TOWARDS A CARBON NEUTRAL ECONOMY HOW CAN PORTUGAL'S ECONOMY GROW WHILE CREATING EMPLOYMENT?

Portugal aspires to be carbon neutral by 2050. Companies need to prepare for this challenge, and therefore it is important to understand how 2030 might look. Achieving climate change commitments, together with economic growth and social equity, is essential.

This study advocates that exergy efficiency can increase GDP, and it is possible to identify a set of technologies that can contribute to such an increase in Portuguese productivity. Nevertheless, to become carbon neutral, it will also be necessary to increase renewable energy penetration and improve carbon sequestration via a contribution from natural systems. Finance (from private and public sources) will be needed. Appropriate fiscal policies will be required, as well as new competences and skills. This represents a challenge for Portugal but also an opportunity. Let's think about the future and prepare Portugal for a sustainable and socially inclusive 4th Industrial Revolution.

MEET2030
BUSINESS, CLIMATE CHANGE AND ECONOMIC GROWTH

MEET2030
imagine the future

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COLLABORATING
TO PREPARE FOR A CARBON
NEUTRAL FUTURE

With a common purpose, several Portuguese companies have come together to create a vision of the future that is greater and far more complete than they would imagine in an isolated exercise.

MEET2030 was an experimental project, involving the direct cooperation of academics and around 30 companies, that established a common vision and several orientations about a future in 2030, targeting a 2050 carbon neutrality society in Portugal, while envisioning economic growth and competitiveness of the several sectors involved.

Today it is clearer than ever that we are in the midst of a technological and sustainable revolution. In this transition we need to secure continuous economic progress and growth while respecting and advancing on human rights, inclusiveness and reduction of global existing disparities. We also need to innovate, bring forward new services and products while addressing the limited resources on the planet and protecting the environment and its biodiversity.

The private sector has been called upon at the international forums to respond to the global challenges and has now an increasingly open dialogue with the international structures and public entities. The business sector has been showing lead through commitments, projects and initiatives that are being implemented and that are actually shaping the low carbon transition and contributing to countries and international agendas.

However, we cannot yet identify all the challenges and opportunities that this transition entails for the business, but we can predict and estimate a possible future and reflect it in our corporate strategies, where our companies and people will thrive and contribute to address the main global challenges, such as climate change, and we can imagine it better if we do it together.

The project was a tall order and the report reveals the complexity involved, but the added value of having a vision on the future that arises from a unique collaborative exercise between sectors is outstanding.

António Mexia
President of BCSD Portugal

A COMMON VISION
IN A COMPLEX CONTEXT

MEET2030 brought together companies of different sizes from different sectors, to imagine the future of Portugal in 2030 as it makes its transition towards a carbon neutral economy by 2050, the commitment made by the Portuguese government at COP 22 in Marrakesh. A shared vision, as set out in this report, was reached by these companies, working together in workshops using economic modelling and scenario planning.

The modelling revealed that increasing energy efficiency is a key driver of economic growth: a 1% increase in energy efficiency leads to a 2% increase in GDP. In addition, it concluded that electrification, automation, digitalization and the circular (bio) economy, the hallmarks of a sustainable fourth industrial revolution, will be the key drivers of economic growth in the drive towards decarbonisation.

However, the combination of the growth in GDP and in energy efficiency leads to an increase in primary energy consumption. The appropriate energy mix required to meet this demand has to be carefully identified and targeted in order to ensure carbon neutrality by 2050.

With that goal in mind, MEET 2030 identified, in particular, the need to encourage renewable sources of energy, thus helping to decarbonise electricity generation, improve air quality and broaden customer choice, and to increase carbon sequestration coupled to multiple environmental benefits, to be achieved by increasing the area of responsibly managed forests, forestry and agriculture products, as well as via technological solutions. Natural gas will also be a required part of the energy mix in order to guarantee energy security.

To achieve all of this, a strengthened, consistent and transparent carbon price mechanism should be established at the EU and worldwide levels. Government investment should target Research & Development projects to develop low carbon technologies at the pre-commercial phase. Public policies should be neutral in relation to the technologies in question, to encourage competition, innovation and a market for low carbon solutions.

In order to achieve an inclusive, carbon neutral economy by 2050 in Portugal, based on innovation, new business solutions and partnerships, identifying the green and e-skills needed to support this transition will be crucial, and, in particular, understanding how existing skills can be adapted and new skills developed to deal with this new reality and avoid the potential unemployment generated by automation.

1.

Executive Summary

1.
EXECUTIVE SUMMARY

THE RELEVANCE

Under the Paris Climate Change Agreement, countries have agreed to achieve a carbon neutral economy as early as possible in the second half of the XXI century. The Portuguese Government has committed to achieving carbon neutrality by 2050 in Portugal. It is therefore important to imagine the changes that such a commitment may bring to the Portuguese economy, so that companies can anticipate these changes and adapt to them during the transition period, and governments can identify and implement the public policies needed.

THE GOALS

The Goals of MEET 2030 were:
- To build scenarios for Portugal in 2030, against the background of a fourth industrial revolution, taking into consideration commitments made at national, European and worldwide levels, in order to achieve carbon neutrality. This was done by identifying one possible primary energy mix for 2030 that, in conjunction with carbon sequestration measures, would be compatible with a trajectory of CO_2 emissions achieving a low carbon economy by 2050, as defined by the Portuguese Environmental Agency (APA,2012).
- 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 over the long term.

- To identify solutions with higher added value.
- To contribute to a policy and plan of action that can promote a transition to a carbon neutral economy in Portugal by 2050.

THE ECONOMIC MODEL USED

To understand how economic growth and job creation are possible in a carbon neutral economy, MEET2030 used the **exergy approach**[1] **to define the economic model that could lead to a trajectory aimed at carbon neutrality. In this model**, GDP is a function of labour, capital and the productivity of energy, i.e., exergy efficiency. This approach is significantly different from the mainstream economic model that is generally used, in which GDP is a function of labour, capital and an exogenous total factor productivity.

THE SCENARIOS DEVELOPMENT PROCESS

Using the exergy approach as a framework for the GDP growth model, MEET2030 was based on a scenario planning process, involving around 30 Portuguese companies, from 13 different sectors, representing approximately 20% of the nation's GDP[2], in four workshops over a period of 10 months, and involving several interactions with other organisations, such as the Portuguese Ministry of Environment, the APA, the Portuguese Energy Agency and the Secretary of State for

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1. Ayres, R.U. and Warr, B. (2005).
2. Calculation: sum of turnover of participating companies divided by Portuguese GDP in 2016 (184,931 million € at current prices).

Industry. These companies, in a cooperatively constructive and bottom-up process, developed two potential scenarios that the economy could face through to 2030: *The Ostrich* Scenario and *the Iberian Lynx* Scenario.

The *Ostrich Scenario* describes a situation in which Portugal lags behind, in a world transformed by new developments in technology, the environment and energy. In this scenario of stagnation, Portugal manages to comply with the existing, less demanding requirements of the National Low-Carbon Roadmap, but with a fall in GDP. Portugal is becoming ever more peripheral in nature, becoming less attractive for investment. The banking system is unable to adequately support economic development, resulting in a fall in the country's stock of capital. There is an inability to align technological development and investments in science, technology and innovation with the great societal challenges that the country faces. Portugal is thus unable to attract and retain talent. At the same time, automation and the fact that there are fewer individuals working or actively searching for jobs contributes to high unemployment and to greater social unrest.

The *Iberian Lynx* is a scenario of high stability, growth and competitiveness, with significant EU economic growth, financial stabilization of the Portuguese economy and higher levels of investment. In this scenario, the recovery is based on strong cooperation between economic agents within the country and between Portugal and other countries. The banking system recovers and helps support economic development. The result is an increase in Portugal's stock of capital each year. There is an effective digitalization policy, with both a vision and goals, supported by a strong political commitment and close cooperation between agents, while coordination between Government policies and the needs of companies exist, in order to address new societal challenges. This leads to an ability to attract and retain talent and in a fall in unemployment rates.

THE MAIN SCENARIO OUTPUTS AND THE LYNX+ SCENARIO

The modelling pointed to GDP growth under *The Iberian Lynx* scenario producing higher GHG emissions than under *The Ostrich*, a situation which would not comply with the CO_2 limits defined under the most stringent scenario established by the APA (2012). This was mainly due to the fact that, under *The Iberian Lynx* scenario, the effect of exergy efficiency on economic growth is so large that the economy ends up with higher carbon emissions than under *The Ostrich* scenario. As a result, other policies, such as higher renewable penetration and higher carbon sequestration, are required.

Therefore, a derivative of the Lynx scenario, named *The Lynx+* Scenario, was created. Under this new scenario, participants in the workshops identified a possible primary energy mix for 2030 that, on the assumption of a strong carbon price and in conjunction with carbon sequestration measures, is compatible with a trajectory of reducing CO_2 emissions according to the most stringent scenario of the National Low Carbon Roadmap (APA, 2012).

As noted previously, this mix should be seen as a "proof of concept", demonstrating the viability of the projected decarbonisation trajectory. Any other primary energy mix that enables the same objectives to be achieved, with the same or better economic and environmental performance (understood in a broad sense, taking into consideration both GHG emissions and other environmental issues), should also be considered for developing public policy.

MAIN CONCLUSIONS FOR ALL SCENARIOS

- Exergy efficiency is highly effective at promoting economic growth.
- Exergy efficiency alone is not enough to reach a carbon neutral economy, since the resulting economic growth results in increased primary energy consumption and hence potential additional CO_2 emissions.

MAIN CONCLUSIONS FOR THE LYNX+ SCENARIO

- Decarbonisation of the electricity system and of the primary energy mix, with an enhanced share of renewables, are key to achieving a low carbon economy and economic growth.

- Promoting carbon sequestration that provides multiple additional environmental benefits will be required.

- It is important to gradually adapt the competences and skills of the labour force (existing and future) to the needs of a low carbon economy, in the context of the disruption introduced by the automation that will be a feature of the fourth industrial revolution

- Additionally, in the transition to a low-carbon future and assuming a strong carbon price, coal is likely to be substituted. To ensure the energy security of supply, natural gas will offer an immediate and material opportunity to limit global emissions. The share of oil products in final energy decreases, but their absolute quantity remains roughly constant in the CO_2 low carbon compliance scenario.

- It was possible to identify a possible power generation mix for 2030 that, together with carbon sequestration measures, will be compatible with the trajectory of CO_2 achieving a low carbon economy by 2050. According to the assumptions made by participants in the project, the power sector mix in 2030 under the Lynx+ scenario will be primarily made up of renewables and natural gas, to total 98% of the mix.

2.

Public Policy Guidelines

2.
PUBLIC POLICY GUIDELINES

Effective climate policy should have, as its long-term objective, the reduction of the risk of the serious impact of climate change on society and ecosystems, while recognizing the fact that abundant, reliable and affordable energy is a requirement to enhance economic growth and competitiveness. As such, Portuguese climate policies should:

- Be science-based;

- Support an effective and economy-wide common carbon pricing system, at least at an EU level (but ideally at a global level);

- Allow markets to drive the choice of solutions, adapting the market design, while supporting the development of pre-commercial phase low carbon technologies;

- Implement effective measures to address potential carbon leakage;

- Promote the concept of the life cycle to identify opportunities, maximize energy efficiency and minimize the carbon footprint and environmental impact of activities and products;

- Recognize the long-term nature of addressing the risks of climate change;

- Be transparent with all stakeholders, while minimizing complexity and administrative costs

- Address both mitigation and adaptation measures;

- Encourage global participation and cross sectoral cooperation.

In line with the main conclusions of the project and as a result of the active participation of several stakeholders during the various moments of interaction among participants, including workshops and meetings, the recommendations below were identified as being the most relevant for creating policy guidelines in different sectors.

2.1
TO IMPROVE DECARBONISATION

Taking into account the results of the model and its consequences, it is felt that higher levels of investment should be made in:

- Decarbonization of the electricity system (e.g., hydro, wind, solar, biomass and geothermal);

- Electrification and improvement of final-to-useful exergy efficiency (e.g., motorway adaptation for automation and robotisation, and electric vehicles; information technology and engineering; demand-side management);

- Carbon sequestration projects;

- Enhancement of bio-economy activities.

For this investment to take place, project participants identified the following measures that could act as catalysts for this:

- Strengthen consistent and transparent carbon price mechanisms worldwide, in particular at an EU level,

which will encourage investment in innovation, employment and a shift towards a low carbon economy;

- Broaden the scope of the EU-ETS across economic sectors, which will lead to a greater effort by businesses to reduce their GHG emissions;

- Increase the level of investment made by Public and Private organisations in energy efficiency and in R&D on environment related technologies, by encouraging the development of research partnerships between European countries with similar challenges.

2.2
TO IMPROVE AGGREGATE EXERGY EFFICIENCY

One result from the exergy efficiency model used, is that it is possible to conclude that electrification is a key aspect to reach the level of efficiency in the economy. Furthermore, it also contributes towards decarbonisation, because the share of renewable energy in electricity is higher than in other energy sectors.

We therefore recommend:
- High levels of electrification in multiple sectors;

- Continued automation in industries and in other sectors (e.g., delivery and mailing services, domestic robots, etc.);

- Promoting efficient lighting technology and substitution of existing stock;

- Expanding the electricity capacity of the Portuguese power grid system.

SPECIFIC RECOMMENDATIONS FOR **INDUSTRY**	
Resulting from the exergy efficiency approach model used	**Resulting from inputs of the participants involved in the project**

• Support for technologies that promote lower primary energy consumption (e.g. high efficiency cogeneration in industry).
 	
• Since electricity is the carrier with the highest final-to-useful efficiency (85%), one way to move into a significantly more energy efficient society is to substitute other energy carriers with electricity uses. This can might be achieved by introducing new industrial sectors into the Portuguese economy as well as new forms of production.
 	
• The goal should be to increase the share of stationary mechanical drive uses. This increase could be achieved by introducing new technologies, such as replacing traditional heat uses by electricity (e.g., furnaces) and a big increase in automation and robotisation in industrial processes. The continuous automation of Industry can be done by replacing low temperature processes with more efficient uses and stabilizing high temperature category shares.
	• Implement efficient manufacturing practices and a general reduction in the use of materials.
	
	• Promote energy management certification.
	
	• There should be a strong policy in relation to the circular economy, namely the:
	   - Mapping of inputs and outputs from each activity/industry with the aim of encouraging industrial symbiosis.
	   - Development of green certification.
	   - Provision of incentives for re-manufacture and re-use.
	   - Encouragement of the use of waste/specific raw materials, and alternative fuels for energy production.

SPECIFIC RECOMMENDATIONS FOR **ROAD TRANSPORT**	
Resulting from the exergy efficiency approach model used	**Resulting from inputs of the participants involved in the project**
• Promote electric & hybrid vehicles. • Promote the use of Natural Gas for vehicles, especially for heavy vehicles. • Encourage the implementation of alternative business models (e.g., car-sharing). • Increase and improve the infrastructure for electrical vehicle charging.	• Public and private partnerships to develop technologies and business models that can lead to lower transport carbon emissions, including the use of ICTs (Information and Communications Technologies), IoT (Internet of Things) and AI (Artificial Intelligence). • Promote multi-modal transport systems and planning. • Sustainable bio-fuels.

SPECIFIC RECOMMENDATIONS FOR **RESIDENTIAL AND COMMERCIAL (SERVICES)**	
Resulting from the exergy efficiency approach model used	**Resulting from inputs of the participants involved in the project**
• Increase the use of more efficient electricity-based heat pumps.	• Implement the Nearly Zero Energy Buildings directive; • Implement a life cycle assessment approach to building construction; • Develop incentives to stimulate the use of sustainable retrofitting and construction methods and materials.

2.3
TO INCREASE EMPLOYMENT

As a result of inputs from participants involved in the project and from the consultation process with other stakeholders, it became clear that "green" and "e-skills" are needed for a low carbon transition in Portugal. We therefore recommend:

- Regular assessment of the skills required by industry and discussion on how to adapt educational policy to these needs, especially for technical/professional education;

- Having an educational system in place that is more adaptable to the requirements of workers and industry. This includes: partnerships between business, universities and government; the development of business clusters; training and internships for school teachers companies; continuous innovation and flexibility in the educational system;

- Policies which target employment among the older generation and the population in rural areas. These segments tend to reduce competitiveness in the early stages of the shift towards the 4th industrial revolution, since, in the absence of specific policies to counteract the trend, new employment opportunities will target younger generations and urban areas;

- Policies to ensure that higher levels of employment are not achieved at the expense of "lower quality" jobs;

- Development of internal mechanisms by companies to attract and retain talent, in particular through better compensation policies.

3.

The Essence of the
MEET2030 Approach

3.
THE ESSENCE OF THE MEET2030 APPROACH

MEET2030 studied how an economy can lower its carbon emissions while simultaneously increasing GDP. It analysed the relationships between capital, labour, exergy, CO_2 emissions and GDP growth at both macroeconomic and intermediate levels, to better understand the potential behaviour of these variables in five different sectors: energy, industry, services, transport and agriculture.

By doing this exercise, Meet2030 provides information to companies about:
- Potential future scenarios for 2030;
- The challenges and opportunities in these scenarios;
- The technologies that are most likely to contribute to a low carbon economy;
- Potential public policy guidelines that are needed in order to achieve the low carbon challenges.

ECONOMIC ACTIVITY AND GREENHOUSE GAS EMISSIONS

To obtain relevant information that is useful for companies, it is essential to start from a macro perspective. Therefore, to understand how an economy can increase GDP while lowering CO_2 emissions, an essential starting point is to know that an economy's contribution to greenhouse gas emissions is made up of three basic components:

1. **Emissions of CO_2 from the burning of fossil fuels** (oil, coal and natural gas);[3]

2. **Flows of CO_2 related to natural cycles that can be either emissions or sinks.** Emissions can come from the burning of biomass, or the loss of

The transition from fossil to renewable fuels in the energy system, although one of the most common approaches to climate change mitigation, takes time.

So MEET2030 will focus specifically on how energy efficiency can be improved (thereby reducing primary energy intensity) while increasing GDP, and therefore achieve the objectives of climate change mitigation within the desired timeframe.

MEET2030 thus helps to identify technologies and public policies that can contribute to a sustainable 4th Industrial Revolution through:

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

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3. In 2014, these accounted for 70% of total emissions in Portugal.

organic material from the soil. Sinks can come from photosynthesis which will be retained as forest biomass or as organic material in the soil. All the forecasts in *The Paris Agreement* assume that GHG emissions will need to be compensated through carbon sinks, in particular through biological processes;

3. **Emissions of other greenhouse gase**s such as methane, which come mostly from waste management practices, ruminants and manure management, or nitrous oxide, which comes mostly from the application of nitrogen fertilizers in agriculture.[4]

Focusing on emissions of CO_2 from fossil fuels, these can fall if there is:

1. A change in the quantity of carbon dioxide emitted by the energy system, for example by **moving towards renewable energies**, since energy can be provided to the economy with fewer carbon emissions;

2. An **improvement in energy efficiency**, in the broadest sense understood as the energy intensity of GDP, also called exergy;

3. A reduction in **GDP** itself.

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4. In 2014, these accounted for 30% of total emissions in Portugal.

4.

The Economic Model Used

4.
THE ECONOMIC MODEL USED

> *If high-quality energy or exergy flows are neither properly measured nor adequately tracked, then business and policy leaders may be misreading the real dynamics of economic activity. That, in turn, may lead to policy prescriptions that are suboptimal…*
> *(2013, American Council for an Energy-Efficient Economy)*

Economic theory argues that economic activity, as measured by GDP, is generated by two main production factors:

1) labour (measured for example by the number of hours worked by people) and,
2) capital (understood as the services provided by factories, machines, roads, infrastructure and vehicles, and other assets).

Nonetheless, capital and labour cannot explain the growth in GDP on their own, a fact originally discovered by Nobel-prize winning economist Robert Solow in the 1950s, in relation to the USA. So a large part of the cause of GDP growth remained unknown.

In an attempt to solve this puzzle, economists looked at other potential factors of production that could contribute towards explaining GDP growth:

3) the level of education of the labour force,
4) the use of energy, a factor that was first proposed fifteen years ago by Robert Ayres and Benjamin Warr.

On examining the contribution of these factors to Portuguese GDP growth, it can be seen that it is only possible to explain GDP growth when energy use is included in the analysis.

Portuguese real exergy efficiency: of the total energy consumed to support economic activity in 2014, only 22% was converted into useful work.

This means that 78% of all the energy used in the Portuguese economy was wasted during that year in producing goods and services.

This waste means a range of costs that weakens the nation's economic and social well-being.

ESTIMATED CONTRIBUTION TO GDP FROM THE COMBINATION OF
CAPITAL AND SCHOOLING-CORRECTED LABOUR (1960-2010)
Source: AMECO; Feenstra et al. (2015); Santos et al. (2016)
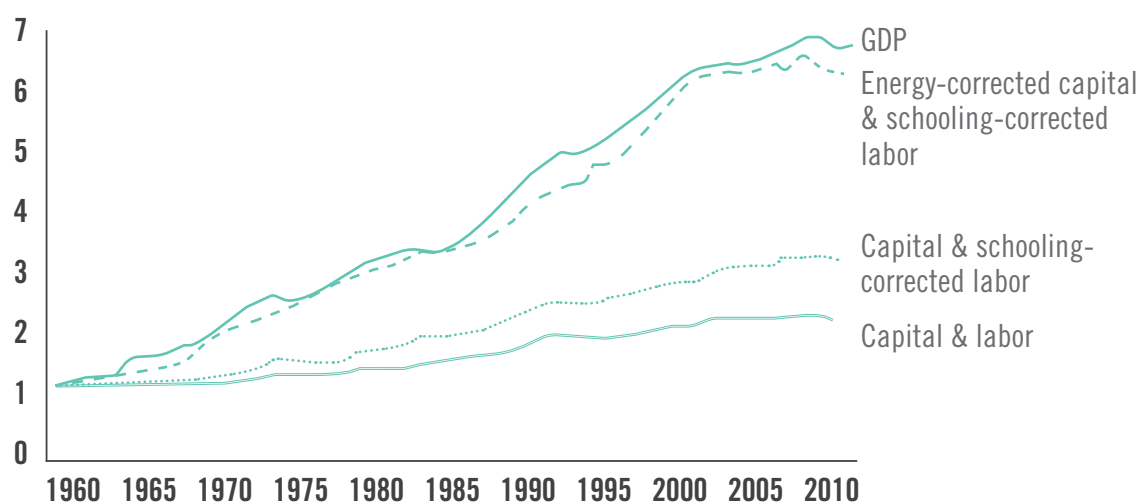
MEET2030 used a macroeconomic model in which energy use is also included as one of the production factors, which helps to explain much of GDP growth. In other words, the conceptual economic model in Meet2030 is based on the belief that the ability that capital has of providing energy to do **useful things and to make society more productive** explains the entire growth of GDP, since it increases the productivity of the economy. The ability of energy to do work is called exergy, which will be explained in the next section.

If the ability of energy to do work increases national productivity and GDP, then MEET2030 wanted to understand the fundamental role that capital plays in transforming

energy, i.e., machines. Machines play this key 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. 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. However, it is important to bear in mind that simply having machines succeed in controlling more energy is not enough on its own to provide economic growth. New business models, management innovations, logistic systems, etc., are also required.

5.

Exergy and not Energy

5.
EXERGY AND
NOT ENERGY

We are used to hearing about Energy Efficiency but not about Exergy Efficiency.

Primary energy is any form of energy that we extract from nature (e.g., coal, oil, wind and solar energy). These forms of energy need to be transformed before being sold to consumers (firms or households). **Final energy** is the energy that consumers buy (resulting from transforming primary energy), e.g., diesel or electricity. We then transform this energy into **useful energy**, the form of energy that we use as consumers, e.g., mechanical work (movement), heat, light.

Exergy is a measure of energy's quality. It is the part of energy that we can transform to produce work. Different forms of energy have different abilities to do this work, so they will have different levels of exergy.

Within exergy, we can also define primary, final and useful exergy. In Portugal, over the past 150 years, the ratio of useful exergy to GDP was essentially constant (Serrenho *et al.*, 2016).

Exergy efficiency in this project refers to the conversion of final exergy to useful exergy, i.e., the conversion of the energy that we buy to the energy that we use to produce economic value. It is this efficiency measure that demonstrates a strong correlation with GDP growth. Improving exergy efficiency leads to GDP growth.

It is the exergy efficiency or the energy productivity that is relevant in enabling us to understand how energy drives the work done by an economy. So, it is exergy efficiency that allows improvements in productivity in the economy, and, as such, decisions on public policies and investments should be taken based on exergy, and not just on energy efficiency.

According to Science Europe (2015), exergy analysis is the true measure of energy efficiency, which could potentially lead to agreement on a common system of measurement for energy use and efficiency, which does not as yet exist.

Energy = Exergy + Anergy

Exergy is defined as the ideal potential of energy to do work. Anergy is the complementary part of the energy that cannot be converted into work.

Therefore, it is possible to have two systems that have the same internal energy, but which have vastly different exergy, because they have very different abilities to do work, and, therefore have different anergies.

An example of the concept of exergy for electricity and heat follows:

1 *Joule* Electricity   1 *Joule* Heat
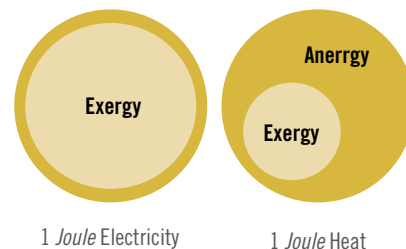
Considering a light bulb, the electricity that enters the bulb has a higher exergy than the light and heat that come out.

Light bulbs consume energy – Wrong!

Light bulbs consume exergy – Correct!

According to Laitner (2013), "to properly understand what drives economic activity we need to understand the differences between energy, exergy, and anergy". If these concepts are not used in a clear manner, then businesses and policymakers may be misled about truly smart solutions to economic development, which are based on the improved and more productive use of exergy, and not energy.

The exergy concept provides companies with a new business opportunity: what are the technologies, processes and business models that can decrease exergy losses? Every process has a characteristic exergy destruction footprint. Knowledge of this footprint can be used to rationalize resource choices before production begins and to monitor the use of energy and resources during production.[5]

Exergy can only be destroyed and cannot be created

Technologies can reduce the exergy footprint

There is no production without an exergy destruction footprint. A systematic effort to reduce exergy destruction to a minimum is the ideal to strive for when developing more environmental-friendly technologies.

When exergy analysis is performed on a process, the exergy losses can be identified and the exergy-destruction footprint can be minimized.

Exergy can be used to compare technologies that rely on different sources of primary energy (non-renewable or renewable), and whether they usefully capture the released energy. For example, the heating service provided from hot water heated by fossil fuels in a boiler has an exergy efficiency of 6%. Most of the energy is wasted. The same heating service could be provided by electricity from a combined-cycle power plant, supplemented by a heat pump, with twice the exergy efficiency.

In Geneva, Switzerland, new city development projects must include the exergy efficiency of the project, enabling the city government to select building projects that truly maximize energy efficiency in the whole energy system.

Source: Favrat *et al*. (2008).

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. 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. Final exergy can be divided into categories, also called energy vectors, essentially the same categories as for primary exergy, with the exception of electricity (here, all sources, both renewable and non-renewable) 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 airplanes), light, other electrical uses (OE) (computers and all information technology hardware), heat, and muscle work (the latter was important 50 years ago but, compared to mechanical drive, has become less relevant in recent decades and has not been considered in the scenarios used here).

CATEGORIES OF PRIMARY EXERGY (LEFT), FINAL EXERGY (CENTRE), AND USEFUL EXERGY (RIGHT)
Source: Project team with André Serrenho
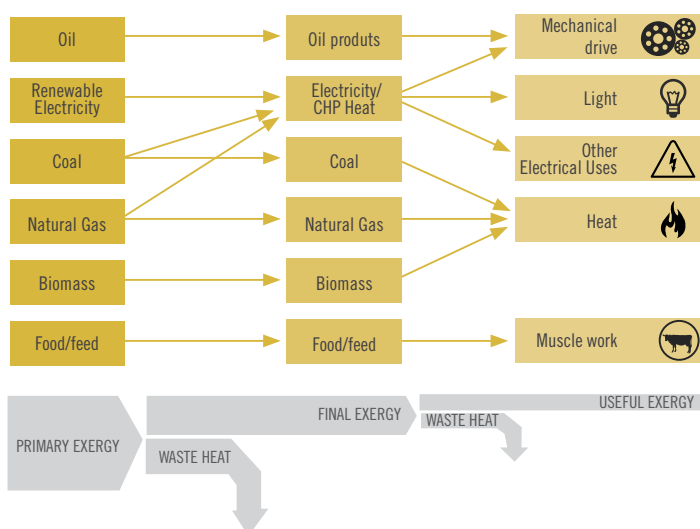
Five Heat categories
- HTH: High Temperature Heat. *final-to-useful efficiency: 46%*
- MTH: Medium Temperature Heat. *final-to-useful efficiency: 26%*
- LTH1: Low Temperature Heat 1. *final-to-useful efficiency: 19%*
- LTH2: Low Temperature Heat 2. *final-to-useful efficiency: 14%*
- LTH3: Low Temperature Heat 3. *final-to-useful efficiency:9%*

Eight types of Mechanical Drive Uses, which are divided by type of fuel/energy carrier used, since engine efficiency varies in accordance with these.
- MW1: Aviation. *final-to-useful efficiency: 27-31%*
- MW2: Gasoline Engines. *final-to-useful efficiency: 10%*

- MW3: Diesel Engines. *final-to-useful efficiency: 12%*
- Navigation: *final-to-useful efficiency: 39%*
- NG for Natural Gas vehicles' motors. *final-to-useful efficiency: 8%*
- Electrics & Hybrid (electric and hybrid vehicles and subways). *final-to-useful efficiency: 25%*
- Electric Stationary Mechanical Uses. *final-to-useful efficiency: 85-88%*
- Other Stationary Mechanical Uses. *final-to-useful efficiency: 38-40%*

Other electrical uses. *final-to-useful efficiency: 11-7%*
Light. *final-to-useful efficiency: 14-16%*

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5. Source: Favrat *et al*. (2008).

In 2014, the energy flow from final to useful exergy for Portugal, shows that 78% of the input was lost, which means that only 22% of final exergy was converted into useful exergy.

EXERGY CHAIN IN 2014 (PJ)

PRIMARY EXERGY

- Solar (0.8)
- Coal (0.2)
- Oil (335.9)
- Natural Gas (74.8)
- Combustible Renewables (101.6)
- Natural Gas (208.6)
- Coal (101.6)
- Biomass (378.2)
- Renewables (114.8)
- Other Non-renewables (386.7)
- Oil (29.7)
- Electricity and co-generation Heat production

FINAL EXERGY

- Oil (335.9)
- Natural Gas (74.8)
- Combustible Renewables (101.6)
- Electricity (174.8)
- Exergy Destruction (1028.5)
- Co-generation Heat (16.3)
- Solar (0.8)
- Coal (0.2)

USEFUL EXERGY

- Exergy Destruction (548.2)
- Oil (51)
- Electricity (68)
- Combustible Renewables (15.2)
- Natural Gas (17.9)
- Co-generation Heat (4)
- Solar (0.07)
- Coal (0.06)

Legend:
- Oil (PJ)
- Natural Gas (PJ)
- Combustible Renewables (PJ)
- Electricity (PJ)
- Coal (PJ)
- Biomass (PJ)
- Renewables (PJ)
- Other Non-renewables (PJ)
- Co-generation Heat (PJ)
- Solar (PJ)
- Exergy Destruction (PJ)

WHAT IS THE 4TH INDUSTRIAL REVOLUTION @MEET2030?

The 1st industrial revolution (IR) was associated with the steam engine; the 2nd IR was based on electricity and the internal combustion engine; and the 3rd IR was based on computing, personal computers, the microprocessor, and the internet.

The 4th IR can be seen as the moment when information technologies connect to the physical world. It begins with the so-called "internet of things", where all physical equipment – such as fridges, smartphones, cars, etc. – have built-in sensors and processors that can communicate with each other. In other words, information technologies, which are ideal for collecting information from the physical world, can manage and process huge quantities of information – called big data – and, using this information, build and use algorithms, machine learning and artificial intelligence, to generate actions that can be executed in the real world. These actions could be carried out by robots in industry, forestry, agriculture, or other forms of automation, in all the systems with which we work and interact. The changes brought about by the 4th Industrial Revolution offer the possibility of being able to increase GDP while at the same time lowering CO_2 emissions, by increasing exergy efficiency. This exergy efficiency will be driven by a combination of several kinds of technologies, where digitalisation is seen as a tool to increase energy efficiency, increase carbon sequestration through more efficient practices in forestry and agriculture, as well as to reduce methane and nitrogen oxide emissions.

6.

Imagining Possible Futures

6.
IMAGINING POSSIBLE FUTURES

To identify policies and actions that should be implemented for the Portuguese economy to grow and be low carbon between 2030 and 2050, possible scenarios that the Portuguese economy might face in 2030 had to be imagined. Only by having such a vision, could a possible path and, therefore, potential policies and actions be identified. An integral part of the rationale associated with the creation of these possible futures – usually called scenarios – is the use of an **exergy efficiency approach in order to define an economic model that can lead to a carbon neutral economy** (and not the mainstream economic model that we are used to working with every day, i.e., a model that considers only labour and capital).

These scenarios aimed at answering the following question: In a low carbon economy, how can Portugal's economy grow through to 2030, while also creating jobs? The time horizon is 2030, but "with an eye on" the 2030-2050 period, so changes that might occur beyond 2030 were also considered.

The scenarios were worked on and developed by using a participatory approach. This process involved around 50 people and 30 companies, representing approximately 20% of Portuguese GDP. To develop them, there were four workshops working individually and together. The companies involved cover a broad range of sectors, such as Airports, Food and Agriculture, Water, Food and Beverage, Automotive, Banking and Insurance, Construction, Energy, Forest, Waste Management, Industry and Retail, Infrastructure, Chemical, Services, Telecommunications and Transport.

The outcomes from their work were discussed with the Portuguese Environment Agency (APA), the Secretary of State for Industry and the Portuguese Agency for Energy (ADENE), so that the final scenarios could be perceived as being plausible for a large range of stakeholders. Therefore, the narratives presented for each

Scenarios Framework

The context in which we thought about the Future of the Portuguese Economy included:

> • the fourth industrial revolution and the relationship between exergy efficiency and economic growth;

> • the national and European commitment to achieving a low carbon economy.

The key background question on which the process was based: "In a low carbon economy, how can Portugal's economy grow through to 2030, while also creating jobs?"

scenario are a collective creation based on input from the participants (through the workshops and other intermediary sessions) over a 10-month period, as well as desk research, and feedback from stakeholder consultation.

6.1
TWO SCENARIOS: *THE OSTRICH* AND *THE IBERIAN LYNX*

The two scenarios — *The Ostrich* Scenario and *The Iberian Lynx* Scenario — were developed based on two plausible configurations for each of the 25 uncertainties identified and discussed during the workshops.

From these contrasting scenarios for the Portuguese economy in 2030, we identified technologies and business models that can put businesses and the Portuguese economy on the path of the more positive scenario. We also identified a set of public policy guidelines that we believe are needed to encourage the development of such technologies and business models.

The scenarios were developed using an economic model that includes exergy efficiency as a variable that contributes to GDP growth (together with labour and capital).

As mentioned, the scenarios were developed based on two plausible configurations from each of the 25 uncertainties identified and discussed during the workshops (see Box: The Extreme World Method).

THE 25 UNCERTAINTIES

1. Market preparedness for industry synergies	2. Sectoral & Cross-sectoral cooperation in climate protection	3. Stability of international geopolitical and demographic situation	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 talent	10. European electric grid integration
11. Strength of EU regulation and incentives encouraging renewable energy production	12. Capacity to develop a digitalisation policy sustained by a strong commitment from industry	13. Effectiveness of more ambitious regulation on energy efficiency in buildings	14. Adaptability of the educational system to industries of the future and market needs	15. Policy on climate change (ambition)
16. Allowing/ promoting geological CCS, CCU and use of CO_2	17. Alignment between Government 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. Impact of automation and digitalisation on different kinds of employment	22. Availability of technologies to tackle climate mitigation and adaptation	23. Electrical vehicle (EV&H2) deployment rates	24. Electric grid ability to integrate electrical vehicles	25. Pace of adoption of energy efficiency technologies and measures and microgeneration

The Extreme-World Method

Due to the diverse backgrounds of the participants and the wide range of the variables identified during the process, which led to 25 structural variables being included in the scenarios, an adaptation of the *Extreme-World Method* for implementing the scenario approach was used. We focused our research and workshop work on the identification of uncertainties with a high impact on the focal issue and a high level of uncertainty, as well as two contrasting but plausible configurations for each uncertainty.
"Extreme-World Method (Goodwin and Wright 2004) constructs scenarios that result from interactions of extreme events. It builds scenarios based on selected elements and trends that are based on an organization's key issues of concern. These scenarios go beyond the normal optimistic and pessimistic by allowing planners to more fully explore the effects of extreme event interactions when there is a high degree of uncertainty about future events. When the consequences of failure in the planning processes are significant, it may be essential to evaluate more extreme scenarios even when the probabilities of specific extreme occurrences are small (Daellenbach and McNickle 2005)."

Source: Shar et al. (2009).

These 25 uncertainties formed the backbone of the scenarios. A conceptual model was developed linking the uncertainties identified in the workshops with GDP, exergy efficiency and GHG emissions. For this, the uncertainties identified by participants were clustered into thematic groups. In each scenario created, the economic model chosen generated different possibilities in relation to GDP growth, exergy, capital, labour and CO_2 emissions.
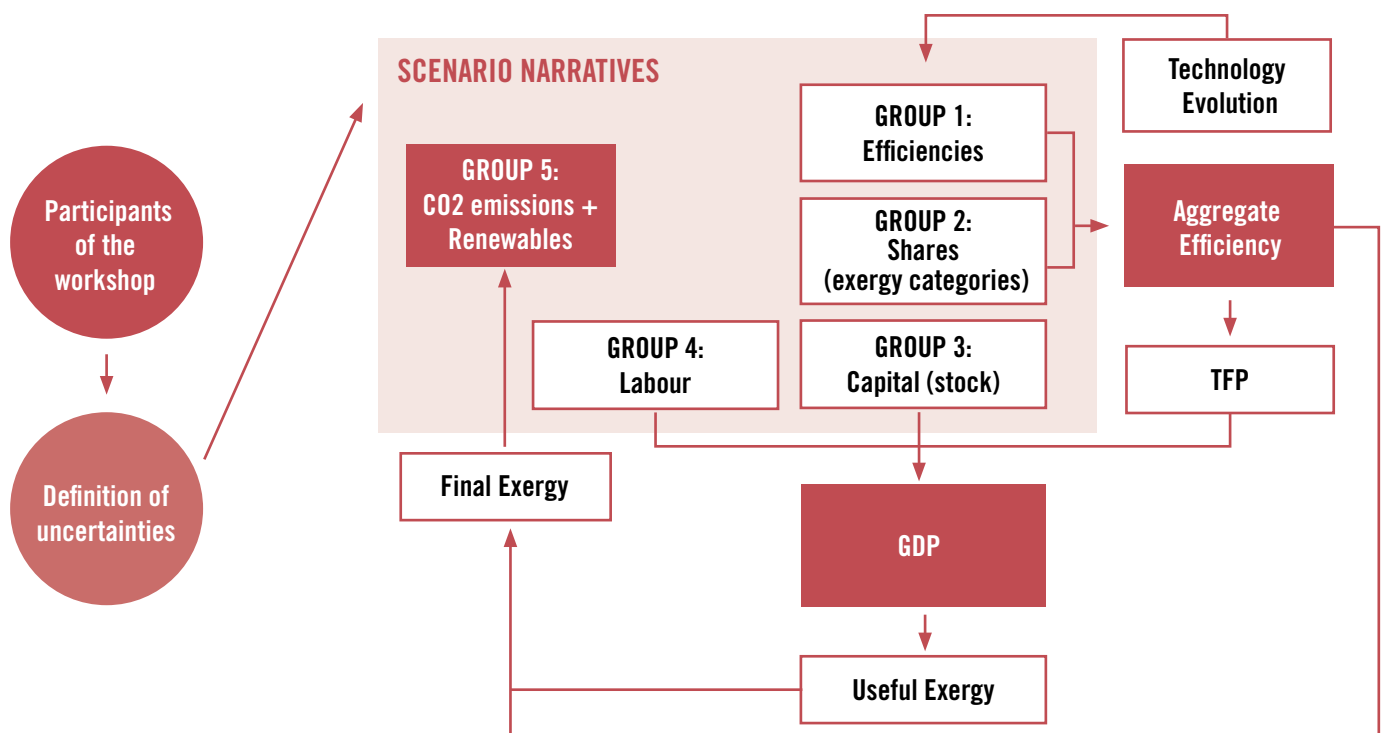
6.2
SCENARIO NARRATIVES

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

THE OSTRICH

Over the last decade and against a difficult external background, Portugal was unable to transform its economy and benefit from 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, and sometimes actions and measures taken were not well coordinated. This process even led a foreign finance minister to compare Portugal to an Ostrich, running around in circles like those fairground carousels.

The Portuguese economy became even more peripheral, unable to attract talent and investment.

THE IBERIAN LYNX

Over the last decade, Portugal became a thriving, dynamic economy. Like the Four Asian Tigers back in the 1960s through to the 1990s, this economic prominence of Portugal lead an economics journalist from a globally known newspaper to give Portugal the nickname of "The Iberian Lynx" in an article published on the 25th of January 2028.

This nickname is still appropriate even today, and has become a reference for a country that took advantage of the opportunities presented by the 4th Industrial Revolution and the global sustainability movement, in an exemplary manner. That was mainly possible because of Portugal's ability to implement a strongly cooperative relationship among the various economic agents in Portugal and other countries. This was achieved by a country that used to be considered as peripheral but that was ultimately able to find its role on the international stage. Nonetheless, the strong rates of economic growth led to major challenges in terms of GHG emissions.

6.2.1
Scenario Narratives

The name "The Ostrich" was chosen because of the public perception of ostriches, namely the myth that ostriches bury their heads in the sand. It is a metaphor for a situation in which Portugal lagged behind in a world transformed by new developments in technology, the environment and energy. The metaphor also takes into account the fact that ostriches do not run away in a straight line but rather in circles, especially when they are frightened. The Ostrich represents a scenario of stagnation. Under it, Portugal manages to comply with the existing, less demanding requirements of the National Low-Carbon Roadmap, but with a fall in GDP.

The background to *the Ostrich* scenario involves a more unstable, geopolitical situation, a rapidly ageing population, where social systems have only a limited ability to adapt, amid tensions in society about migration flows, and an increasing level of distrust worldwide. In relation to the European Union, the scenario sees a greater likelihood of more countries "exiting" the union. Regulations and policies are weak and ineffective, with a low level of cooperation between business, government and civil society.

There is a great instability and Portugal is becoming ever more peripheral in nature, becoming less attractive for investment. The banking system is unable to adequately support economic development, resulting in a fall in the country's stock of capital of an average of 0.8% per year, reaching the same level as 2003 in 2030. Gross fixed capital formation (GFCF), also known as the investment in capital (which can be measured as a percentage of the previous year's GDP) has fluctuated, in the past, between 15% and 27%, with an average of approximately 21%. Under this scenario, GFCF is at the lowest historically observed value for the last 50 years, i.e. 15% of the previous year's GDP.

Portugal has a weak digitalization strategy and resources are thinly spread with no effective cooperation between agents. There is an inability to align technological development and investments in science, technology and innovation

with the great societal challenges that the country faces. Portugal is thus unable to attract and retain talent. At the same time, automation and the fact that there are fewer individuals working or actively searching for jobs contributes to unemployment levels continuing at 2014 levels of 11.1% and to greater social unrest. This scenario also includes an educational system that is unable to adapt to industry's new requirements for different competences and skills, and no new effective policies on retirement, health, justice and education. The number of hours worked per individual remains at the same level as in 2016, i.e. between 35 hours and 40 hours per week on average.

In terms of energy, *The Ostrich* scenario is conservative. There are low levels of cooperation and low social capital as far as cooperation between and behaviour of the different players involved. The different parties in the marketplace do not work together to close the loop to create a circular economy (industry synergies). Regulations and policies are weak and ineffective, with low cooperation between agents (National and European wide). Few results are achieved in designing and implementing more ambitious regulations for energy efficiency in buildings.

In terms of aggregate exergy efficiencies, from 2000 to 2014, Portugal's aggregate final-to-useful exergy efficiency was relatively constant. In this scenario, this trend continues through to 2030, where aggregate efficiency increases less than 1.3% from 2014 to 2030 and about 2.4% from 2000 to 2030, reaching a peak of 23.5%. This slight increase occurs because of the assumptions made at the more disaggregated level of several energy end-uses (explained in detail in the technical report).

The efficiency shown is a final-to-useful efficiency, in other words, it is the relationship between the energy available for use with the energy that is in fact used. The change achieved in this efficiency is mainly due to electrification, with the increasing use of electrical appliances. This change in energy share and the fact that electricity usage has a higher efficiency than that of any other energy carrier, results in the increase shown in aggregate energy efficiency.

There is also a lightening or weakening of EU regulations and incentives for encouraging renewable energy production. Frequent changes in governments, programmes and priorities lead to changing and unstable priorities and approaches towards climate change. Geological CCS, CCU and use of CO_2 are neither allowed nor encouraged.
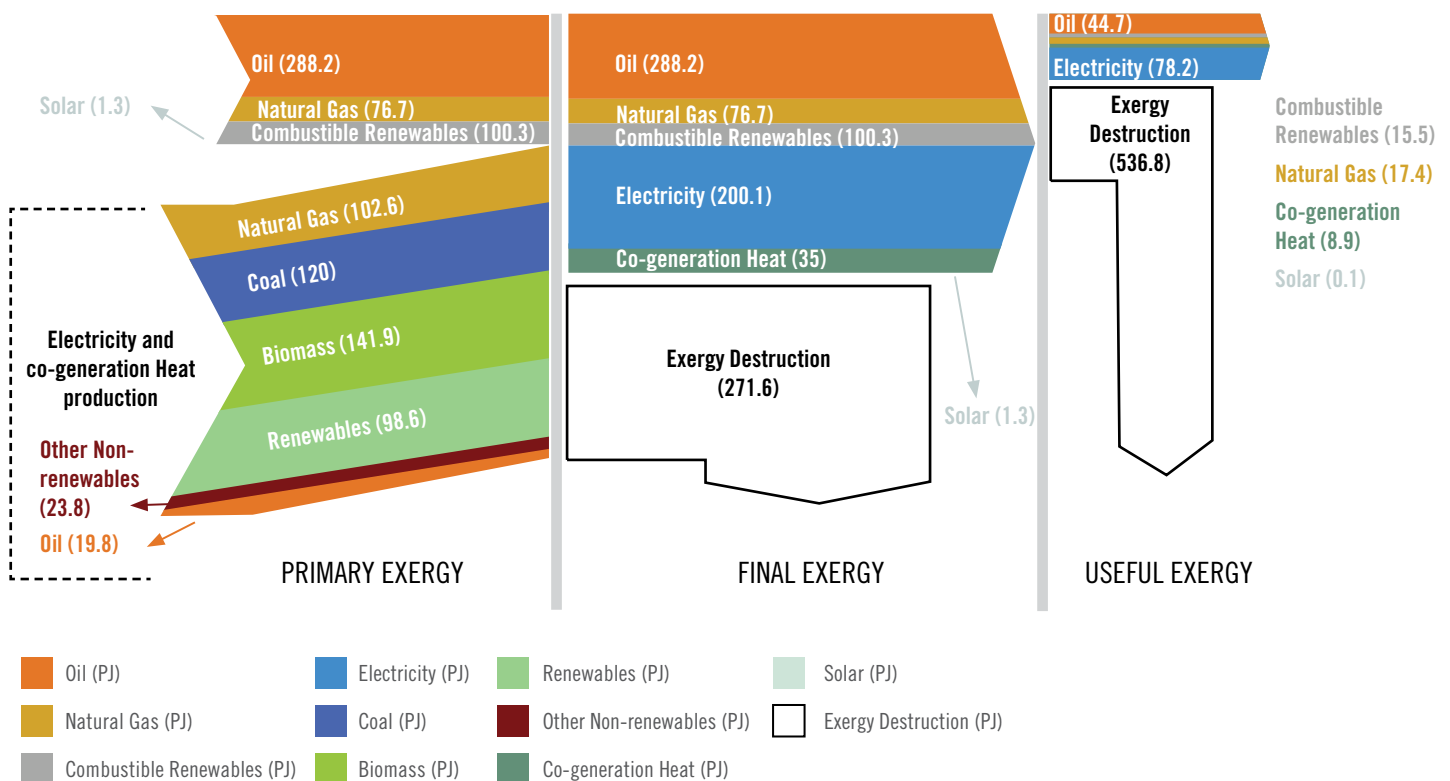
In particular:

- There are no effective measures taken to address carbon leakage;

- Portugal is unable to continue developing and implementing proactive policies to tackle climate change – a reactionary approach is the rule;

- There is limited CO_2 licensing;

- The scope of the current EU-ETS is maintained;

- The carbon trading price is not high enough, which increases the risk of market distortions and does not provide an environment conducive to innovation and employment;

- There are no fiscal policies to reward zero CO_2 businesses.

Under the Ostrich scenario, the energy flow in 2030 from final exergy to useful exergy in Portugal shows that 77% of input was lost, meaning that only 23% of final exergy was converted into useful exergy.

OSTRICH SCENARIO: EXERGY CHAIN (PJ)

PRIMARY EXERGY

- Solar (1.3)
- Oil (288.2)
- Natural Gas (76.7)
- Combustible Renewables (100.3)
- Natural Gas (102.6)
- Coal (120)
- Biomass (141.9)
- Renewables (98.6)
- Electricity and co-generation Heat production
- Other Non-renewables (23.8)
- Oil (19.8)

FINAL EXERGY

- Oil (288.2)
- Natural Gas (76.7)
- Combustible Renewables (100.3)
- Electricity (200.1)
- Co-generation Heat (35)
- Exergy Destruction (271.6)
- Solar (1.3)

USEFUL EXERGY

- Oil (44.7)
- Electricity (78.2)
- Exergy Destruction (536.8)
- Combustible Renewables (15.5)
- Natural Gas (17.4)
- Co-generation Heat (8.9)
- Solar (0.1)

Legend:
- Oil (PJ)
- Natural Gas (PJ)
- Combustible Renewables (PJ)
- Electricity (PJ)
- Coal (PJ)
- Biomass (PJ)
- Renewables (PJ)
- Other Non-renewables (PJ)
- Co-generation Heat (PJ)
- Solar (PJ)
- Exergy Destruction (PJ)

6.2.2
The Iberian Lynx Scenario

The name *The Iberian Lynx* was chosen as a symbol of the potential that cooperation can have at several levels. In fact, the recovery in the wild of the Iberian *Lynx* was the result of a program that followed a multidisciplinary approach between national, regional and international organizations. The success in the recovery of this species was therefore the result of the ability of different interested parties to cooperate together. In *The Iberian Lynx* scenario, we see signs of recovery based on strong cooperation between economic agents within the country and between Portugal and other countries.

The Iberian Lynx scenario considers a more stable international geopolitical context, with strong political cooperation, an ability to manage an ageing population and migration, leading to an increase in overall trust. In this scenario, the EU becomes more cohesive.

It is a scenario of **high stability, growth and competitiveness**, with significant EU economic growth, financial stabilization of the Portuguese economy and higher levels of investment of 2% per annum. The banking system recovers and helps support economic development. The result is an **increase of** 1% to 3% **in Portugal's stock of capital each year.** Gross fixed capital formation (GFCF), also known as the investment in capital, grows at a constant annual rate of 2%, the same average annual growth rate as in the 1960s, reaching 21% in 2030.

There is an effective digitalization policy, with both a vision and goals, supported by a strong political commitment and close cooperation between agents, while coordination between Government policies and the needs of companies exist, in order to address new societal challenges. This leads to an ability to attract and retain talent. The scenario also sees the educational system adapt successfully to the new requirements of industry and effective policies implemented in the areas of retirement, health, justice and education. The result is a fall in unemployment rates to 5%-7% in 2030. The number of hours worked per engaged individual is also reduced on about 5-10%.

The Iberian Lynx is a scenario with fast-economic growth and a rapid increase in aggregate final-to-useful exergy efficiency. There is cooperation, stability and trust between the different players in the market, who work together to close the loop to create 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, and are developed in a cooperative environment. Effective and more ambitious regulations promoting energy efficiency in buildings are implemented. Energy efficiency is a clear priority, and energy efficiency measures and technologies, including microgeneration, are quickly adopted.

Oil and Electricity uses are the energy carriers where the main changes occur, compared to the present day. 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 by electricity uses. This happens in different uses, including vehicles (adoption of the electrical vehicle).
In terms of aggregate efficiencies, by 2030 the aggregate final-to-useful exergy efficiency grows by approximately 5%, equal to 27.3% in 2030. The trend in efficiency is explained at the end-use level and, in this scenario, is mainly based on the substitution of energy carriers and on a more accentuated (than in *The Ostrich*) shift in electrification towards electric appliances. Since gasoline, diesel and heat have high useful and final exergy shares but low efficiencies (bringing aggregate efficiency to lower levels), while electricity has high shares and efficiency, replacing mechanical drive Oil uses with Electric uses (e.g., vehicles) leads to increases in aggregate efficiency. Aggregate final-to-useful efficiency is higher, although continuing the same historic trends of end-use efficiencies. This is mainly due to the change in the shares of electric uses, given that, in *The Iberian Lynx*, stationary mechanical drive uses have a share of approximately 50% of the Electricity consumed.

Thus, although appliances' individual efficiencies might increase through time, shifting the consumption of energy towards new appliances, which are often not as efficient, and taking into consideration changes in consumption patterns, a fall in aggregate efficiency could occur in some cases. This

indicates that consumer habits and behaviour influence aggregate efficiency.

Under this scenario, strong sectoral and cross-sectoral cooperation is evident, including for tackling climate change. Across Europe, electricity markets/grids are integrated. There are strong and effective regulations and incentives for renewable energy production, leading to important changes in businesses. Policies dealing with GHG emissions and related issues are consistent and stable. Geological CCS, CCU and use of CO_2 are allowed and encouraged. In terms of the ambition of climate change policies and regulations, this scenario assumes that:
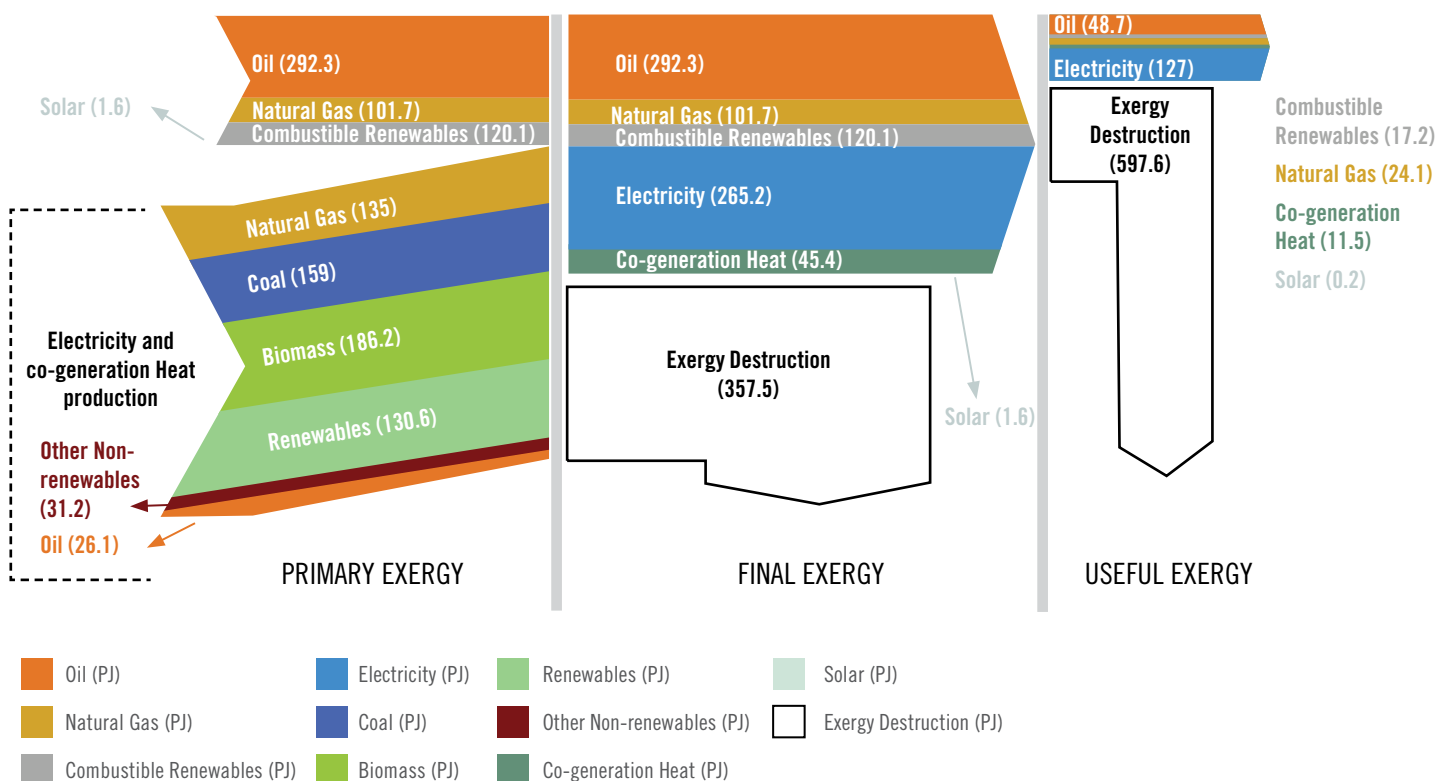
- Effective measures to address carbon leakage are taken globally across all sectors;

- Portugal is able to develop and implement proactive policies on climate change;

- There is a robust carbon price, encouraging a healthy investment environment for innovation, employment and a shift towards a low carbon economy;

- The scope of the EU-ETS is broadened across economic sectors, leading to a greater effort by businesses to reduce their GHG emissions;

- Existing fiscal policies to encourage zero CO_2 businesses are strengthened, providing incentives to use more sustainable technologies and raw materials.

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

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.

IBERIAN LYNX SCENARIO: EXERGY CHAIN (PJ)

PRIMARY EXERGY

Solar (1.6)
Oil (292.3)
Natural Gas (101.7)
Combustible Renewables (120.1)
Natural Gas (135)
Coal (159)
Biomass (186.2)
Renewables (130.6)
Electricity and co-generation Heat production
Other Non-renewables (31.2)
Oil (26.1)

FINAL EXERGY

Oil (292.3)
Natural Gas (101.7)
Combustible Renewables (120.1)
Electricity (265.2)
Co-generation Heat (45.4)
Exergy Destruction (357.5)
Solar (1.6)

USEFUL EXERGY

Oil (48.7)
Electricity (127)
Exergy Destruction (597.6)
Combustible Renewables (17.2)
Natural Gas (24.1)
Co-generation Heat (11.5)
Solar (0.2)

Oil (PJ)
Natural Gas (PJ)
Combustible Renewables (PJ)
Electricity (PJ)
Coal (PJ)
Biomass (PJ)
Renewables (PJ)
Other Non-renewables (PJ)
Co-generation Heat (PJ)
Solar (PJ)
Exergy Destruction (PJ)

6.3
COMPARING SELECTED VARIABLES

Taking into consideration the 25 uncertainties, it was possible to obtain quantified variables for the 2 scenarios. These variables are the following:
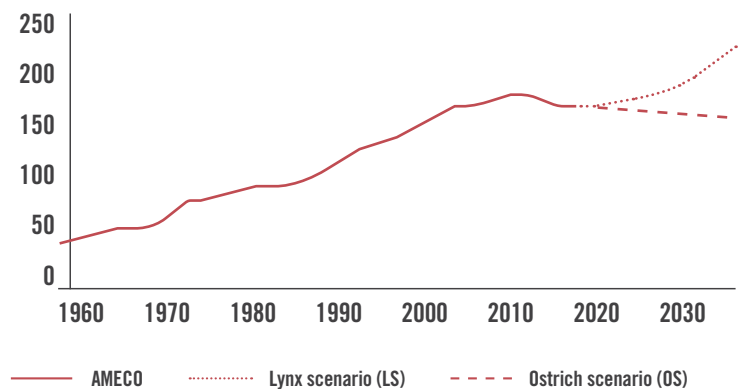
- *GDP* as a function of: *Capital Investment; Labour; Useful Exergy*

- CO_2 emissions resulting from GDP growth, aggregate exergy efficiency and options chosen on renewables
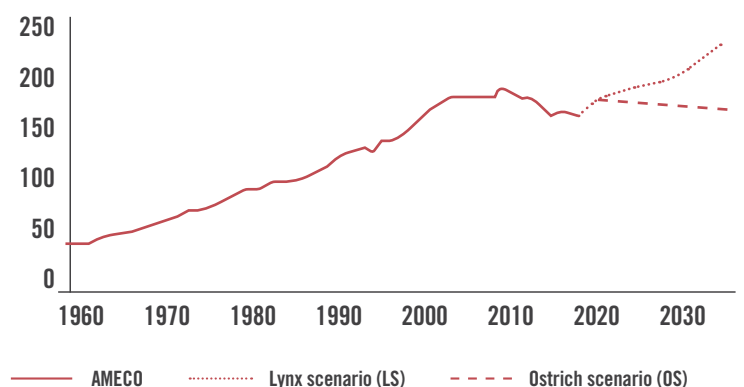
6.3.1
GDP

In *The Ostrich*, projected GDP continues to follow the falling trend experienced in prior years, with the result that GDP in 2030 is at the same level as just before Portugal entered the Eurozone.

In *The Iberian Lynx*, projected GDP grows significantly, reaching 228 thousand million € by 2030 (in 2016, Portuguese GDP was 185 thousand million €). Rapid economic growth leads to a higher total useful exergy consumption (233 PJ in 2030) than in the Ostrich (161 PJ in 2030), i.e., economic growth offsets increasing exergy efficiency.

GDP (THOUSANDS OF MILLION €)

—— AMECO ········· Lynx scenario (LS) – – – Ostrich scenario (OS)

USEFUL EXERGY (PJ)

—— AMECO ········· Lynx scenario (LS) – – – Ostrich scenario (OS)

6.3.2
Capital Investment

Under *The Ostrich* scenario, there is great instability in Portugal and in Europe generally, and Portugal becomes progressively more peripheral, and less attractive for investment, which leads to gross fixed capital formation (GFCF), also known as investment in capital, reaching the lowest historically observed level for the last 50 years, i.e. 15% of the previous year's GDP.

Under *The Iberian Lynx* scenario, there is high stability, growth and competitiveness, which means that gross fixed capital formation (GFCF) grows at a constant annual rate of 2%, the same average annual growth rate achieved in the 1960s, reaching 21% in 2030.

This means that under the Iberian Lynx scenario the economy was able to:

• Increase the stock of tangible fixed assets (such as machines, factories, land, buildings, transport equipment, animals, etc.);

• Increase intangible fixed assets (such as aerial topography; computer software and large databases, etc.); and

• See significant improvements in tangible assets related to land and forests.[6]

Many of these increases and improvements will be in technologies and infrastructure with higher levels of efficiency, because of the existence of an effective digitalization policy, integrated electricity markets/grids across Europe, and strong and effective regulations and incentives for renewable energy production.

INVESTMENT IN CAPITAL ASSETS (AS PERCENTAGE OF PREVIOUS YEAR GDP)

| | AMECO | Lynx scenario (LS) | Ostrich scenario (OS) |
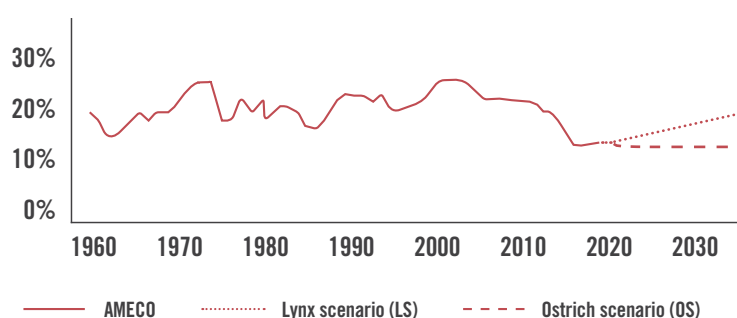
MAIN VARIABLES AND CONFIGURATIONS FOR CAPITAL INVESTMENT IN BOTH SCENARIOS

	THE OSTRICH	THE IBERIAN LYNX
EU economic growth capacity	Stagnation/retraction	Growth
Capacity of the banking system to support economic development	Banking system is not able to adequately support economic development	Banking system recovers and supports economic development
Financial stability of the Portuguese economy	Recurrent instability of the Portuguese economy	Financial stabilisation of the Portuguese economy
Investment capacity in the Portuguese economy (c)	Constant: 15% of the previous year's GDP(c)	Increases 2% annually, reaching 21% of previous year's GDP in 2030
Stock of capital (a) (b)	Decrease 0.8%per annum, falling to 2003 levels in 2030	Increases from 0,5% to 3.5% per annum until 2030

Notes to the table: Variable (a) was defined by the research team in order to link the uncertainties to the GDP trend. All configurations were defined and discussed with workshop participants. The exception was for (b), values for which are dependent on the configurations made for the remaining variables. These were discussed with participants. (c) It is assumed that investment in climate mitigation technologies is included within this value.

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6. Source: based on the Instituto Nacional de Estatística definition.
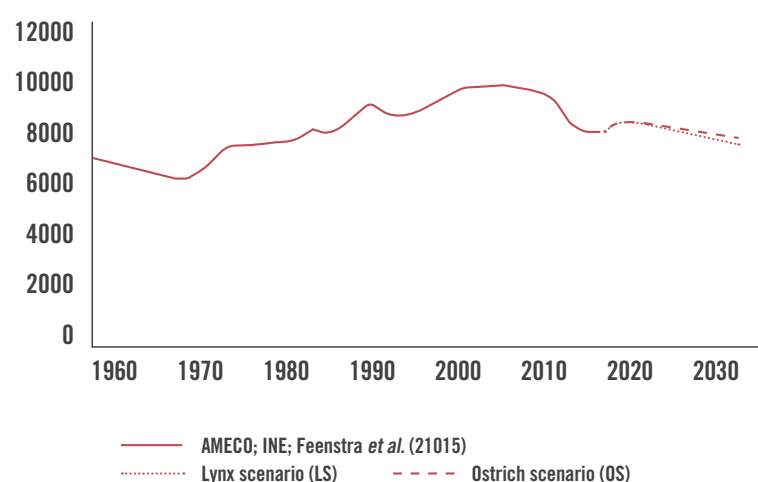
6.3.3
Labour

Under the *Ostrich scenario*, the unemployment rate projected for the period 2017-2030 remains constant at 11.1%. The total human labour inputs to production falls to 7625 million hours by 2030[7], explained by both the unemployment rate of 11.1% and the decrease in the number of individuals working or actively searching for a job.

Under the Iberian *Lynx scenario*, the unemployment rate projected for the period 2017-2030 declines at a constant annual rate of 6%, to reach 5%-7% of the total labour force by 2030. The total human labour inputs to production also fall to 7515 million hours by 2030 (this fall was agreed with participants at the last workshop).

Despite the different unemployment rates, the total human labour inputs to production are very similar under the two scenarios.

HUMAN LABOUR INPUTS TO ECONOMIC PRODUCTION (MILLIONS OF HOURS WORKED, BY ALL ENGAGED INDIVIDUALS IN THE ECONOMY)

— AMECO; INE; Feenstra *et al.* (21015)
.... Lynx scenario (LS)   – – – Ostrich scenario (OS)

MAIN VARIABLES AND CONFIGURATIONS FOR LABOUR IN BOTH SCENARIOS

	THE OSTRICH	THE IBERIAN LYNX
Alignment between Government policies and business needs, to address new societal challenges [a]	No alignment between Government's policies and business needs, to address new societal challenges, namely attracting and retaining talent	Alignment between Government policies and business needs to address new societal challenges, namely attracting and retaining talent
Effectiveness of national policies on retirement, health, justice, education [a]	No new effective policies	Effective policies in place
Adaptability of the educational system to future industry and market needs [b]	Educational system is unable to adapt to new industry requirements	Educational system adapts to new industry requirements
Impact of automation and digitalisation on unemployment rates [b]	Unemployment rate stays constant at 2014 levels	Unemployment rates fall
Impacts of automation and digitalisation on the type of employment [b]	Automation contributes to maintaining the current level of unemployment and to greater social unrest	Automation leads to smarter, higher paid jobs that sustain the Social State

7. In 2016, the total human labour inputs to production were approximately 8061 million hours.

	THE OSTRICH	THE IBERIAN LYNX
Unemployment rates [c]	Constant at 11% of the total labour force	Falls to reach a 5%-7% unemployment rate by 2030
Portugal's ability to attract and retain talent [a]	Portugal is unable to compete in establishing a talent pool	Portugal is able to compete and establish a talent pool
Number of engaged individuals in the economy [d]	Decreases to 4 million individuals by 2030	Decreases at an annual average of 0.3%, to reach approx. 4,4 million individuals in 2030.
Annual average number of hours worked per engaged individual [c]	Remains the same as today, between 35 and 40 hours/week	Falls at a rate of minus 0.6% per year, to reach between 32 and 37h/week
Human labour inputs to economic production [d]	Falls to 7625 million hours by 2030	Falls 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) and selected by the research team.
(c) Defined by the research team in order to link the uncertainties to the GDP trend.
All configurations were defined and discussed with workshop participants. The exception was for (d), values for which were dependent on the configurations made for the remaining variables. These values were discussed with the participants during the MEET 2030 process.

6.3.4
Useful Exergy

To calculate the useful exergy by end-use category, a range of variables and configurations, which can influence exergy use, were considered. Not all of them will have a direct quantitative impact but they provide a framework for the quantitative assumptions used in the scenarios. For the assumptions, data from the IEA (2016) was used while the energy carriers considered were: Coal, Oil, Combustible Renewables (such as wood), Natural Gas, Electricity, Cogeneration of heat, and Solar photovoltaic.

	THE OSTRICH	THE IBERIAN LYNX
Market preparedness for industry synergies [a]	Market players do not work together to close the loop towards the circular economy	Market players work together to close the loop towards the circular economy
Capacity to develop a digitalisation policy sustained by a strong commitment from industry, looking to take Portugal to a position of leadership in digitalisation and connectivity [a]	A weak national digitalisation strategy continues, and resources are thinly spread with no effective cooperation between economic agents	Existence and effectiveness of such a digitalisation policy. There is a vision and goal backed by a strong political will, and close cooperation exists between agents

MAIN VARIABLES AND CONFIGURATIONS FOR EXERGY USE
IN BOTH SCENARIOS (*Cont.*)

	THE OSTRICH	THE IBERIAN LYNX
Useful exergy shares (exergy by end use category) [c]	The trend observed between 2000 and 2014 continues for all uses, except for some heat and mechanical drive uses from Oil products (i.e., HTH, MTH, LTH3, MW2, MW3 and navigation). For these, this scenario maintains the averages achieved in recent years (between 2009 and 2014)	- MW2 share falls by approx. 1.5% (to around 2% of total useful exergy) - Diesel uses decrease drastically to almost half of their share from 15.4% (2014) to 9% (2030); - Heat requirements from electric appliances fall by around 1.6% to reach 3.1% of total useful exergy; - Electricity MD uses increase to make up 50% of Electricity's useful exergy.
Electrical vehicle (EV and H_2) deployment rates [b]	Slow adoption — account for approximately 6% of vehicles in circulation by 2030	Fast adoption - approximately 20% of vehicles in circulation by 2030
Ability of electric grid to support electrical vehicles [b]	Slow and limited	Fast and comprehensive
Final-to-useful exergy efficiencies [c]	Technology specific final-to-useful efficiencies are constant [although, aggregate exergy efficiency increases marginally].	Diesel-electric vehicle efficiency increases by up to 30% (around 5% more than 2014); Natural Gas vehicle efficiency increases by up to 9.4% (around 1,4% more than 2014); Light efficiency increases by approx. 5 p.p.
Effectiveness of more ambitious regulations on energy efficiency in buildings [a]	Limited results from more ambitious regulations for energy efficiency in buildings; LTH3 decreases by about 1% in final exergy over the period 2014-2030 (approx. 0.6% in useful exergy)	- More ambitious regulations encouraging energy efficiency in buildings are effective - LTH3 exergy consumption decreases by around 1,4p.p. over the 2014-2030 period
Pace of adoption of energy efficiency technologies and measurements, and microgeneration [a]	Limited adoption of energy efficiency technologies and measurements	Energy efficiency is a clear priority. Fast adoption of energy efficiency measurements and technologies

Acronyms: HTH – High temperature heat; MTH – Medium temperature heat; LTH3 – Low temperature heat 3; MW2 – Gasoline/ LPG engines; MW3 – Diesel engines.

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) and selected by the research team.

(c) Defined by the research team in order to link the uncertainties to the GDP trend.

All configurations were defined and discussed with the workshops' participants. Exception was for (d), values for which were dependent on the configuration of the remaining variables. These values were discussed with the participants during the MEET 2030 process.
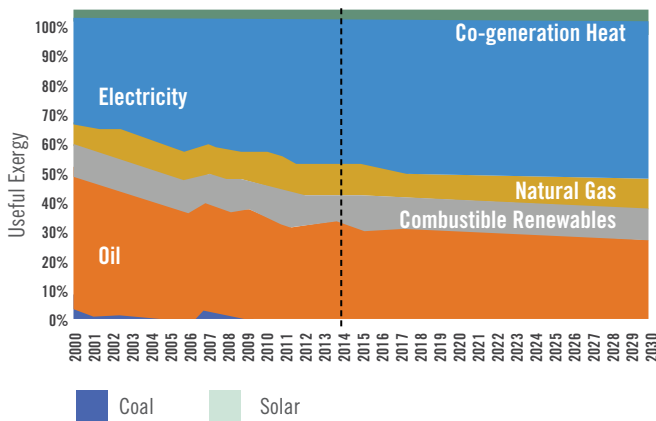
6.3.4.1
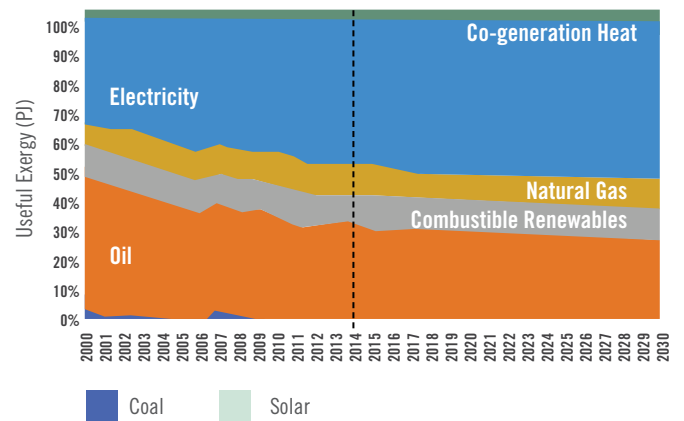## Projections to 2030 for Portugal: Useful Exergy Shares
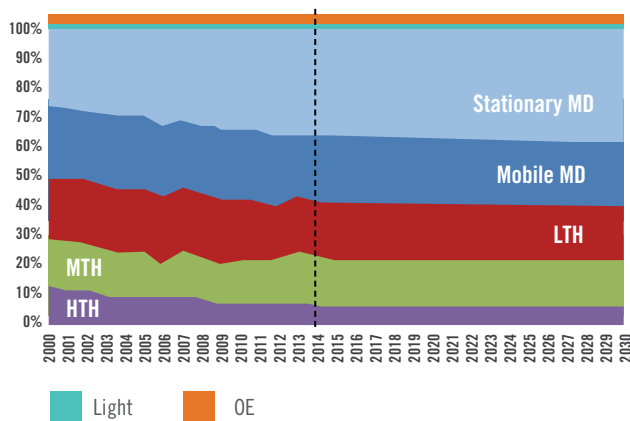
OSTRICH SCENARIO (OS)

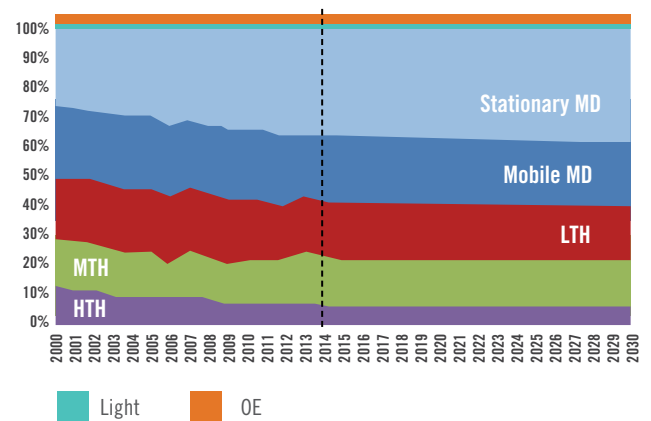LYNX SCENARIO (LS)

Useful exergy shares per energy carrier

Useful exergy shares per energy carrier

Useful exergy shares per end-use

Useful exergy shares per end-use

The **useful exergy shares per energy carrier** are the shares of useful energy of each energy carrier used in the economy

Under *the Ostrich* scenario, the trends for useful exergy shares during the period 2000 to 2014 will continue through to 2030, with the exception of Oil-heat (HTH, MTH, LTH3), mechanical work (Gasoline, Diesel, Navigation) and electricity and co-generation heat. For oil heat and mechanical work, useful exergy shares move at a rate equal to that recorded in recent years, i.e. falls of around 6%. For electricity and co-generation heat, the estimates were calculated separately from other energy carriers. The methodology used was: different end-use shares were applied to the industry & energy sectors than those used for Residential/commercial services & agriculture/fishing, i.e. different shares were applied to electricity consumed in the industry and residential/commercial sectors. This resulted in increases of 3% in the electricity share, despite, under the Ostrich scenario, there being a slow adoption of electrical vehicles and a slow and limited ability of the electric grid network to support electric vehicles.

In terms of useful exergy share per end-use, i.e. the energy needed for use by the technologies involved, there is a high proportion of Mobile Mechanical Drive (with efficiencies ranging from 10% to 70%) and Low Temperature Heat (with efficiencies between 9% and 20%).

Under the Iberian *Lynx Scenario*, Oil and Electricity uses are the energy carriers[8] where major changes occur. **An electrification of the economy takes place, leading to a partial substitution of oil uses by electricity uses.** This occurs across end uses, including vehicles (adoption of the electrical vehicle). In this respect, the trends for Oil and Electricity uses increase faster than in The Ostrich Scenario. In addition, energy efficiency is a clear priority. There is a rapid adoption of energy efficiency measures and technologies.

In terms of useful exergy share per end-use, i.e. used by the technologies, under The Iberian Lynx scenario, exergy shares follow past trends, with the exception of electrification processes, which accelerate. Stationary MD absorbs up to 50% of Electricity consumption (a growth rate of 4.5%/year in the total useful exergy for stationary MD) for mostly electric motors.

Note that biofuels were not given significant consideration in MEET 2030 projections, in particular as produced in a biorefinery approach. They should be considered in further analyses.

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8. This report uses the typology for energy carriers as defined by the IEA (IEA 2016): coal, oil, combustible renewables (such as wood), natural gas, electricity, cogeneration heat and solar photovoltaic.

THE IBERIAN LYNX SCENARIO
SOME OF THE AVAILABLE TECHNOLOGIES THAT CAN BE USED BY EACH SECTOR
Proposed by participating companies

Most significant final energy carriers consumed by sector in 2030
(energy carriers with the highest (>3%) consumption (final) per sector)

SECTORS	FINAL ENERGY CARRIER	END USE	CURRENT FINAL-TO-USEFUL EFFICIENCIES	EXAMPLES OF TECHNOLOGIES
Industry	Electricity	Mechanical Drive (stationary)	85%	Use of energy robots to manage airplanes and portable machine to perform all services on the aircraft side of the airport Advance grinding technology; separate grinding 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 available high pressure off-gas
Transportation	Oil	Mechanical Drive (MW2 & MW3)	10% 13%	LPG/Gasoline vehicles; Diesel vehicles
	Combustible Renewables	Mechanical Drive (MW3) stationary	38%	Acidification/diversification of raw materials of residual origin for production of 2G biodiesel Production and supply of bio-methane as CNG
Residential/ Commercial	Electricity	Heat (LTH2) & OE	15% 9%	Heat pump
	Combustible Renewables	Heat (LTH3)	9%	Use of alternative fuels replacing conventional fossil fuels, such as biogas and biofuels
	Oil	Heat (LTH3)	9%	Current technologies
Agriculture/ Fishing	Electricity	Mechanical Drive (stationary)	85%	Use of robots, drones for monitoring and management Automation/robotisation of the sorting processes; Intelligent Housing Systems for animal production
	Oil	Mechanical Drive (MW3)	13%	Diesel vehicles

Main messages

Under *The Ostrich* scenario, in which there are low levels of cooperation, a weak environmental policy with limited results concerning more ambitious regulations for energy, slow adoption of electrical vehicles and little adoption of energy efficiency technologies:

- Portugal has a larger useful exergy share of LTH and Mobile MD than in the Lynx scenario. LTH and Mobile MD have efficiencies ranging from 9% to 20% (heat) and 10% to 40% (mobile MD) (much lower than Stationary MD with efficiencies of 85% and mobile MD with electric vehicles with efficiencies of 70%, which both increase in the Lynx scenario). As a result, the final aggregate exergy efficiency of the Portuguese economy remains close to 2014 levels (22.2%), reaching 23,5% in 2030;

Under *The Lynx* scenario, in which there exists cooperation among agents, an effective ability to develop a digitalisation policy, and where priority is given to energy efficiency, leading to a rapid adoption of electrical vehicles and an increase in final-to-useful exergy efficiencies:

- Portugal has a greater useful exergy of Stationary MD (with efficiencies of 85%), than in the Ostrich scenario. In the Lynx scenario, electrification of the economy takes place, leading to a partial substitution of oil uses by electricity uses, including vehicles. As a result, the final aggregate exergy efficiency of the Portuguese economy increases by 5%, reaching 27.3% in 2030;

- In general terms for this scenario, it is important to highlight the 7% increase in final exergy consumption of electric motors, including the electric vehicle (in MD uses). This change is linked to the rapid implementation of advances in technology in the ongoing process of automation in manufacturing and other sectors (e.g. delivery and mailing services, domestic robots, etc.).

6.3.5
CO_2 emissions

Under *The Ostrich Scenario*, fossil fuel GHG emissions by 2030 total 46.2 Mt $CO_{2\,eq}$, thus complying with the less stringent scenario of the National Low-Carbon Roadmap (APA, 2012) (about 48 Mt CO_2e for fossil fuel emissions). However, under this scenario, Portuguese GDP falls to levels close to those recorded before the country entered the Eurozone.

Under the *Lynx Scenario*, fossil fuel GHG emissions by 2030 are approximately 55.0 Mt CO_2e. Under this scenario, GDP increases very significantly due to increasing energy efficiency, leading to an increase in CO_2 emissions, which are, by 2030, in excess of those of the less stringent scenario of the National Low-Carbon Roadmap (APA, 2012).

PORTUGAL'S GHG TOTAL EMISSIONS FOR BOTH SCENARIOS IN 2000-2030 (kt $CO_{2\,eq}$)
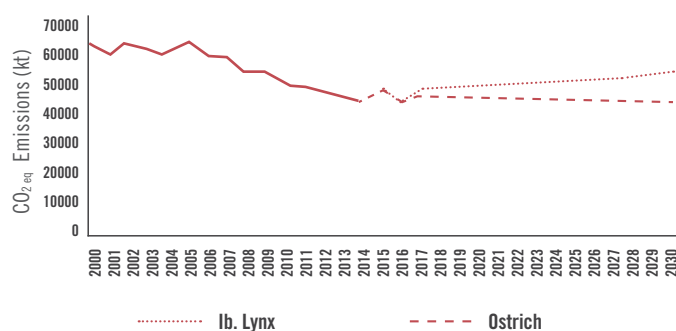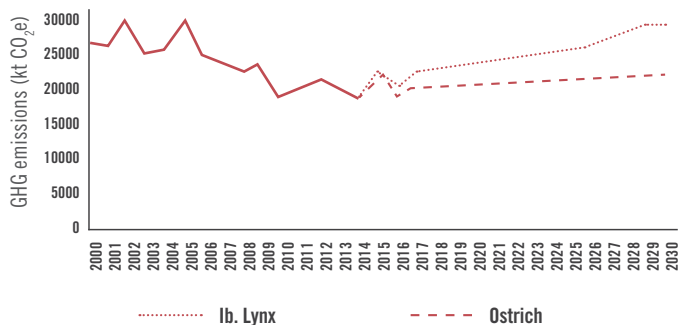

In both scenarios, it is assumed that the mix of resources consumed to produce Electricity is the same: 60% from renewable resources (Biomass, Hydro, Wind, Geothermal and Solar) and 40% from non-renewable (Thermo-electricity production, excluding the use of Biomass).

MAIN VARIABLES FOR GHG EMISSIONS IN BOTH SCENARIOS

	THE OSTRICH	THE IBERIAN LYNX
Electricity mix [c]	60% of renewable resources	60% of renewable resources
Allowing/ encouraging geological CCS, CCU and use of CO_2 [a]	Geological CCS, CCU and use of CO_2 not allowed	Geological CCS, CCU and use of CO_2 allowed and encouraged
Availability of technologies for climate change mitigation and adaptation [b]	Not available, immature or costly	Available and affordable
European electric grid integration [a]	Inability of electricity markets across Europe to integrate	Integration of electricity markets across Europe
Sectoral and cross-sectoral cooperation to protect climate [a]	Weak sectoral and cross-sectoral cooperation, including for climate change	Strong 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 unable to continue to develop and implement proactive policies on climate change - reaction is the 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 - Maintains the scope of the current EU-ETS; - No fiscal policies exist to encourage zero CO_2 businesses	- 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 adaptation policies, as well as mitigation policies; - There is a robust carbon price, promoting a healthy investment environment to encourage innovation, employment and a shift towards a low carbon economy; - Scope of EU-ETS is broadened across all sectors; - Mandatory to be climate change neutral; - Fiscal policies exist to encourage zero CO_2 businesses
Strength of EU regulations and incentives encouraging renewable energy production [b]	Regulation is weak or alleviated	Strong regulation leading to significant changes in business and industry
Stability of climate change policies worldwide: actors, programs and priorities [a]	Change of Political Actors in Governments/Change of programs/priorities leading to unstable priorities and approaches to climate change	Policies move forward on GHG Emissions and related issues
Pace of adoption of energy efficiency technologies and measurements, and microgeneration [a]	Limited adoption of energy efficiency technologies and measures	Energy efficiency is a clear priority. Fast adoption of energy efficiency measures and technologies
GHG emissions from the IPCC (2006)'s Energy category [d] ... in the energy sector ... in the industry sector ... in the transport sector ... in the residential/ commercial sector ... in the agriculture and fishing sector	46.2 Mt CO_2e ... 22.3 Mt CO_2e ... 6.2 Mt CO_2e ... 13.9 Mt CO_2e ... 2.8 Mt CO_2e ... 1.1 Mt CO_2e	55.0 Mt CO_2e ... 29.3 Mt CO_2e ... 8.4 Mt CO_2e ... 12.6 Mt CO_2e ... 3.3 Mt CO_2e ... 1.4 Mt CO_2e

PORTUGAL'S GHG EMISSIONS FROM **ENERGY** (kt CO$_{2\,eq}$)

.... **Ib. Lynx**   - - - - **Ostrich**

PORTUGAL'S GHG EMISSIONS FROM **INDUSTRY** (kt CO$_{2\,eq}$)

.... **Ib. Lynx**   - - - - **Ostrich**
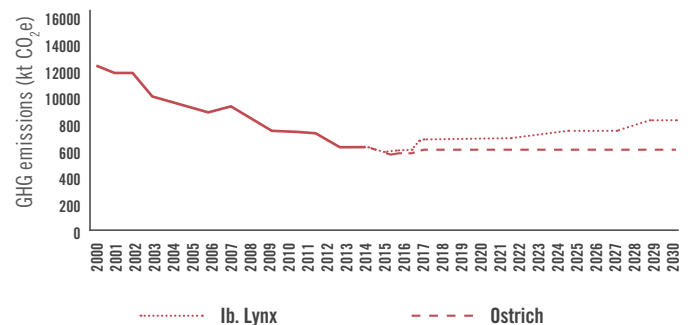
PORTUGAL'S GHG EMISSIONS FROM **TRANSPORT** (kt CO$_{2\,eq}$)

.... **Ib. Lynx**   - - - - **Ostrich**
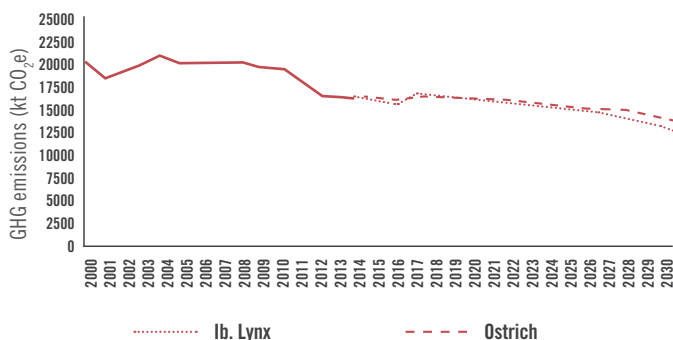
PORTUGAL'S GHG EMISSIONS FROM **RESIDENTIAL/ COMMERCIAL** (kt CO$_{2\,eq}$)

.... **Ib. Lynx**   - - - - **Ostrich**
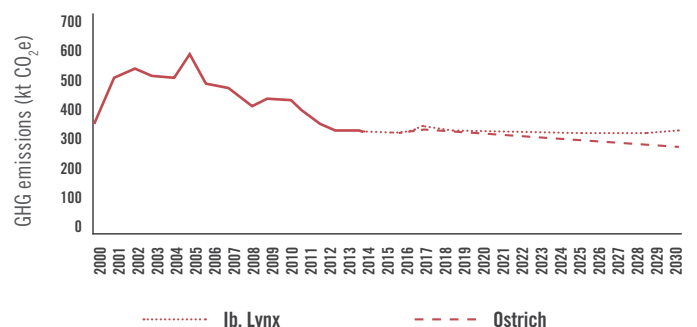
PORTUGAL'S GHG EMISSIONS FROM **AGRICULTURE/ FISHERIES** (kt CO$_{2\,eq}$)

.... **Ib. Lynx**   - - - - **Ostrich**
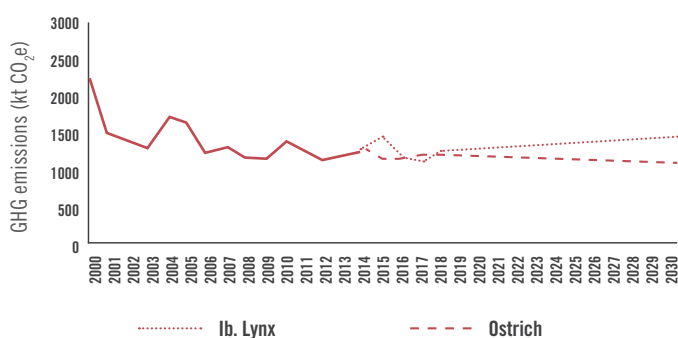
Emissions for the energy sector increase, reaching 29.3 Mt CO$_2$e by 2030. Although the share of renewable resources in the electricity mix remains constant from 2014 to 2030, the absolute production of renewable energy is higher due to the increase in electricity consumption (from electrification).

GHG emissions from the industrial sector increase to 8.4 Mt CO$_2$e by 2030 due to rapid economic growth and the resulting increase in energy consumption.

GHG emissions from the transport sector fall to 12.6 Mt CO_2e by 2030. For transport, GHG emissions under the Iberian Lynx are lower than under the Ostrich scenario, mainly due to the uptake of electric vehicles, which, under the Iberian Lynx, will account for 20% of vehicles in circulation by 2030, compared to 6% under the Ostrich.

GHG emissions from the residential sector increase slightly to 3.3 Mt CO_2e by 2030.

GHG emissions from agriculture increase, to a total of 1.4 Mt CO_2e by 2030.

6.4
THE LYNX+ SCENARIO COMPATIBLE WITH A LOW CARBON ECONOMY

From the model results, it can be seen that the assumptions made for a low carbon energy mix in *The Iberian Lynx* scenario are not enough to offset the impact that the high productivity of energy has on GDP. Under The Iberian Lynx scenario, the aggregate exergy efficiency of the Portuguese economy reaches 27.3% in 2030, but the level of CO_2 emissions is not compatible with the low carbon commitments in the national low carbon roadmap for Portugal (APA 2012). This means that the existing optimistic expectations for the future under this scenario are not enough to enable the economy to be on a low carbon path towards 2050 they are projected to lead to GDP growth and job creation, but not a carbon neutral economy.

Therefore, in order to answer the key starting question of Meet2030 - "In a low carbon economy, how can Portugal's economy grow and create employment?" - new uses for the wealth created by high GDP growth in the Lynx scenario need to be considered, using the additional resources to increase the level of decarbonisation through:

 a. Increased penetration of renewable energies; and

 b. Implementation of ecosystem-based carbon sequestration projects that provide multiple ecosystem services.

At the last workshop, participants agreed that by 2030 total human labour inputs to production would be approximately 7,515 million hours compared to today's 8,061 million hours. Therefore, there was broad agreement that the number of hours worked per person would not further decrease significantly, and that therefore the fall in CO_2 emissions could only be achieved by increasing renewable energy penetration and through carbon sequestration.

The consensus reached about the assumptions needed to reach a Lynx+ scenario that would be able to comply with the National Low-Carbon Roadmap (APA, 2012) were the following:

A) Electricity Mix
- Increase renewable based electricity to 75%, in the electricity mix; and
- Lower coal based electricity to 0%.

This leads to the following electricity mix:

	IBERIAN LYNX	"LYNX+"
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	**100.0%**	**100.0%**

B) 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% (in the Iberian Lynx) to 75% renewable electricity (as defined in the 4th Workshop), comes from wind turbines (one third) and solar panels (two thirds).

This leads to the following renewable electricity source breakdown:

	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.

Energy source	Electricity mix in Iberian Lynx and the Ostrich	Absolute values		
		2014	2030	2030
			Ostrich	Iberian Lynx
Renewable sources	60%	32 903 GWh	28 784 GWh	38 010 GWh
Wind	44.20%	14 543 GWh	12 723 GWh	16 800 GWh
Solar	2.80%	921 GWh	806 GWh	1064 GWh
Hydro	47.30%	15 563 GWh	13 615 GWh	17 979 GWh
Biomass	4.98%	1 639 GWh	1 433 GWh	1 893 GWh
Geothermal	0.76%	250 GWh	219 GWh	289 GWh
Natural gas	12.30%	1 401 GWh	5 885 GWh	7 771 GWh
Coal	25.40%	10 258 GWh	16 138 GWh	16 083 GWh

C) Carbon sequestration
- Replacing shrubland by native forest (oak) in central and northern Portugal; and
- Replacing natural pastures by sown biodiverse pastures in the Alentejo region.

It was agreed in the 4th Workshop that the MEET2030 team would present realistic figures. The results arrived at by the research team are presented in the following table.

Carbon sequestration in the Lynx+ scenario for the period between 2017 and 2030

	2014	Maximum area available	Annual increment		CO_2 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**

The above assumptions, result in the following CO_2 emissions:

NET GHG EMISSIONS t CO_2e
GHG emissions only include the IPCC sectors of Energy and LULUC
(assuming no changes in agriculture and waste emissions)

Historical
Lynx +
Iberian Lynx
Ostrich
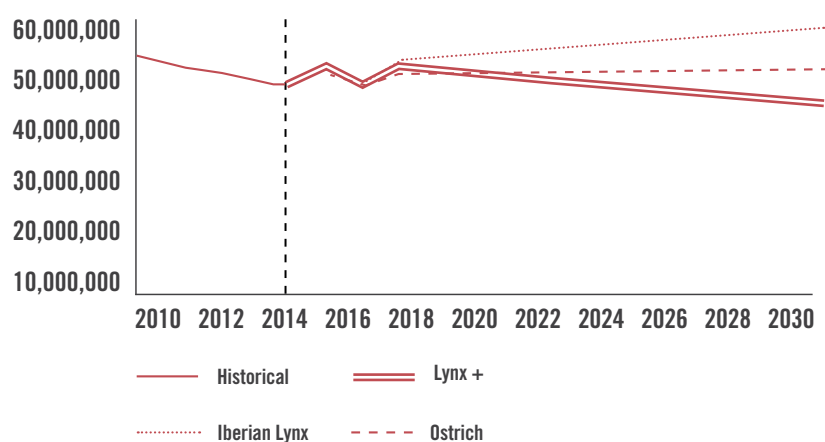
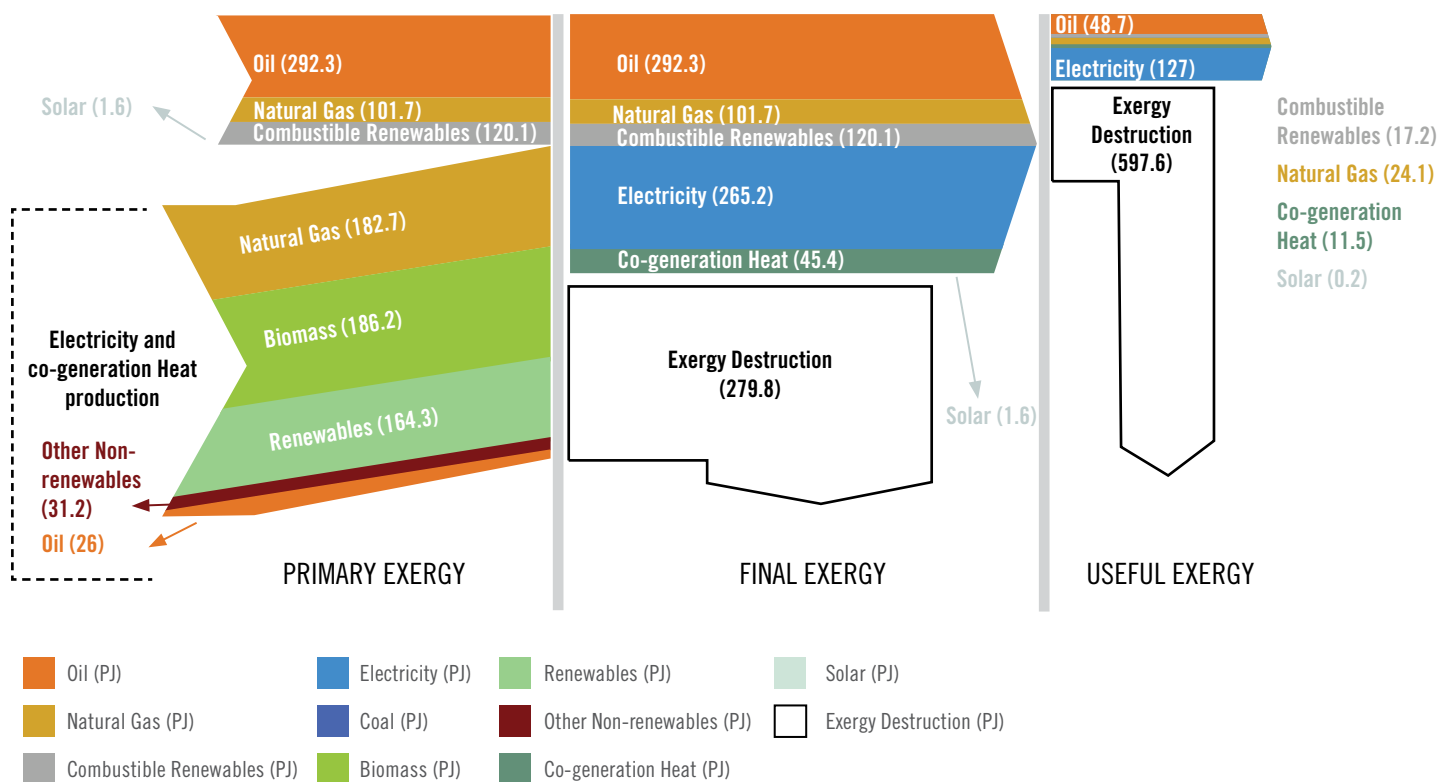Fossil fuel GHG emissions for the *Lynx+* scenario are approximately 40.7 Mt CO_2e by 2030.

These are equal to the GHG emission projections of the most stringent scenario under the National Low-Carbon Roadmap (APA, 2012), the scenario which will put Portugal on track for a low carbon development. In this new scenario, as in the Lynx, GDP grows very significantly as a result of increasing energy efficiency.

Under the Lynx+ scenario, the exergy flow from final to useful exergy for Portugal in 2030 shows that 72% of the input was lost, meaning that only 28% of final exergy was converted into useful exergy.

2+1 SCENARIO: EXERGY CHAIN (PJ)

PRIMARY EXERGY

Solar (1.6)
Oil (292.3)
Natural Gas (101.7)
Combustible Renewables (120.1)
Natural Gas (182.7)
Biomass (186.2)
Renewables (164.3)

Electricity and co-generation Heat production

Other Non-renewables (31.2)
Oil (26)

FINAL EXERGY

Oil (292.3)
Natural Gas (101.7)
Combustible Renewables (120.1)
Electricity (265.2)
Co-generation Heat (45.4)

Exergy Destruction (279.8)

Solar (1.6)

USEFUL EXERGY

Oil (48.7)
Electricity (127)

Exergy Destruction (597.6)

Combustible Renewables (17.2)
Natural Gas (24.1)
Co-generation Heat (11.5)
Solar (0.2)

Legend

- Oil (PJ)
- Natural Gas (PJ)
- Combustible Renewables (PJ)
- Electricity (PJ)
- Coal (PJ)
- Biomass (PJ)
- Renewables (PJ)
- Other Non-renewables (PJ)
- Co-generation Heat (PJ)
- Solar (PJ)
- Exergy Destruction (PJ)

The primary energy mixes considered in the Lynx scenario and the Lynx+ variant should be considered as "proof of concept", and demonstrates the viability of the projected trajectory of decarbonisation. Any other primary energy mix that allows the same objectives, with the same or improved economic and environmental performance (understood in a broad sense, considering both GHG emissions and other environmental issues) to be achieved, should be considered. Components of the primary energy mix should thus be evaluated from a life cycle perspective. In particular, biofuels, which were not considered to any significant extent in the MEET 2030 projections, should be analysed and considered, namely the building and operation of biorefineries.

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

The move from *The Iberian Lynx* scenario, with significant GDP growth but with higher CO_2 emissions, to a *Lynx+* scenario can only be achieved with a range of policies and initiatives that would have to be implemented in a cooperative spirit by several sectors, and between private and public entities. To reach a carbon low carbon economy with GDP growth, policies, technologies, finance and skills will be needed. It also needs to be understood that carbon neutrality can only be attained by maximizing synergies with other areas and policies. Some examples of key policy areas to achieve this ambition are:

- investment in natural capital: the ecosystems to be created/improved can promote biodiversity and ecosystem services, including carbon sequestration;
- circular economy:
  – carbon retained 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.

SYNERGIES BETWEEN THE EXERGY APPROACH, CLIMATE POLICIES AND OTHER AREAS

NATURAL CAPITAL

Investment in natural capital, in particular 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 soil organic matter (and thereby fertility). By doing this, it is possible to create higher quality and more extensive ecosystems, which will help to promote biodiversity and ecosystem services. So, synergies exist between policies promoting natural capital, biodiversity and ecosystem services.

CIRCULAR ECONOMY

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. Other examples are reducing the amount of heat loss (circularity within energy use) and material waste (reducing landfill emissions) through industrial symbiosis.

CLIMATE MITIGATION

There are other synergies with climate change mitigation 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).

EU COMMON AGRICULTURE

Finally, there are synergies with the most significant policy of the European Union in budget terms (38%), given that issues relating to methane, nitrogen oxide, woodland, soils etc. are connected to activities covered by the CAP (Common Agricultural Policy).

7.

Final Remarks

7.
FINAL REMARKS

Achieving carbon neutrality is a challenge. If we consider the productivity impact that energy has on the economy, and given that we need energy in our everyday life, then one would expect the development of green technology to stimulate GDP. Higher levels of GDP imply greater levels of consumption levels and greater production, which ends up in fact implying higher primary energy consumption and potentially higher CO_2 emissions. Therefore, energy efficiency through greener technologies will not be enough for carbon neutrality to be achieved.

MEET2030 has been clear in demonstrating the need to increase electrification in the energy system, and that the share of renewables will have to increase considerably. Carbon sequestration is also part of the solution and new business models in this area need to be found by the private sector. Such a paradigm change implies very close collaboration between central government, local authorities, companies, universities, and society in general. The tax and financial systems will need to adjust to these challenges and be the catalysts for low carbon technologies and business models. For this to happen, not only technological and scientific research but also work on relevant management, economic and risk evaluation models. Cooperation and the sharing of knowledge between these areas will be needed, if we want new business models that will be able to respond socially to these technological possibilities.

The future will see the creation of several disruptive business models and businesses. Some of these may be related to the following aspects:

1. **Connecting the digital and the physical world of company activities and processes**, thus allowing all important stakeholders to participate by either co-designing services, products and events, or by just accessing their asset data. Example: in electrical utilities, the data from smart meters could be shared with customers, as well as the gains from co-designed innovations.

2. **Combining products beyond traditional business and company frontiers** with other **incumbents** and new **IT firms**. Example: electric transport could be developed through auto manufacturers (providing the mobile assets), road managers (providing supply point infrastructures), electrical utilities (feeding the power to supply points) and IT companies (providing software for fleet and power management) working together.

3. **Implementing Mixed Syndicated Structures**, such as adapted platforms working with data, AI and physical products. Examples: Intelligent mobility, where the client only states the starting/ending points and the time. The rest is done by a team, made up of humans, computers and mobility assets; intelligent waste collection by using a waste data collector and drone collection in remote areas, where it is not economically viable to send a truck.

4. **Using "augmented human beings"**, such as Human/IT/Prosthetics work in industrial processes such as waste sorting or handling and transformation of poultry. These can be operated remotely.

5. **Focusing on systems resilience**. Example: building completely resource independent houses/ neighborhoods or industrial factories/offices. These could operate off-grid for some of the time, and be self-sufficient in energy (electrical or other), water and food.

Some economists argue that economic growth is a direct consequence of previous, effective investment in R&D and recommend heavy investment in innovation on the grounds that it offers the most significant route for the solution of environmental problems (Jacobs and Mazzucato, 2016). Decarbonizing the economy provides the opportunity for both Government and companies to invest in R&D. MEET2030 has explored this potential.

8.

List of Acronyms

8.
LIST OF ACRONYMS

CARBON NEUTRALITY
Carbon neutrality, or having a net zero carbon footprint, refers to achieving net zero carbon emissions by offsetting a measured amount of carbon released with an equivalent amount sequestered or offset, or buying enough carbon credits to make up the difference. It is used in the context of carbon dioxide releasing processes associated with transportation, energy production, and industrial processes, such as production of carbon neutral fuel.

CO_2
Carbon dioxide. Is a colourless, odourless and non-poisonous gas formed by combustion of carbon and in the respiration of living organisms and is considered a greenhouse gas. Emissions means the release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time (as defined by OECD).

CCS
Carbon Capture and Storage. Is a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location, and long term isolation from the atmosphere (as defined by OECD).

CCU
Carbon capture and utilization. Includes the utilization of CO_2, in addition to carbon capture and storage. CO_2, as source of carbon, has the potential to be used in the manufacture of fuels, carbonates, polymers and chemicals. Currently in the development-to-demonstration phases, CCU represents a new market for CO_2, as a raw material (as defined by the Smart Specialization Platform).

EU ETS
The EU emissions trading system is a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost effectively. It is the world's first major carbon market and remains the biggest one (as defined by European Commission/Climate Action).

GDP
Gross Domestic Product is an aggregate measure of production equal to the sum of the gross values added of all resident institutional units engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs). It is equal to the sum of the final uses of goods and services (all uses except intermediate consumption) measured in purchase prices, less the value of imports of goods and services, or the sum of primary incomes distributed by resident producer units (as defined by OECD).

GHG
Greenhouse gases. Any of various gaseous compounds (such as carbon dioxide) that absorb infrared radiation, trap heat in the atmosphere, and contribute to the greenhouse effect.

GFCF
Gross fixed capital formation. Resident producers' investments, less disposals, in fixed assets over a given period. It also includes certain additions to the value of non-produced assets made by producers or institutional units. Fixed assets are tangible or intangible assets produced as outputs from production processes that are used repeatedly, or continuously, for more than one year (as defined by Eurostat).

9.

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9.
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