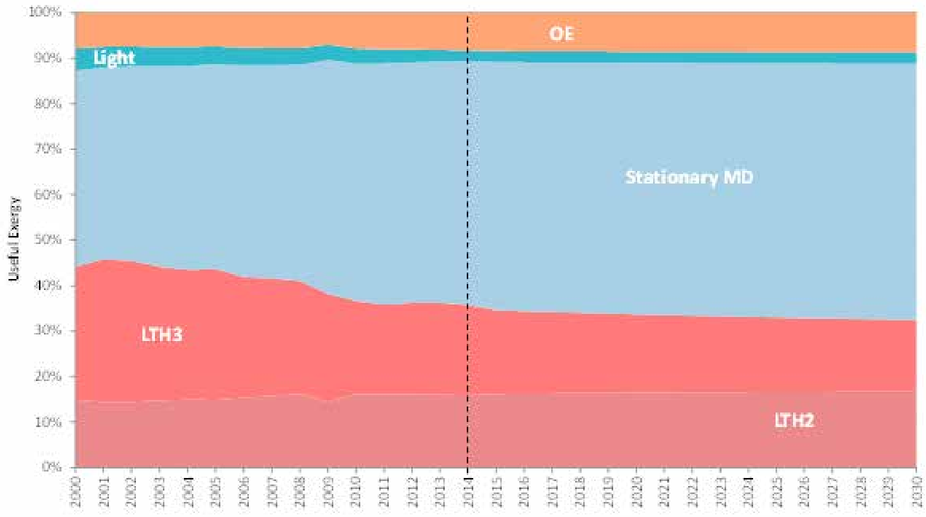
Figure 34: Useful exergy shares in Transports 2000-2030 for the Ostrich scenario



Acronyms: NG – natural gas.

Stationary MD uses' useful exergy share are highest in the Residential/Commercial sector (Figure 35). This is explained by cooling devices included in this category (such as refrigerators and air conditioners) and, also, due to considering a high final-to-useful efficiency for these uses (electric motors). In fact, LTH3 is the category with the highest share of final exergy of this sector. Heat uses LTH2 and LTH3 are mostly associated to Residential and Services sectors, being, these sectors more affected by any changes in this uses' projections. In the case of LTH2 end-uses associated to Electricity, such as radiators, the average temperature considered is 80ºC.

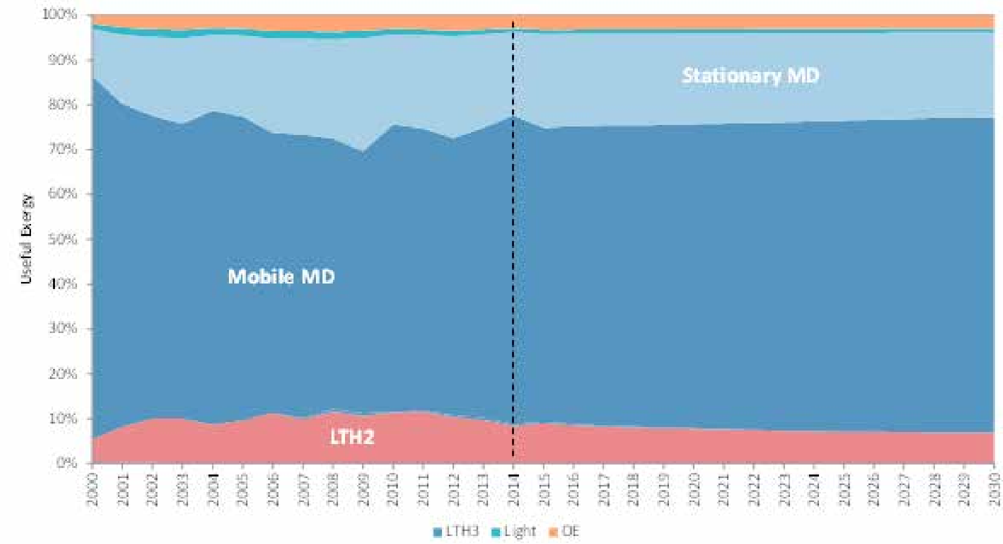
Figure 35. Useful exergy shares in Residential/Commercial 2000-2030 for the Ostrich scenario



Acronyms: MD – Mechanical Drive; LTH3 – Low Temperature Heat <60ºC; LTH2 – Low Temperature Heat 60-90ºC; OE – Other Electrical uses.

The Agriculture/Fishing sector (Figure 36), which has a relevant role in terms of emissions, has little significance regarding final and useful exergy, corresponding to 2-3% of total consumptions. Mechanical drive uses have the highest useful shares of this sectors, for uses such as tractors (mobile motors – MD) and water pump (stationary motors – stationary MD).

Figure 36. Useful exergy shares in Agriculture/Fishing 2000-2030 for the Ostrich scenario



Acronyms: MD – Mechanical Drive; LTH3 – Low Temperature Heat <60ºC; LTH2 – Low Temperature Heat 60-90ºC; OE – Other Electrical uses.

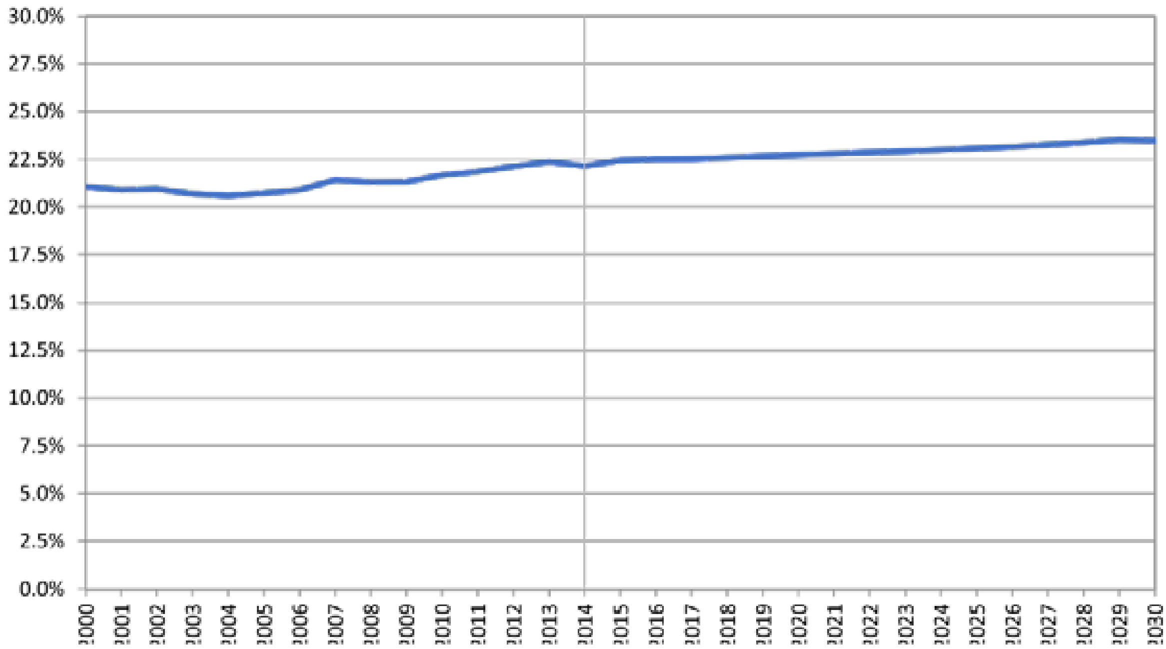
In relation to Light and Other Electrical uses, these are the categories with the lowest shares of consumption (both final and useful). For the Ostrich scenario, there is a trend that shows a relatively constant projection of Light and a small growth of OE uses.

Final-to-useful Aggregate Exergy Efficiency

Aggregate efficiencies were estimated based on the assumptions made for the efficiencies and shares per energy carrier and type of end-use. From 2000 to 2014, Portugal's aggregate final-to-useful efficiency has been relatively constant (Figure 37). This tendency remains until 2030, **where aggregate efficiency increases around 1.3% from 2014 to 2030** and about 2.4% from 2000 to 2030, reaching 23.5%. The slight increase is due to the assumptions made at the more disaggregated level of energy's several end-uses.

The change in this efficiency is mainly related to the appliances used by consumers. This change in energy shares and the fact that the use of electricity has a higher efficiency than the use of any other energy carrier, leads to the increase verified in the aggregate energy efficiency.

Figure 37. Portugal's aggregate final-to-useful efficiency 2000-2030 in the Ostrich scenario

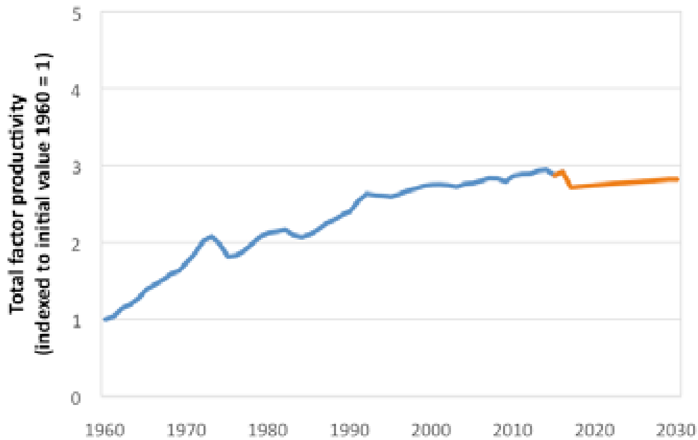


4.1.4. Total Factor Productivity

While projections for capital and labour inputs to production have been addressed (Sections 4.1.1 and 4.1.2 from this report) – based on assumptions related to investment capacity and hours worked in the economy – total factor productivity is projected for the period 2017-2030 by taking into account the final-to-useful aggregate exergy efficiency derived from participants' assumptions (Section 4.1.3).

Based on these projections for final-to-useful aggregate exergy efficiency, TFP projection is calculated using the observed historical relationship between these two variables (see Figure 17). Total factor productivity increases from 2014 to 2030 at a slightly smaller average rate (0.3% per annum) compared to its average growth between 2000 and 2014 (Figure 38).

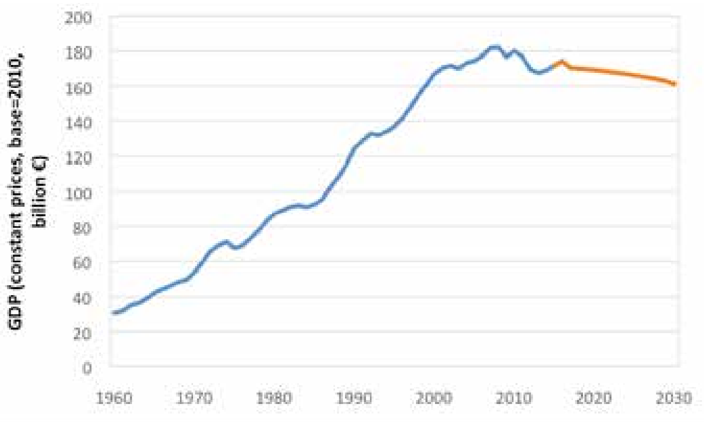
Figure 38. Total factor productivity in the Ostrich for 2017-2030 [Source of historical data: AMECO]



4.1.5. Gross Domestic Product and Exergy Consumption

Gross domestic product is obtained as an aggregate production function of TFP, as well as capital and labour inputs to production (as detailed in Section 7.6) – see Figure 39. In the Ostrich scenario, **projected GDP for 2017-2030 follows the decreasing trend from the past years**, reaching by 2030 the same level of GDP as the one observed before the Portuguese entrance to the Euro-area in 1999.

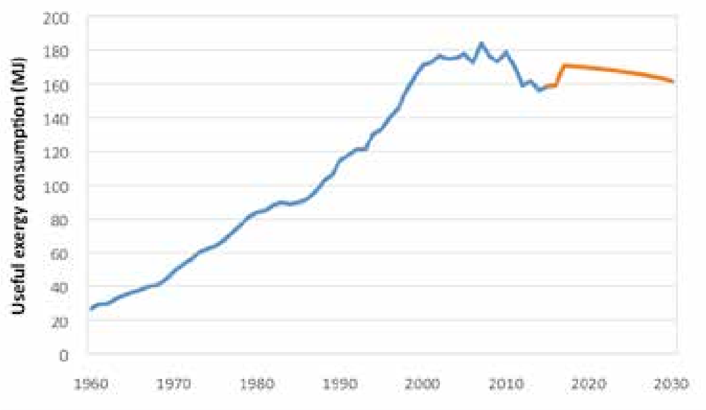
Figure 39. GDP in the Ostrich for 2017-2030 [Source of historical data: AMECO]



Useful exergy consumption is obtained through the stable long-run useful exergy intensity empirically verified for the Portuguese economy (Figure 14), i.e., useful exergy intensity is assumed to maintain its stability, at approximately 1 MJ of useful exergy per 1 € of GDP.

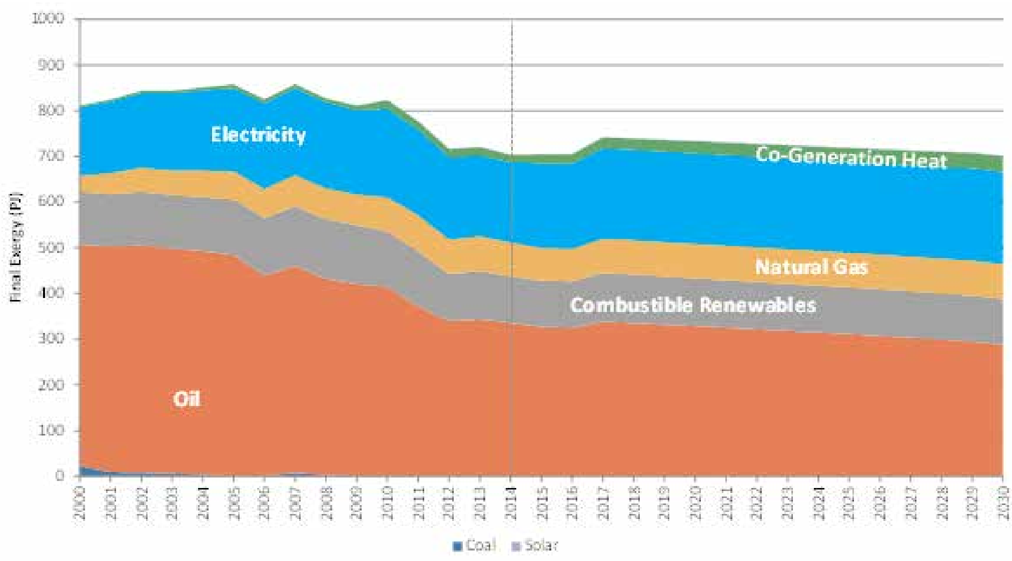
As a result, useful exergy consumption projected for the period 2017-2030 follows the same trends as projected for GDP (Figure 40).

Figure 40. Useful exergy consumption in the Ostrich for 2017-2030 [Source of historical data: Serrenho et al. (2016)]



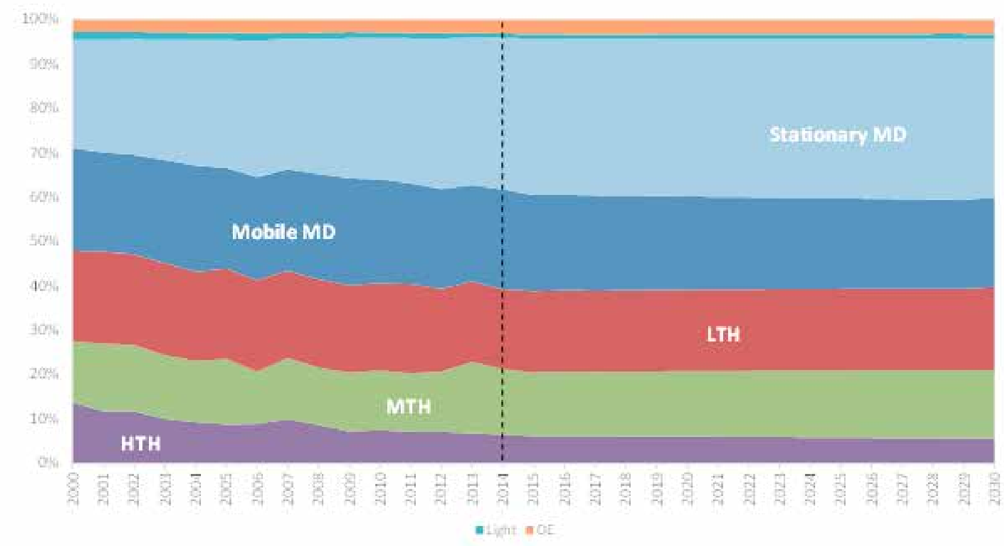
From the aggregate useful exergy projections computed from projected GDP and assuming constant useful exergy intensity, projections for aggregate final exergy can be obtained, dividing aggregate useful exergy by final-to-useful aggregate efficiency projections (Figure 41). **Final exergy consumption follows the same patterns as the evolution of the shares of exergy uses.** A summary table with useful and final shares as well as considered efficiencies per sector, energy carrier and end use is presented in Appendix 7.5.1.

Figure 41: Final exergy consumption per energy carrier in the Ostrich scenario



In terms of the overall consumption of Portuguese society, it does not change much: 704 PJ (2014) compared to 702 PJ (2030) of final exergy and 156 (2014) compared to 165 (2030) of useful exergy. In this scenario there is a relatively small increase in total exergy consumption, associated to a slow growth in the economy. After an expected rebound effect up until 2017, final and useful exergy consumption totals remain approximately constant until 2030 for most energy carriers observed except, as mentioned before, for Electricity and Oil uses (Figure 42).

Figure 42. Portugal useful exergy shares per end-use 2000-2030 in the Ostrich scenario



Acronyms: MD – Mechanical Drive; LTH – Low Temperature Heat (<120ºC); MTH – Medium Temperature Heat (500-120ºC); HTH – High Temperature Heat (>500ºC); OE – Other Electrical uses.

In particular:

- There are no effective measures to address carbon leakage established;
- Portugal is not able to continue to develop and implement proactive policies for tackling climate change - Reaction is the rule;
- There is limited CO_2 licensing;
- Current EU-ETS scope is maintained;
- No robust carbon price, increasing the risk of market distortions and not providing an environment of innovation and employment;
- There are no fiscal policies for zero CO_2 businesses.

4.1.6. Decarbonisation of the Economy: Primary-to-Final Exergy Efficiency

In this scenario, there are a low level of cooperation and a low social capital in terms of cooperation and behaviour of the different players. At the corporate level, there is a weak sectoral and cross-sectoral cooperation, including for tackling climate change. Regulations and policies are weak and ineffective, with low cooperation between agents (National and European wide). There is alleviation or weakening of EU regulation and incentives for inducing renewable energy production. Frequent changes of the political actors in governments/change of programs/priorities lead to unstable priorities and approaches towards climate change. Geological CCS, CCU and use of CO_2 not allowed nor promoted.

The result is a low investment in climate change mitigation technologies, either in terms of research and mass production/ mass adoption.

The main characteristics of this scenario regarding decarbonisation are identified in Table 12.

Table 12. Main variables and configurations for GHG emissions in the Ostrich

	CONFIGURATIONS
Electricity mix [c]	60% of electricity comes from renewable resources
Allowing/ promoting geological CCS, CCU and use of CO_2 [a]	Geological CCS, CCU and use of CO_2 not allowed
Availability of technologies for climate mitigation and adaptation [b]	Not available, immature or costly
European electric grid integration [a]	Incapacity for the integration of the electricity markets across Europe
Sectoral and cross-sectoral cooperation in climate protection [a]	Weak sectoral and cross-sectoral cooperation, including for climate change
Policy on climate change (ambition) [b]	No promotion of effective measures to address carbon leakage; Portugal is not able to continue to develop and implement proactive policies on climate change - Reaction as a rule; Focus on mitigation policies, rather than on mitigation and adaptation; Limited CO_2 licensing; No robust carbon price, increasing the risk of market distortions and not providing an environment of innovation and employment; Maintaining current EU-ETS scope; Non existing fiscal policies for zero CO_2 businesses;
Strength of EU regulation and incentives inducing renewable energy production [b]	Regulation alleviation or weak Regulation

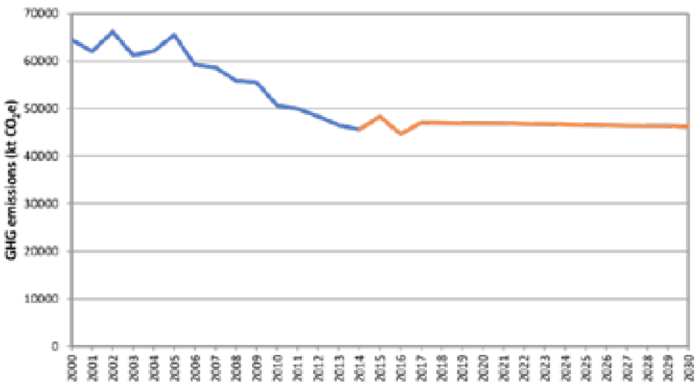
Table 12. Main variables and configurations for GHG emissions in the Ostrich (Cont.)

	CONFIGURATIONS
Stability of climate change policies worldwide: actors, programs and priorities [a]	Change of Political Actors in Governments/Change of programs/priorities leading to unstable priority and approaches for climate change
Pace of adoption of energy efficiency technologies and measures and microgeneration [a]	Scarce adoption of energy efficiency technologies and measures
GHG emissions from the IPCC's Energy category [d]	46.2 Mt CO_2e
... in the energy sector	... 22.3 Mt CO_2e
... in the industry sector	... 6.2 Mt CO_2e
... in the transport sector	... 13.9 Mt CO_2e
... in the residential/ commercial sector	... 2.8 Mt CO_2e
... in the agriculture and fishing sector	... 1.1 Mt CO_2e

See Table 8 for further notes.

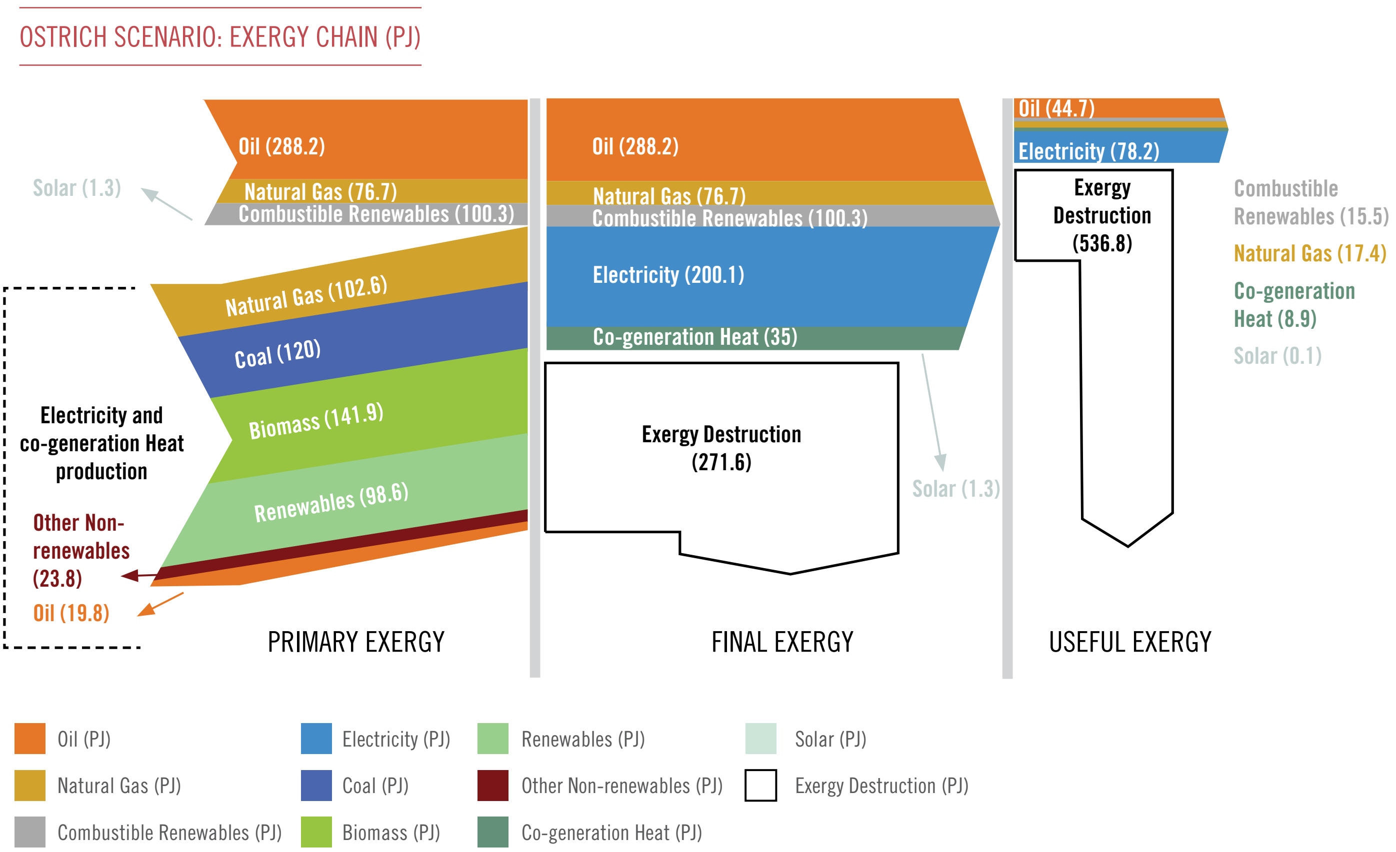
Figure 43 presents total GHG emissions for the Ostrich. The **mix of resources consumed to produce Electricity is made up of 60% from renewable resources** (Biomass, Hydro, Wind, Geothermal and Solar) and 40% from non-renewable (Thermo-electricity production excluding the use of Biomass). GHG emissions from the Ostrich reach 46.2 Mt $CO_{2\ eq}$ in 2030. This scenario **complies with the less stringent scenario of the National Low-Carbon Roadmap** (APA, 2012).

Figure 43. Portugal's GHG total emissions in the Ostrich for 2000-2030



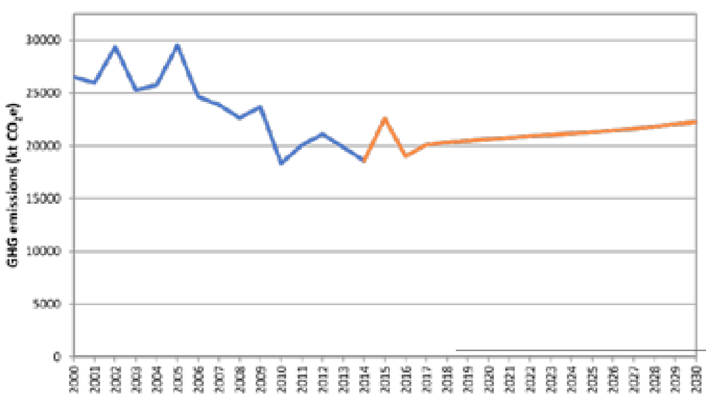
The energy flow considered from primary to useful is the one presented in Figure 44. In the Ostrich, in 2030 the energy flow from final exergy to useful exergy for Portugal, shows that 77% of the input is lost, which means that only 23% of final exergy was converted into useful exergy.

Figure 44. Sankey diagram for the Ostrich



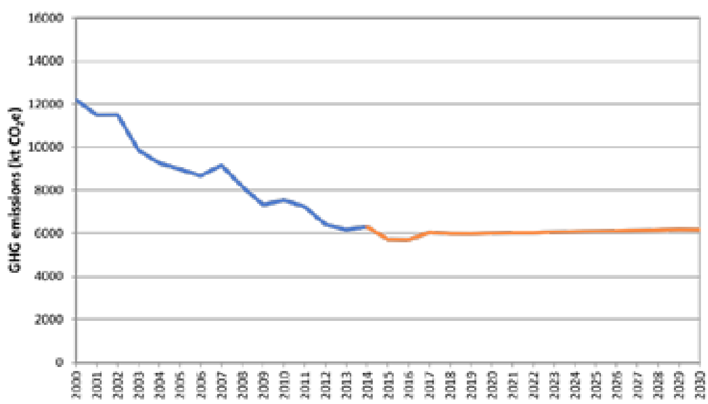
The Energy sector is the one with the highest GHG emissions associated (Figure 45), it is also the sector in which GHG emissions from Electricity production and co-generation heat are included. In 2030, **GHG emissions are of 22.3 Mt CO_2e**, this value is close to the GHG emissions in 2009.

Figure 45. Portugal's GHG emissions for the Energy sector in the Ostrich, 2000-2030



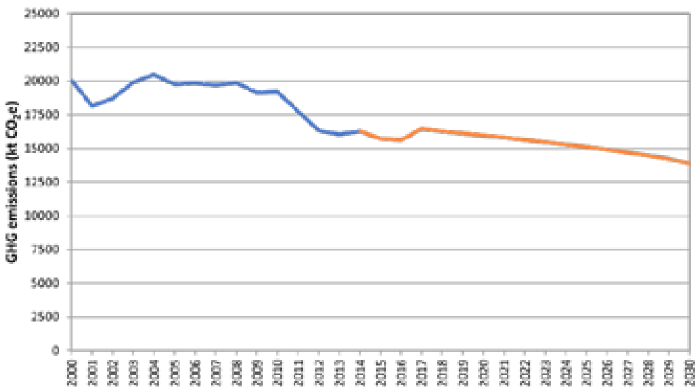
The GHG emissions associated to the Industrial sector stabilise from 2017 to 2030 (Figure 46), in a similar value to the one verified in 2014.

Figure 46. GHG emissions in the Ostrich for the Industry sector, 2000-2030



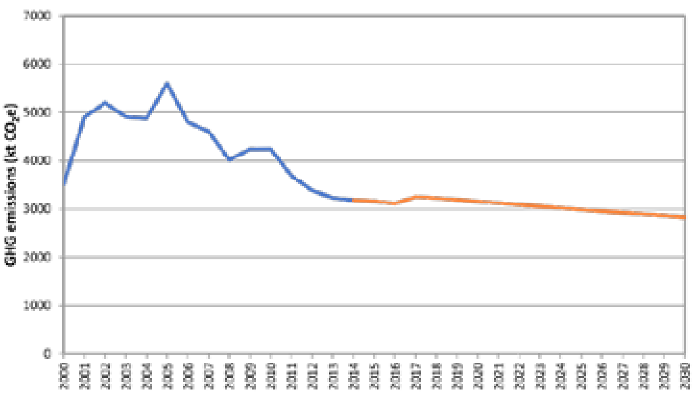
The Transport sector is the one with the second highest total GHG emissions after the Energy sector (Figure 47).

Figure 47. GHG emissions from the Transportation sector in the Ostrich, 2000-2030



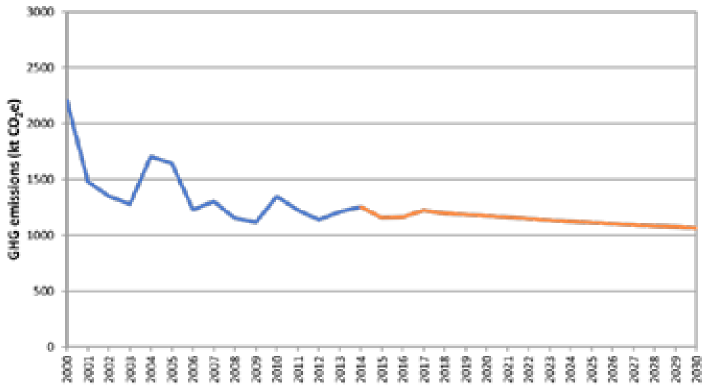
In Figure 48 it is possible to observe GHG emissions f**or the Residential/Commercial sector**, which **decrease** until 2030.

Figure 48. GHG emissions from Residential/Commercial sector for the Ostrich, 2000-2030



The GHG emissions from the energy use in Agriculture/ Fishing sector are the emissions with the lowest value associated (Figure 49) because the consumption shares are also the lowest, for this analysis. The values presented here do not include process emissions from agricultural activities (emissions from cattle, manure, soils, amongst others), which typically represent the larger component of GHG emissions from the agriculture sector. These emissions fall outside the Energy category from IPCC's and have not been included.

Figure 49. GHG emissions from Agriculture/Fishing for the Ostrich, 2000-2030



4.2. THE IBERIAN LYNX

Imagine, once again that we are in 2030, looking back at the past...

> ***During the last decade, Portugal became a thriving dynamic economy. In resemblance to the Four Asian Tigers back in the 1960s through to the 1990s, this economic prominence of Portugal lead Martin Wolf to nickname Portugal as "The Iberian Lynx" in his Financial Times article published on the 25th of January of 2025.***
>
> ***This nickname stands up even nowadays and it has become a reference for a country that took the opportunities brought by the 4th Industrial Revolution and the global sustainability movement in an exemplary manner. That was mainly possible due to the ability that Portugal had in implementing strong cooperation relationship within the several economic agents in Portugal and with other countries. A country that used to be considered as peripheral but that was able to find its role in the international agenda.***
>
> ***However, in 2030, new and strong challenges linked to the emissions arose: did the Iberian Lynx reproduce too fast, deplete resources and was the victim of its own success?***

The scenario considers more stable international geopolitical and demographic contexts, in terms of political issues, ageing population, migrations, and an increasing global trust. In this scenario, the EU becomes more cohesive and within a stable political context.

In the following sub-sections, the scenario is described in more detail in terms of the capital stock (4.2.1), employment (4.2.2), energy use (4.2.3 and 4.2.4), economic growth (4.2.5) and GHG emissions (4.2.6).

4.2.1. Capital Investment

In terms of capital investment, there is **high stability, growth and competitiveness**. The scenario considers EU economic growth, a financial stabilisation of the Portuguese economy and a higher investment capacity. The banking system recovers and helps supporting the economic development. The result is an **increase in the stock of capital for Portugal**. Table 13 summarises the main characteristics of the scenario in terms of capital investment.

Table 13. Capital investment in the Iberian Lynx scenario

In terms of the investment in capital (GFCF), the Iberian Lynx results in a growth at a constant annual rate of 2%, the same average annual growth rate observed in the 1960s (Figure 50).

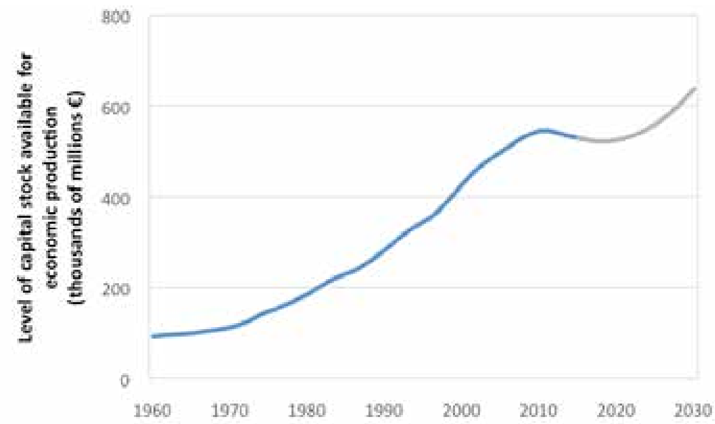
	CONFIGURATIONS
EU economic growth capacity	Growth
Capacity of the banking system to support economic development	Banking system recovers and supports economic development
Financial stability of the Portuguese economy	Financial stabilisation
Investment capacity in the Portuguese economy (c)	Increases 2% / year
Stock of capital (a) (b)	Increase between 0.5% and 2.5%

Notes to the table: Variable (a) was defined by the research team in order to link the uncertainties to GDP evolution. All configurations were defined and discussed with the workshops' participants. Exception was for (b), were values are a consequence from the remaining variables' configurations. These values were discussed with participants. (c) Includes investments in climate mitigation.

Figure 50. Investment in capital assets for 2017-2030. Projections for the Iberian Lynx scenario [Source of historical data: AMECO]

Similarly to what happens to the Ostrich scenario, the consumption of fixed capital (CFC), remains equal to its historical average value of 5.4% of the level of capital stock available. Based on GFCF and CFC, the capital available for production grows between 1% and 3% reaching approximately 640 thousand million € by 2030 (Figure 51).

Figure 51. Level of capital stock for 2017-2030. Projection for the Iberian Lynx scenario [Source of historical data: AMECO]



4.2.2. Labour

Regulations and policies are strong, flexible (towards new challenges) and effective, in a cooperative environment. There is an effective digitalisation policy, with both the vision and the goals being supported by a strong political commitment and a close cooperation between agents and there is an alignment between Government's policies and companies' needs in order to address new societal challenges. This leads to a capacity to attract and retain talents. This scenario also considers a strong adaptability of the educational system to industry's new requirements and that there are effective policies on retirement, health, justice, education in place. Recalling the example of the farmer with a 100 horse power tractor, 300 years ago, when the industrial revolution got started in England (not so much in agriculture, but in the industry) the concern was the same as it is nowadays: that there will be no jobs. It was the need to enable people to work with new machines (such as training a farmer on how to drive a truck) that brought about compulsory education in countries as they proceeded along the multiple industrial revolutions. The **result is a decrease on unemployment rates to 5-7% in 2030. The number of hours worked per engaged individual also decreases,** Table 14 summarises the main aspects of labour considered in the Iberian Lynx scenario.

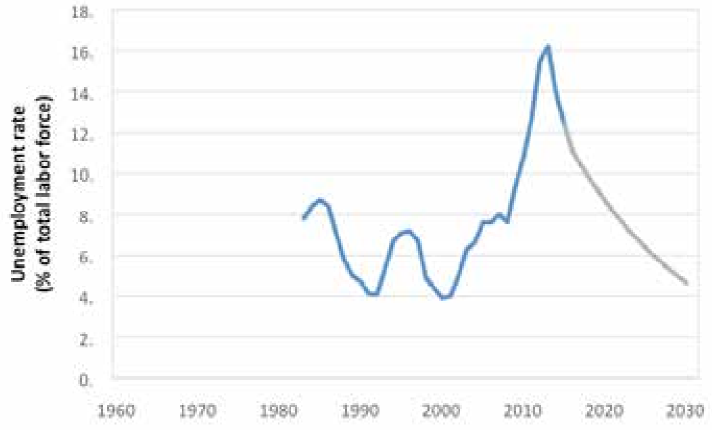
Table 14. Labour in the Iberian Lynx scenario

	The Iberian Lynx
Alignment between Government's policies and companies' needs to address new societal challenges (a)	Alignment between Government's policies and companies' needs to address new societal challenges, namely talent attraction and retention
Effectiveness of national policies on retirement, health, justice, education (a)	Effective policies in place
Adaptability of the educational system to the future industries and market needs (b)	Educational system adapts to industry's new requirements
Impacts of automation and digitalisation on unemployment rates (b)	Unemployment rates decrease
Impacts of automation and digitalisation on the type of employment (b)	Automation leads to smarter, higher paid jobs that sustain the Social State
Unemployment rates (c)	Decrease to 5-7% by 2030
Portugal's capacity to attract and retain talents	Portugal is able to compete and create a pool of talents
Labour force (d)	Decrease
Average annual hours worked per employed individual (c)	Unchanged trend
Total hours worked by all employed individuals (d)	Decrease to 7515 million hours by 2030

Notes to the table:
(a) Defined and selected by participants in the 1st Challenge and the 2nd Workshop.
(b) Defined by participants (in the 1st Challenge) selected by the research team.
(c) Defined by the research team in order to link the uncertainties to GDP evolution.
All configurations were defined and discussed with the workshops' participants. Exception was for (d), were values are a consequence from the remaining variables' configurations. These values were discussed with the participants during the MEET 2030 process.

The unemployment rate projected in this scenario for the period 2017-2030 decreases at a constant annual rate of 6%, r**eaching 5 to 7% of the total labour force by 2030.** Historically, unemployment has varied between 4% and 16% of the total labour force, over the past decades and therefore, the Iberian Lynx scenario does not reach the lowest unemployment rate ever achieved in Portugal.

Figure 52. Unemployment rates for the Iberian Lynx scenario for 2017-2030
[Source of historical data: AMECO; INE]



The number of employed individuals in the economy is obtained by subtracting the unemployed individuals from the total labour force. Historically, the number of employed individuals has varied between approximately 3 million and 5 million, for the last 50 years, with an average value of approximately 4 million (Figure 53).

Figure 53. Engaged individuals for the Iberian Lynx scenario for 2017-2030
[Source of historical data: Feenstra et al. (2015)]

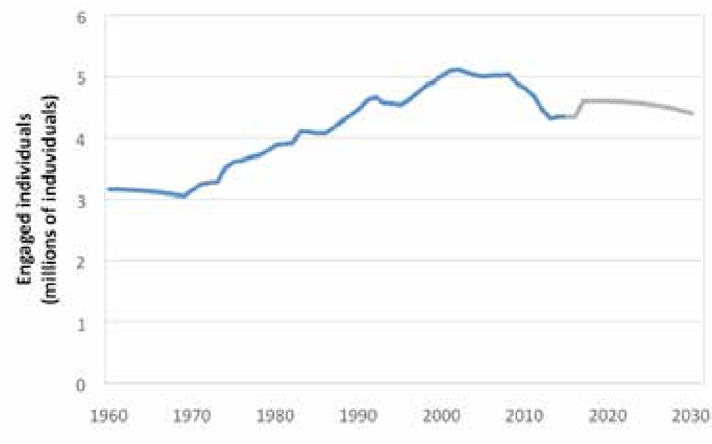
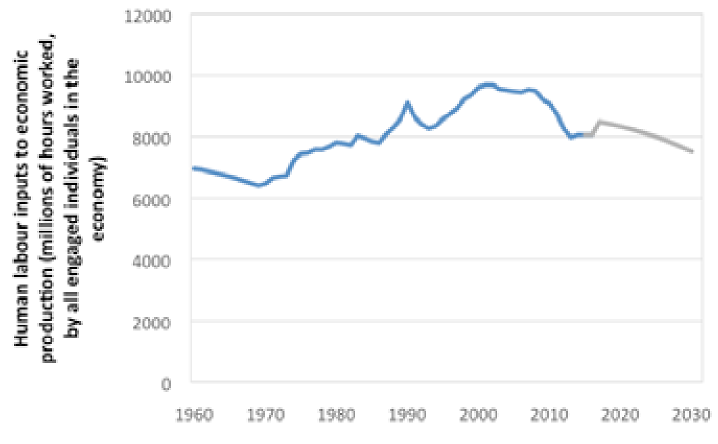
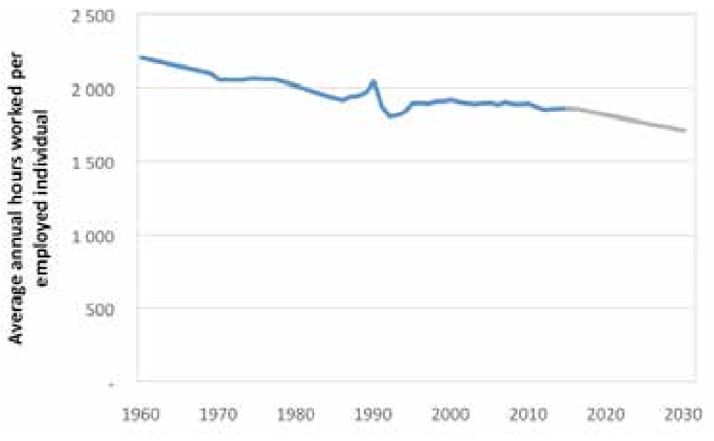


Figure 55. Human labour inputs to economic production for the Iberian Lynx scenario for 2017
[Source of historical data: AMECO; INE; Feenstra et al. (2015)]



The average annual hours worked per employed individual continue to **decrease,** at the same historically observed rate for the past decades (Figure 54), at approximately minus 0.6% per year, reaching approximately 1700 h/ year by 2030 (around 35h/week per average individual).

Figure 54. Average annual hours worked per employed individual for the Iberian Lynx for 2017-2030
[Source of historical data: Feenstra et al. (2015)]



Although unemployment rates decrease, the number of hours worked per employed individual reduces leading to a decrease of total hours worked by all employed individuals in the economy to 7515 million hours by 2030 (Figure 55).

4.2.3. Final to Useful Exergy Efficiencies and Useful Exergy Shares

Overview

The Iberian Lynx is a scenario with a fast economic growth and a rapid increase in aggregate final-to-useful exergy efficiency. Table 15 summarises the main characteristics of this scenario.

Table 15. Main variables and configurations for exergy use by category in the Iberian Lynx scenario

	CONFIGURATIONS
Market preparedness for industry synergies [(a)]	Market works together to close the loop in terms of circular economy
Capacity to develop a digitalisation policy sustained in a strong commitment from the industry, looking into taking Portugal to the leadership on digitalisation and connectivity [(a)]	Existence and effectiveness of such a digitalisation policy, taking on the vision and goal with a strong political will and close cooperation between agents

Table 15. Main variables and configurations for exergy use by category in the Iberian Lynx scenario (Cont.)

	CONFIGURATIONS
Useful exergy shares (exergy by end use category) (c)	Electrification: MW2 share decreases approx. 1.5 p.p. to be approx. 2% of total useful exergy; Diesel uses decrease drastically to almost half of their share from 15.4% (2014) to 9% (2030); Heat needs from electric appliances diminish circa 1.6% to be 3.1% of total useful exergy; Electricity MD uses increase to represent 50% of Electricity's useful exergy.
Electrical vehicles circulating by 2030 (EV and H_2) (b)	Fast adoption - 20%
Electric grid ability to integrate electrical vehicles (b)	Fast and comprehensive
Final-to-useful exergy efficiencies (c)	hybrid-electric vehicles' efficiency increases 5p.p. by 2030; NG vehicles' efficiency increase 1.4p.p. by 2030; Lighting efficiency increases 5 p.p. by 2030.
Energy efficiency in buildings (a)	Exergy for heating decreases 1.4p.p. by 2030 (improved efficiency)
Pace of adoption of energy efficiency technologies and measures and microgeneration (a)	Energy efficiency is a clear priority. Fast adoption of energy efficiency measures and technologies

See Table 14 for further notes.

In this scenario, there is cooperation, trust and stability of the different players. Market players work together to close the loop for a circular economy (industry synergies). Policies, incentives and systems are in place facilitating the shift towards the circular economy. **Regulations and policies are strong, flexible (towards new challenges) and effective, developed in a cooperative environment.** There are effective and more ambitious regulations promoting energy efficiency in buildings in place.

Oil and Electricity uses are the energy carriers[5] where main changes occur, compared to the present. These changes occur in terms of both, final-to-useful efficiencies and exergy shares. In this scenario, **there is an electrification of the economy leading to a partial substitution of oil uses by electricity uses.** This happens in terms of different uses including vehicles (adoption of the electrical vehicle). For that, the trends for Oil and Electricity uses are steeper than in the Ostrich (Figure 56 and Figure 57). Note that although the share of oil products in final energy decreases (relatively), its absolute quantity remains roughly constant. Additionally, energy efficiency is a clear priority. There is a fast adoption of energy efficiency measures and technologies.

5. This report uses the typology for energy carriers as the IEA (IEA 2016): coal, oil, combustible renewables (such as wood), natural gas, electricity, co-generation heat and solar photovoltaic.

Figure 56. Useful exergy shares per energy carrier 2000-2030 for the Iberian Lynx scenario

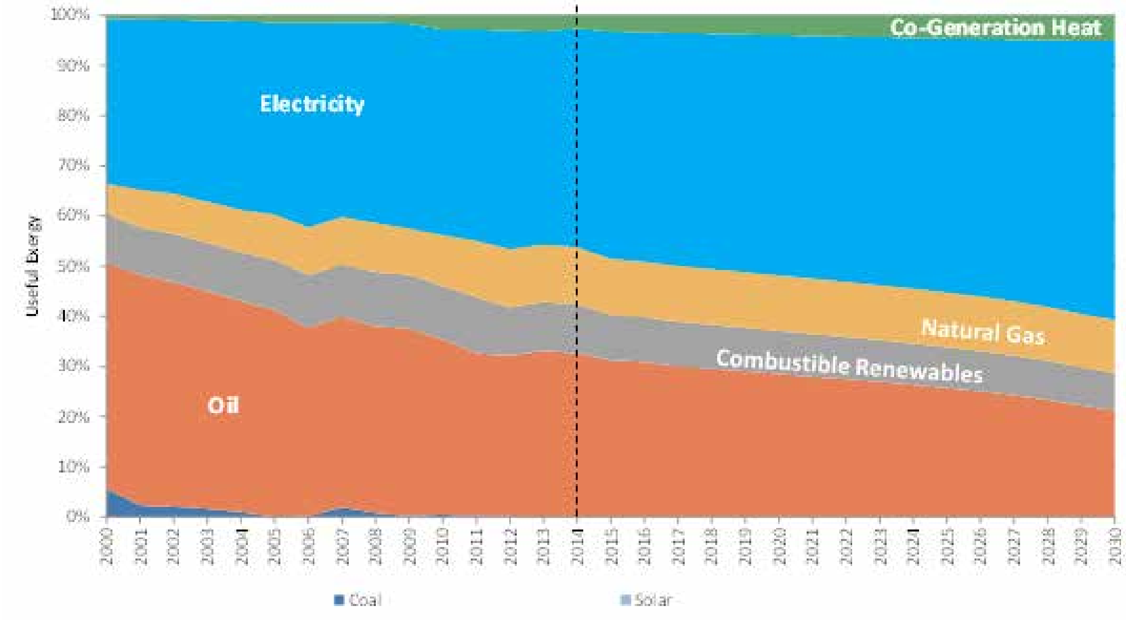
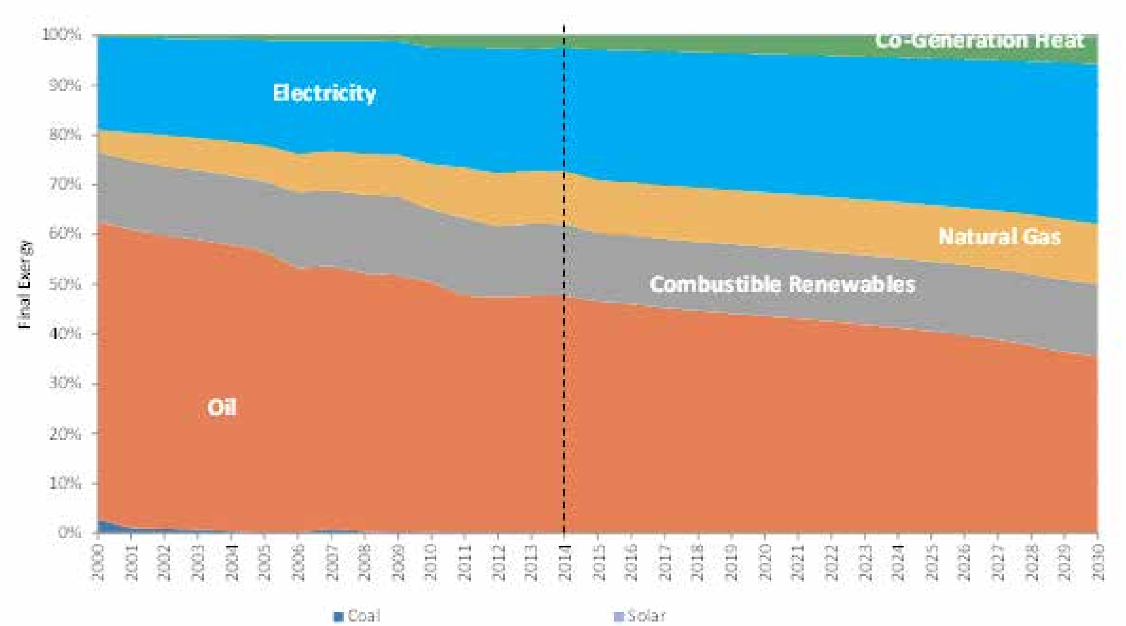


Figure 57. Final exergy shares per energy carrier 2000-2030 for the Iberian Lynx scenario



For a closer view of the exergy consumption projected for 2030, Table 16 shows the energy carriers with the highest (>3%) final exergy consumption per sector in 2030. Having the highest shares means that changes in the consumption of these energy carriers lead to higher impacts on exergy projections, since changes on their consumption patterns correspond to modifications in the largest consumption shares. Identifying the end-use with the highest consumption, shown also in **Table 16 helps each business, within each sector, understanding which technologies might contribute to the Iberian Lynx scenario.**

Final exergy shares

Considering Portugal's total consumption, the sectors with higher shares of final exergy consumption (and consequently with the highest influence on the exergy projections) are the Residential/Commercial (Services) and the Industry.

Table 16. Most significant energy carriers consumed by sector in 2030 in the Iberian Lynx

SECTORS	ENERGY CARRIER	END-USE
Industry	Electricity	Mechanical Drive (stationary)
Transportation	Oil Products	Mechanical Drive (MW2 and MW3)
	Combustible Renewables	Mechanical Drive (MW3)
Residential/ Commercial	Electricity	Heat (LTH2) and OE
	Combustible Renewables	Heat (LTH3)
	Oil Products	Heat (LTH3)
Agriculture/ Fishing	Electricity	Mechanical Drive (stationary)
	Oil Products	Mechanical Drive (MW3)

Acronyms: MTH - Medium Temperature Heat (120º-500ºC); LTH1 - Low Temperature Heat 90º-120ºC; LTH2 – Low Temperature Heat 60-90ºC; LTH3 - Low Temperature Heat <60ºC); MW2 - Gasoline/LPG Engines; MW3 - Diesel Engines; OE – Other Electrical uses.

For the particular case of the energy sector, both the IEA (2016) data and the variables introduced by participants in the workshops do not take into account recent changes in the sector, namely the tendency for oil refineries' to substitute fuel oil by natural gas, something already implemented by oil refineries in Portugal. Nevertheless, the weight of fuel oil consumption within the energy sector is not significant to have an impact on the estimations provided by MEET2030.

For the Industry case, Electricity becomes the only carrier with a final share higher than 3%. However, Paper, Pulp & Print industry, which is the greatest consumer of final exergy, continues to consume more final exergy from Combustible renewables for LTH1 uses – which cannot be changed due to this industry's processes characteristics. Therefore, LTH1 using Combustible Renewables still has the second highest share (approximately 2.9%).

Natural Gas continues to be the third energy carrier most consumed, in Industry, for LTH1 uses, increasing its share up to circa 2.3%. In 2030, the highest consumers are Non-Metallic Minerals (which includes the production of Clay, Cement and Glass), Food and Tobacco, Textile & Leather, Chemical & Petrochemical and Paper, Pulp & Print industries.

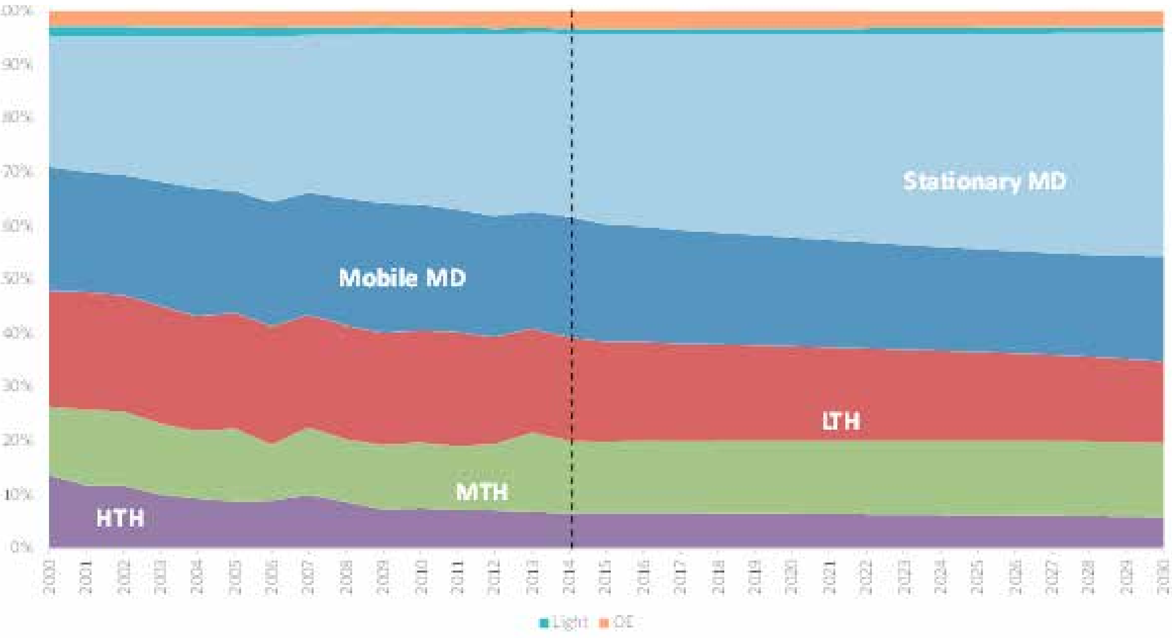
In Transportation, there is a growth of Combustible Renewable consumptions mainly due to a shift towards the consumption of biofuels – corresponding mainly to biodiesel which is a MW3 use.

Residential/Commercial sector has an increase in final consumption of approx. 6% of Electricity uses, being the highest and second highest shares from stationary MD and OE uses respectively.

Useful exergy shares

A general view of the Iberian Lynx useful exergy consumption by end-use is shown in Figure 58). Table 17 presents examples of technologies that are used within the Iberian Lynx.

Figure 58. Useful exergy shares 2000-2030 in the Iberian Lynx



Acronyms: MD – Mechanical Drive; LTH – Low Temperature Heat (<120ºC); MTH – Medium Temperature Heat (500-120ºC); HTH – High Temperature Heat (>500ºC); OE – Other Electrical uses

Table 17. Examples of technologies suggested by participants that can contribute to the Iberian Lynx scenario

SECTORS	FINAL ENERGY CARRIER	END USE	EXAMPLES OF TECHNOLOGIES
INDUSTRY	Electricity	Mechanical Drive (stationary)	Use of energy robots to manage airplanes and portable machine to do all services on the air side of the airport Advance grinding technology; separate gridding of raw material components and grinding & blending by fineness; optimised use of grinding aids; increased cement performance by optimised particle size distribution (PSD) Automation/robotisation of the sorting processes, AI Intelligent Housing Systems for Poultry production - optimization of energy consumption, robotisation/automation Installation of turbo-expander that uses high pressure off-gas available
TRANSPORTATION	Oil	Mechanical Drive (MW2 & MW3)	Hybrid vehicles, LPG, electric (light, heavy and sea/river)
	Combustible Renewables	Mechanical Drive (MW3)	Acidification/diversification of raw materials of residual origin for production of 2G biodiesel Production and supply of bio-methane as CNG

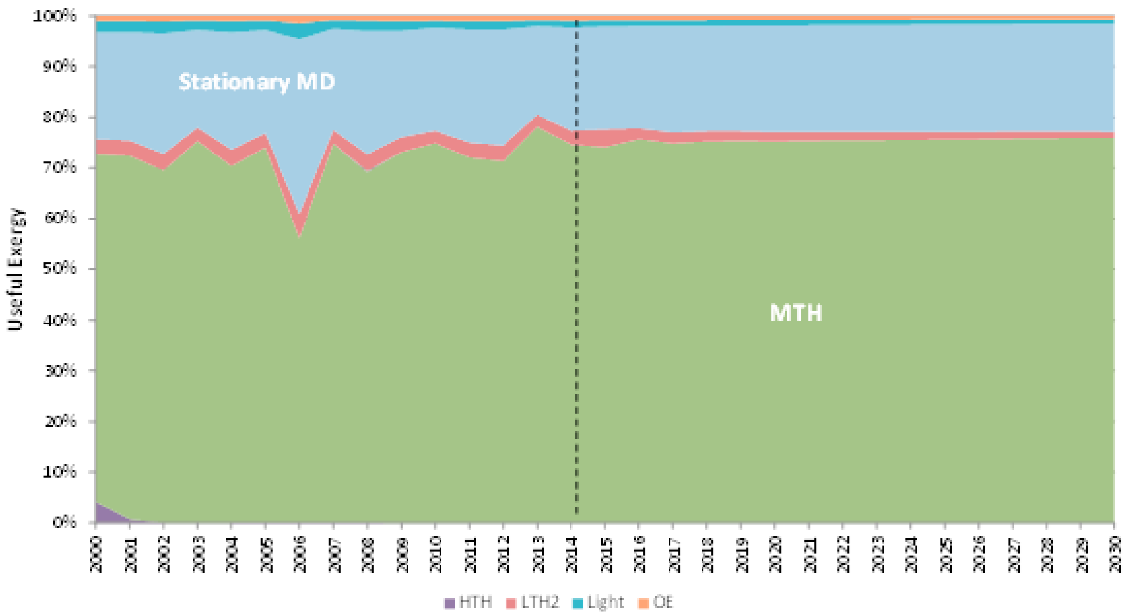
Table 17. Examples of technologies suggested by participants that can contribute to the Iberian Lynx scenario (Cont.)

SECTORS	FINAL ENERGY CARRIER	END USE	EXAMPLES OF TECHNOLOGIES
RESIDENTIAL/ COMMERCIAL	Electricity	Heat (LTH2) & OE	Heat pump
	Combustible Renewables	Heat (LTH3)	Use of alternative fuels replacing conventional fossil fuels, such as biogas and biofuels
	Oil	Heat (LTH3)	Current technologies
AGRICULTURE/ FISHING	Electricity	Mechanical Drive (stationary)	Use of robots and drones for monitoring and management Automation/robotisation of the sorting processes Intelligent Housing Systems for animal production
	Oil	Mechanical Drive (MW3)	Hybrid vehicles, LPG vehicles (light, heavy)

In this scenario, exergy shares follow the past trends, with the exception for the electrification processes which are accelerated. Stationary MD is composed of up to 50% of Electricity's consumption (a growth rate of 4.5%/ year in the total useful exergy for stationary MD) of the - mostly electric motors.

For the Energy sector, there is a slight decrease in the LTH2 share, though the overall consumption of each end-use does not change much from 2014 to 2030 (Figure 59). At the useful level, it is important to keep in mind that the energy production sector is seen as a consumer. The shares presented refer to the sector's own consumption and not including the natural resources consumed to produce Electricity (which is considered to be at a primary level of the energy chain and not at the useful level).

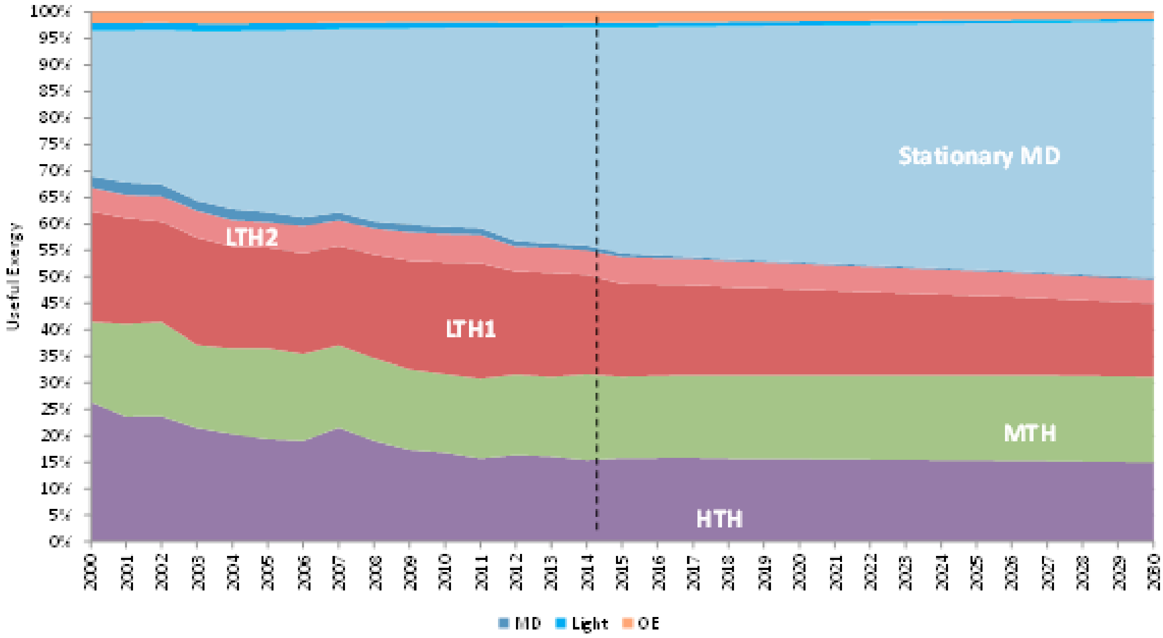
Figure 59. Useful exergy shares in the Energy sector 2000-2030 in the Iberian Lynx



Acronyms: MD – Mechanical Drive; LTH2 – Low Temperature Heat 60-90ºC; MTH – Medium Temperature Heat (500-120ºC); HTH – High Temperature Heat (>500ºC); OE – Other Electrical uses.

For the Industrial sector, end-use categories with higher shares (Figure 60) are the same as in the Ostrich. **Projections show a growing share of stationary MD** uses as the main difference compared to the Ostrich. **This increase mirrors the introduction of new technologies, such as replacing traditional heat uses by electricity (e.g. furnaces) and a strong increase in automation in processes.**

Figure 60. Useful exergy shares in Industry 2000-2030 in the Iberian Lynx



Acronyms: MD – Mechanical Drive; LTH2 – Low Temperature Heat 60-90ºC; LTH1 – Low Temperature Heat 90-120ºC; MTH – Medium Temperature Heat (500-120ºC); HTH – High Temperature Heat (>500ºC) ; OE – Other Electrical uses.

From 2000 to 2014, there has been already a shift from higher temperature processes (HTH and MTH) towards stationary MD. This has been occurring due to the increasing use of electric motors.

From 2014 onwards, **the increased stationary MD share observed in the Iberian Lynx is related to the continuous implementation of automation and robotisation processes in the Industry.** This continuous automation of the Industry is done by reducing low temperature processes (LTH1 and LTH2), replacing their share with more efficient uses and stabilising high temperature categories shares. This leads to an increase in aggregate efficiency. Due to these choices, the 4,5% growth rate of stationary MD leads to much lower growth rate of other uses, such as 0.29% for LTH categories. **As electricity is the carrier with the highest final-to-useful efficiency, one way to move into a considerably more efficient society is to substitute other energy carriers by electricity uses.**

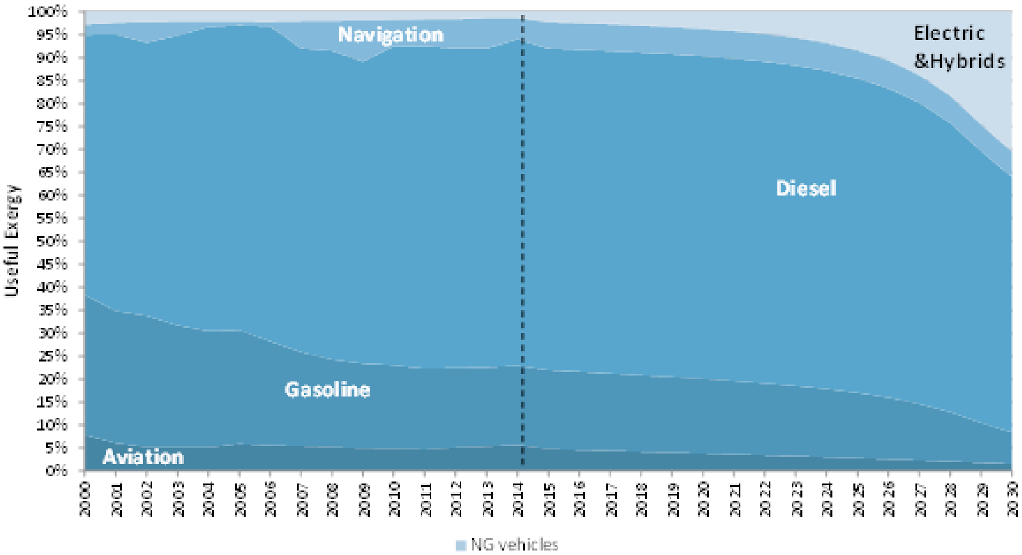
An increase of stationary MD uses contemplates the possibility for new industrial sectors in Portuguese Economy as well as new forms of production, which should be the focus of technological efforts if trying to make this re-distribution of consumption shares in Industry.

In Transport's shares, Gasoline useful shares have a projection similar to the evolution in the Ostrich, while **Diesel useful share grows.** However, if considering Portugal's total useful consumption (in all five sectors), Diesel and Gasoline MD uses consumption shares decrease from 2014 to 2030 (see Appendix 7.5.2 for further details).

Both **Diesel** and Gasoline **shares include biofuels**. Therefore, a growth in one of these categories does not necessarily mean an increase in GHG emissions, as that is influenced by the weight of biofuels in the mixtures consumed (which is one of various factors that affect emissions).

Electric & Hybrid vehicles are the end use that considerably changes between scenarios, **growing its share to represent around 30% of the transport sector useful exergy**. The growth is due to an increase in final consumption share – representing electric cars, in 2030, about 20% of the circulating vehicles - as well as an efficiency improvement in hybrids efficiency of about 5%. The projections for Electric & Hybrid vehicles **accommodate massive implementation of alternative business models** such as car-sharing and Uber.

Figure 61. Useful exergy shares in Transportation 2000-2030 in the Iberian Lynx

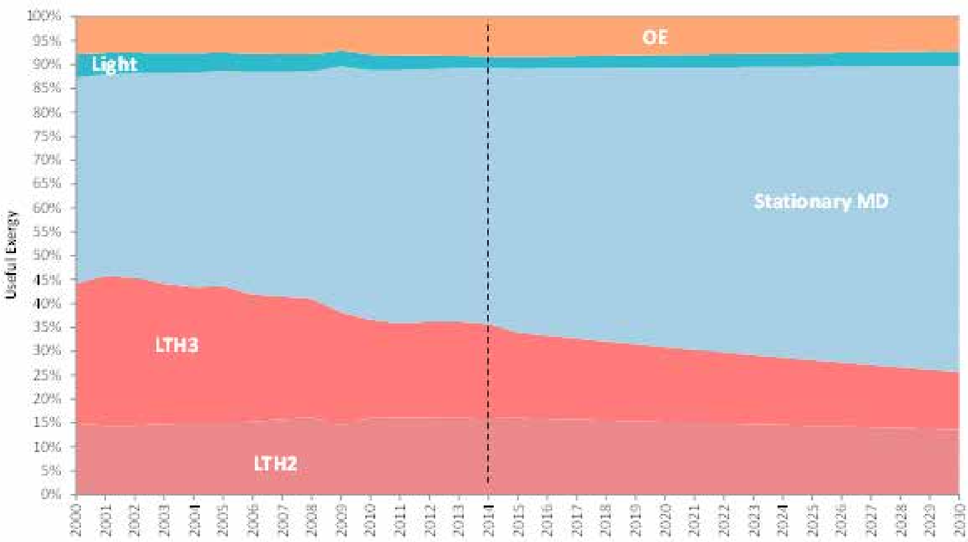


Acronyms: NG – natural gas.

In the Residential/Commercial sector, the main changes are in the LTH3 and stationary MD (Figure 62). The LTH3 is a category related to **buildings' heating needs**, so a **decrease** in its share is associated to an effort to diminish these needs and **increase the use of more efficient electricity-based heat pumps** (in accordance to current national policies on building energetic efficiency), increasing stationary MD. In this sector stationary MD corresponds to any cooling devices such as refrigerators and air conditioners and machines (e.g., washing and dishwashing).

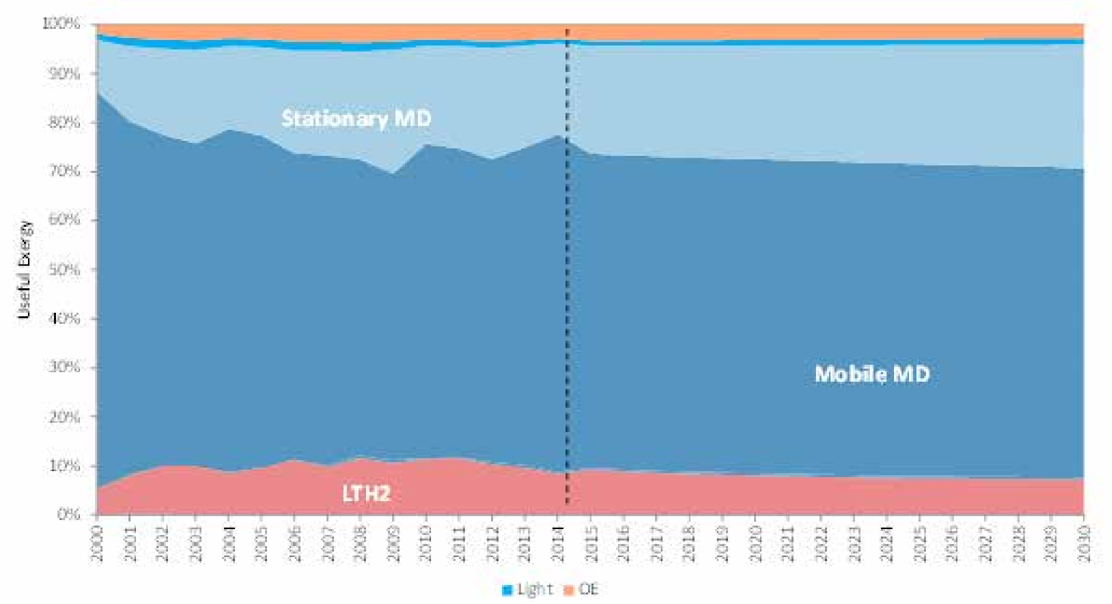
Regarding Agriculture/Fishing, in Figure 63 is visible that projections in this scenario lead to developments in mobile and stationary MD uses opposite to the Ostrich's projection. This means a decrease in mobile MD useful share while stationary MD has an increasing share, which follows the Electrification trend.

Figure 62. Useful exergy shares in the Residential/ Commercial sector 2000-2030 in the Iberian Lynx



Acronyms: MD – Mechanical Drive; LTH3 – Low Temperature Heat <60ºC; LTH2 – Low Temperature Heat 60-90ºC; OE – Other Electrical uses.

Figure 63. Useful exergy shares in Agriculture/Fishing 2000-2030 in the Iberian Lynx



Acronyms: MD – Mechanical Drive; LTH3 – Low Temperature Heat <60ºC; LTH2 – Low Temperature Heat 60-90ºC; OE – Other Electrical uses.

For the Iberian Lynx in general, a particular change that is worth highlighting is the **6% increase in** final exergy consumption by **electric motors** (in MD uses). This change **is associated with** the rapid implementation of **technology advances in the continued process of automation in industries and in other sectors** (e.g. delivery and mailing services, domestic robots, etc.).

For the Iberian Lynx scenario Light technology and substitution of standing stock might allow an increase of 5% by 2030 in final-to-useful efficiency but this has no significant effect in Light's final share. Meanwhile, for OE uses, due to a very low final-to-usful efficiency, these uses share decreases slightly (approx.. 0.3 p.p. in useful share) in the period 2014-2030.

Aggregate final-to-useful exergy efficiency

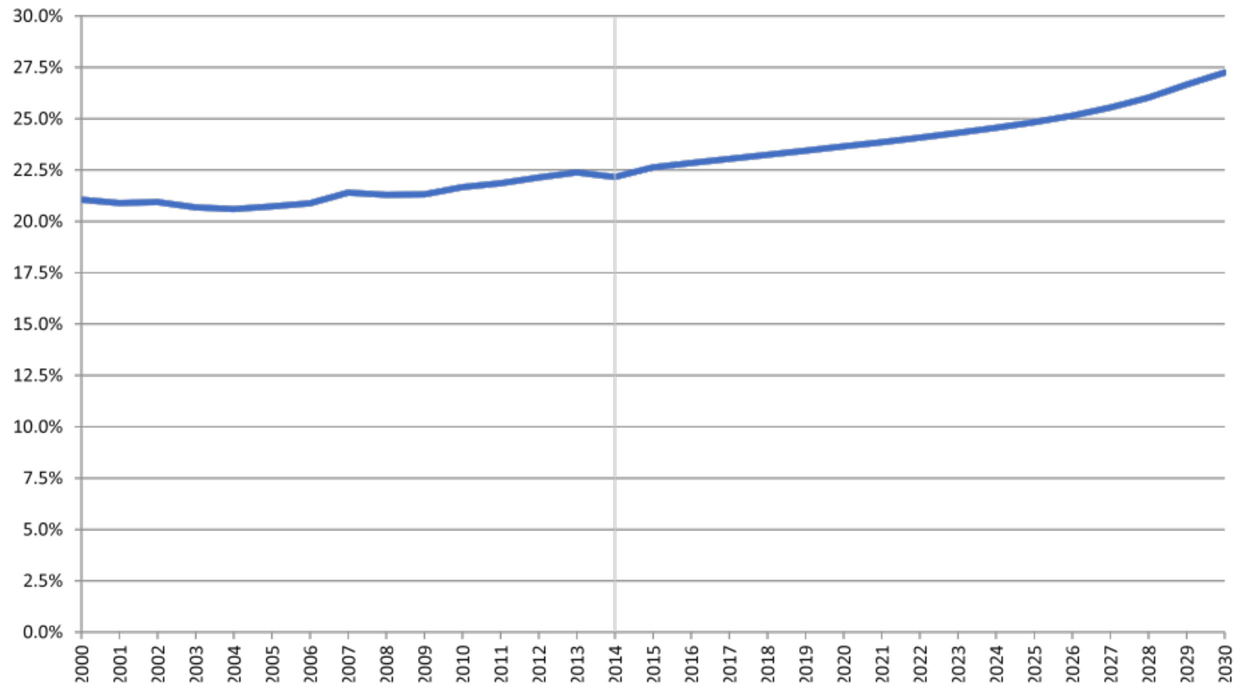
Aggregate efficiencies were estimated based on the assumptions made for the efficiencies and shares per energy carrier and type of end-use (Section 4.2.3 from this report).

The aggregate final-to-useful exergy efficiency for 2030 grows approximately 5%, representing 27.3% in 2030 (Figure 64). The evolution of the efficiency is explained at the end-use level and, in this simulation, **it is mainly based on the substitution of energy carriers' and a more accentuated (than in the Ostrich) shift in electrification** and towards electric appliances.

Since gasoline, diesel and heat have high useful and final exergy shares but low efficiencies (pushing aggregate efficiency to lower values), while electricity has high shares and efficiency, replacing mechanical drive Oil uses by Electric uses (e.g., vehicles) leads to increases in aggregate efficiency. Aggregated final-to-useful efficiency is higher, although maintaining the same past trends of end-use efficiencies. This is mainly due to the change in the shares of electric uses, considering that with the Iberian Lynx stationary mechanical drive uses have a share of approximately 50% of the Electricity consumed.

Therefore, and although appliances' individual efficiencies might increase throughout time, shifting the consumption of energy towards new appliances – many times not as efficient – and considering changes in consumption patterns, could lead to a decrease in aggregate efficiency in some cases. This means that **consumers, habits and behaviour influence the aggregate efficiency.**

Figure 64. Portugal's aggregate final-to-useful efficiency 2000-2030 in the Iberian Lynx

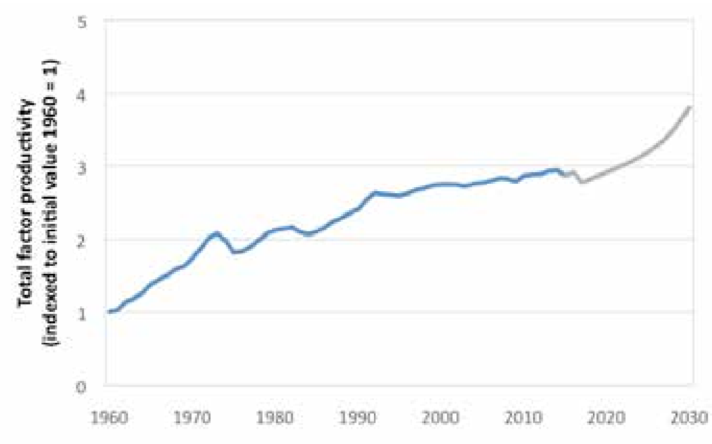


4.2.4. Total Factor Productivity

While projections for capital and labour inputs to production have been addressed (Sections 4.2.1 and 4.2.2 from this report) – based on assumptions related to investment capacity and hours worked in the economy – total factor productivity is projected for the period 2017-2030 by taking into account the final-to-useful aggregate exergy efficiency derived from participants assumptions (Section 4.2.3).

Based on these projections for final-to-useful aggregate exergy efficiency, TFP projection is calculated using the observed historical relationship between these two variables (Figure 14). Total factor productivity increases from 2017 to 2030 (Figure 65).

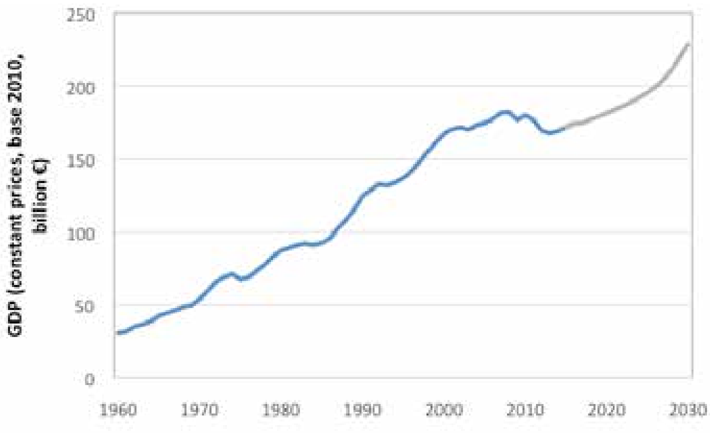
Figure 65. TFP in the Iberian Lynx for 2017 to 2030 [Source of historical data: AMECO]



4.2.5. Gross Domestic Product and Exergy Consumption

GDP is obtained as an aggregate production function of TFP, as well as capital and labour inputs to production (as detailed in Section 7.6) – see Figure 66. In the Iberian Lynx, **projected GDP** for 2017-2030 **follows a very accentuated increasing trend, growing at approximately an annual growth rate of 2.0%**, and reaching 227.8 billion Euro by 2030.

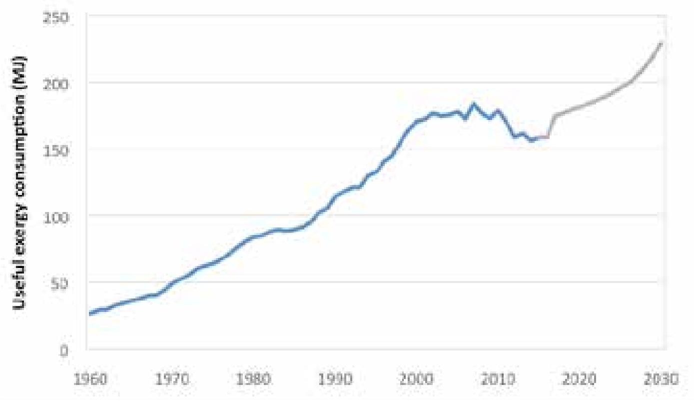
Figure 66. GDP in the Iberian Lynx for 2017-2030
[Source of historical data: AMECO]



Useful exergy consumption is obtained through the stable long-run useful exergy intensity empirically verified for the Portuguese economy (Figure 14), i.e., useful exergy intensity is assumed to maintain its value of approximately 1 MJ of useful exergy per 1 € of GDP.

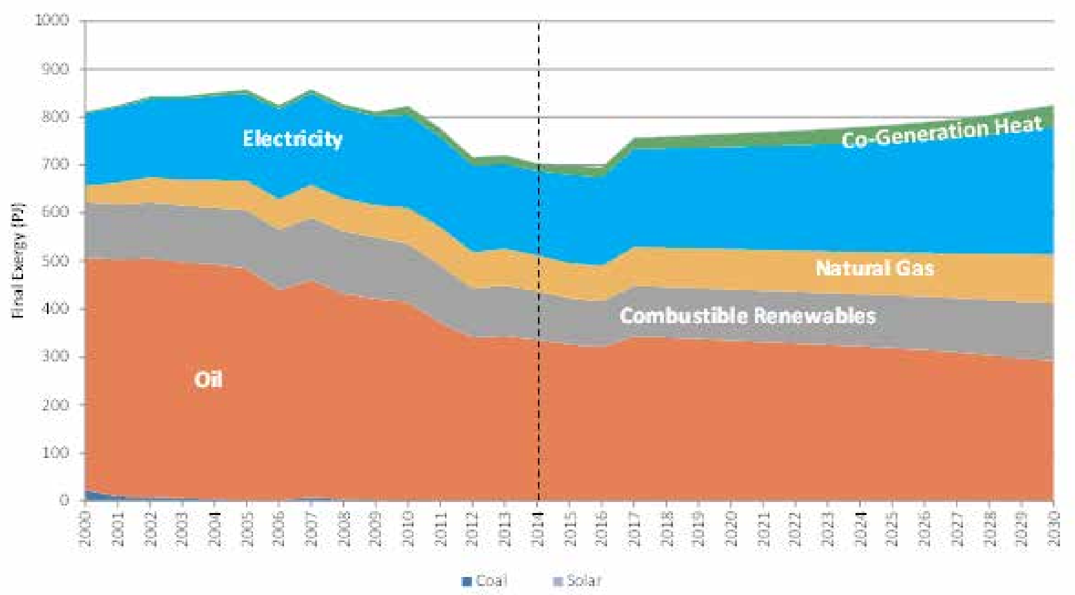
As expected, useful exergy consumption projected for the period 2017-2030 follows the same trends as projected for GDP (Figure 67).

Figure 67. Useful exergy consumption in the Iberian Lynx for 2017-2030
[Source of historical data: Serrenho et al. (2016)]



From the aggregate useful exergy projections computed from projected GDP and assuming constant useful exergy intensity, projections for aggregate final exergy can be obtained, dividing aggregate useful exergy by final-to-useful aggregate efficiency projections (Figure 68). Regarding oil products, although their final exergy share decreases, their absolute consumption remains constant until 2030.

Figure 68. Final exergy consumption per energy carrier for the Iberian Lynx scenario



The rapid economic growth leads to a higher total useful exergy consumption (229 PJ in 2030) than in the Ostrich (165 PJ in 2030). This is also true for final exergy consumption (839 PJ consumed in this scenario). In the Iberian Lynx, even though aggregate efficiency increases strongly, final exergy does not diminish because overall consumption is higher.

If the Iberian Lynx efficiency was the same as in the Ostrich (about 23.5%) a final consumption of 839 PJ would result only in approximately 197 PJ of useful consumption (less 32 PJ than what is projected with the 27.3% Iberian Lynx efficiency).

4.2.6. Decarbonisation of the Economy: Primary-to-Final Exergy Efficiency

In this scenario, there is a strong cooperation, trust and stability of the different players. There is also a strong sectoral and cross-sectoral cooperation, including for climate change tackling. Across Europe, electricity markets/ grids are integrated. There are strong regulations and incentives for renewable energy production, leading to strong changes in businesses. There are stability of policies evolution on GHG emissions and related themes. Geological CCS, CCU and use of CO_2 allowed and promoted.
In particular, in terms of the ambition of climate change policies and regulations, this scenario considers that:

- Effective measures to address carbon leakage are taken globally across all sectors;
- Portugal is able to develop and implement proactive policies on climate change;
- There is a robust carbon price promoting a healthy investment environment for innovation, employment and a shift towards a low carbon economy;
- Enlarged EU-ETS scope across economic sectors, leading to a larger effort of businesses to reduce their GHG emissions;
- Existing fiscal policies for zero CO_2 businesses, providing incentives for the substitution of technologies and raw materials' use for more sustainable ones.

The result is a high investment in climate change mitigation technologies, both in terms of research and in terms of mass production/ mass adoption.

Table 18 summarises the main characteristics for the Iberian Lynx.

Table 18. Main variables and configurations for GHG emissions in the Iberian Lynx

	CONFIGURATIONS
Electricity mix [c]	60% of renewable resources
Allowing/ promoting geological CCS, CCU and use of CO_2 [a]	Geological CCS, CCU and use of CO_2 allowed and promoted
Availability of technologies for climate mitigation and adaptation [b]	Available and affordable
European electric grid integration [a]	Integration of electricity markets across Europe
Sectoral and cross-sectoral cooperation in climate protection [a]	Strong sectoral and cross-sectoral cooperation, including for climate change
Policy on climate change (ambition) [b]	Effective measures to address carbon leakage are taken globally across all sectors; Portugal is able to develop and implement proactive policies on climate change; Promotion of adaption policies, together with mitigation policies; There is a robust carbon price promoting a healthy investment environment for innovation, employment and a shift towards a low carbon economy; Enlarged EU-ETS scope across all sectors; Existing fiscal policies for zero CO_2 businesses.
Strength of EU regulation and incentives inducing renewable energy production [b]	Strong regulation leading to strong changes in businesses
Stability of climate change policies worldwide: actors, programs and priorities [a]	Policies Evolution on GHG Emissions and related themes

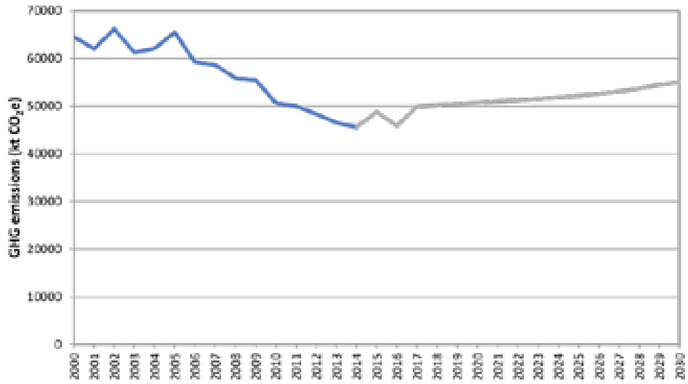
Table 18. Main variables and configurations for GHG emissions in the Iberian Lynx (Cont.)

	CONFIGURATIONS
Pace of adoption of energy efficiency technologies and measures and microgeneration [a]	Energy efficiency is a clear priority. Fast adoption of energy efficiency measures and technologies
GHG emissions from the IPCC's Energy category [d]	55.0 Mt CO_2e
... in the energy sector	... 29.3 Mt CO_2e
... in the industry sector	... 8.4 Mt CO_2e
... in the transport sector	... 12.6 Mt CO_2e
... in the residential/ commercial sector	... 3.3 Mt CO_2e
... in the agriculture and fishing sector	... 1.4 Mt CO_2e

See Table 14 for further notes.

By 2030, GHG emissions from the Iberian Lynx (approximately 55.0 Mt CO_2e) are higher than the ones in the Ostrich (46.2 Mt CO_2e). This is **related to the increase in energy consumption.**

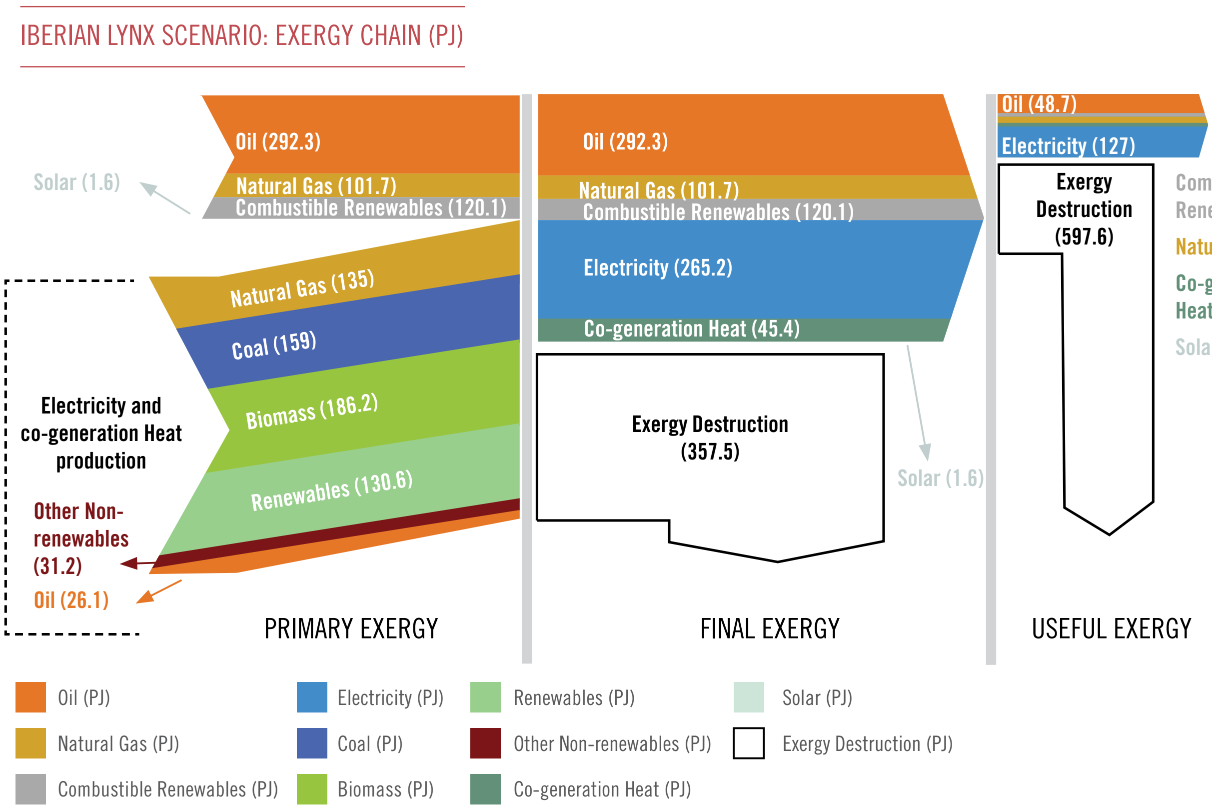
Figure 69. GHG total emissions for the Iberian Lynx, 2000-2030



In Figure 69, there is an overview of the total GHG emissions for the Iberian Lynx. **The mix of resources consumed to produce Electricity is the same for both scenarios: 60% from renewable resources** (Biomass, Hydro, Wind, Geothermal and Solar) and 40% from non-renewable (Thermo-electricity production excluding the use of Biomass).

The energy flow considered from primary to useful are the one presented in Figure 70. In the Iberian Lynx scenario, in 2030 the energy flow from final exergy to useful exergy for Portugal, shows that 72% of the input is lost, which means that only 28% of final exergy was converted into useful exergy.

Figure 70. Sankey diagram for the Iberian Lynx

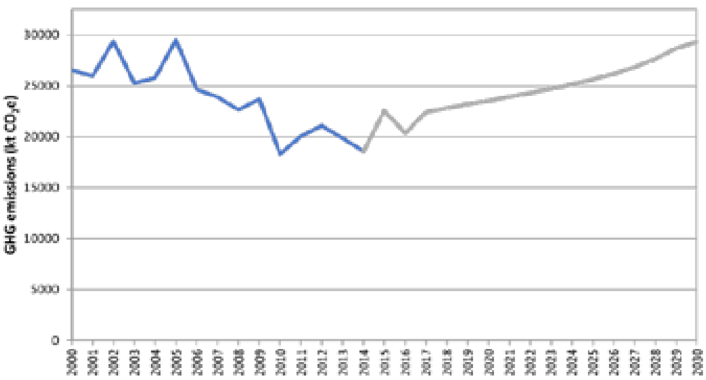


The Energy sector is the one with the highest GHG emissions; it is also the sector in which GHG emissions from Electricity production and co-generation heat are included. **Emissions for the energy sector increase** (Figure 71) **reaching 29.3 Mt CO_2e by 2030.** GHG emissions are higher (circa 7 Mt CO_2e) than in the Ostrich. This is due to an faster increase in Electricity consumption and taking into account the sector's own consumption emissions.

The GHG emissions associated to the energy sector are the ones that have the greatest disparity in values between scenarios by 2030.

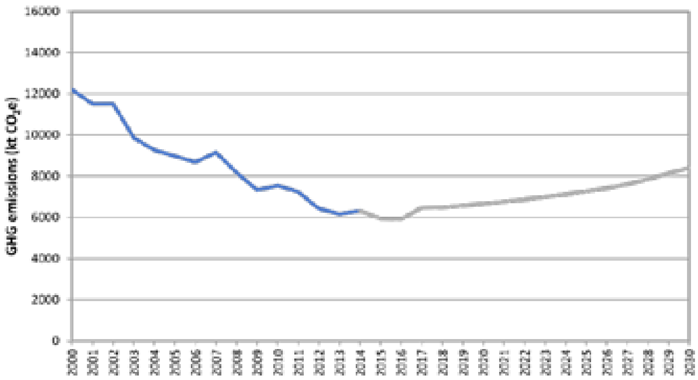
Although the share of renewable resources in the electricity mix remains constant from 2014 to 2030, given the increase in electricity consumption (from electrification), the absolute production of renewable energy is higher each year. This also means that increasing the renewables share in the mix requires an even larger effort from the Energy production sector and the use of renewable resources.

Figure 71. GHG emissions from the Energy sector in the Iberian Lynx, 2000-2030



GHG emissions from the industrial sector increase (Figure 72) **reaching 8.4 Mt CO_2e by 2030.** The increase in emissions is **due to the rapid economic growth and consequent increase in energy consumption** verified in this scenario. Furthermore, this is one of the sectors with higher energy consumption in the Portuguese society as well as a wider range of types of fuels used. Some **combustibles with high emission factors are consumed by this sector** leading to higher GHG emissions.

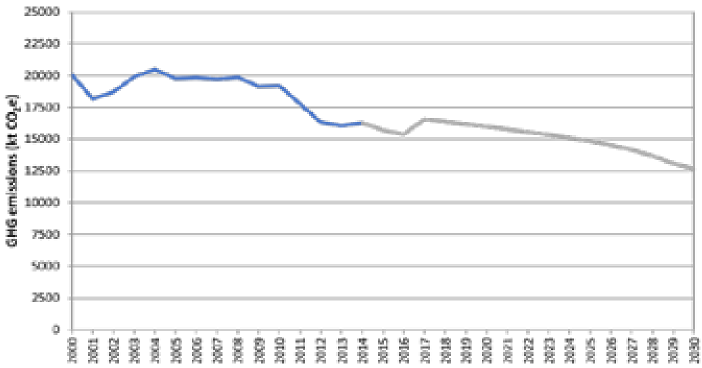
Figure 72. GHG emissions from Industry in the Iberian Lynx, 2000-2030



GHG emissions from the transport sector decrease (Figure 73), **to 12.6 Mt CO_2e by 2030**. The Transport sector is the one with the second highest total GHG emissions after the Energy sector.

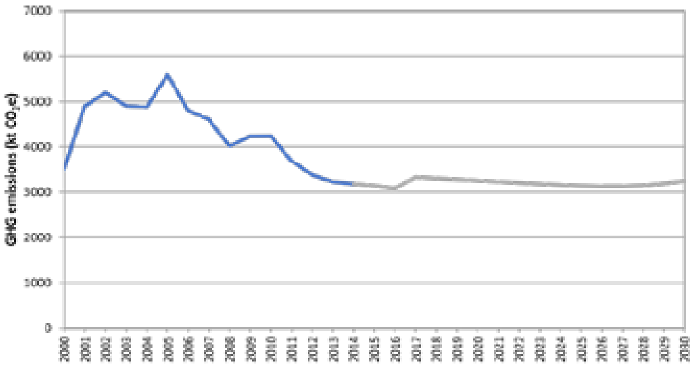
GHG emissions are 1.3 Mt CO_2e lower than in the Ostrich. This is mainly due to the rapid adoption of electric vehicles. Also, although the shares of diesel and gasoline diminish, in absolute terms these increase.

Figure 73. GHG emissions from the Transport sector in the Iberian Lynx, 2000-2030



GHG emissions from the residential sector increase (Figure 74) **slightly to 3.3 Mt CO_2e by 2030.** These emissions are approx. 0.5 Mt CO_2e higher than in the Ostrich, mainly due to the increase in consumption in the Iberian Lynx, despite the strong electrification which removes GHG emissions from this sector (and transfers to the energy sector).

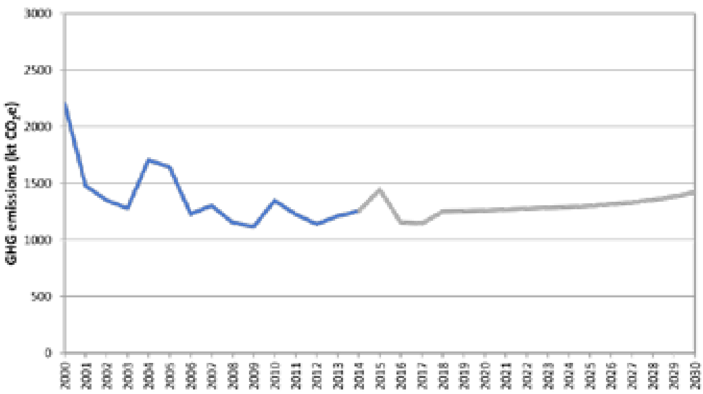
Figure 74. GHG emissions from the Residential/Commercial sector in the Iberian Lynx, 2000-2030



GHG emissions from agriculture increase (Figure 75), **reaching a value of 1.4 Mt CO_2e** by 2030. The Agriculture/ Fishing sector is the sector with the lowest GHG emissions because the exergy consumption shares are also the lowest. Nevertheless, the emissions represented here refer only to energy use and do not take into account other emissions such as cattle, soil, manure management, amongst other emissions (i.e., emissions included in the IPCC's Agriculture category). These other emissions represent a significant proportion of GHG emissions from agriculture.

Technological shifts can play an important role on decarbonising the Economy, as with only efficiency improvements still lead the Iberian Lynx having a total of GHG emissions projected for 2030 higher than the Ostrich.

Figure 75. GHG emissions from the Agriculture/Fishing sector in the Iberian Lynx, 2000-2030



4.3. THE LOW CARBON CHALLENGE: THE LYNX+ SCENARIO

As seen in Section 4.2.5, the Iberian Lynx leads to economic growth, due to an increase in capital stock, but mainly due to the improvement in final to useful exergy efficiency and its effect on total factor productivity. This increase in GDP leads to an increase in GHG emissions (see Section 4.2.6), as more energy is required to increase economic output.

Therefore, although the Iberian Lynx includes the more optimistic configurations of the uncertainties used as the skeleton for the scenarios, GHG emissions are higher than in the Ostrich. This is because increasing useful exergy efficiency increases GDP. However, increasing GDP increases GHG emissions (rebound effect).

The challenge is how to reduce these GHG emissions. This was the main subject of the 4th workshop, where possibilities for reducing GHG emissions in the Iberian Lynx were discussed. The result was a new adjusted scenario, the Lynx+ scenario.

Two main variables were taken into consideration:

- The electricity mix;
- Carbon sequestration through processes that enhance ecosystem services.

Regarding the first, both the Iberian Lynx and the Ostrich consider maintaining the current electricity mix in relative terms, i.e., 60% of renewable based electricity, 12.3% of natural gas and 25.4% of coal. Although the electricity mix was assumed constant, because there is electrification in the Iberian Lynx (and therefore, an increase in electricity consumption), in absolute terms this means that in 2030 renewable based electricity is 1.16 times higher in the Iberian Lynx compared to 2014, natural gas consumption increases 5.5 times and coal increases 1.6 times (Table 19).

Table 19. Electricity consumption in both scenarios

ENERGY SOURCE	ELECTRICY MIX IN IBERIAN LYNX AND THE OSTRICH	ABSOLUTE VALUES		
		2014	2030 Ostrich	2030 Iberian Lynx
Renewable sources	60%	32 903 GWh	28 784 GWh	38 010 GWh
Natural gas	12.3%	1 401 GWh	5 885 GWh	7 771 GWh
Coal	25.4%	10 258 GWh	16 138 GWh	16 083 GWh

In the 4th Workshop, participants agreed to:

- Increase renewable based electricity to 75%, in the electricity mix; and
- Decrease coal based electricity to 0%.

The electricity mix obtained is presented in Table 20.

Table 20. Electricity mix for the Iberian Lynx and the Lynx+ scenario

	IBERIAN LYNX	Lynx+[a]
Renewable electricity	60.0%	75.0%
Natural gas	12.3%	22.7%
Coal	25.4%	0.0%
Oil	2.3%	2.3%
Other	0.0%	0.0%
Total	**100%**	**100%**

a. From the 4th Workshop discussion.

Regarding renewable electricity sources used within the electricity mix:

- Hydroelectricity, Biomass, and geothermal remain the same, in absolute terms, as in the Iberian Lynx;
- The remaining additional renewable electricity required to satisfy the increase from 60% electricity (in the Iberian Lynx) to the 75% renewable electricity (defined in the 4th Workshop), 1/3 is satisfied through wind electricity and 2/3 through solar electricity.

These assumptions are presented in Table 21.

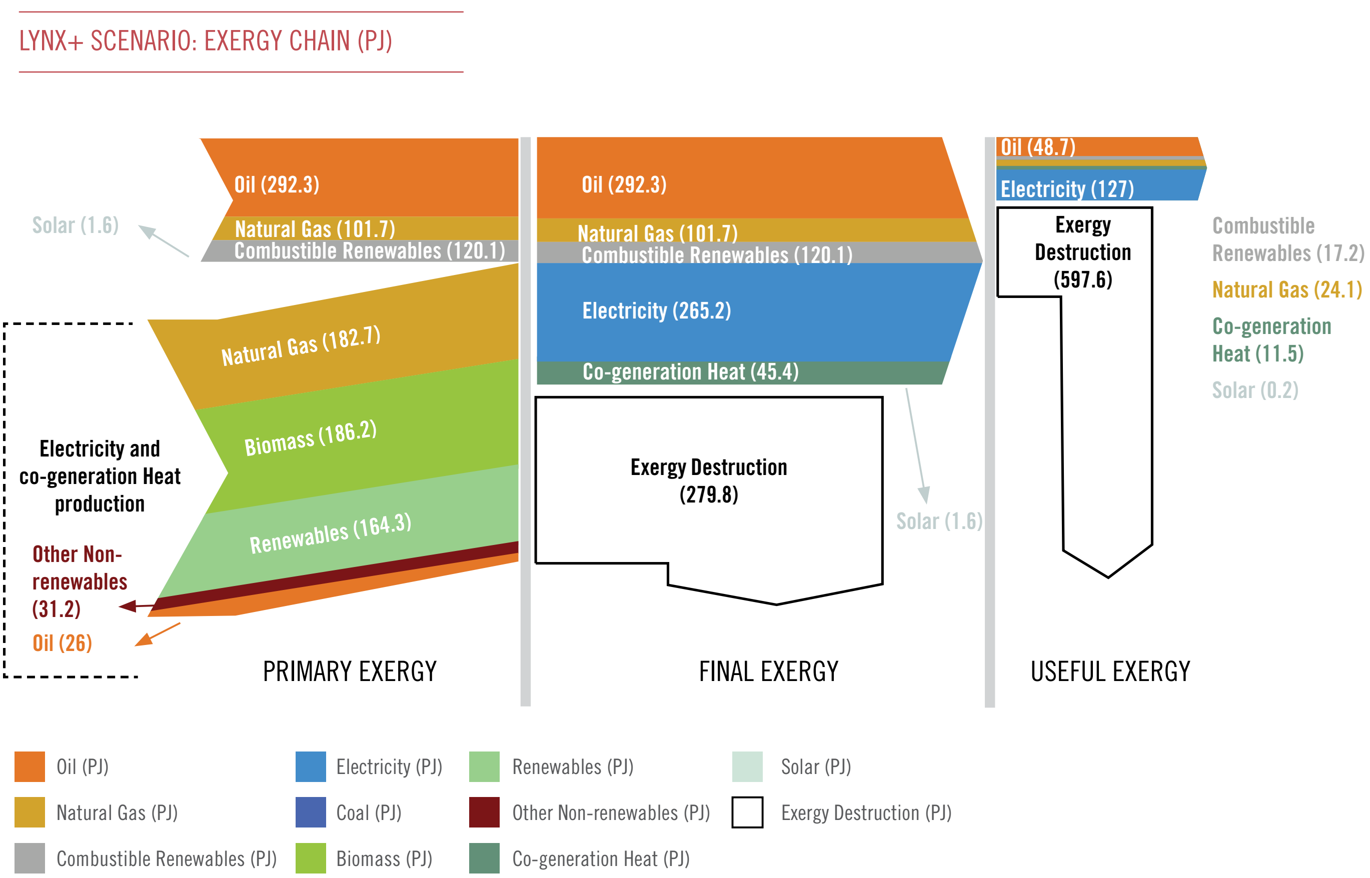
Table 21. Renewable sources used for electricity production

	Iberian Lynx[a]	Lynx+[b]		
	%	%	GWh	Increase relative to 2014 (%)
Wind	44.2%	47.7%	22 686	72.8%
Solar	2.7%	7.6%	3 617	432.1%
Hydro	47.3%	40.0%	19 005	6.9%
Biomass	5.0%	4.0%	1 900	74.2%
Geothermal	0.8%	0.6%	304	36.6%
Total	100.0%	100.0%	47 512	100.0%

a. Assumed constant from 2014 onwards.
b. Resulting from the 4th Workshop discussions.

These changes result in the Sankey diagram presented in Figure 76, where the differences between this scenario and the Iberian Lynx are in the primary energy component.

Figure 76. Sankey diagram for the Lynx+ scenario



The primary energy mixes considered in the Lynx scenario and the Lynx+ variant should be considered as a "proof of concept", showing the viability of the projected decarbonisation trajectory. Any other primary energy mix that allows attaining the same objectives, with the same or superior economic and environmental performance (understood broadly, considering both GHG emissions and other environmental issues), should be considered. Components of the primary energy mix should thus be evaluated in a life cycle perspective. In particular, biofuels, which were not significantly considered in the MEET 2030 projections, should be analysed and considered, namely within a biorefinery perspective.

Additionally, in the Lynx scenario and the 2+1 variant, the share of oil product in final energy decreases, but their absolute quantity remains roughly constant.

Regarding carbon sequestration, two options were discussed:

- Replacing shrubland by native forest (oakland) in central and northern Portugal; and
- Replacing natural pastures by sown biodiverse pastures in Alentejo.

The description of the sequestration factors used for determining the carbon sequestered is presented in Appendix 7.8.

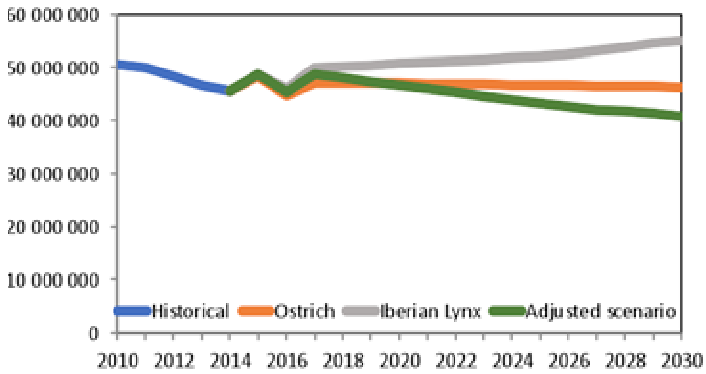
It was agreed in the 4th Workshop that the MEET2030 team would present a reasonable value. The results defined by the research team are presented in Table 23.

Table 23. Carbon sequestration in the Lynx+ scenario

	2014	Maximum area available	Annual increment		Total carbon Sequestered
	(ha)	(ha)	(ha)	%	(t CO_2)
Biodiverse pastures	137 000	963 000	12 000	8.8	7 919 520
Native forest	180 000	725 000	21 585	12.0	11 493 519
Total	317 000	1 688 000	33 585	20.8	19 413 039

Based on the assumptions above, the adjusted scenario results in a reduction in GHG emissions, reaching values lower than in the Ostrich and within a path that will allow for accomplishing the GHG emissions targets set by 2050. The resulting GHG emissions are presented in Figure 77 and in Table 23.

Figure 77. Net GHG emissions evolution for the Ostrich, the Iberian Lynx and the Lynx+ (t CO_2)



GHG emissions only include the IPCC sectors of Energy and LULUC.

Table 24. GDP and GHG emissions for 2014 and 2030 in the Ostrich, Iberian Lynx and the Lynx+

	2014	2030		
		Ostrich	Iberian Lynx	Lynx+
GDP (Billion Euros)	169.1	161.4	227.8	**227.8**
Net GHG Emissions (Mt CO_2)	45.6	46.2	55.0	**40.8**

5.
FINAL NOTES

5. FINAL NOTES

This project aimed to:

- Create scenarios for Portugal in 2030, in the context of the fourth industrial revolution taking into account national, European and worldwide compromises in order to reach a low carbon development, the challenges of the various economic sectors and the research which has been led by associates of the BCSD;
- Identify potential new sectors of economic activity, innovation in products and processes and the competitive advantage necessary to enable companies to maintain sustainable growth in the long term;
- Identify solutions with higher added value and contribute to a policy action, which permits us to define strategic priorities on a national and international level.

The main outputs achieved were:

- The process of developing scenarios, combining a new economic model where exergy efficiency is key, with a participatory process for identifying uncertainties, quantifying variables and identifying technologies and policies that could lead to these scenarios;
- Having companies to think about the 4th industrial revolution, carbon neutrality and exergy efficiency, namely in terms of how the future might look like, what technologies, business models and policies could help companies to move forward. This was achieved throughout the workshops and the challenges provided;
- A list of uncertainties on the development of Portugal through to 2030;
- Two possible scenarios for Portugal for 2030;
- Recommendations or orientation guidelines for companies;
- Recommendations or orientations for policies to contribute to carbon neutrality, energy efficiency and economic growth.

A central aspect of this project was the use of an economic model where GDP is a function of capital stock, human labour and useful exergy.

The labour component as used here does not include the fact that new jobs will inevitably target younger generations and will be placed in urban centres. Older and rural population will have more difficulties in terms of jobs, in earlier stages of the shift towards the 4th industrial revolution, policies to address this are required. Furthermore, this labour component does not include directly the satisfaction of the labour force with their jobs and job conditions. There is always a risk the higher employment is achieved at the expense of "lower quality" jobs. Policies on education and employment are essential to ensure to provide social benefits to society.

Regarding the useful exergy contribution to GDP, this was the novelty in the model used. The central message is that energy efficiency (final to useful exergy efficiency) promotes economic growth. For energy efficiency, electrification is key. Examples of actions that help improving broad exergy efficiency:

- strong electrification in all sectors (including agriculture), uses such as the several electronic appliances may increase about 1.5% their final exergy consumption share;
- Continued process of automation in industries and in other sectors (e.g., delivery and mailing services, domestic robots, etc.);
- Light technology and substitution of standing stock might allow an increase of 5.5% by 2030 in final-to-useful efficiency.

Taking a methodological option towards the use of useful exergy in order to use its relation with GDP, brings out a few issues. Some are methodological and others emerged from the challenges and workshops. Most of the issues are related to the Transport sector as EV play an important role in projected near future (2030).

Historical exergy series used for projections do not take into account upgrades in internal combustion motors. This is because useful exergy accounts for the work done by the shaft of the vehicle solely. Upgrades in design, weight and size of the vehicles (that increase consumption efficiency) are not taken into account as are at the services stage of energy chain, after useful, where each service has its own units, thus, it is not possible to sum all services.

Also, it was pointed out that EV efficiency considered was for electric motors, not considering different battery efficiencies, production investments and options that would influence it. The variability and uncertatinty associated to this issue is such that made it impossible to study it in depth. Another issue, related EV was the projected shares for 2030. Comments on this value have given a range fro 20-60% of electric vehicles circulating by 2030. However, the shares considered are in accordance with recent studies on the area such as Cherif *et al*. (2017). Further work focused on electric vehicles is required to take into account many variables and uncertainties refered.

Economic growth can generate higher GHG emissions (see the Iberian Lynx scenario). This constitutes a rebound effect, resulting from the improvement of exergy efficiency. However, economic growth provides investment capacity to:

- Increase renewable energy use (e.g., wind, solar, biomass and biofuels); and
- Promote carbon sequestration and ecosystem services.

Additional efforts are required to reduce GHG emissions resulting from the economic growth powered by energy efficiency improvements. These efforts will need to came from increasing renewable sources in the electricity mix, eliminating coal, increasing carbon sequestration and behaviour and habit changes of consumers so to minimise the rebound effect of energy efficiency improvements.
All energy sources will be needed to meet demand. For example, in the transition to a low-carbon future, and for energy security of energy supply, natural gas can offer an immediate and material opportunity to reduce global emissions through fuel-switching.

The Business Report from MEET2030 develops further this aspects of public policies required to shift towards a better future.

MEET 2030 showed that joint efforts are necessary from different areas such as Energy, Economy, Industry (Technology regulations and incentives), Employment and Education, Environment (e.g., Climate change mitigation, Circular Economy, Ecosystem Services), and Agriculture in order to have a future with economic growth and carbon neutrality within the new challenge of the Fourth Industrial Revolution.

6.
REFERENCES

6. REFERENCES

APA, 2012. Roteiro Nacional de Baixo Carbono - Análise Técnica das Opções de Transição para uma Economia de Baixo Carbono Competitiva em 2050. Agência Portuguesa do Ambiente (APA), Amadora.

APA, 2017. Portuguese National Inventory Report on Greenhouse Gases, 1990-2015. Agência Portuguesa do Ambiente (APA), Amadora.

Ayres, R.U. and Warr, B., 2005. Accounting for growth: the role of physical work. Structural Change and Economic Dynamics 16, 181-209.

Cherif, R., Hasanov, F., Pande, A., 2017. Riding the energy transition: Oil beyond 2040. Published 24/09/2017. Available on http://voxeu.org/article/riding-energy-transition-oil-beyond-2040.

European Commission – JRC – IPTS, 2005. FOR LEARN - Support for mutual learning between foresight managers, practitioners, users and stakeholders of policy-making organisations in Europe. European Commission, http://forlearn.jrc.ec.europa.eu/index.htm (last access: November 2017).

Favrat, D., Marechal, F., Epelly, O., 2008. The challenge of introducing an exergy indicator in a local law on energy. Energy, 33, 130–136.

Feenstra, R.C., Inklaar, R., Timmer, M.P., 2015. The next generation of the Penn World Table. American Economic Review, 105(10), 3150-3182.

Goodwin, P., Wright, G., 2014. Decision Analysis for Management Judgment. John Wiley & Sons Ltd., West Sussex.

IEA, https://www.iea.org/statistics/relateddatabases/energybalancesofoecdcountries/ (Last access: October 2017).

Instituto Nacional de Estatística (INE) – Projecções de População Residente 2012-2060. Published in 28/03/2014. Available online at: www.ine.pt.

International Energy Agency (IEA), 2016. Energy Balances of OECD Countries.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). IPCC, https://www.ipcc-nggip.iges.or.jp/public/2006gl/ (last access: November 2017).

Kander, A., P. Malanima, P. Warde (2014). Power to the People: Energy in Europe Over the Last Five Centuries. Princeton University Press, Princeton and Oxford.

Meinert, S., 2014. Field manual - Scenario building. European Trade Union Institute (ETUI), Brussels, https://www.etui.org/Publications2/Guides/Field-manual-Scenario-building (last access: November 2017).

Postma, T. J. B. M., Liebl, F., 2005. How to improve scenario analysis as a strategic management tool? Technological Forecasting and Social Change 72(2), 161-173.

Rhisiart, M., Störmer, E., Daheim, C., 2016. From foresight to impact? The 2030 Future of Work scenarios. Technological Forecasting and Social Change, 30/11/2016.

Santos, J., Domingos, T., Sousa, T. and St. Aubyn, M., 2016. Does a small cost share reflect a negligible role for energy in economic production? Testing for aggregate production functions including capital, labor, and useful exergy through a cointegration-based method. https://mpra.ub.uni-muenchen.de/id/eprint/70850. Munich Personal RePEc Archive (MPRA) Paper.

Serrenho, A. C., Warr, B., Sousa, T., Ayres, R. U., and Domingos, T., 2016. Structure and dynamics of useful work along the agriculture-industry-services transition: Portugal from 1856 to 2009. Structural Change and Economic Dynamics, 36, 1-21.

Shar, H., Componation, P., Anderson, M., Youngblood, A. 2009. Transportation Model Validation Using Extreme-World Method Scenario Construction. Journal of the Transportation Research Forum, 48(1), 105-116.

Teixeira, R.F.M., 2010. Sustainable Land Uses and Carbon Sequestration: The Case of Sown Biodiverse Permanent Pastures Rich in Legumes. Ph.D. dissertation, Instituto Superior Técnico, Lisboa.

Teixeira, R.F.M., Domingos, T., Costa, A.P.S.V., Oliveira, R., Farropas, L., Calouro, F., Barradas, A.M., Carneiro, J.P.B.G., 2011. Soil organic matter dynamics in Portuguese natural and sown grasslands. Ecological Modelling, 222: 993-1001.

7.
APPENDIX

7. APPENDIX

7.1. REVIEW OF SCENARIO BUILDING EXERCISES

In the next table we explore similarities and differences between key characteristics of the MEET 2030 scenario building process and other scenario projects.

# of structural variables	Structural variables	# of scenarios	Methodology	Time horizon	Participants	Notes
MEET 2030 (2017)						
25	1 - Market preparedness for industry synergies; 2 - Sectoral & Cross-sectoral cooperation in climate protection; 3- Stability of international geopolitical and demographic context; 4 - The political future of the EU; 5 - EU economic growth capacity; 6 - Capacity of the banking system to support economic development; 7 - Financial stability of the Portuguese economy; 8 - Investment capacity in the Portuguese economy; 9 - Portugal's capacity to attract and retain talents; 10 - European electric grid integration; 11 - Strength of EU regulation and incentives inducing renewable energy production; 12 - Capacity to develop a digitalisation policy sustained in a strong commitment from the industry; 13 - Effectiveness of more ambitious regulation on energy efficiency in buildings; 14 - Adaptability of the educational system to the future industries and market needs; 15 - Policy on climate change (ambition); 16 - Allowing/ promoting geological CCS, CCU and use of CO_2; 17 - Alignment between Government's policies and companies' needs to address new societal challenges; 18 - Effectiveness of national policies on retirement, health, justice, education; 19 - Stability of climate change policies worldwide: actors, programs and priorities; 20 - Impacts of automation and digitalisation on unemployment rates; 21 - Impacts of automation and digitalisation on the type of employment; 22 -Availability of technologies for climate mitigation and adaptation; 23 - Electrical vehicle (EV&H_2) deployment rates; 24 - Electric grid ability to integrate electrical vehicles; 25 - Pace of adoption of energy efficiency technologies and measures and microgeneration	2+1	Adaptation of the intuitive-logics method (workshops) and of the extreme-world method (configurations and structure)	2030, with and eye in the 2030-2050 period	BCSD Portugal members, with consultation / discussion with key public policy actors	(a)

# of structural variables	Structural variables	# of scenarios	Methodology	Time horizon	Participants	Notes
$HybCO_2$: Hybrid approaches to evaluate the economic, environmental and technological impact of long-term low carbon scenarios – the Portuguese case (2011)						
4+10	"Through a co-creative process with the selected national stakeholders, the following four main critical uncertainties in world development were identified: 1) the emergence of a new techno-economic paradigm (disruptive or incremental), 2) religion (coexistence or conflict), 3) globalization (total or mitigated), and 4) rule(s)settings (participatory democracy — "western ideas" or new paradigm). (...) the following ten national critical uncertainties were chosen and explored: 1) the specialization of the economy; 2) financial sustainability; 3) political system and state configuration; 4) institutional capacity building; 5) cultural values and the ability to generate social capital; 6) strategic leadership and pro-activity of the economic agents; 7) the evolution of the social cohesion model; 8) the typology and role of the cities; 9) generational uncertainty, i.e., how the next generation will interact with the older generation; and 10) the evolution of the education and training systems." [Fortes, Patrícia; Alvarenga, A; Seixas, J; Rodrigues, S (2015); Long-term energy scenarios: Bridging the gap between socio-economic storylines and energy modelling, Technological Forecasting and Social Change, Volume 91, February, pp. 161-178].	2	Mix of several methodologies. Intuitive-logics as the basis for the workshops (global scenarios) ; An adaptation of morphological for structuring the variable of the national scenarios; an inductive approach for the construction of narratives.	2050	Limited number of participants / experts from both the public and private sectors.	(b)
Future Energy Scenarios, National Grid (2017)						
2	Prosperity: the amount of money available in the economy for government expenditure, businesses to invest and consumers to spend ("more money available" vs. "less money available") Green Ambition: reflects the level at which society and policies engage with becoming environmentally friendly to help reduce our carbon emissions and increase sustainability ("more focus" vs. "less focus")	4	Intuitive-logics; 2 axis	2050	"The FES is published every year and involves input from stakeholders across the energy industry. This year we have enhanced our stakeholder engagement activities and we consulted 391 organisations, increasing our engagement from 362 in 2016" [http://fes.nationalgrid.com/media/1253/final-fes-2017-updated-interactive-pdf-44-amended.pdf]	(c)

# of structural variables	Structural variables	# of scenarios	Methodology	Time horizon	Participants	Notes
New Lens Scenarios, Shell (2013)						
30	Persistent Patterns (Legacy positions and human behaviour; Counter-currents); Paradoxes (Prosperity; Leadership; Connectivity); Pathways (Room to Manoeuvre; Trapped Transitions); Other Features (Creativity; Preservation; Relationships; Popular ideologies); Energy Demand (Choice; Prices; Efficiency technology; Efficiency behaviour; Economics); Energy Resources (Oil; Gas; Coal; Nuclear; Electric renewables; Biomass); Energy Technology (Innovation; Implementation; Transport; Electricity); Environment (Land use; Local pollution; Climate/Biodiversity; Adaptation)	2	A more inductive approach (different from the traditional	2060	Internal and external experts	(d)
Horizons 2020, Siemens (2004)						
76	76 "critical descriptors" (see http://prea2k30.scicog.fr/ressources/accesfichier/32.pdf, pp. 153-281)	2	Questionnaires about the future led to 38 descriptors; «The 116 questionnaires returned in the first round were processed and the "non-critical" descriptors — in other words, the areas where most of the experts were in agreement — were filtered out. The remaining descriptors were divided into "critical" descriptors — here, the experts split into two opposing camps — and those marked by a wide diversity of opinions. For the latter group, a new questionnaire was sent out, and this time the experts were informed about the opinions that had been expressed by their colleagues throughout Europe. "This made the responses more definite," explains Scharioth. As a result of the two questionnaires and the meetings of the advisory board, TNS Infratest identified a total of 76 critical descriptors, 32 non-critical descriptors and 10 megatrends. "That makes this Siemens study one of the most comprehensive and complex	2020	"several hundred experts throughout Europe": experts at universities; company CEOs; European political leaders [https://www.siemens.com/content/dam/internet/siemens-com/innovation/pictures-of-the-future/pof-archive/pof-fall-2004.pdf]	(e)

# of structural variables	Structural variables	# of scenarios	Methodology	Time horizon	Participants	Notes
			ones I know of," says Scharioth. Normally, he adds, research companies are commissioned to carry out much more specific studies. For example, automakers such as BMW or VW wish to find out about the future of mobility, and companies like Shell are interested in trends in the energy supply sector. "So far, I haven't heard of any other companies commissioning a study that examines every area of people's lives and works with as many as 76 critical descriptors," he says. "Of course, one reason for this is that such broadly conceived scenarios do not serve purely economic corporate goals, since they cannot make reliable predictions about the likelihood of these scenarios actually taking place," adds Scharioth. After all, in purely mathematical terms, 76 critical descriptors yield 276 = 75 x 1021 (75 billion trillion) possible futures. It wouldn't make much sense to carry out a statistical evaluation of that much data. Evaluating Europe's Future. Scharioth's team therefore investigated which alternatives the experts judged to be especially important, how often they were mentioned and the extent to which they were correlated with a "positive future index." To this end, the experts were asked their opinions about how positive the future would be in their respective regions and fields of expertise. A total of 38 percent of the experts believed that living conditions in Europe in 2020 would be very good or excellent, whereas only 16 percent expected good			

# of structural variables	Structural variables	# of scenarios	Methodology	Time horizon	Participants	Notes
			economic conditions in 2020, and a mere seven percent believed the social climate would be positive. By contrast, 56 per cent of the experts expected cultural life in Europe to be exciting in 2020. "All in all, we received 38 different descriptor impressions that are likely to have a positive impact on the future," says Scharioth. "» "Additional input came from the Pictures of the Future scenarios, as worked out by Siemens experts from Corporate Technology and the Groups. These deal with the most important technological trends of the future. " [https://www.siemens.com/content/dam/internet/siemens-com/innovation/pictures-of-the-future/pof-archive/pof-fall-2004.pdf]. An apparently inductive organization of the 2 scenarios.			
World Energy Scenarios : Composing energy futures to 2050, WEC (World Energy Council) (2013)						
5	Economics/finance/trade Resource availability and access Energy systems and technologies Consumer behaviour and acceptance Government policies	2	The WEC's approach is distinctively different from the scenario building approach that others have undertaken. It is open, inclusive and transparent: Open – as every move has been meticulously documented, the assumptions and the quantification results, including 'the model' are publicly available; Transparent – as the WEC has set out clearly how its scenario stories have been translated into assumptions and from there into quantification results; Inclusive – as a wide range of stakeholders have been consulted, from producers and governments to consumer representatives and energy supply enterprises	2050	Experts and stakeholders, including producers, governments, consumer representatives and energy supply enterprises.	(f)

# of structural variables	Structural variables	# of scenarios	Methodology	Time horizon	Participants	Notes
Germany 2064: The World of Our Children, A.T. Kearney (2015)						
6	Society Value creation Small and medium-size enterprises Infrastructure Financial sector Germany in the world	2	In-house research.	2064	(Six roundtables—featuring) experts in the fields of economics, science, politics, and societal change among others	(g)
The future of mobility: Scenarios for China in 2030, RAND Corporation (2015)						
24 descriptors	Demography (Total population; Geographic distribution of population; Urbanization; Average commute distance; Household type); Economy (Economic growth; Share of the economy in the eastern region; Income distribution; Labor-force participation; Domestic vehicle production; Percentage of GDP spent on transportation infrastructure); Energy (Oil price; Oil consumption; Introduction of effective GHG emission–reduction systems; Adoption of electric and hybrid passenger cars; Adoption of E-2Ws); Transportation supply and constraints (Constraints on driving; Constraints on vehicle ownership; Convenience of public transit; Convenience of interurban rail; Demand for domestic air travel; Parking management in urban areas; Convenience of taxis and car-sharing; Infrastructure for non-motorized transportation (i.e., walking and bicycling))	2 + 1	"a six-step process to develop two scenarios that address this question. The six steps are (1) select influencing areas (domains that affect mobility directly: demographics, economics, energy, and transportation supply and constraints); (2) elicit projections on descriptors (via expert workshops in Washington, D.C., and Beijing); (3) integrate these into scenario frameworks (using two analysis methods and a computer-based tool); (4) produce scenario narratives (based on the clusters produced by the tool); (5) draw qualitative consequences for future mobility; and (6) create a wild-card scenario (by looking at events that might disrupt trends)."; "Our approach combined expert opinion, gathered via in-person workshops, with cross-impact analysis, consistency analysis, and cluster analysis using specialized computer tool support" [https://www.rand.org/pubs/research_reports/RR991.readonline.html]	2030	Experts (including from RAND)	(h)

# of structural variables	Structural variables	# of scenarios	Methodology	Time horizon	Participants	Notes
Where Do We Go from Here? The Future of English Higher Education, Jeroen Huisman, Harry de Boer and Paulo Charles Pimentel Bótas (Higher Education Quarterly) (2012)						
21	"The opinions and argumentations of the respondents have been interpreted and clustered and were used to develop internally consistent lines of reasoning (to the extent possible) that form the backbone of the scenarios. Scenarios are well-informed 'stories' that have a logical reasoning departing from a number of themes or assumptions. The underlying themes that have been picked to develop the scenarios are <u>the number and kind of institutions</u>, <u>research</u>, <u>teaching</u>, <u>students and funding</u>" [Huisman, J., de Boer, H. and Bótas, P. C. P. (2012); the underlying is ours] If we consider that the Delphi statements were the key differentiated factors of the scenarios, then we can consider them as being building blocks of the scenarios. Delphi statements: In English higher education in 2025, the number of universities has decreased by 20%; In English higher education in 2025, the division between pre-1992 and post-1992 is sharper due to mission differentiation; In English higher education in 2025, the functional stratification of the system is highly visible in funding mechanisms, missions, activities and performance; In English higher education in 2025, universities are much more specialised in terms of their educational offer; In English higher education in 2025, private providers cater for 15% of students In English higher education in 2025, only about 10% of the universities include in their mission elements like: independent contribution to intellectual and cultural life; citizenship; critical thinking; and academic freedom; In English higher education in 2025, the number of branch campuses abroad of English universities has decreased significantly; In English higher education in 2025, the network model is the dominant organisational model; In English higher education in 2025, basic research is carried out in about 20 research universities; In 2025, English universities are still significantly represented among the world-class universities in global rankings; In English higher education in 2025, the European Research Council funds more than 70% of basic research conducted at English universities; In English higher education in 2025, research performance measurement is institutionalised at the departmental levels; Towards 2025, increasingly and significantly native English academics migrate to other English-speaking countries;	2	"Based on the Delphi-method; the opinions and argumentations of the respondents have been interpreted and clustered and were used to develop internally consistent lines of reasoning (to the extent possible) that form the backbone of the scenarios." [Huisman, J., de Boer, H. and Bótas, P. C. P. (2012) General agreement scenario and counter-scenario. Delphi and an inductive way of building the narratives with a consensus - counter-consensus logic.	2025	Experts (field of higher education policies and practices)	(i)

# of structural variables	Structural variables	# of scenarios	Methodology	Time horizon	Participants	Notes
	In English higher education in 2025, the participation rate has dropped by more than 5%; In English higher education in 2025, access has widened; In English higher education in 2025, student feedback mechanisms (course evaluations, National Student Survey) and other quality assurance instruments (institutional audits) are obsolete; Towards 2025, outgoing mobility of English students increased significantly; In English higher education in 2025, the quality of study programmes is consistently high across all universities; In English higher education in 2025, fees will vary by institution, but are at least £15,000 per year; In English higher education in 2025, the 'average university' receives more than 10% of its revenues from private sources (excluding tuition fees); In English higher education in 2025, less than 1% of the gross domestic product (GDP) is spent on higher education; In English higher education in 2025, there are clearly differentiated fees for undergraduate programmes." [Huisman, J., de Boer, H. and Bótas, P. C. P. (2012)					
Electricity Scenarios for New Zealand 2005–2050, Office of the Parliamentary Commissioner for the Environment (2005)						
9	"Both scenarios start with the same resources (...). Most of the global and national influences (...) are the same. However, over time people's mindsets and approaches, and the influence of different groups, help to shape changes in: • investments in education, training, and research; • institutional designs; • choice of technologies; • economic developments. The scenarios diverge significantly over time because of these differences" (www.pce.parliament.nz/media/pdfs/future_currents.pdf) What's the aim? (Meeting the demand for electricity vs. Meeting the demand for energy services); What about environmental concerns? ('A matter of balance' (trade-offs) vs. 'A matter of smart design' (win–wins); Decision making (Short-term thinking, top down, and often reactive vs. Long-term thinking, participatory, and proactive); Intervention to improve energy efficiency (Low vs. High); Prices (Low-cost electricity vs. Low-cost energy services); Investment priority (Economic capital (physical infrastructure) vs. Human capital (education and expertise); Research funding (Mostly energy supply vs. Energy efficiency and energy supply); Favoured technologies (Large, established Innovative technologies vs. technologies designed to fit locally); New infrastructure (Based around national grid vs. Distributed close to where electricity is used)	2	Qualitative desk research and narrative writing by a small group of experts. Use of a quantitative model to consider where some trends could lead in each scenario.	2050	Small group of experts with experience of the New Zealand's electricity system; external reviewers.	(j)

# of structural variables	Structural variables	# of scenarios	Methodology	Time horizon	Participants	Notes
Two scenarios for carbon capture and storage in Vietnam, Minh Ha-Duong, Hoang Anh Nguyen Trinh (2016)						
6	Government stance on CCS (Laisser faire. Climate policy instruments are generic vs. Intervention to promote it with specific incentives); Economic growth until 2050 (Trapped at middle-income level vs. Catches up with South Corea and Japan); CCS technology costs (A global ban on coal hurts CCS scale up vs. General adoption of CCS in China and elsewhere push costs down); Carbon price trajectory (Implicitly weak, below 30USD/tCO_2 in 2050 vs. Most nations adopt a notional price of carbon reaching 50 USD/tCO_2 in 2050); Social acceptance (No, an international convention against onshore CCS is discussed vs. Yes, most storage in Vietnam is offshore); Alternative technologies (Solar and wind win the cost race vs. Coal with CCS remain more expensive for new capacities, but capture-ready plants are retrofit rather than closed)	2	Key drivers ("variables"), each one with configurations; each configuration corresponds to one of the scenarios, basically as disincentives or incentives to a more ambitious use of CCS.	2050	(limited) expert-based and desktop research	**(k)**

Notes: (a) http://meet2030.pt/; (b) http://cenariosportugal.apambiente.pt/en/main.asp; (c) http://fes.nationalgrid.com/fes-document/, Permanent process: scenarios updated annually and a very participated process; (d) http://www.shell.com/content/dam/royaldutchshell/documents/corporate/scenarios-newdoc.pdf; (e) https://www.siemens.com/content/dam/internet/siemens-com/innovation/pictures-of-the-future/pof-archive/pof-fall-2004.pdf; http://prea2k30.scicog.fr/ressources/accesfichier/32.pdf; (f) https://www.worldenergy.org/wp-content/uploads/2013/10/World-Energy-Scenarios_Composing-energy-futures-to-2050_Full-report1.pdf; (g) https://www.atkearney.com/documents/10192/6735616/Germany+2064.pdf/d0de8742-0fcf-4304-b36d-c1dcd3584cc6; (h) https://www.rand.org/pubs/research_reports/RR991.readonline.html; (i) Huisman, J., de Boer, H. and Bótas, P. C. P. (2012), Where Do We Go from Here? The Future of English Higher Education. Higher Education Quarterly, 66: 341–362. doi:10.1111/j.1468-2273.2012.00532.x; (j) www.pce.parliament.nz/media/pdfs/future_currents.pdf; (k) https://hal-agroparistech.archives-ouvertes.fr/hal-01547646/document .

7.2. THE 1ST CHALLENGE

7.2.1. The Questions in the 1st challenge

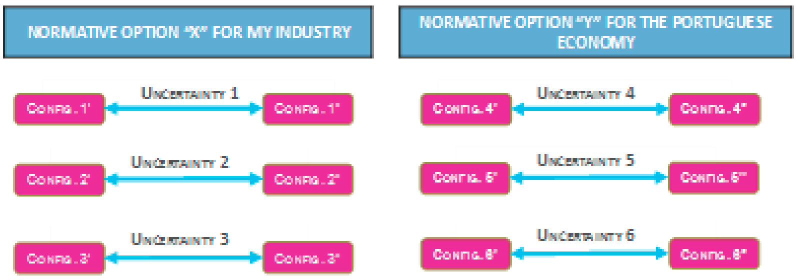
The 1st Challenge was comprised of three main questions.
These are presented in Figure 78.

Figure 78. Questions for the 1st Challenge

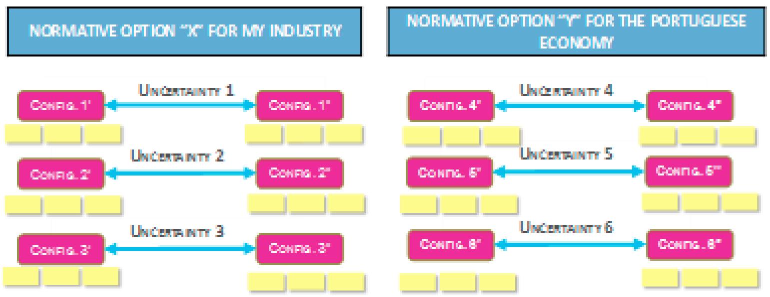
1) Identify possible normative options (e.g. strategies, strategic responses, actions, portfolio options, capability options, internal factors of competitiveness, visions) aligned with the 4th industrial revolution and reflecting the energy efficiency – economic growth relation (3 for your industry and 3 for the Portuguese economy as a whole);

Normative options aligned with the 4th industrial revolution and reflecting the energy efficiency – economic growth relation			
FOR MY INDUSTRY		FOR THE PORTUGUESE ECONOMY	
1IND		1PT	
2IND		2PT	
3IND		3PT	

2) Pick one normative option for your industry and one normative option for the Portuguese economy. For each one of them, generate 3 potential key uncertainties affecting those normative options. For each uncertainty, generate 2 plausible, contrasted and challenging configurations;



3) Identify evidence / (deep/explicative) causes for each configuration of the uncertainties.



7.2.2. List of Normative Options obtained in the 1st challenge

A list of normative options was obtained from the 1st Challenge. This list was organised by themes and is presented in Table 25. This list was further complemented with a desk research and expert inputs. The final resulting list, the List of Inspirational Technologies presented in Table 26.

Table 25. List of normative options defined by participants and organised by the research team

NORMATIVE OPTION RELATED WITH...	NUMBER OF NORMATIVE OPTIONS
3D Printing	1
Artificial intelligence	4
Building efficiency	1
Business digitalization	2
Carbon capture	2
Carbon capture in materials	5
Green cities	2
Circular economy industry	10
Cluster aquaculture	1
Cluster renewable energy	1
Cluster pharmaceutical/ derma cosmetics	0
Community driven business	1
Decentralisation of operations	1
Digitalisation	3
Distance education	1
Education	1
Energy production	2
Renewable energies	4
Energy efficiency in industry	2
EU vs. Portugal (political evolution)	1
Forests as carbon sinks	1
Distributed energy generation	3
Macroscale landscape management	1
Water management	1
Demand management (electricity)	1
Energy management	4
Fleet management	1
Intelligent materials	1
IT Connectivity	1
Electrical mobility	5
Nuclear power	1
Process optimisation	3
Neutral carbon footprint	6
Wild fires prevention	1
Remote wild fire prevention	1
Robotisation	1
Smart buildings	1
Smart meters	1
Sustainability of the food/feed supply chain	1
Technology upgrade core nets	1
Zero people factories	2

Table 26. List of Inspirational Technologies
Source: participants in the 1st Challenge and the Research Team

AUTOMATION
Sensor networking
Distributed sensors with intelligence
Remote machine operation
The ability to communicate/access/operate/control a machine from a remote distance
Robots (+ drones)
A robot is a mechanism guided by automatic controls, is a machine capable of executing complex actions automatically
A drone is an unmanned aircraft or space craft

ARTIFICIAL INTELLIGENCE
Robotics
Technology dealing with the design, construction and operation of robots in automation
Virtual and augmented reality
Augmented reality is the integration of digital information with the user's environment in real time
Virtual reality is an artificial environment that is created with software
Machine learning
Machine learning is a type of artificial intelligence that provides computers with the ability to learn without being explicitly programmed
Distributed Intelligent Systems
Distributed intelligent systems is a model in which components of a system are shared among multiple locations
Distributed computing/parallel computing
Is a model in which components of a software system are shared among multiple computers to improve efficiency and performance
Internet of things
System of interrelated computing devices, mechanical and digital machines with the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction
Predictive Analytics
Advanced analytics that uses both new and historical data to forecast future activity, behaviour and trends

EXPANSION
Bionics
Engineering based on the application of biological methods and systems
Cyborgs
Augmented self includes human and intelligence expansion through artificial brain/processing, Human and mechanical expansion through prosthetics and others to augment human capacities
Bioengineering
Application of engineering principles to biological systems
Application of biological techniques (as genetic recombination) to create modified versions of organisms, as crops, in lab built organs such as brain, eyes, liver, kidneys, heart
Expandable technology
Technology built by components that can be added up functionally like a tech Lego
Technology that can change its properties: dimension, physical properties

EXPANSION
3 D Printing
3-D printing is a manufacturing process that builds layers to create a three-dimensional solid object from a digital model
Quantum technology
Quantum mechanics is the branch of physics that explains the behaviour of matter and energy at the atomic scale. Quantum technology applies the weird physical properties of quantum physics
Virtual currencies
Virtual currencies (VC) are digital representations of value, issued by private developers and denominated in their own unit of account

EDUCATION
Learning with/through machines
Use machines to develop human skills

ENERGY
Energy storage
Energy storage is the capture of energy produced at one time for use at a later time
Efficiency increase
Increase in the efficiency of energy conversion through new technological developments
Renewable generation
Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat
Energy market model
The change in energy model from centralized generation to decentralized one and costumer centric

7.2.3. List of Potential Uncertainties obtained in the 1st challenge

The list of the potential uncertainties obtained from the analysis of the 1st Challenge is presented in Table 27. This list was classified into two different typologies that were developed during the analysis. One of these typologies organised the 86 uncertainties into 12 themes. Figure 89 presents these 12 themes and presents the number of uncertainties per each of them. This typology – Typology A, allows for a better overview of the themes covered by the uncertainties, which is relevant to help identifying if some aspects were left out of the analysis or if there is redundancy. A second typology – Typology B - was also developed during the analysis. This typology divides the uncertainties in 6 themes (see Figure 80). Typology B is more policy oriented and it is expected to play a more relevant role in latter stages of the project.

Table 27. List of potential uncertainties resulting from the analysis of the 1st challenge

MAIN THEMES	REORGANISED UNCERTAINTIES	NUMBER OF ORIGINAL UNCERTAINTIES
Energy supply	Availability of technologies for alternative or low carbon energy production	3
	Availability and capacity of energy storage technologies	3
	Integration of microproduction into the grid	2
	Renewable energy penetration	1
	Strength of EU regulation inducing renewable energy production	1
	Main forms of EU inducing renewable energy production	1
	European electric grid integration	1
	National policy for oil & gas exploration and production	1
	Energy policy: long vs short term goals	1
	Competitiveness/prices of renewable energy sources compared to fossil fuels	5
	Competitiveness of a scenario with 100% renewable energy sources	1
	EU funding/Public funds for renewable energy	3
Energy efficiency in buildings	Availability of public funding/ fiscal incentives for energy efficiency in buildings	2
	Effectiveness of more ambitious regulation on energy efficiency in buildings	2
	Economy electrification	1
	Pace of adoption of energy efficiency technologies and measures	1

Table 27. List of potential uncertainties resulting from the analysis of the 1st challenge (Cont.)

MAIN THEMES	REORGANISED UNCERTAINTIES	NUMBER OF ORIGINAL UNCERTAINTIES
Mobility and transport	Acceptance from users of multimodality apps coupled to connected cars	1
	Effects of privatisation experiences of public transport on quality of life and mobility	1
	Electrical vehicle deployment rates	1
	Impact on mobility from multimodality apps coupled to connected cars	1
	Electric grid capacity to absorb electric vehicles	1
	(physical) Dissemination of EV battery charging facilities	1
	Impact on GHG emissions from multimodality apps coupled to connected cars	1
	Existence of effective carbon tax on transport and mobility	1
	Effects of a carbon tax on the cost of implementing solutions on transport and mobility	1
	The future of regulation promoting electric vehicle adoption	1
IoT, connectivity, digitalisation	Contribution of digitalisation to efficiency and effectiveness of businesses	1
	Role of State as an agent in intelligent and collaborative networks between industries	1
	Capacity to develop a digitalisation policy sustained in a strong commitment from the industry, looking into taking Portugal to the leadership on digitalisation and connectivity	2
	Cooperation between industries and industry sectors for a shared/ collaborative economy	1
	Communities, organisations and industry's reaction to the movement towards digital connectivity	2
	Availability of (public and private) investments for intelligent and connected buildings	1
AI, Robotics	Availability of technologies for robotisation in different sectors (e.g., forestry)	2
	Scale and speed of adoption of robotics process automation	2
	Industry and societal acceptance of intelligent robotisation (e.g., in forestry operations)	2
	Competitiveness of intelligent robotisation (in, for e.g., forestry operations)	1
Circular economy / wastes	Evolution of the recycling model of home appliances	1
	Decoupling waste production from economic growth	1
	Evolution of market niches for high quality remanufacture goods	1
	Manufacture industry's preparedness for a circular economy (i.e., producing recyclable products)	1
	Regulation promoting Eco-design	1
	Availability and effectiveness of a policy framework for a "Circular economy"	3
	Incentives for reducing packaging/ increase recycling of packaging	1

Table 27. List of potential uncertainties resulting from the analysis of the 1st challenge (Cont.)

MAIN THEMES	REORGANISED UNCERTAINTIES	NUMBER OF ORIGINAL UNCERTAINTIES
Industry	Delocalization vs renaissance of EU industry	1
	Availability of raw material supply for the feed industry	1
	Biosecurity hazards (i.e., avian flu)	1
	Strength of national long-term policies for industry 4.0	1
	Procedural focus of EU regulations	2
	Level of access to EU's subsidies (for a technology shift)	1
	Level of control in the access to EU subsidies	1
	Financial strength of support services for an integrated and multidisciplinary offer capability	1
Climate change	Availability of technologies for climate mitigation	1
	Industry's investment in low carbon related R&D and Technology	1
	Sectoral & Cross-sectoral cooperation in climate protection	2
	Effectiveness of global action towards major climate change impacts	1
	Cities leading climate change mitigation and adaptation	1
	Main world players adherence and impact of the Paris agreement	2
	Carbon leakage policy	1
	Ability of Portugal to develop and implement proactive policies for climate change	1
	Allowing/promoting geological CCS	1
	Adaptation policies	1
	Effects of climate and energy policy on the construction sector in Portugal	1
	Neutrality vs Carbon licenses (EU-ETS)	2
	Carbon price (EU-ETS)	1
	Scope of companies included in EU-ETS	1
	One EU market for carbon vs. several national markets (EU-ETS)	1
	Fiscal policies for new zero CO_2 businesses	1
	Effectiveness of recycling revenues from carbon taxation	1
Employment	Impacts of automation and digitalisation on unemployment rates	2
	Impacts of automation and digitalisation on the type of employment	1
	Adaptability of the educational system to the future industries and market	1

Table 27. List of potential uncertainties resulting from the analysis of the 1st challenge (Cont.)

MAIN THEMES	REORGANISED UNCERTAINTIES	NUMBER OF ORIGINAL UNCERTAINTIES
Economy	Economic growth capacity	2
	Portuguese banking system supporting development	1
	Financial sustainability of the Portuguese economy	1
	Investment capacity in the Portuguese economy	1
	Societal awareness of the need to make economic development compatible with sustainable development	1
	Portugal's capacity to attract talents	1
	Alignment between Government's policies and industry needs to address new societal' s needs	1
Geopolitics	OGM market control	1
	EU integration process	2
	Stability of climate change policy policies in the EU: actors, programs and priorities	1
	Stability of international geo politic context	2
	Balance of political power within the EU and its member states	1
National politics	Decentralisation in Portugal	1
	Evolution in the judicial sphere in terms of integration of skills/capacities	1
	Corporate reaction to decentralisation	2
TOTAL:	86	115

Figure 79. Number of uncertainties per each theme (Typology A)

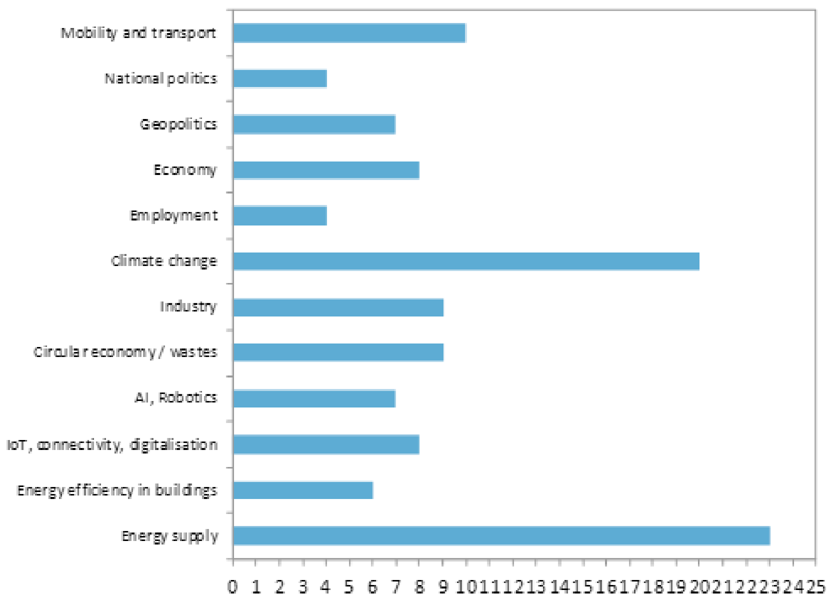
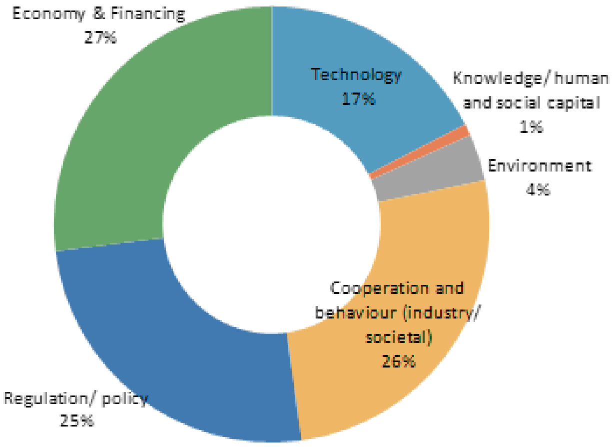


Figure 80. Percentage of total uncertainties under each theme (Typology B)



7.3. RESULTS FROM THE 2ND WORKSHOP

Table 28 presents a list of the 58 uncertainties resulting from participant discussion on the 2nd Workshop. The results from the votings from participants are presented in Figure 81. In order to better cover the different topics and to closely link the qualitative and quantitative parts of the scenarios (especially to link the uncertainties with the evolution of the GDP and energy use), the research team added nine additional uncertainties to the scenario structure. These uncertainties focused on energy supply (2), mobility and transport (2), employment (3) and climate change (2). These were:

- Strength of EU regulation and incentives inducing renewable energy production;
- European electric grid integration;
- Electrical vehicle (EV&H2) deployment rates;
- Electric grid ability to integrate electric vehicles;
- Impacts of automation and digitalisation on unemployment rates;
- Impacts of automation and digitalisation on the type of employment;
- Adaptability of the educational system to the future industries and market needs;
- Availability of technologies for climate mitigation and adaptation;
- Policy on climate change.

The 25 resulting uncertainties are presented in Table 29.

Table 28. Uncertainties resulting from the first exercise of the 2nd Workshop

THEMES	REORGANISED UNCERTAINTIES
Energy supply	Availability of technologies for alternative or low carbon energy penetration (production and storage)
	Integration of microproduction into the grid
	Strength of EU regulation and incentives inducing renewable energy production
	European electric grid integration
	National policy for oil & gas exploration and production
	Main forms of EU inducing renewable energy production
	European electric grid integration
	National policy for oil & gas exploration and production
	Energy policy: long vs short term goals
	Competitiveness/prices of renewable energy sources compared to fossil fuels
	Competitiveness of a scenario with 100% renewable energy sources
	EU funding/Public funds for renewable energy
IoT, Connectivity, Digitalisation	Contribution of digitalisation to efficiency and effectiveness of businesses
	State acting as an agent in intelligent and collaborative networks between industries
	Capacity to develop a digitalisation policy sustained in a strong commitment from the industry, looking into taking Portugal to the leadership on digitalisation and connectivity
	Cooperation between industries and industry sectors for a shared/ collaborative economy
	Communities, organisations and industry's reaction to the movement towards digital connectivity
	Cyber security
	Availability of (public and private) investments for intelligent and connected country

Table 28. Uncertainties resulting from the first exercise of the 2nd Workshop (Cont.)

THEMES	REORGANISED UNCERTAINTIES
Industry	Delocalization vs renaissance of EU industry
	Availability of raw material supply for the industry
	Biosecurity hazards (i.e., avian flu)
	Strength of national long-term policies for industry 4.0
	Procedural focus of EU regulations
	Access and control to EU subsidies
	Capacity of companies to organise and adapt to the new industrial paradigm
Mobility and Transport	Dissemination and adoption of multimodality apps coupled to connected cars
	Adoption of collaborative (public and private) experiences of collective transport on innovative, quality of life and mobility
	Electrical vehicle (EV&H2) deployment rates
	Autonomous vehicles deployment rates
	Electric grid ability to integrate electric vehicles
	Impact on GHG emissions from multimodality apps coupled to connected cars
	Pace and scope of regulation (taxes, incentives, incl. paid parking) promoting smart mobility adoption
Energy Efficiency in buildings (incl. industrial buildings)	Availability of public funding/ fiscal incentives for energy efficiency in buildings
	Effectiveness of more ambitious regulation on energy efficiency in buildings
	Economy electrification
	Pace of adoption of energy efficiency technologies and measures including microgeneration
Circular economy	Decoupling waste production from economic growth
	Industry and market preparedness for a circular economy
	Market preparedness for industry synergies
	Regulation promoting Eco-design
	Availability and effectiveness of a policy framework for a "Circular economy"

THEMES	REORGANISED UNCERTAINTIES
Employment	Impacts of automation and digitalisation on unemployment rates
	Impacts of automation and digitalisation on the type of employment
	Adaptability of the educational system to the future industries and market needs
Climate change	Availability of technologies for climate mitigation and adaptation
	Sectoral & Cross-sectoral cooperation in climate protection
	Effectiveness of actions towards major climate change impacts
	Policy on climate change
	Allowing/ promoting geological CCS, CCU and use of CO_2
Economy	EU economic growth capacity
	Banking system supporting development
	Financial sustainability of the Portuguese economy
	Investment capacity in the Portuguese economy
	Societal awareness of the need to make economic development compatible with sustainable development
	Portugal's capacity to attract and retain talents
	Alignment between Government's policies and companies' needs to address new societal needs
	Population growth in Europe
Geopolitics	OGM market control
	Stability of climate change policy policies worldwide: actors, programs and priorities
	Stability of international geopolitical and demographic context
	The political future of the EU
National Politics	Decentralisation in Portugal
	Corporate reaction to decentralisation
	Effectiveness of national policies on retirement, health, justice, education

Figure 81. Results from the voting of participants (impact and level of uncertainty)

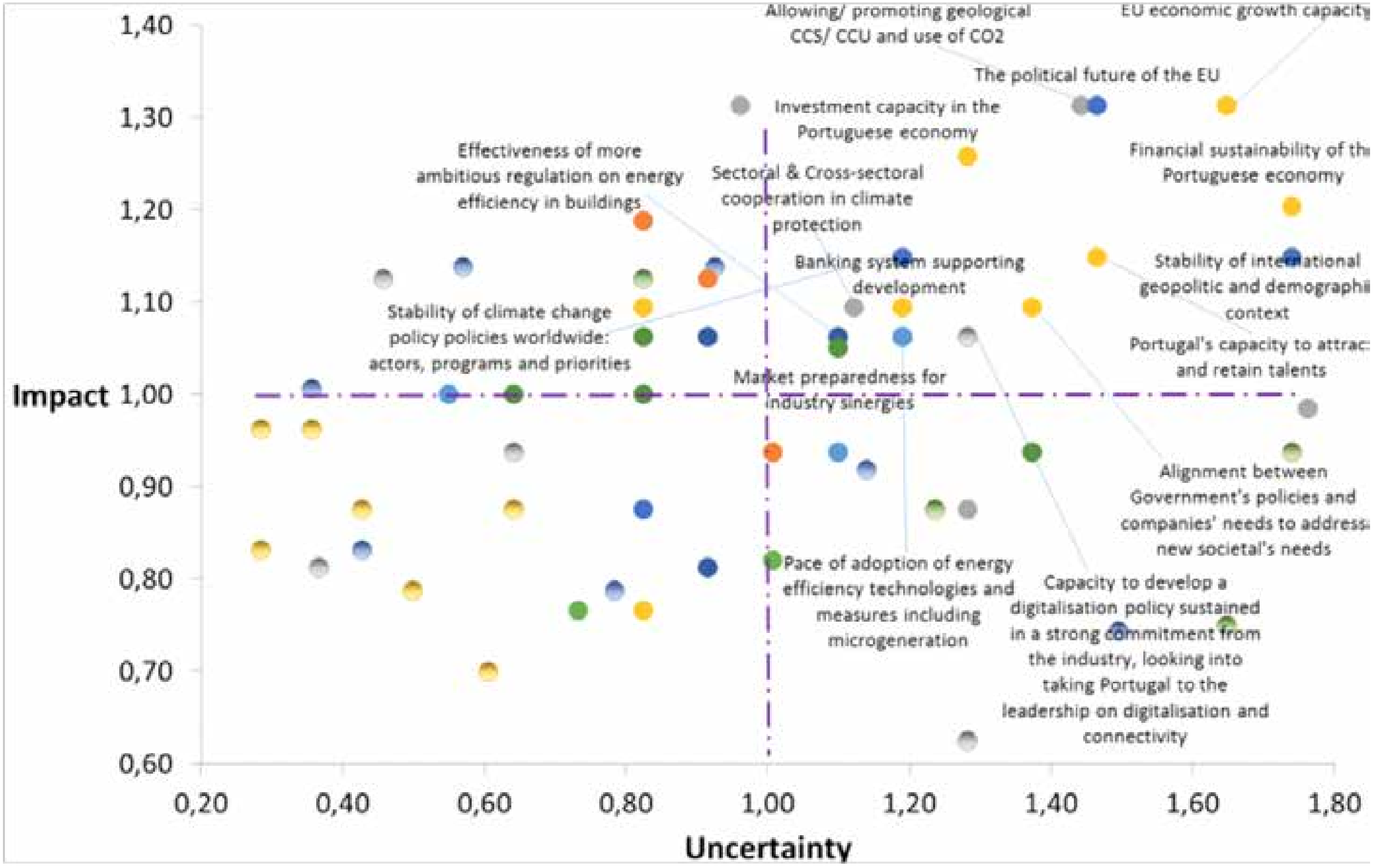


Table 29. The 25 uncertainties resulting from participants' and the research team's evaluation

Typology A	Uncertainty	Configurations		Source
		Optimistic	Pessimistic	
Mobility and Transport	Electrical vehicle (EV&H2) deployment rates	Fast adoption	Slow adoption	Research Team
Mobility and Transport	Electric grid ability to integrate electrical vehicles	Fast and comprehensive	Slow and limited	Research Team
Energy Efficiency in buildings (incl. industrial buildings)	Pace of adoption of energy efficiency technologies and measures and microgeneration	Energy efficiency is a clear priority. Fast adoption of energy efficiency measures and technologies	Scarce adoption of energy efficiency technologies and measures	1st Challenge
Circular economy	Market preparedness for industry synergies	Market works together to close the loop	Market does not work together to close the loop	Defined in W2
Climate Change	Sectoral & Cross-sectoral cooperation in climate protection	Strong sectoral and cross-sectoral cooperation, including for climate change	Weak sectoral and cross sectoral cooperation, including for climate change	1st Challenge

Table 29. The 25 uncertainties resulting from participants' and the research team's evaluation (Cont.)

Typology A	Uncertainty	Configurations		Source
		Optimistic	Pessimistic	
Geopolitics	Stability of international geopolitical and demographic context	Stable (political, migrations, ageing) with improved global trust	Unstable (political, ageing, migrations) with global distrust	1st Challenge
Geopolitics	The political future of the EU	EU Stability/ cohesive	Sequential exits / disintegration	1st Challenge
Economy	EU economic growth capacity	Growth	Stagnation/ retraction	1st Challenge
Economy	Capacity of the banking system to support economic development	Banking system recovers and supports economic development	Banking system is not able to adequately support economic development	1st Challenge
Economy	Financial stability of the Portuguese economy	Financial stabilisation of the Portuguese economy	Recurrent instability of the Portuguese economy	1st Challenge
Economy	Investment capacity in the Portuguese economy	Higher investment capacity	Lower investment capacity	1st Challenge
Economy	Portugal's capacity to attract and retain talents	Portugal is able to compete and create a pool of talents	Portugal is not able to compete to create a pool of talent	1st Challenge
Energy Supply	European electric grid integration	Integration of electricity markets across Europe	Incapacity for the integration of the electricity markets across Europe	Research Team
Energy Supply	Strength of EU regulation and incentives inducing renewable energy production	Strong regulation and incentives, leading to strong changes in businesses	Regulation alleviation or weak Regulation	Research Team
Iot, Connectivity, Digitalisation	Capacity to develop a digitalisation policy sustained in a strong commitment from the industry	Existence and effectiveness of such a digitalisation policy, taking on the vision and goal with a strong political will and close cooperation between agents	Maintain a diffused national digitalisation strategy and dispersion of resources with no effective cooperation between agents	1st Challenge
Energy Efficiency in buildings (incl. industrial buildings)	Effectiveness of more ambitious regulation on energy efficiency in buildings	More ambitious regulations promoting energy efficiency in buildings are effective	Little results of more ambitious regulations for energy efficiency in buildings	1st Challenge
Employment	Adaptability of the educational system to the future industries and market needs	Educational system adapts to industry's new requirements	Educational system is unable to adapt to industry's new requirements	Research Team

Table 29. The 25 uncertainties resulting from participants' and the research team's evaluation (Cont.)

Typology A	Uncertainty	Configurations		Source
		Optimistic	Pessimistic	
Climate Change	Allowing/ promoting geological CCS, CCU and use of CO_2	Geological CCS, CCU and use of CO_2 allowed and promoted	Geological CCS, CCU and use of CO_2 not allowed	1st Challenge
Economy	Alignment between Government's policies and companies' needs to address new societal challenges	Alignment between Government's policies and companies' needs to address new societal challenges, namely talent attraction and retention	No alignment between Government's policies and companies' needs to address new societal challenges, namely talent attraction and retention	1st Challenge
National Politics	Effectiveness of national policies on retirement, health, justice, education	Effective policies in place	No new effective policies	Defined in W2
Employment	Impacts of automation and digitalisation on unemployment rates	Unemployment rates decrease	Unemployment rates increase	Research Team
Employment	Impacts of automation and digitalisation on the type of employment	Automation leads to smarter, higher paid jobs that sustain the Social State	Automation leads to higher unemployment and social unrest	Research Team
Climate Change	Availability of technologies for climate mitigation and adaptation	Available and affordable	Not available, immature or costly	Research Team

7.4. THE 2ND CHALLENGE

Q1 – Specify all the outputs (with economic value) of your company?

Q2 - Which is(are) the final societal service(s) that your company is contributing to? How?

SOCIETAL SERVICES	HOW?

Q3 – For each technology used in your company, identify the energy carrier and the end-use? (a list of energy carriers and end-uses is provided in the Supporting Material)

Energy Carrier	Technology	Energy End-Use

Q4 - Identify 2 or 3 technologies that would allow your company to:

1) use energy & material wastes and/or
2) decrease energy consumption and/or
3) use more renewable energy and/or
4) decrease CO_2 emissions

in its own production process.

Current technology	New technology	Description

Q5 – Identify 1 (or more) technology(ies) or products or services that would allow your company to decrease the materials & energy consumption outside its production process with an impact in society (a list of technologies will be provided for inspiration).

SOCIETAL SERVICES	HOW?

Q6 – In the past, what were the technologies that have deeply transformed your sector? How?

Past	Present	Changes

Q7 - In the future, what are the technologies that might transform your sector (the more disruptive, the better)? How? (a list of technologies will be provided for inspiration).

Present	Future	Changes

7.5. Quantitative assumptions for the scenarios

Summary tables with the figures for efficiencies, useful and final shares per sector, energy carrier and end-use.for the years 2000, 2014 and 2030, are presented bellow. Tables with assumed general Electricity shares are also included.

7.5.1. Ostrich Scenario summary table

ENERGY CARRIER	TYPE OF END-USE	USEFUL SHARE			FINAL SHARE			EFFICIENCY		
		2000	2014	2030	2000	2014	2030	2000	2014	2030
Energy sector										
COAL	HTH	0.29%	0.00%	0.00%	0.13%	0.00%	0.00%	46.81%	46.80%	46.80%
	LTH1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	19.55%	19.53%	19.53%
OIL	MW3 smd	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12.56%	12.61%	12.61%
	MTH	**4.85%**	**4.63%**	**4.38%**	**3.96%**	**3.90%**	**3.90%**	26.36%	26.34%	26.34%
NAT. GAS	MW3 smd	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	38.40%	39.58%	39.58%
	HTH	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	46.81%	46.80%	46.80%
	MTH	0.00%	1.04%	1.82%	0.00%	0.88%	1.62%	26.36%	26.34%	26.34%
ELECTRICITY	Ind	1.92%	**3.09%**	2.83%	1.04%	1.28%	1.17%	47.54%	53.54%	56.80%
HEAT	MTH	0.00%	1.04%	2.37%	0.00%	0.87%	2.11%	26.36%	26.34%	26.34%
Industry										
COAL	HTH	**4.88%**	0.02%	0.00%	2.27%	0.01%	0.00%	46.81%	46.80%	46.80%
	MTH	0.25%	0.01%	0.00%	0.15%	0.01%	0.00%	26.36%	26.34%	26.34%
OIL	HTH	**5.18%**	2.22%	1.76%	2.99%	1.34%	1.13%	46.81%	46.80%	46.80%
	MTH	**4.75%**	2.20%	1.75%	2.79%	1.34%	1.12%	26.36%	26.34%	26.34%
	LTH1	**3.53%**	0.31%	0.25%	**3.87%**	0.35%	0.29%	19.55%	19.53%	19.53%
	LTH2	0.78%	0.24%	0.07%	1.11%	0.35%	0.12%	14.97%	14.95%	14.95%
	MW2	0.03%	0.03%	0.02%	0.07%	0.06%	0.05%	10.12%	10.37%	10.37%
	MW3 d	1.03%	0.36%	0.31%	1.77%	0.63%	0.58%	12.56%	12.61%	12.61%
	MW3 smd	0.37%	0.21%	0.03%	0.64%	0.37%	0.05%	12.56%	12.61%	12.61%
COMB.RENEW	HTH	0.00%	0.01%	0.03%	0.00%	0.01%	0.02%	46.81%	46.80%	46.80%
	MTH	0.00%	0.74%	1.27%	0.00%	0.62%	1.13%	26.36%	26.34%	26.34%
	LTH1	**6.31%**	**5.59%**	**4.94%**	**6.93%**	**6.35%**	**5.94%**	19.55%	19.53%	19.53%
	LTH2	0.34%	0.11%	0.01%	0.49%	0.16%	0.01%	14.97%	14.95%	14.95%
	MW3 d	0.00%	0.01%	0.02%	0.00%	0.01%	0.03%	12.65%	12.96%	12.96%
	MW3 smd	0.00%	0.07%	0.19%	0.00%	0.04%	0.12%	38.40%	39.58%	39.58%

ENERGY CARRIER	TYPE OF END-USE	USEFUL SHARE			FINAL SHARE			EFFICIENCY		
		2000	2014	2030	2000	2014	2030	2000	2014	2030
NAT.GAS	HTH	2.71%	**3.96%**	2.97%	1.56%	2.32%	1.79%	46.81%	46.80%	46.80%
	MTH	2.46%	**3.33%**	2.14%	1.44%	2.02%	1.37%	26.36%	26.34%	26.34%
	LTH1	0.43%	1.35%	1.74%	0.47%	1.53%	2.09%	19.55%	19.53%	19.53%
	LTH2	0.10%	0.53%	0.87%	0.15%	0.78%	1.37%	14.97%	14.95%	14.95%
ELECTRICITY	Ind	**13.46%**	**19.36%**	**18.57%**	**7.25%**	**8.02%**	**7.68%**	47.54%	53.54%	56.80%
HEAT	HTH	0.37%	0.28%	0.88%	0.17%	0.13%	0.44%	46.81%	46.80%	46.80%
	MTH	0.11%	0.57%	0.65%	0.09%	0.48%	0.58%	26.36%	26.34%	26.34%
	LTH1	0.13%	0.65%	1.42%	0.15%	0.74%	1.71%	19.55%	19.53%	19.53%
Transports										
OIL	MW1	1.53%	1.16%	1.31%	1.25%	0.83%	1.00%	26.16%	30.94%	30.94%
	MW2	**5.94%**	**3.55%**	2.63%	**12.62%**	**7.59%**	**5.95%**	10.12%	10.37%	10.37%
	MW3 d	**11.01%**	**13.63%**	**11.03%**	**18.84%**	**23.97%**	**20.53%**	12.56%	12.61%	12.61%
	Navigation	0.44%	0.96%	0.99%	0.25%	0.54%	0.59%	38.40%	39.58%	39.58%
	Diesel-electric	0.36%	0.07%	0.06%	0.32%	0.07%	0.06%	24.33%	25.35%	25.35%
COMB.RENEW	MW2	0.00%	0.01%	0.01%	0.00%	0.01%	0.02%	10.12%	10.37%	10.37%
	MW3 d	0.00%	1.01%	0.90%	0.00%	1.73%	1.63%	12.65%	12.96%	12.96%
NAT. GAS	NG vehicles	0.00%	0.03%	0.05%	0.01%	0.08%	0.14%	8.00%	8.00%	8.00%
ELECTRICITY	Electric & Hybrid	0.19%	0.18%	1.69%	0.16%	0.16%	0.72%			
Residential / Commercial (Services)										
COAL	LTH3	0.10%	0.00%	0.00%	0.23%	0.00%	0.00%	8.80%	8.80%	8.80%
OIL	LTH3	2.32%	1.58%	1.38%	5.68%	3.97%	3.67%	8.80%	8.80%	8.80%
	MW2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.12%	10.37%	10.37%
COMB.RENEW	LTH3	2.76%	2.16%	1.99%	6.74%	5.44%	5.30%	8.80%	8.80%	8.80%
	MW3 d	0.00%	0.01%	0.02%	0.00%	0.01%	0.04%	12.65%	12.96%	12.96%
NAT.GAS	LTH3	0.29%	1.18%	0.95%	0.72%	2.98%	2.53%	8.80%	8.80%	8.80%
ELECTRICITY	Other	18.01%	20.32%	23.86%	9.70%	14.93%	18.57%	29.30%	30.16%	30.16%
HEAT	LTH3	0.01%	0.04%	0.06%	0.02%	0.10%	0.15%	8.80%	8.80%	8.80%
SOLAR THERMAL	LTH3	0.01%	0.05%	0.07%	0.02%	0.12%	0.19%	8.80%	8.80%	8.80%
Agriculture / Fishing										
OIL	LTH2	0.04%	0.04%	0.00%	0.06%	0.06%	0.01%	14.97%	14.95%	14.95%
	LTH3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.80%	8.80%	8.80%
	MW1	0.00%	0.20%	0.17%	0.00%	0.15%	0.13%	26.16%	30.94%	30.94%
	MW2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.12%	10.37%	10.37%
	MW3 d	2.10%	1.23%	1.01%	3.58%	2.17%	1.88%	12.56%	12.61%	12.61%

ENERGY CARRIER	TYPE OF END-USE	USEFUL SHARE			FINAL SHARE			EFFICIENCY		
		2000	2014	2030	2000	2014	2030	2000	2014	2030
COMB.RENEW	LTH3	0.00%	0.01%	0.00%	0.00%	0.02%	0.00%	8.80%	8.80%	8.80%
	MW3 d	0.00%	0.01%	0.04%	0.00%	0.02%	0.07%	12.65%	12.96%	12.96%
NAT.GAS	LTH2	0.00%	0.02%	0.02%	0.00%	0.03%	0.03%	14.97%	14.95%	14.95%
	LTH3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.80%	8.80%	8.80%
ELECTRICITY	Other	0.60%	0.59%	0.50%	0.32%	0.43%	0.39%	29.30%	30.16%	30.16%
HEAT	LTH1	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	19.55%	19.53%	19.53%

7.5.2. Ostrich scenario Electricity shares

	Heat	Mechanical drive	Other electric uses	Light
2000	23.79%	36.41%	27.86%	11.94%
2001	23.89%	36.30%	28.18%	11.63%
2002	23.94%	36.33%	28.44%	11.29%
2003	24.20%	36.12%	28.70%	10.98%
2004	24.22%	36.19%	28.96%	10.62%
2005	24.34%	36.15%	29.23%	10.28%
2006	24.38%	35.97%	29.73%	9.92%
2007	24.55%	35.64%	30.24%	9.58%
2008	24.64%	35.45%	30.70%	9.21%
2009	24.03%	34.38%	30.36%	11.23%
2010	23.89%	36.66%	27.81%	11.63%
2011	24.10%	36.34%	28.57%	10.99%
2012	24.24%	36.13%	29.09%	10.54%
2013	24.36%	35.94%	29.45%	10.26%
2014	24.37%	35.84%	29.69%	10.10%
2015	24.36%	35.77%	29.70%	10.18%
2016	24.37%	35.74%	29.76%	10.12%
2017	24.39%	35.72%	29.81%	10.07%
2018	24.41%	35.70%	29.87%	10.02%
2019	24.42%	35.68%	29.93%	9.97%
2020	24.44%	35.65%	29.98%	9.92%
2021	24.46%	35.63%	30.04%	9.87%
2022	24.47%	35.61%	30.09%	9.82%
2023	24.49%	35.59%	30.15%	9.78%
2024	24.50%	35.57%	30.20%	9.73%

	Heat	Mechanical drive	Other electric uses	Light
2025	24.52%	35.55%	30.25%	9.69%
2026	24.53%	35.53%	30.30%	9.64%
2027	24.54%	35.51%	30.35%	9.60%
2028	24.56%	35.49%	30.39%	9.56%
2029	24.57%	35.47%	30.44%	9.51%
2030	**24.59%**	**35.46%**	**30.49%**	**9.47%**

7.5.3. Iberian Lynx Scenario summary table

ENERGY CARRIER	TYPE OF END-USE	USEFUL SHARE			FINAL SHARE			EFFICIENCY		
		2000	2014	2030	2000	2014	2030	2000	2014	2030
Energy sector										
COAL	HTH	0.29%	0.00%	0.00%	0.13%	0.00%	0.00%	46.81%	46.80%	46.80%
	LTH1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	19.55%	19.53%	19.53%
OIL	MW3 smd	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12.56%	12.61%	12.61%
	MTH	**4.85%**	**4.63%**	**4.21%**	**3.96%**	**3.90%**	**4.36%**	26.36%	26.34%	26.34%
NAT. GAS	MW3 smd	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	38.40%	39.58%	39.58%
	HTH	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	46.81%	46.80%	46.80%
	MTH	0.00%	1.04%	1.52%	0.00%	0.88%	1.58%	26.36%	26.34%	26.34%
ELECTRICITY	Ind	1.92%	**3.09%**	3.06%	1.04%	1.28%	1.30%	47.54%	53.54%	63.92%
HEAT	MTH	0.00%	1.04%	1.79%	0.00%	0.87%	1.85%	26.36%	26.34%	26.34%
Industry										
COAL	HTH	**4.88%**	0.02%	0.00%	2.27%	0.01%	0.00%	46.81%	46.80%	46.80%
	MTH	0.25%	0.01%	0.00%	0.15%	0.01%	0.00%	26.36%	26.34%	26.34%
OIL	HTH	**5.18%**	2.22%	1.69%	2.99%	1.34%	1.26%	46.81%	46.80%	46.80%
	MTH	**4.75%**	2.20%	1.68%	2.79%	1.34%	1.25%	26.36%	26.34%	26.34%
	LTH1	**3.53%**	0.31%	0.24%	**3.87%**	0.35%	0.33%	19.55%	19.53%	19.53%
	LTH2	0.78%	0.24%	0.22%	1.11%	0.35%	0.41%	14.97%	14.95%	14.95%
	MW2	0.03%	0.03%	0.03%	0.07%	0.06%	0.07%	10.12%	10.37%	10.37%
	MW3 d	1.03%	0.36%	0.08%	1.77%	0.63%	0.17%	12.56%	12.61%	12.61%
	MW3 smd	0.37%	0.21%	0.03%	0.64%	0.37%	0.06%	12.56%	12.61%	12.61%
COMB.RENEW	HTH	0.00%	0.01%	0.03%	0.00%	0.01%	0.02%	46.81%	46.80%	46.80%
	MTH	0.00%	0.74%	1.22%	0.00%	0.62%	1.26%	26.36%	26.34%	26.34%
	LTH1	**6.31%**	**5.59%**	**2.10%**	**6.93%**	**6.35%**	**2.93%**	19.55%	19.53%	19.53%
	LTH2	0.34%	0.11%	0.00%	0.49%	0.16%	0.01%	14.97%	14.95%	14.95%
	MW3 d	0.00%	0.01%	0.02%	0.00%	0.01%	0.04%	12.65%	12.96%	12.96%
	MW3 smd	0.00%	0.07%	0.15%	0.00%	0.04%	0.10%	38.40%	39.58%	39.58%
NAT.GAS	HTH	2.71%	**3.96%**	3.24%	1.56%	2.32%	2.28%	46.81%	46.80%	46.80%
	MTH	2.46%	**3.33%**	2.44%	1.44%	2.02%	1.82%	26.36%	26.34%	26.34%
	LTH1	0.43%	1.35%	1.67%	0.47%	1.53%	2.33%	19.55%	19.53%	19.53%
	LTH2	0.10%	0.53%	0.82%	0.15%	0.78%	1.50%	14.97%	14.95%	14.95%
ELECTRICITY	Ind	**13.46%**	**19.36%**	**20.05%**	**7.25%**	**8.02%**	**8.55%**	47.54%	53.54%	63.92%
HEAT	HTH	0.37%	0.28%	0.84%	0.17%	0.13%	0.49%	46.81%	46.80%	46.80%
	MTH	0.11%	0.57%	0.97%	0.09%	0.48%	1.00%	26.36%	26.34%	26.34%
	LTH1	0.13%	0.65%	1.36%	0.15%	0.74%	1.90%	19.55%	19.53%	19.53%

ENERGY CARRIER	TYPE OF END-USE	USEFUL SHARE			FINAL SHARE			EFFICIENCY		
		2000	2014	2030	2000	2014	2030	2000	2014	2030
Transports										
OIL	MW1	1.53%	1.16%	0.28%	1.25%	0.83%	0.24%	26.16%	30.94%	30.94%
	MW2	**5.94%**	**3.55%**	1.24%	**12.62%**	**7.59%**	**3.25%**	10.12%	10.37%	10.37%
	MW3 d	**11.01%**	**13.63%**	**7.67%**	**18.84%**	**23.97%**	**16.59%**	12.56%	12.61%	12.61%
	Navigation	0.44%	0.96%	0.99%	0.25%	0.54%	0.68%	38.40%	39.58%	39.58%
	Diesel-electric	0.36%	0.07%	0.36%	0.32%	0.07%	0.33%	24.33%	25.35%	30.00%
COMB.RENEW	MW2	0.00%	0.01%	0.01%	0.00%	0.01%	0.02%	10.12%	10.37%	10.37%
	MW3 d	0.00%	1.01%	2.33%	0.00%	1.73%	4.90%	12.65%	12.96%	12.96%
NAT. GAS	NG vehicles	0.00%	0.03%	0.05%	0.01%	0.08%	0.16%	8.00%	8.00%	9.40%
ELECTRICITY	Diesel-electric	0.19%	0.18%	5.09%	0.16%	0.16%	1.94%	24.33%	25.35%	30.00%
Residential / Commercial (Services)										
COAL	LTH3	0.10%	0.00%	0.00%	0.23%	0.00%	0.00%	8.80%	8.80%	8.80%
OIL	LTH3	2.32%	1.58%	1.15%	5.68%	3.97%	3.58%	8.80%	8.80%	8.80%
	MW2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.12%	10.37%	10.37%
COMB.RENEW	LTH3	2.76%	2.16%	1.58%	6.74%	5.44%	4.90%	8.80%	8.80%	8.80%
	MW3 d	0.00%	0.01%	0.02%	0.00%	0.01%	0.04%	12.65%	12.96%	12.96%
NAT.GAS	LTH3	0.29%	1.18%	0.77%	0.72%	2.98%	2.39%	8.80%	8.80%	8.80%
ELECTRICITY	Other	18.01%	20.32%	26.57%	9.70%	14.93%	20.67%	29.30%	30.16%	35.02%
HEAT	LTH3	0.01%	0.04%	0.05%	0.02%	0.10%	0.17%	8.80%	8.80%	8.80%
SOLAR THERMAL	LTH3	0.01%	0.05%	0.07%	0.02%	0.12%	0.21%	8.80%	8.80%	8.80%
Agriculture / Fishing										
OIL	LTH2	0.04%	0.04%	0.00%	0.06%	0.06%	0.01%	14.97%	14.95%	14.95%
	LTH3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.80%	8.80%	8.80%
	MW1	0.00%	0.20%	0.61%	0.00%	0.15%	0.54%	26.16%	30.94%	30.94%
	MW2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.12%	10.37%	10.37%
	MW3 d	2.10%	1.23%	0.80%	3.58%	2.17%	1.74%	12.56%	12.61%	12.61%
COMB.RENEW	LTH3	0.00%	0.01%	0.01%	0.00%	0.02%	0.03%	8.80%	8.80%	8.80%
	MW3 d	0.00%	0.01%	0.04%	0.00%	0.02%	0.09%	12.65%	12.96%	12.96%
NAT.GAS	LTH2	0.00%	0.02%	0.04%	0.00%	0.03%	0.07%	14.97%	14.95%	14.95%
	LTH3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.80%	8.80%	8.80%
ELECTRICITY	Other	0.60%	0.59%	0.80%	0.32%	0.43%	0.62%	29.30%	30.16%	35.02%
HEAT	LTH1	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	19.55%	19.53%	19.53%

7.5.4. Iberian Lynx scenario Electricity shares

	Heat	Mechanical drive	Other electric uses	Light
2000	23.79%	36.41%	27.86%	11.94%
2001	23.89%	36.30%	28.18%	11.63%
2002	23.94%	36.33%	28.44%	11.29%
2003	24.20%	36.12%	28.70%	10.98%
2004	24.22%	36.19%	28.96%	10.62%
2005	24.34%	36.15%	29.23%	10.28%
2006	24.38%	35.97%	29.73%	9.92%
2007	24.55%	35.64%	30.24%	9.58%
2008	24.64%	35.45%	30.70%	9.21%
2009	24.03%	34.38%	30.36%	11.23%
2010	23.89%	36.66%	27.81%	11.63%
2011	24.10%	36.34%	28.57%	10.99%
2012	24.24%	36.13%	29.09%	10.54%
2013	24.36%	35.94%	29.45%	10.26%
2014	24.37%	35.84%	29.69%	10.10%
2015	22.06%	38.84%	29.12%	9.98%
2016	21.50%	39.72%	28.94%	9.85%
2017	20.96%	40.57%	28.76%	9.72%
2018	20.43%	41.39%	28.59%	9.59%
2019	19.93%	42.18%	28.42%	9.47%
2020	19.44%	42.94%	28.26%	9.35%
2021	18.97%	43.68%	28.11%	9.24%
2022	18.51%	44.40%	27.96%	9.13%
2023	18.07%	45.09%	27.82%	9.02%
2024	17.65%	45.76%	27.68%	8.92%
2025	17.23%	46.41%	27.54%	8.82%
2026	16.83%	47.03%	27.41%	8.72%
2027	16.44%	47.64%	27.28%	8.63%
2028	16.07%	48.24%	27.16%	8.54%
2029	15.70%	48.81%	27.04%	8.45%
2030	**15.26%**	**49.88%**	**26.60%**	**8.26%**

7.6. METHODOLOGY FOR ESTIMATING GDP, TFP AND FINAL-TO-USEFUL EXERGY EFFICIENCIES

The scenario-making process followed for MEET2030 is represented in Figure 22, showing all its qualitative and quantitative components. Though shown as a closed process, it has a loop in it, making the process iterative and open to updates and changes if needed.

In relation to the exergy efficiency and all exergy calculations, one may choose as a starting point the two inputs that initiate the "green path" in the schematic representation: information on technological evolution and assumptions as well as choices needed for each scenario to, then, use both efficiencies and shares that are more adequate to each situation described in the narratives. Data series on final energy consumption are taken from IEA (2016) and calculations of final-to-useful exergetic efficiencies as well as the allocation per end-use needed for disaggregated shares are based on the literature, mainly on Serrenho *et al.* (2013, 2016).

Based on results obtained for 2000-2014, useful shares at their more disaggregated level are computed as well as initial projections of useful exergy shares for each scenario in order to obtain an aggregate final-to-useful efficiency. Having the shares disaggregated in a higher level than end-use, all shares within the same category end-use by different types of fuel (e.g. charcoal and renewable municipal residues are both combustible renewables used for LTH1), are summed within sectors and categories to reach a more aggregate level (categories of end-use described in the present document). Electricity is treated separately, calculating its final totals per sector first and, then, applying end-use shares and efficiencies to those to obtain the useful shares by end-use.

Based on this input of shares and efficiencies, a series of aggregate final-to-useful efficiencies is calculated for the period of the simulation, using it afterwards to calculate GDP. This GDP calculation process is described in Sections 3.3, 4.1.5 and 4.2.5 and generates a series of useful exergy, from which a final exergy series is calculated by dividing it for the aggregate efficiency series, previously mentioned.

Although both useful and final exergy uses may be computed from GDP, only useful exergy is directly an output from that calculation process.

Following, the input to calculate final exergy in detail (disaggregated) are: the series of absolute values of total useful exergy, useful exergy shares disaggregated by energy carrier and type of end-use, as well as final-to-useful efficiencies with the same disaggregation of consumption shares. The outputs from these calculations are final exergy shares and consumption (absolute values) disaggregated per end-use and energy carrier.

With this level of disaggregation by energy carrier, it is possible to compute primary exergy and CO_2 emissions that result from national energy consumption.

The macroeconomic component of the project aims to develop projections for economic output – measured as gross domestic product (GDP) – from assumptions related to capital investment and human labor used in production, as well as assumptions on the evolution of final-to-useful aggregate exergy efficiency, and total factor productivity (TFP).

Annual TFP growth rates are computed resorting to a growth accounting framework – equation (1).

$$g_{TFP} = g_{GDP} - \alpha_K g_K - \alpha_L g_L \quad (1)$$

Where g_i, $i = GDP, K, L$ correspond to annual growth rates for GDP, capital stock used in production, and human labor, respectively. The exponents α_i, $i=K,L$ represent output elasticities for each factor of production – indicating how much, in percentage, GDP grows when one of these factors is increased by 1%, keeping all else constant. These output elasticities can be equated – from an income perspective – with the payments attributed to each of these factors of production. For the historical period between 1960 and 2016, all empirical data regarding these variables can be obtained directly from the European Commission's annual macroeconomic database (AMECO).

Empirically, a stable relationship can be observed between TFP and final-to-useful aggregate exergy efficiency (EFF) in Portugal, over the past 50 years. For each time period t, this relationship is mathematically written as:

$$TFP_t = \left(\frac{EFF_t}{EFF_0}\right)^{1.87} \quad (2)$$

Here EFF_0 is the level of final-to-useful aggregate exergy efficiency in Portugal in 1960. Historical data regarding final-to-useful aggregate exergy efficiency for Portugal are obtained directly from the empirical work of Serrenho *et al.* (2016).

Future TFP projections depend on assumptions related with the evolution of final-to-useful aggregate exergy efficiency.

Capital inputs used in economic production (K) are measured as the total amount of capital assets available to participate in productive processes, in monetary terms. Historical data for this variable can be obtained directly from the AMECO database.

The total amount of capital assets available to production in each period t can be obtained resorting to the perpetual inventory method (PIM), which determines the level of capital in a given period from the level of capital in the previous period, by adding new investment in capital assets for the present year, and simultaneously subtracting capital no longer available to production due to depreciation. Hence, the stock of capital assets used in production for a given year is dependent on assumptions related to capital investment (i) – measured as a percentage of GDP (the "saving rate") – and depreciation of capital, i.e., consumption of fixed capital (δ) – measured as a percentage of capital stock in the same period. Historical data for these variables are obtained directly from the Instituto Nacional de Estatística (investment capacity in capital assets) and the AMECO database (depreciation rates).

Projections for capital used in economic production depend on assumptions regarding saving rate and consumption of fixed capital.

Human labour used in economic production (L) is measured as the total number of hours worked by all engaged individuals in the economy. Historical data for this variable is directly obtained from the Penn World Tables international database - Feenstra *et al.* (2015).

Human labour used in production is computed by multiplying the number of hours worked by engaged individual in the economy (h) by the number of engaged individuals. This last variable is obtained taking into account the working age population – understood as the population over 15 and under 64 years of age – (Pop_{15-64}), the labor force participation rate (LP), and the unemployment rate (ur).

Historical data for all these variables are obtained directly from the Penn World Tables international database (h), AMECO database (ur; LP), and INE (Pop_{15-64}). Regarding the latter, INE provides a set of alternative scenarios for the future evolution of the population (*high, central,* and *low* scenarios).

Hence, human labour projections will depend on assumptions related to the evolution of the number of hours worked by engaged individuals in the economy, unemployment rate, and working age population.

Computing projections for TFP, capital used in production (K), and human labor used in production (L), the level of GDP for a given time period t will be given by an aggregate Cobb-Douglas production function:

$$GDP = TFP \cdot K^{\alpha K} \cdot L^{\alpha L} \quad (3)$$

7.7. THE 3RD CHALLENGE

The 3rd Challenge was launched on 11th of September, resulting in 10 responses. The respondents were then asked to present their work at the 4th Workshop. The questions that composed the 3rd Challenge were:

1. Para o seu setor, concorda com a evolução das eficiências e das shares de usos de exergia apresentados nos gráficos anteriores? Acha que a evolução das eficiências ou das shares deveriam ser diferentes das apresentadas?

2. Imagine a sua empresa no cenário do Lince:

2.1. Seriam necessárias novas tecnologias na sua empresa para atingir os níveis de eficiências ou mudança de tipos de energia? Que tecnologias e para que tipos de uso de energia? (tenha em conta as suas respostas às questões Q3, Q4 e Q5 do Desafio 2)

2.2. Para a sua empresa ir na direção do cenário do Lince Ibérico, que novos modelos de negócio seriam necessários para a sua empresa, quer para permitir as novas tecnologias ou para ultrapassar possíveis constrangimentos de políticas?

2.3. Que políticas públicas ajudariam na transição da sua empresa para o cenário do Lince Ibérico?

7.8. CARBON SEQUESTRATION

Two forms of carbon sequestration were taken into account:

- Sown biodiverse pastures
- Native forest

The sequestration factors are explained below.

7.8.1. Sown Biodiverse Pastures

Sequestration factors considered are the ones from the National Inventory Report (APA, 2017) and in Teixeira *et al.* (2011). The first year of sowing is 2018 and the time horizon for sequestration is 2030.

According to NIR and Teixeira (2010), the reference system used, semi-natural pastures, is carbon neutral.

The sequestration values considered take into account that:

- Sequestration varies with the age of the pasture (APA, 2017 and Teixeira *et al.*, 2011),
- There is an expected area of sown biodiverse pastures that will occur anyway without any further incentives (Teixeira, 2010, see Table 30). Therefore, not all area available for sown biodiverse pastures is available for sequestering carbon to neutralise emissions from the Iberian Lynx.

Table 30. Carbon sequestered in sown biodiverse pastures (APA, 2017) and non-additional area of pastures (Teixeira, 2010) for each project year where 1=2018

Year	Carbon sequestered (tCO_2/ha/year)	Estimated annual sown area (non-additional, ha)
1	14.70	133
2	11.54	87
3	9.15	56
4	7.30	37
5	5.86	24
6	4.72	16
7	3.82	10
8	3.10	7
9	2.53	4
10	2.06	3
11	0.00	2
12	0.00	1
13	0.00	1
Average (10 years)	6.48	

7.8.2 Native Forest

For carbon sequestered by new native forest, NIR (APA, 2017) was used for the sequestration factor. The values used take into account:

- Surface biomass,
- Belowground biomass,
- Litter (e.g., leaves and other organic matter),
- Soil carbon.

The sequestration values are presented in Table 31. Soil carbon stock is only achieved after 20 years. For the sequestration values used for MEET2030, we have assumed a substitution of shrubland by native forest. In order to maximise general environmental benefits, the native forest considered here is oakland (*Carvalhal*) that in Table 31 is classified as other hardwoods.

Table 31. Carbon stock (t C/ha) in forest ecosystems, by dominant species (according to APA, 2017).

	CARBON STOCK (t C/ha)			
	SURFACE BIOMASS	UNDERGROUND BIOMASS	LITTER	SOIL
Pinus pinaster	26.74	3.14	2.96	113
Quercus suber	20.04	2.94	2.04	66
Eucalyptus spp.	17.97	4.2	1.85	98
Quercus rotundifolia	8.37	4.92	2.04	65
Quercus spp.	15.87	4.69	1.85	89
Other hardwoods	30.79	13.34	1.85	107
Pinus pinea	18.79	1.46	2.41	93
Other conifers	14.51	1.76	2.96	93
Shrubs	8.78	4.94	4.96	107

The carbon stock for the Oakland presented in Table 30 was assumed to be accumulated for 20 years. Harvesting and forest fires were not taken into account. For the case of the reference situation, shrubland, carbon stock is assumed to be lost every four years (due to regular shrub cuts and fires). This means that at any moment, we can assume that the average carbon stock is approximately half of the maximum the shrubland can reach (in terms of surface biomass and litter). Given the maximum of carbon stock is of 8,78 t C/ha for surface biomass and of 4,96 t C/ha for litter, the average carbon stock for these components in each moment is of 4.39 and 2.48 t C/ha, respectively. Underground biomass and soil carbon are not affected by fires and cuts.

For the carbon sequestered, we have used the difference between the carbon stock between Oakland and shrubland in each of the four components

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