2050

Heat Roadmap Europe

A low-carbon heating and cooling strategy

Baseline scenario of the total energy system up to 2050

Insights from JRC-EU-TIMES for Lead-Users

Deliverable 5.4: Energy Tools Manual for Lead-Users

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Introduction

The overall objective of the Heat Roadmap Europe 4 (HRE4) project is to provide new capacity and skills for lead-users in the heating and cooling (H&C) sector, including policy-makers, industry and researchers at local, national and EU levels, by developing the data, tools, methodologies, and results necessary to quantify the impact of implementing more energy efficient measures on both the demand and supply side of the sector.

To that end, key activities within HRE4 related to the European Commission's JRC-EU-TIMES model are to:

- project the annual evolution of the EU energy system up to 2050 under different conditions,
- transfer those modelling results into the hourly-energy model EnergyPLAN (carried out by Aalborg University in the same work package, WP5), and
- ensure that the solutions compared in these studies are technically robust – the linkage of these two energy system models is a key improvement from previous projects.

This document briefly explains the JRC-EU-TIMES model and how the results generated within HRE4, in particular the baseline scenario of the total EU energy system through 2050 (described even in more detail in D5.2), can be used by European lead-users, especially those in the fourteen EU member states[1] which comprise HRE4's primary focus.

Furthermore, it should be noted that while the overall HRE4 project focuses primarily on the H&C sector, the baseline scenario talked about in this document deals with the overall projection of the entire energy system, where of course both electricity and H&C play very key roles with important implications across the whole system. The presence of so much content in this report oriented towards the power sector is by design, though of course there are also many valuable H&C-oriented messages to be gained here as well[2]. HRE4 deems it as crucial for understanding the larger energy context, including electricity's role in it, in order to appreciate the ways that the H&C sector can, should and will contribute to decarbonisation.

[1] Though insights from JRC-EU-TIMES are applicable across Europe, HRE4 especially concentrates on those fourteen countries with the highest H&C demands: Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, the Netherlands, Poland, Romania, Spain, Sweden and the UK.

[2] Those readers interested in H&C-specific results are strongly encouraged to look into other HRE4 deliverables (such as D5.2) which deal with H&C in even more detail.

Key messages from the JRC-EU-TIMES baseline scenario

1	**Sweeping changes should be expected for the EU's future energy demand mix, with significantly less reliance on most fossil fuels and an ever-increasing integration of renewable energy sources (RES).**

- The JRC-EU-TIMES baseline envisions that by 2050, in terms of primary energy, coal consumption will be halved and oil consumption will be reduced by a third. Natural gas will likely remain an important energy carrier, with consumption levels similar to 2015 values.
- From a production standpoint, the RES share of total primary energy production will increase from 10% in 2015 to 22% by 2050. The share of variable RES (from wind, solar and ocean) will increase from 2% in 2015 to 9% by 2050. The share of non-variable RES consists mainly of biomass that will increase from 5% to 9% by 2050.
- By 2040, already 28% of electricity will be generated from variable RES (VRES), 18% produced from other RES (e.g. geothermal and hydro) and the remaining 55% will still be supplied by fossil fuel and nuclear power plants. Figure 1 shows a benchmarking of the JRC-EU-TIMES baseline scenario for HRE4 with selected energy projections from other key sources.

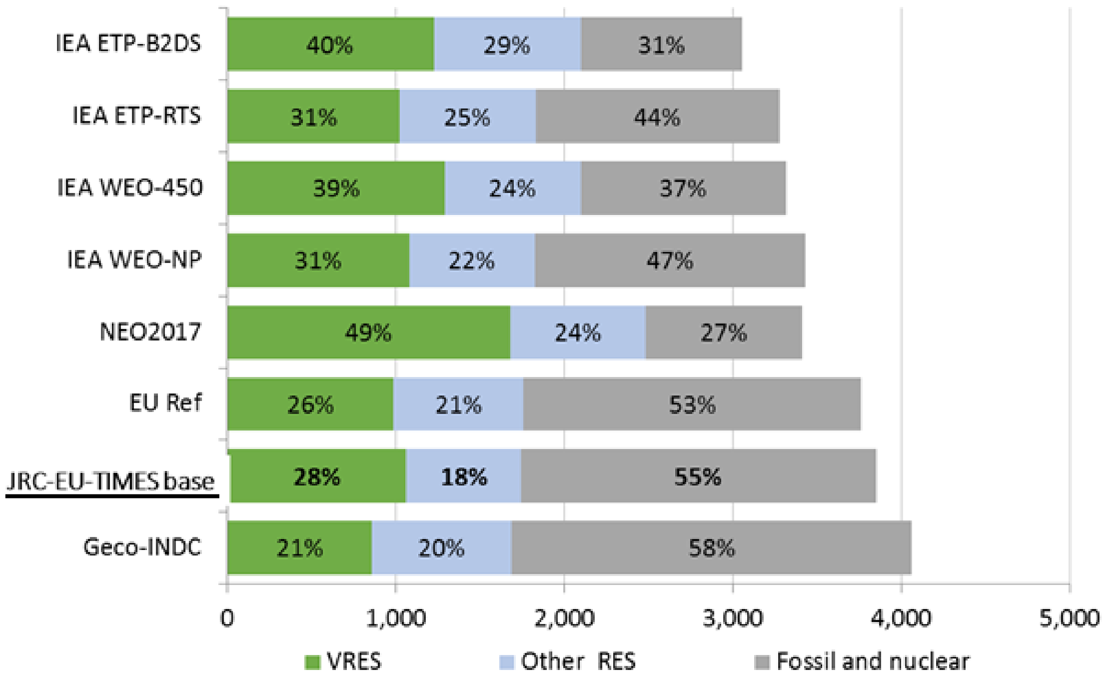


Figure 1: HRE4 baseline (power sector), variable RES balance across different key EU28 scenarios for 2040[3]

[3] Sources: 1) IEA ETP-B2DS and IEA ETP-RTS: IEA, 2017. Energy Technology Perspectives 2017. International Energy Agency, 2) IEA WEO-450 and IEA WEO-NP: IEA, 2016. World Energy Outlook 2016. International Energy Agency, 3) NEO2017: BNEF, 2017. New Energy Outlook 2017. Bloomberg New Energy

The graph compares the share of variable RES, other RES and fossil fuel and nuclear power generation. As can be seen, the HRE4 baseline VRES balance results are nearly in line with the EU Reference Scenario from the European Commission, and actually even more conservative than the IEA ETP scenario.

- The final energy consumption of residential and tertiary (i.e. commercial and public services) buildings will decrease by 30% and 15% respectively compared to 2015. The most important driving factor for these reductions will be a lower demand for heating largely due to improved energy efficiency and more investment in efficiency measures.

2	**Investment in the EU energy system should also evolve significantly by 2050 in order to take advantage of the economic benefits inherent in energy efficiency and RES. Nuclear power will continue to grow as well.**

- Between 2020 and 2050 (and even up to 2065), 450 billion EUR of investments in residential buildings will be made in improved building envelopes, e.g. insulation, efficient windows, etc. Industry and tertiary buildings already tend to be much more efficient, largely driven by national/EU efficiency targets and policies, not to mention pure financial motives of building owners wishing to minimise their costs.
- Wind and solar alone will make up almost 50% of investments made into new power generation capacities, with nuclear power plants accounting for 40%.

3	**The current popularity of electric vehicles should only continue to grow as technologies improve, costs decline and the ancillary benefits of more sustainable transport come to be more fully realised.**

- The JRC-EU-TIMES baseline scenario sees electric vehicles already becoming cost-effective before 2030, largely due to significant cost reductions from improved technologies, especially in batteries.
- By 2030, around a sixth of all 300 million vehicles in the EU should be fuelled by electricity.
- Electric vehicles' potential to facilitate power grid management will grow in prominence, especially their contribution to augmenting grid flexibility and storage.

Finance, 4) EU Ref: Capros et al., 2016. EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050, and 5) Geco-INDC: Kitous et al., 2016. GECO 2016. Global Energy and Climate Outlook Road from Paris. Joint Research Centre.

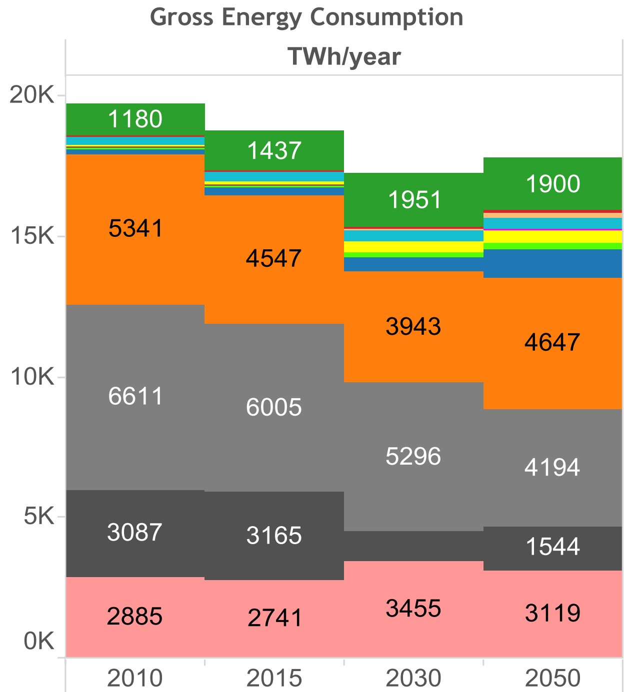
4 **Other than from RES, the decarbonisation of EU energy systems driven by EU and national-level energy efficiency targets across multiple sectors should continue to drastically reduce CO_2 emissions.**

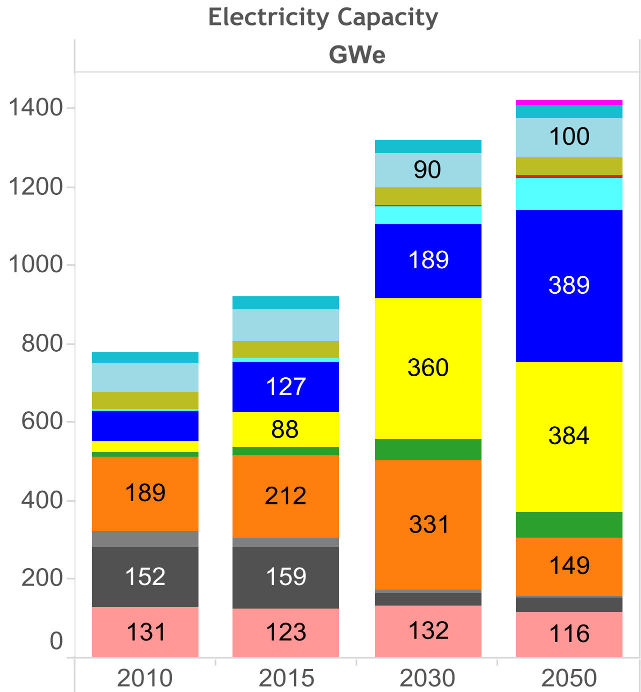
- The JRC-EU-TIMES baseline scenario for this project includes the new proposed 30% energy efficiency target for 2030 at the EU level, which has a goal to limit primary energy consumption to just 1320 Mtoe. This is equivalent to a 23% decrease with respect to the energy consumption in 2005.
- The proposed emission targets for individual member states to achieve a 30% reduction in GHG emissions by 2030 under the EU's Effort Sharing Regulation (ESR), meaning from non-ETS (Emissions Trading System) sectors, will end up pushing down emission levels (2010 ⇨ 2050) from residential buildings by over half (482 ⇨ 228 MtCO2) and the transport sector by nearly a fifth (1200 ⇨ 1041 MtCO2).
- Despite a 30% increase foreseen for passenger and freight demand, CO2 emissions from transport are still expected to be reduced by 10% from 2015 levels by 2050.

5 **In the baseline scenario the final energy used for heating and cooling decreases with 23%. Coal and oil boilers are gradually abandoned in buildings, while biomass displaces fossil fuels in the industry.**

- The total final energy used for heating and cooling decreases by 23% by 2030, from 7000 TWh in 2010 to 5400 TWh. This 23% decrease is in line with the proposed overall energy efficiency target of 30% target for 2030, bearing in mind the 23% equivalent reduction when compared to historical consumption. After 2030, no more major reduction of energy use is occurring.
- Due to improvements in building insulation as well as heating and cooling technologies, energy use in buildings decreases by 32% by 2030, from 4100 TWh in 2010 to 2800 TWh. Coal and oil boilers are gradually abandoned.
- Energy use for heating and cooling in the industry remains relatively stable from 2010 to 2050, but biomass replaces gas, and other fossil fuels.

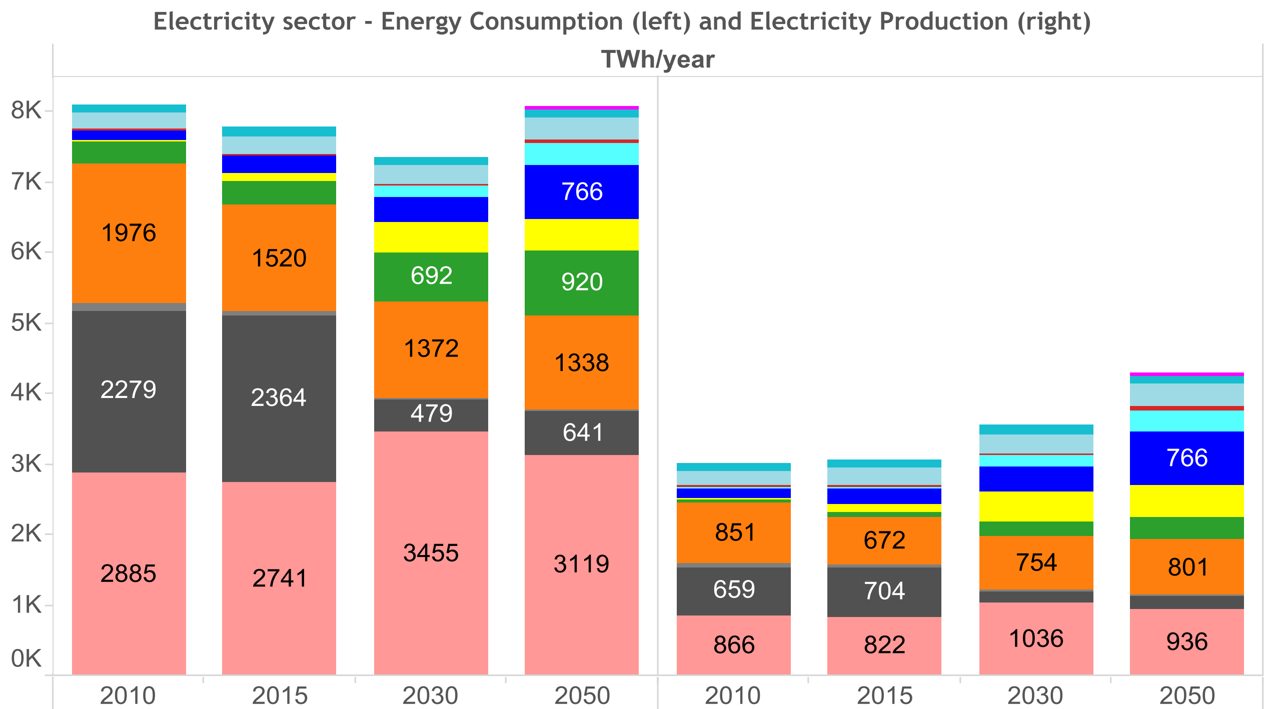
Baseline results for EU28





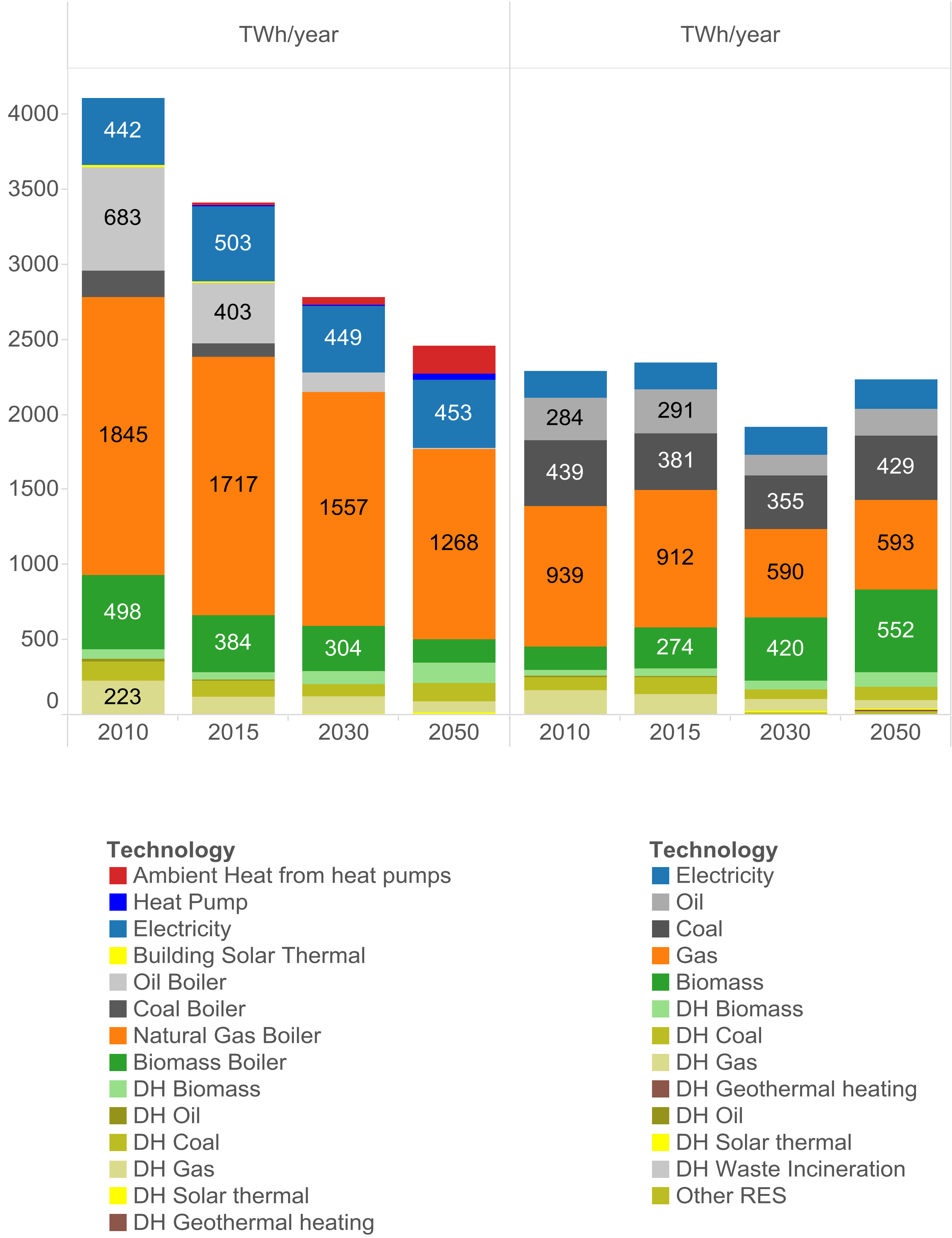
Technology

- Tidal power
- Hydro run-of-river
- Hydro dam
- Hydro Pumped
- Geothermal
- Offshore wind
- Onshore wind
- Solar PV
- Biomass
- Gas
- Oil
- Coal
- Nuclear



Final energy for Heating & Cooling - Buildings (left) and Industry (right)

For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.



JRC-EU-TIMES and its HRE4 baseline

The JRC-EU-TIMES model aims to analyse the role of energy technologies and their innovativeness for meeting European policy targets related to energy and climate change. A typical question that JRC-EU-TIMES can address is which technological improvements are needed to make technologies competitive under various low-carbon energy scenarios.

Such technology-oriented policy analyses complement the climate and energy policy analysis that is at the core of a series of published impact assessments from the European Commission. The JRC-EU-TIMES model's algorithm solves for the optimum investment portfolio of technologies along the entire supply chains for five sectors, while still fulfilling the energy-services demand. JRC-EU-TIMES is therefore very useful for supporting studies which require:

1. modelling at the level of an energy system,
2. a high detail of technologies, and
3. intertemporal results on the evolution of the energy system.

The JRC-EU-TIMES model produces projections (or scenarios) of the EU energy system showing its annual evolution up to 2050 under different sets of specific assumptions and constraints. In each projection the energy system evolves in a different way, representing a possible future in which assumed technological performances and costs interact with user-defined policies and environmental impacts, all subject to different macro-economic and demographic hypotheses.

JRC-EU-TIMES does not estimate any probability of occurrence for the scenarios, therefore they should not be regarded as actual forecasts of the future. Since the number of possible scenarios is infinite, it is necessary to define a set of alternative, plausible and self-consistent scenarios that cover a range of meaningful variations. A comparison of these possible futures is then used to draw insights useful for policy-making.

Figure 2: Scenario-thinking creates a set of plausible futures from a vast range of options

The scheme outlined above includes two types of elements:

- Normative: the overall climate and energy policy goals exogenously defined by the user, and
- Exploratory: the technology choices selected endogenously by the model as it solves for an optimisation model.

How does the JRC-EU-TIMES model work?

The JRC-EU-TIMES is a model of the energy system within the EU28 and certain neighbouring countries (Iceland, Norway, Switzerland and the Western Balkans). It provides a coherent framework to quantitatively assess the development needs for each of the identified technology sectors under different climate and energy pathways in Europe, up to 2050.

The model consists of two main components: 1) the TIMES model generator (a model code owned by the IEA's Energy Technology Systems Analysis Program, ETSAP), and 2) the JRC-EU-TIMES database.

Figure 3: Structure of the JRC-EU-TIMES model (GAMS = General Algebraic Modelling System)

The TIMES model generator from ETSAP allows for a detailed techno-economic description of resources, energy carriers, conversion technologies and energy demands. Most TIMES-based energy system models include upstream energy flows up to the level of resource-mining and imports. After its transformation from primary energy (through refineries and power plants, among other technology options), final energy can be consumed within different economic sectors (e.g. residential, tertiary/services, industry or transportation). An important difference to other models which cover only a single subsector of the energy system is that in TIMES the subsectors can interact with each other.

Meanwhile, the JRC-EU-TIMES database contains all relevant information for the updated model used within HRE4:

1. **JRC-EU-TIMES logic**: includes those specific equations (and relationships) between different variables of the model which are not included in the general TIMES model generator from ETSAP. Specific equations introduced by JRC include, for example, relationships between the operation of dispatchable power plants and the amount of variable power generation (e.g. from certain RES).
2. **JRC-EU-TIMES data**: includes fixed numeric techno-economic parameters representing the energy system such as:
    a. End-use energy services and materials' demand
    b. Present and future sources of primary energy supply and their potentials
    c. Key characteristics of existing and future energy-related technologies, such as efficiency, technological stock, availability, investment costs, O&M (operation and maintenance) costs and discount rates
    d. Policy constraints, such as emission limits or energy efficiency targets and other policy assumptions.

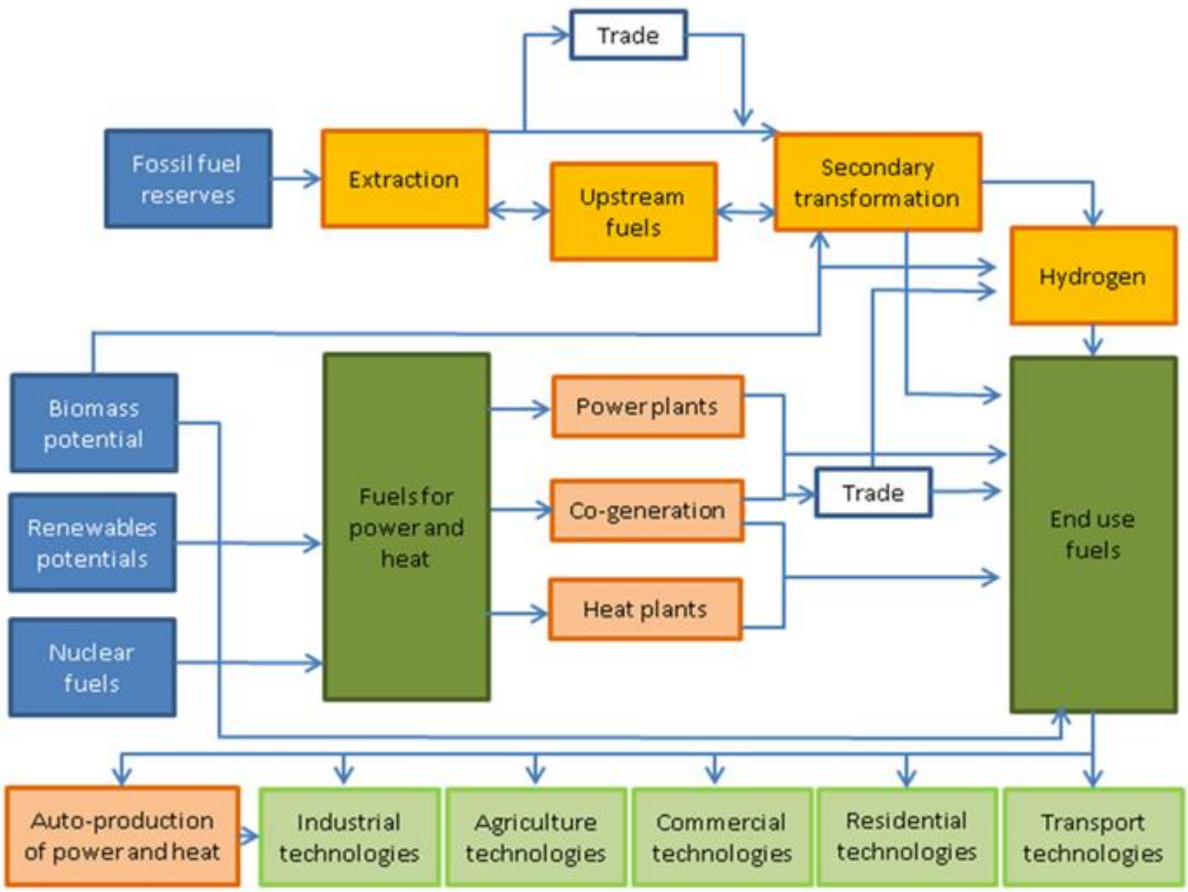


Figure 4: Building blocks of an energy system, as used by the JRC-EU-TIMES model

The JRC-EU-TIMES model solves an optimisation problem for the horizon 2005-2065 by minimising the total discounted energy-system cost needed to meet the future demand for energy services. The energy-system cost includes investments in supply and demand technologies, operational expenses and fuel costs.

The optimisation horizon is divided into 9 periods. Each period consists of equal years that are divided in 12 time-slices that represent an average of day, night and peak demand for each of a year's four seasons. To address flexibility issues, each time-slice of the power sector is further split into two sub-periods – this additional dimension allows differentiation of situations where variable RES electricity generation exceeds demand from those situations where this is not the case. Using this approach, the JRC-EU-TIMES model is able to model and compare curtailment with different transformation or storage options in cases of excessive variable RES electricity production.

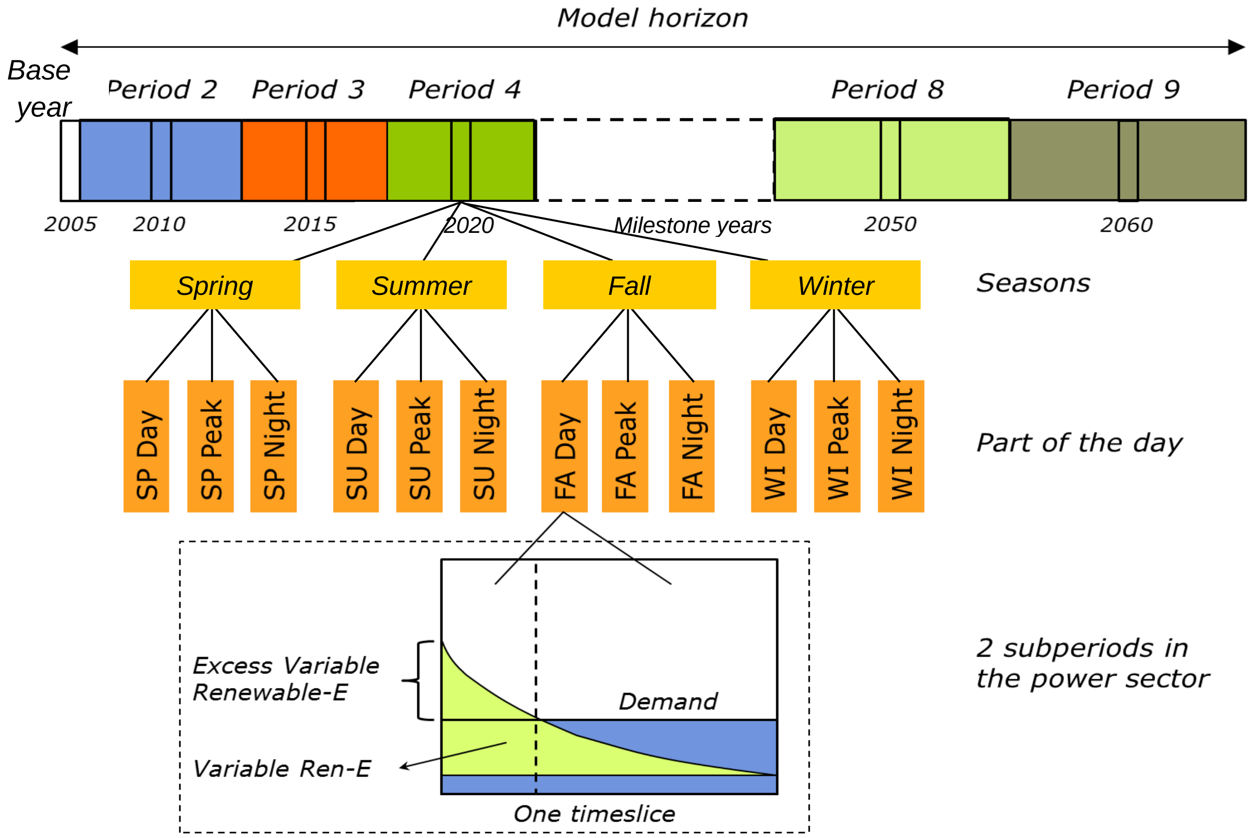


Figure 5: Time resolution of the JRC-EU-TIMES model, including time-slices within a single year

Who should use the baseline scenario?

The baseline scenario produced by the JRC-EU-TIMES model covers the EU28 member states and certain neighbouring countries, projecting the energy system in these regions through 2050. Given the scale and resolution of the projections, they are useful mainly for policy-makers, energy agencies, industries/companies and NGOs acting at EU or national levels.

Though the outputs produced by JRC-EU-TIMES in the framework of HRE4 can be publicly shared, the model itself is not directly accessible to external stakeholders. JRC-EU-TIMES is an improved offspring of previous European energy system models developed under several EU-funded projects, such as NEEDS, RES2020, REALISEGRID, REACCESS and COMET, using the model generators developed in the context of IEA's ETSAP. The members of the ETSAP network, which includes the European Commission, carry out a joint program of energy technology systems analyses, and ETSAP grants its members a licence to use the ETSAP models generators according to certain conditions, including the following:

- ETSAP owns all intellectual property within the source code for the TIMES model generator and the related non-commercial support utilities and files needed to run such generators.
- The ETSAP models generators are provided by ETSAP free of charge.
- The TIMES code, developed with GAMS (General Algebraic Modelling System), is provided in an open format so as to permit experimentation with new research ideas and algorithms. The licensing organisation is encouraged to experiment with and to improve the code. Such variants will become the intellectual property of ETSAP.

The JRC is currently exploring possibilities to offer the JRC-EU-TIMES model as an open platform, managed by the JRC, so that lead-users in the public can even more directly take advantage of HRE4 results. In any case, it should be mentioned that the results of the JRC-EU-TIMES model are produced under the overall assumptions and boundaries of the HRE4 project, and therefore do not represent any official position of the European Commission.

What are the main benefits of JRC-EU-TIMES?

Beyond the JRC-EU-TIMES results, more fully described in D5.2, and the outline already provided in this document, it can be emphasised that the JRC-EU-TIMES model may be used for analysing energy scenarios with different purposes such as:

- using analyses of the HRE4 scenarios to support the development of
    - a resilient Energy Union
    - National Energy Efficiency Action Plans (NEEAP)
    - National Renewable Energy Action Plans (NREAP)
- developing cost-effective policy recommendations to decarbonise the EU's H&C sector
- projecting the performance and penetration of different H&C technologies across the EU, but within the HRE4 context, especially in the project's fourteen focal countries.

How does JRC-EU-TIMES model fit into HRE4?

The JRC-EU-TIMES model's annual energy projections per country are combined with HRE4's results from within its own work package, WP5, and other WPs (namely H&C potentials and demands from WP2, H&C profiles from WP3, potentials for demand reduction from WP4, and hourly energy supply and demand profiles from WP5) in order to produce the 2050 baseline scenario of the total energy system, which is then analysed at an hourly level alongside WP5's EnergyPLAN model.

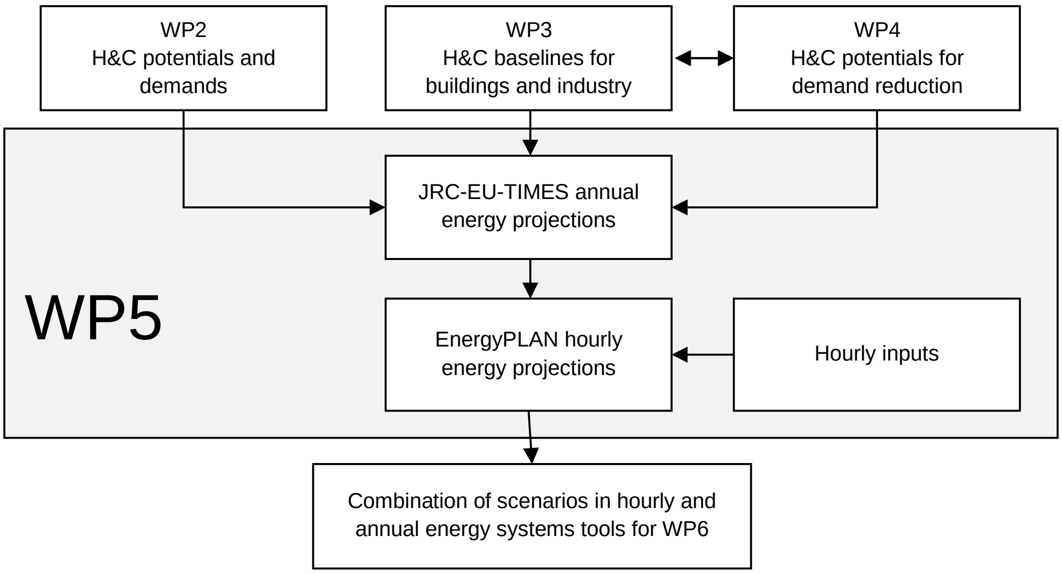


Figure 6: The JRC-EU-TIMES model within HRE4's WP5

The projections produced by the JRC-EU-TIMES model will continue to be used during 2018 as an important input for WP6 in order to evaluate different H&C scenarios for the 14 member states considered in HRE4. This will then form the basis of in-depth policy recommendations and roadmaps resulting from the HRE4 project.

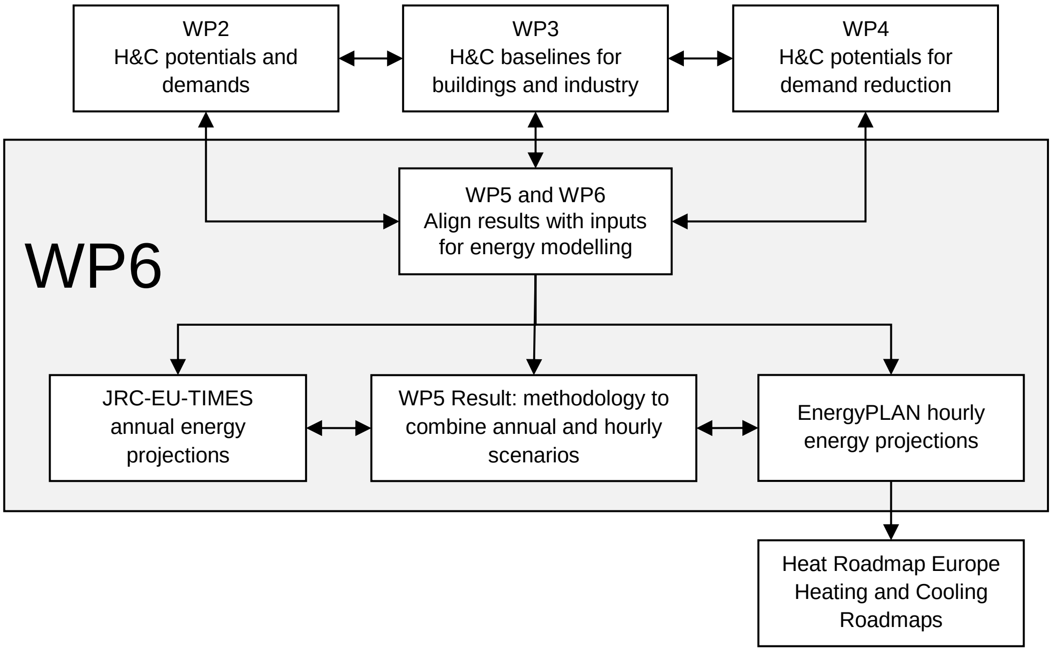


Figure 7: The JRC-EU-TIMES model in WP6