Baseline scenario of the total energy system up to 2050

JRC-EU-TIMES model outputs for the 14 MS and the EU

Deliverable 5.2: Business-as-usual reference scenarios

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1. Introduction

In Europe there is a clear long-term objective to decarbonise the energy system, but it is currently unclear how this will be achieved in the heating and cooling sector. The overall objective of the Heat Roadmap Europe project (HRE4) is to provide new capacity and skills for lead-users in the heating and cooling sector, including policymakers, industry, and researchers at local, national, and EU level, by developing the data, tools, methodologies, and results necessary to quantify the impact of implementing more energy efficiency measures on both the demand and supply side of the sector. Thus, HRE4 will enable new policies and prepare the ground for new investments by creating more certainty in relation to the changes that are required. HRE4 is co-funded by the European Union, brings together 24 academic, industrial, governmental and civil society partners, and runs from 2016-2019.

The Joint Research Centre of the European Commission contributes to HRE4 in work packages 5 and 6. This report focuses on work package 5, which aims at 1) projecting the annual evolution of the EU energy system up to 2050 and 2) transferring those modelling results from the European Commission's JRC-EU-TIMES model to the AAU's hourly energy model EnergyPLAN. The linkage of these two energy system models is a key improvement from previous HRE4 projects. 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.

The present document explains the JRC-EU-TIMES model and its inputs and assumptions as well as the results from the baseline scenario of the total EU energy system up to 2050. The results are presented in an annex for the EU28 as a whole and for each of the 14 MSs considered in HRE4.

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.

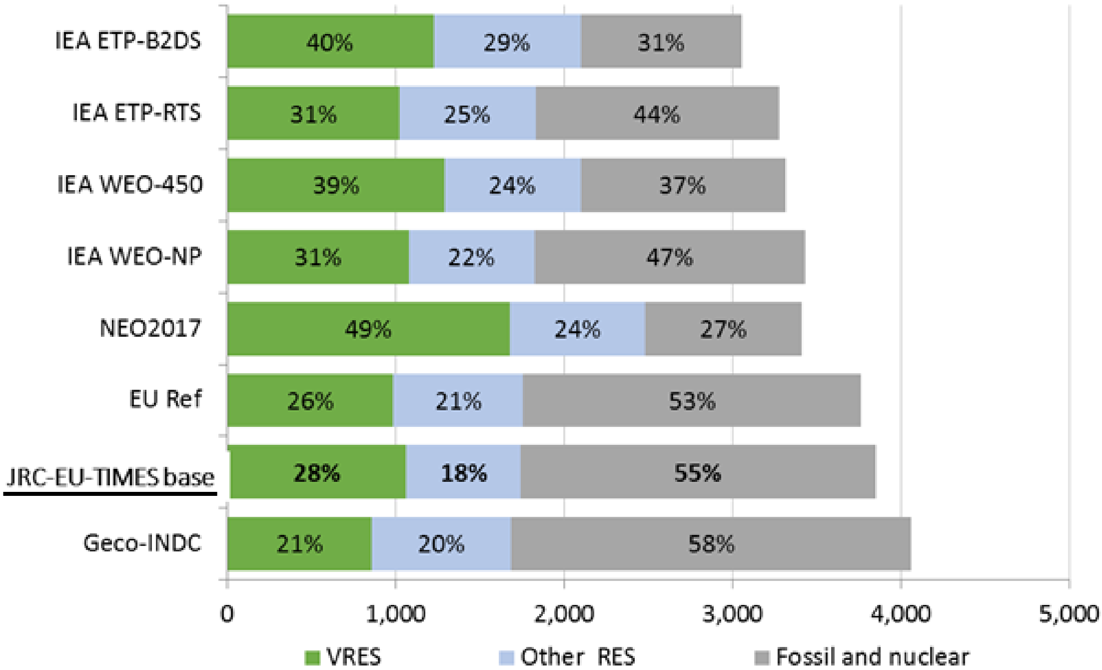


Figure 1: HRE4 baseline (power sector), variable RES balance across different key EU28 scenarios for 2040[1]

[1] 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 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.

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.

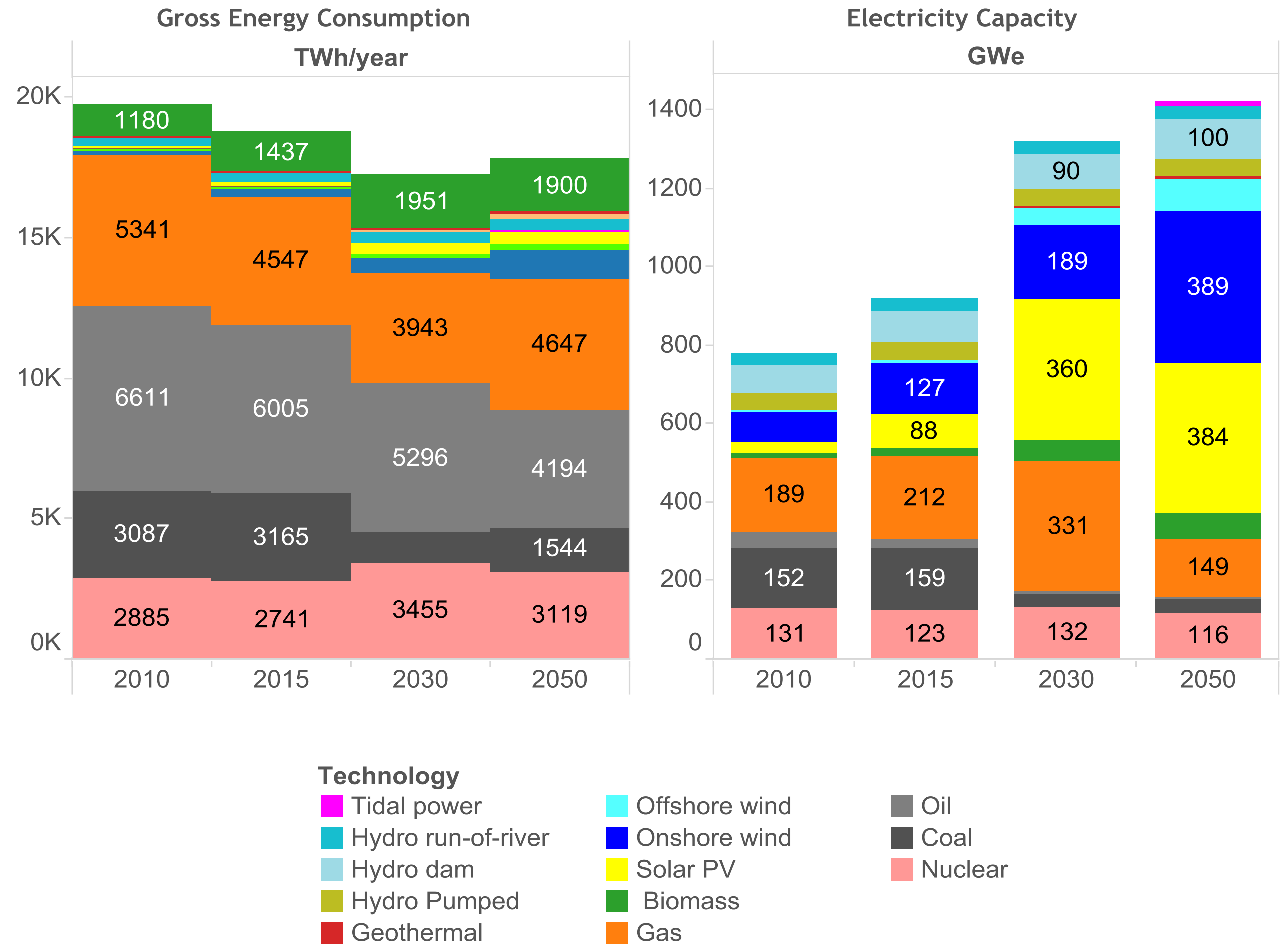
4	**Other than from RES, the decarbonisation of EU energy systems driven by EU and national-level energy efficiency targets across multiple sectors should continue to drastically reduce CO_2 emissions.**

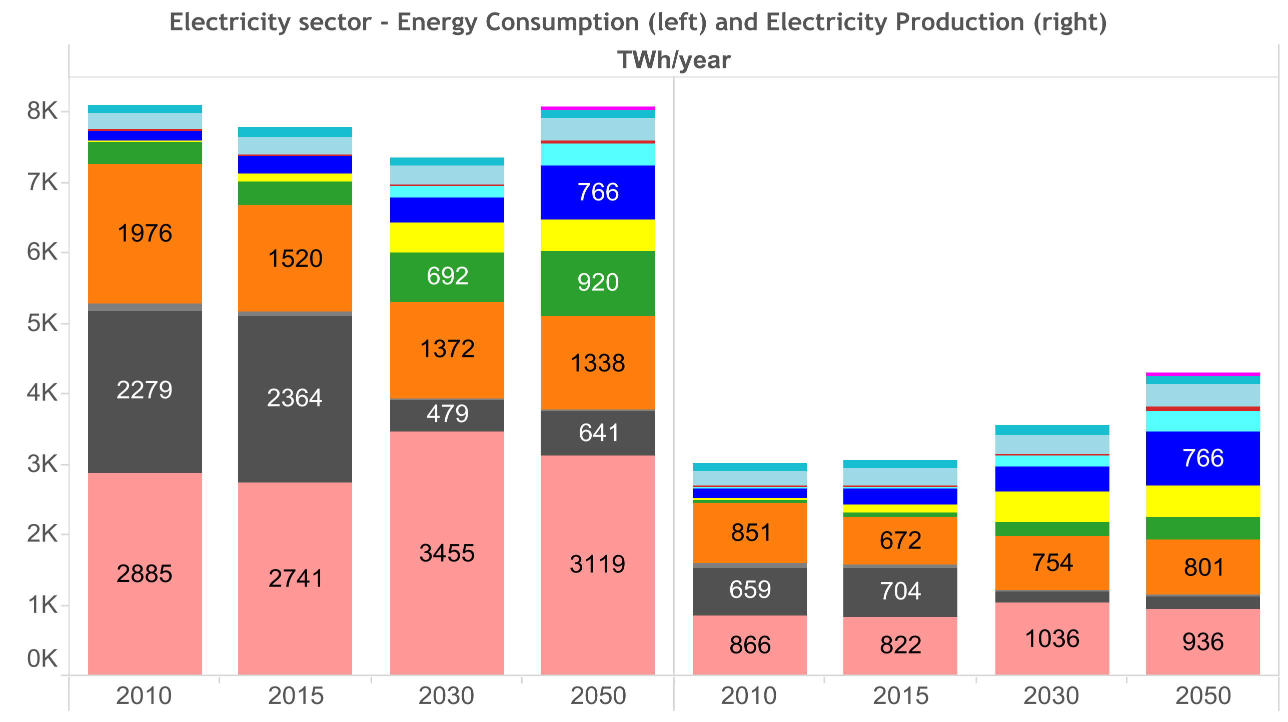
- The JRC-EU-TIMES baseline scenario for this project includes the new proposed 30% energy efficiency target for 2030 at the EU level, which has a goal to limit primary energy consumption to just 1320 Mtoe. This is equivalent to a 23% decrease with respect to the energy consumption in 2005.
- The proposed 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.

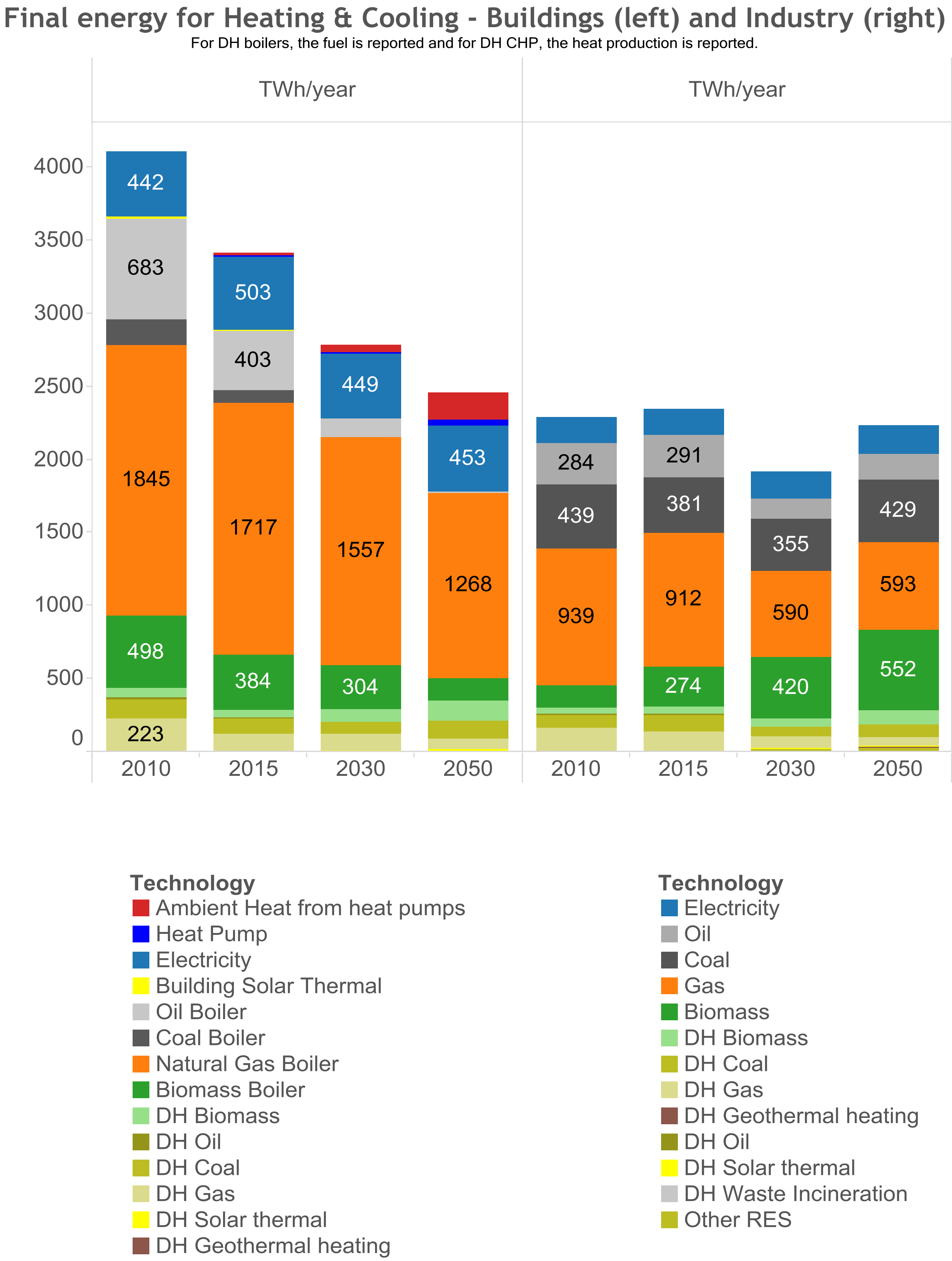
5	**In the baseline scenario the final energy used for heating and cooling decreases with 23%. Coal and oil boilers are gradually abandoned in buildings, while biomass displaces fossil fuels in the industry.**

- 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






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.
TWh/year
TWh/year
4000
3500
3000
2500
2000
1500
1000
500
0
442
683
1845
498
223
503
403
1717
384
449
1557
304
453
1268
284
439
939
291
381
912
274
355
590
420
429
593
552
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Ambient Heat from heat pumps
Heat Pump
Electricity
Building Solar Thermal
Oil Boiler
Coal Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
DH Oil
DH Coal
DH Gas
DH Solar thermal
DH Geothermal heating
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass
DH Coal
DH Gas
DH Geothermal heating
DH Oil
DH Solar thermal
DH Waste Incineration
Other RES

2. JRC-EU-TIMES in a nutshell

The JRC-EU-TIMES model aims to analyse the role of energy technologies and their innovation for meeting Europe's energy and climate change related policy targets. A typical question that can be addressed by JRC-EU-TIMES is what technology improvements are needed to make technologies competitive under various low carbon energy scenarios. Such technology policy analysis complements the climate and energy policy analysis that is at the core of a series of published impact assessments of the European Commission. The model's algorithm solves for the optimum investment portfolio of technologies along the whole supply chains for five sectors, while fulfilling the energy services demand. JRC-EU-TIMES supports studies that require (1) modelling at an energy system level, (2) a high technology detail and (3) intertemporal results on the evolution of the energy system.

The JRC-EU-TIMES model is a linear optimization bottom-up technology-rich model (Loulou, Remme et al. 2005; Loulou, Remme et al. 2005). It represents the EU28 energy system plus Switzerland, Iceland and Norway from 2005 to 2050, with each country constituting one region of the model. As a partial equilibrium model, JRC-EU-TIMES does not represent the economic interactions outside of the energy sector. However, the macro-economic feedback between the economy and energy systems is considered through price elasticities of service demands. Moreover, it does not consider in detail the mathematical formulation underlying demand curves functioning and non-rational aspects that condition investment in new and more efficient technologies. Such issues have to be dealt with via exogenous constraints to represent non-rational decisions.

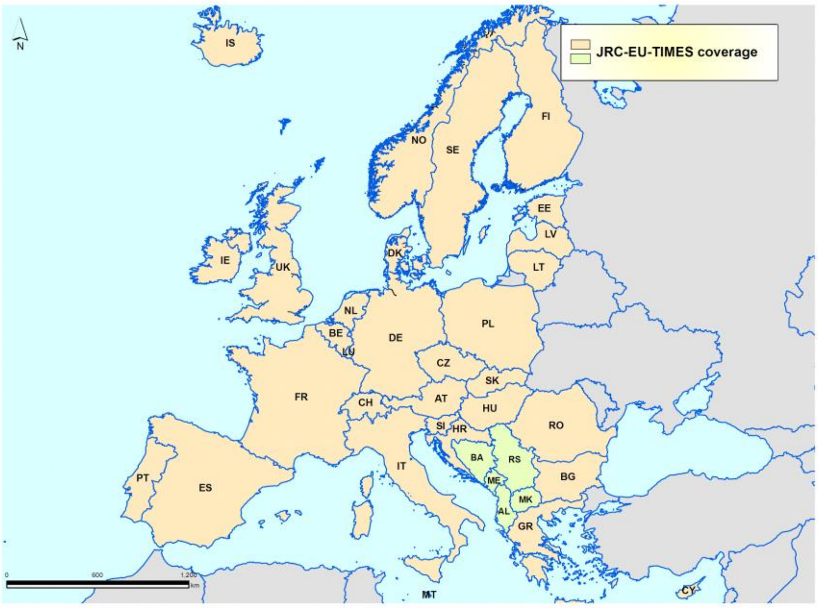


Figure 2 – Regions considered in JRC-EU-TIMES

The most relevant model outputs are the annual stock and activity of energy supply and demand technologies for each region and period. This is accompanied by associated energy and material flows including emissions to air and fuel consumption, detailed for each energy carrier. Besides technical outputs, the associated operation and maintenance costs, the investment costs for new technologies, all energy and materials commodities prices (including for emissions if an emission cap is considered), are obtained for every time step.

2.1. Exploring the future: the purpose of scenario analysis

Exploring different possible futures unfolds possible interactions between the performance of technologies, policies, environmental impacts and associated costs. Scenario analysis is one approach to explore such different yet plausible futures for the development of the energy system. The methodology consists in capturing the uncertainty in the assumption by focussing on a number of plausible and self-consistent sets. In each scenario the energy system evolves in a different way.

It is imperative to emphasize that scenarios are not intended to be forecasts. We do not attach a probability to the scenario assumptions (even if based on agreed goals of the EU) and the assumptions might deviate strongly from current trends. Scenarios are rather plausible futures under sets of specific assumptions and constraints.

In the JRC-EU-TIMES model, each scenario consists of a set of options which lead to an outcome. There is a need to reduce the theoretically infinite number of possible scenarios. A first selection can be made based on anticipated values of key variables such as environmental impact, costs and social externalities to name a few.

Figure 3: Scenario thinking creates a set of plausible futures from a vast range of options

Consideration of strategic technology options or cost-time trends can further reduce the number of options. The scenario outcome is determined by cost optimisation i.e. the cheapest solution, from these still numerous options, while internalizing some of the non-cost related impacts such as the greenhouse gas emissions.

2.2. Modelling energy system transitions

Energy systems evolve over time and are affected by many internal and external factors. To model the transition between 2 periods in time, one needs a tool that both can deal with operation of the given elements in the system as well as with investments. The JRC-EU-TIMES models the transition from start to finish within the model itself, rather than as separate years by the user. For this baseline, a transition was modelled from 2010 (base year) to 2065 with intervals as given in Table 1. For this study, we report periods P1, P3, P6 and P8 representing respectively 2010, 2015, 2030 and 2050.

Table 1 Period definition in the JRC-EU-TIMES for the HRE4 runs

	P1	P2	P3	P4	P5	P6	P7	P8	P9
Start	**2010**	2011	**2013**	2018	2023	**2028**	2033	**2045**	2056
Mid	**2010**	2011	**2015**	2020	2025	**2030**	2038	**2050**	2060
End	**2010**	2012	**2017**	2022	2027	**2032**	2044	**2055**	2065
Length	**1**	2	**5**	5	5	**5**	12	**11**	10

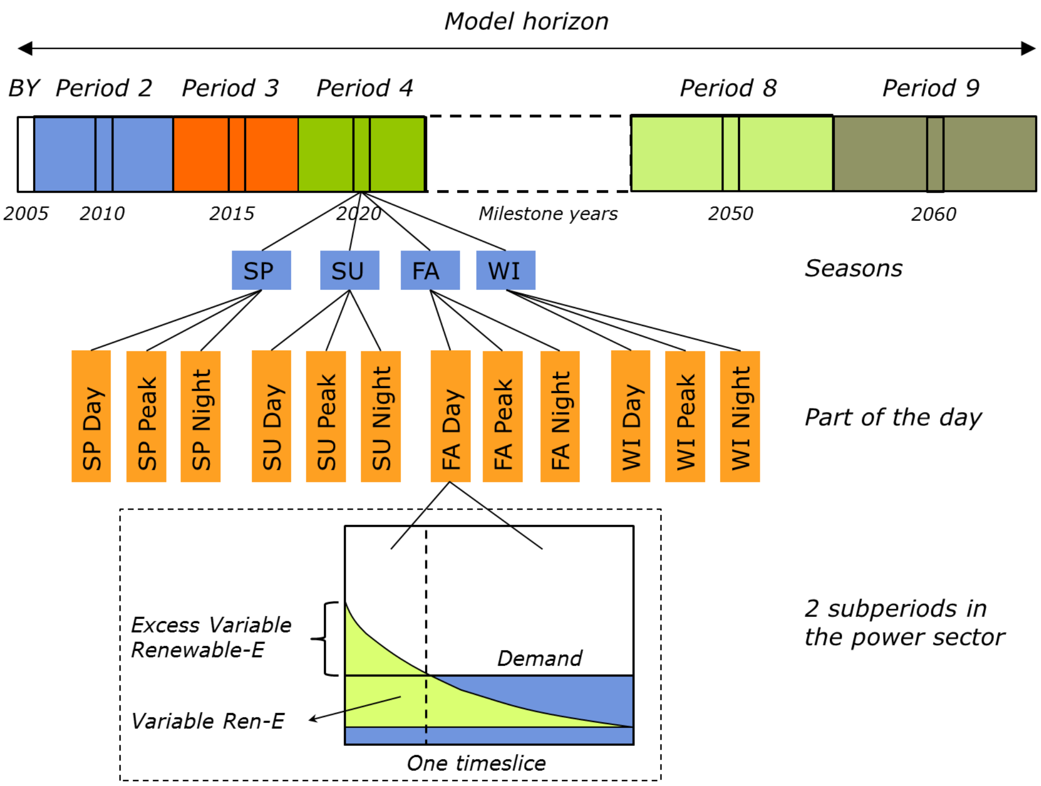


Figure 4: Illustration of the time resolution of the JRC-EU-TIMES model (BY: Base Year).

Each period consists of equal years that are divided in 12 time-slices that represent an average of day, night and peak demand for every one of the four seasons of the year. To address flexibility issues, each time-slice of the power sector is further split into two sub-periods. This additional dimension allows differentiating situations where variable renewable generation exceeds demand from situations where this is not the case. Using this approach, the JRC-EU-TIMES model is able to capture the competition amongst curtailment and different transformation and storage options in case of excessive variable renewable electricity production.

2.3. Technology rich bottom-up

The TIMES platform allows for 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. Figure 5 shows the main building blocks of a typical energy system. After its transformation from primary energy through refineries and power plants among other technology options, final energy can be consumed within different sectors of the economy, such as the residential, the commercial, the industrial or the transportation sector to name a few. An important difference to models that cover only one subsector of the energy system is that in TIMES the subsectors can interact with each other, e.g. between the transportation and power sectors.

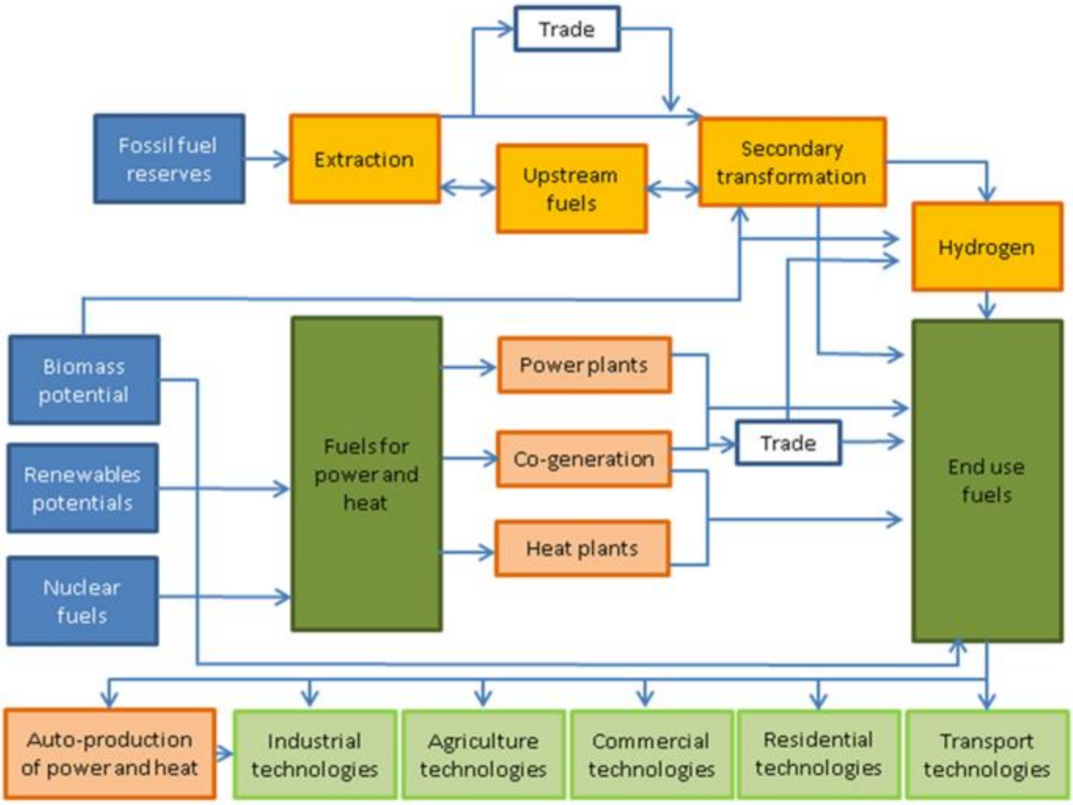


Figure 5: Building blocks of an energy system, as used by the JRC-EU-TIMES model

A TIMES model minimises the total discounted energy system cost[2] 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. Figure 6 shows the main inputs and outputs of the JRC-EU-TIMES model.

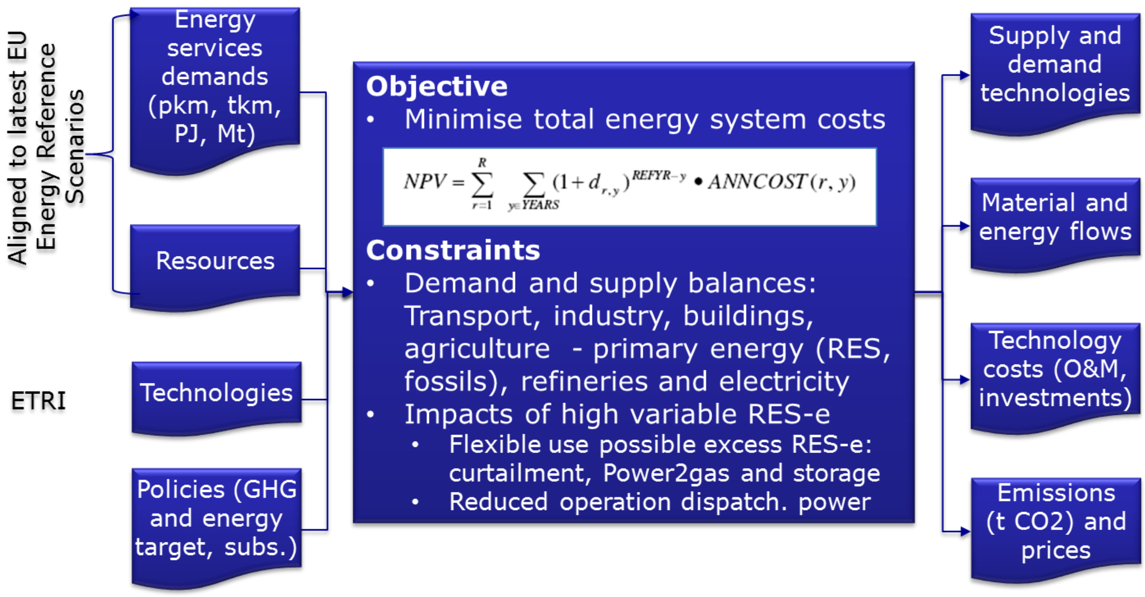


Figure 6: Inputs, outputs and model objective of the JRC-EU-TIMES. (NPV: Net Present Value, ANNCOST: total annual energy system cost, d: general discount rate, REFYR: Reference year, R: regions)

TIMES models are bottom-up representations of the energy system as technologies are explicitly characterised. This allows the model to identify possible technological interactions across sectors that could have an impact on the energy system. For instance carbon emission reductions resulting from the installation of heat pumps are directly competing with the decarbonisation of the power sector. Top down levels would first determine the relations between sectors before addressing technology choices with a subsector. However, some model inputs, such as projections of energy service demands and other underlying macroeconomic assumptions come from top-down models.

The objective of a TIMES model is to find the evolution of the energy system that satisfies the energy services and material demands while minimises the discounted net present value of energy system costs, subject to several constraints (like policies, energy targets, etc.). For this purpose, TIMES simultaneously decides on equipment investment and operation, primary energy supply and energy trade.

[2] Opposed to the calculation of the Levelised Cost Of Energy/Electricity (LCOE) this allows determining an optimum usage of each technology over time. Technologies with a very high LCOE could be deployed if these are the most cost effective for a certain time period (geothermal might be the most cost effective option in a dark winter night).

3. Baseline scenario assumptions

The main drivers and exogenous inputs of the JRC-EU-TIMES are: (1) the end-use energy services and materials demand (derived from macroeconomic inputs aligned with the EU Energy Reference Scenario 2016); (2) characteristics of the existing and future energy related technologies, such as efficiency, stock, availability, investment, operation and maintenance costs, and discount rate; (3) present and future sources of primary energy supply and their potentials; and (4) policy constraints and assumptions. An extensive description of the model, including inputs and output values, can be found in Simoes et al.[3], and Ruiz Castelló et al.[4].

3.1. Macro-economic parameters

Energy services demand

The materials and energy services demand projections for each country are differentiated by economic sector and end-use energy service, using as starting point historical 2010 data. The underlying macroeconomic projections, as well as sector specific assumptions regarding, for instance, the number of buildings, have been updated in line with the EU Reference Scenario 2016 (European Commission 2014). The evolution of EU28 sectorial demands over time is shown in Figure 7 implementing to the extent possible the assumptions of the EU Reference Scenario 2016. All these demand projections are in line with the GDP and population projections from the EU Energy Reference Scenario 2016. The basis for these are demographic assumptions based on Eurostat population projections and long-term economic outlook as given in the 2015 Ageing Report[5] and the DG ECFIN short and medium term GDP growth projections (EC 2014). Table 2 shows the fossil fuel cost considered for the HRE4 baseline runs.

Table 2 Fossil fuel prices (EUR 2010/boe) for the JRC-EU-TIMES HRE4 baseline runs

Fossil fuel	2020	2030	2040	2050
Oil	70	90	99	104
Gas	45	54	60	62
Coal	13	20	22	23

[3] Simoes, Nijs, Ruiz, Sgobbi, Radu, Bolat, Thiel, Peteves (2013), The JRC-EU-TIMES model. Assessing the long-term role of the SET Plan Energy technologies. JRC Scientific and Policy Reports. Luxemburg. doi: 10.2790/97596.

[4] Ruiz Castello Pablo; Sgobbi Alessandra; Nijs Wouter; Thiel Christian;et al (2015). The JRC-EU-TIMES model. Bioenergy potentials for EU and neighbouring countries. . JRC Scientific and Policy Reports. Luxemburg. doi: 10.2790/39014

[5] http://ec.europa.eu/economy_finance/publications/european_economy/2015/ee3_en.htm

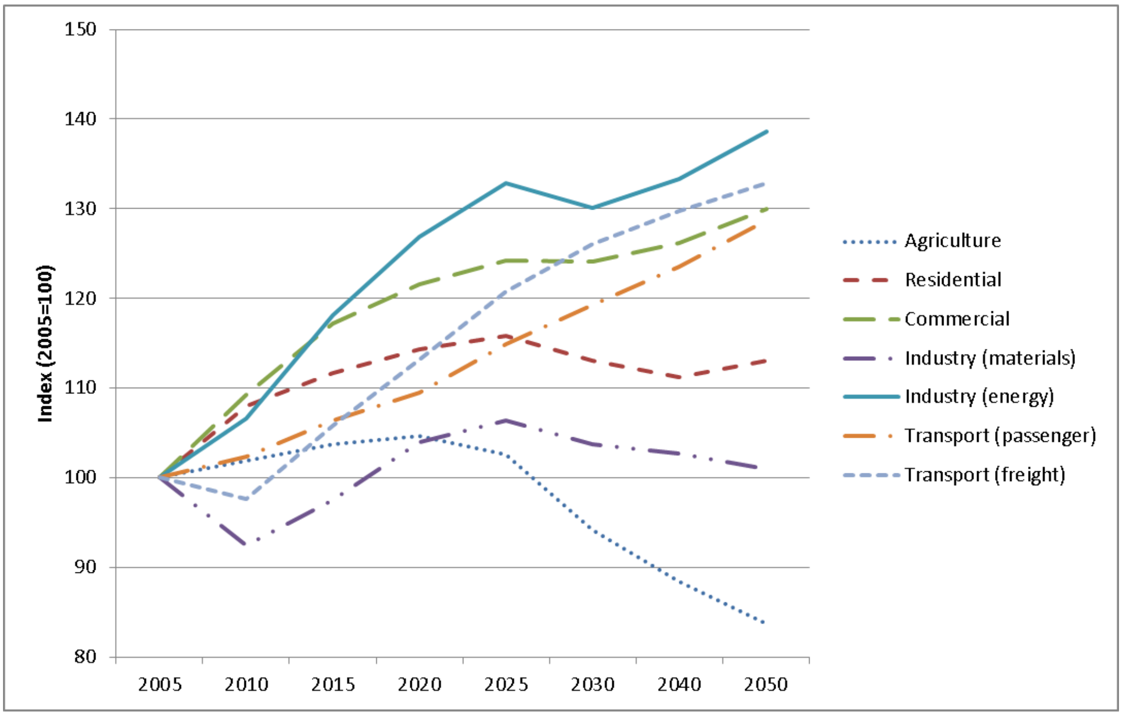


Figure 7 Index evolution demand for each of the end use sectors

3.2. Links with other models

The JRC-EU-TIMES baseline scenario is aligned to the following inputs of the Reference Scenario 2016 in the long run, up to 2050:

- Energy services demand or demand growth
- Fuel prices
- Total CO_2 emissions reduction trajectory
- Building stock projection
- The total MS capacities of coal power plants from the Reference Scenario 2016 are used as an upper limit for coal power plants without CCS in JRC-EU-TIMES.

Following indicators are aligned with outputs from FORECAST model produced for the HRE4 project:

- Residential: space heat delivered
- Tertiary: space heat and space cool delivered
- Industry: ex-post TIMES alignment. Process heat (> 100 degree C) is calculated as JRC-EU-TIMES total heat minus all other categories.

3.3. Baseline scenario policies

JRC-EU-TIMES includes exploratory and normative elements. It is normative with respect to the overall climate and energy policy goals but exploratory with respect to technology choices. Table 3 shows the formulation of the main global policy targets.

Table 3: Overall climate and energy policy goal as formulated for the JRC-EU-TIMES HRE4 baseline

	2030	2050	Ref year
Renewable Energy	27%	31%	-
Primary Energy	-23% (-30%)	-20%	2005 (2030)
CO_2 total	-40%	-48%	1990
CO_2 total	-36%	-44%	2005
Emissions Trading Scheme (ETS)	-43%	-62%	2005
Non-ETS	-30%	-28%	2005

As mentioned above, the JRC-EU-TIMES HRE4 baseline is aligned to the inputs of the EU Energy Reference Scenario 2016 up to 2050. Figure 8 gives an overview of the major agreed and proposed energy related targets for 2030. However for 2030, JRC-EU-TIMES is aligned to EUCO30[6] in order to meet the referred targets.

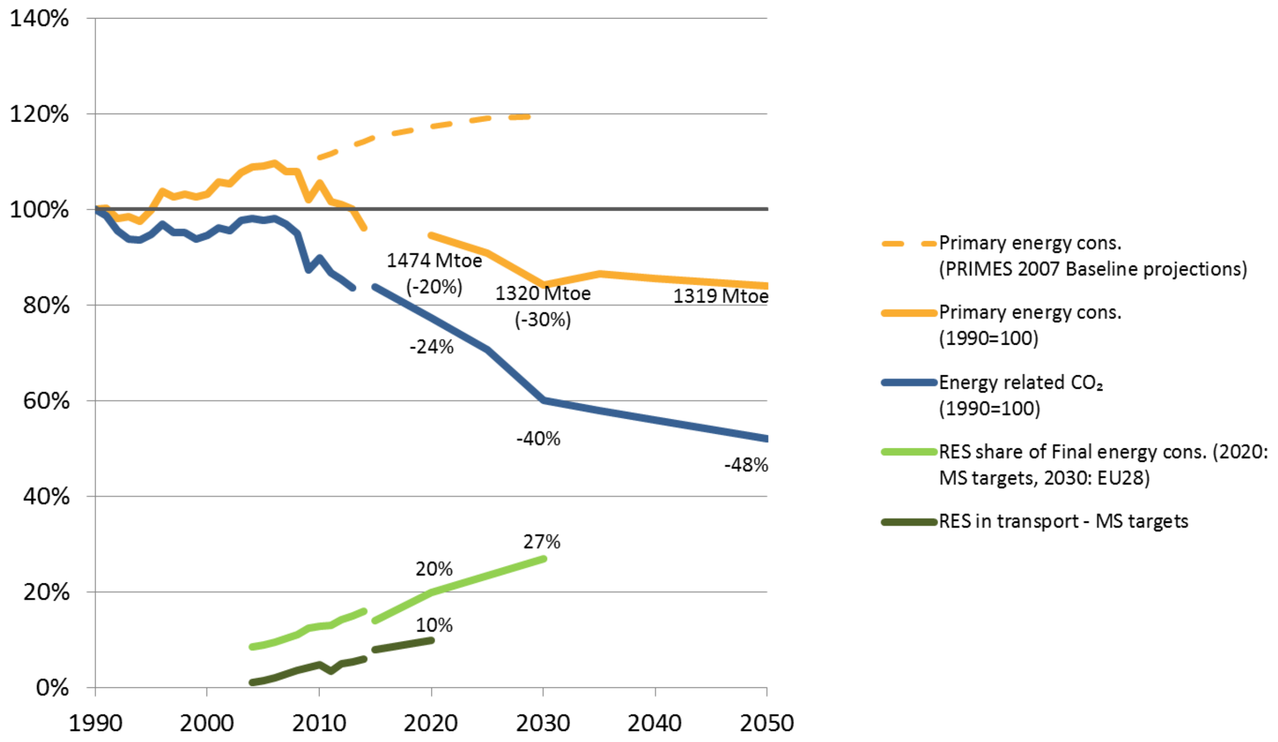


Figure 8 Main global policy targets trajectories for CO_2 emissions, RES and Energy Efficiency as primary energy reduction.

The targets for reducing energy and greenhouse gas emissions are formulated with respect to different reference years. In Figure 9, these reductions are all normalised to the same reference year 2005.

[6] EUCO30 is one of the reference scenarios created for the Impact Assessment accompanying the proposal for the revised Energy Efficiency Directive. Full details can be check at: http://charts-move.mostra.eu/en/content/euco30

1. At the European Council in October 2014, a minimum share of **27% RES** was agreed. The European Commission proposes EU actions that will ensure the Union to meet the at least 27% RES target. Within JRC-EU-TIMES, there is a minimum share of 27% RES in place for the final energy consumption.
2. The Energy Efficiency target:
   In the EU Reference scenario 2016, the primary energy consumption is 1436 Mtoe and that is 23.9% lower, evaluated against the 1886 Mtoe of the 2007 PRIMES Baseline projection for 2030. At the European Council in October 2014, a higher level of 27% level was agreed. The JRC-EU-TIMES baseline for this project includes however the **new proposed 30% target for 2030 at EU level**. The goal of that target is to limit the primary energy consumption to 1320 Mtoe, which is a 30% decrease compared to the same 2030 baseline. The 30% target is equivalent to a reduction of 23%, when compared to the historical energy consumption of 2005.
3. Overall greenhouse gases:
   The collective EU target is to reduce the economy wide greenhouse gases **with at least 40% compared to 1990**. The 40% target is equivalent to a reduction of 36%, when compared to the historical emissions of 2005.
4. There is an **EU wide ETS target of -43% emission** reductions compared to 2005.
   An **ESR (non-ETS) target is proposed for 2030: -30% below 2005 levels**, comprising ESD and LULUCF.
   - Within JRC-EU-TIMES we have included the MS specific targets from proposal COM 2016/482. This is different from the outputs of the EUCO30 scenario where there is a cost optimal MS effort sharing.
   - ESR CO_2 emission reductions seem to differ from the official numbers in the proposal but this is because we only take CO_2 whereas the official numbers are for all GHG.
   - We assume the linear reduction starts in 2018 with a value of the emissions projection of EUCO30 for 2020 which is lower than the 2018 emissions.

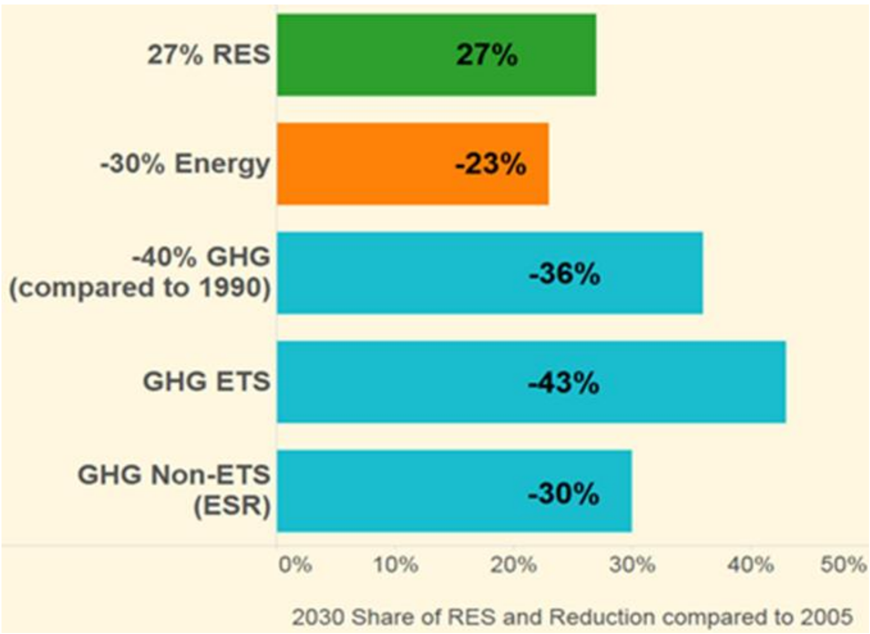


Figure 9 Normalization of all main energy policy targets to 2005

Table 4 shows historical and targeted ESR CO_2 emissions (excluding marine bunkers).

Table 4 ESR CO_2 trajectories and 2030 targets

	2005	2010	2015	2020	2030	Reduction
EU28	**1952**	**1857**	**1751**	**1584**	**1338**	**-31%**
Austria	46	42	38	36	28	-39%
Belgium	60	59	56	50	36	-40%
Bulgaria	15	13	13	12	18	27%
Croatia	11	11	10	9	12	7%
Cyprus	3	3	3	2	2	-35%
Czech Republic	43	40	40	37	40	-8%
Denmark	23	22	19	17	10	-55%
Estonia	3	3	3	3	3	-9%
Finland	24	24	20	18	13	-46%
France	255	240	227	201	138	-46%
Germany	348	338	324	286	208	-40%
Greece	39	34	29	26	38	-2%
Hungary	33	27	26	25	34	5%
Ireland	25	23	21	19	10	-61%
Italy	242	215	204	188	158	-35%
Latvia	5	5	5	4	5	0%
Lithuania	6	6	6	6	6	1%
Luxembourg	9	9	8	8	5	-45%
Malta	1	1	1	1	1	-18%
Netherlands	87	88	84	77	49	-44%
Poland	110	131	126	122	107	-3%
Portugal	32	28	24	22	29	-9%
Romania	33	30	32	31	40	23%
Slovakia	18	18	17	17	17	-6%
Slovenia	8	8	7	7	7	-10%
Spain	162	149	131	116	114	-29%
Sweden	30	28	24	21	16	-48%
United Kingdom	282	261	250	222	195	-31%

3.4. Energy technologies

The techno-economic parameters for new energy supply technologies are based on the Energy Technology Reference Indicators (ETRI) projections for 2010-2050 ETRI[7]. The JRC-EU-TIMES model has a high level of technological detail, with the explicit representation of more than 300

[7] https://ec.europa.eu/jrc/en/science-update/etri

technologies in the supply and demand sectors. The data on cars have been updated according to the paper by Thiel 2016[8].

To model an expected inertia in the transition to electric cars, there is a maximum share of EV and PHEV cars in the new fleet as depicted in Figure 10, in line with the assumptions made by Bloomberg for their New Energy Outlook[9].

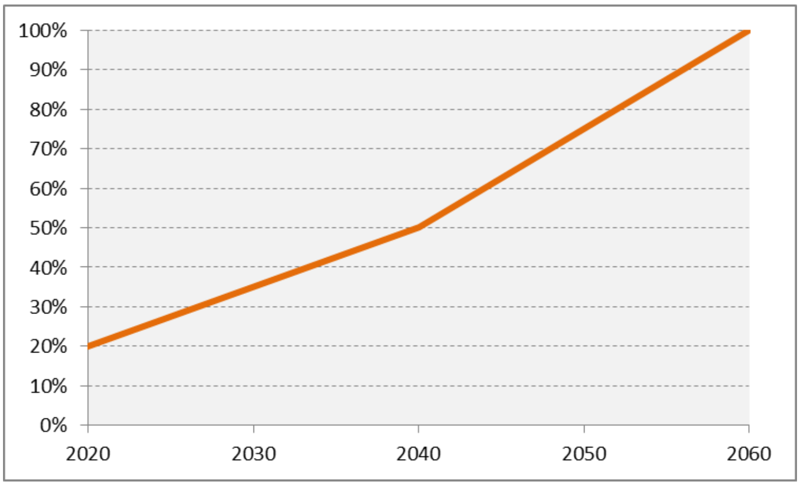


Figure 10 Maximum adoption rate for EV modelled as a share of new bought cars

The data on heating in the residential sector has been updated based on the unpublished JRC report "Techno-economic projections until 2050 for relevant heating and cooling technologies in the residential and tertiary sector in the EU".

3.5. Discounting

For discounting future cash flows, the JRC-EU-TIMES model follows a hybrid approach. Within a given time period, costs of capital are differentiated by technology and between businesses and households as shown in Table 5. The technology-specific discount rates are the ones used in the PRIMES model for the EU Energy Roadmap 2050. For weighting costs across the different modelling periods, a social discount rate of 5% is used.

Table 5: Discount rates in JRC-EU-TIMES (2030)

Sector/group of technologies	Discount rate	Sector/group of technologies	Discount rate
Passenger cars	17.5%	CHP and industry	12%
Freight transport	12%	Centralised electricity generation	9%
Busses and passenger trains	8%	Geothermal electricity generation	12%
Residential	10%	CCS and CCUS	12%
Commercial	9%	Energy distribution	7%
Retrofitting of buildings	9%		

[8] Christian Thiel, Wouter Nijs, Sofia Simoes, Johannes Schmidt, Arnold van Zyl, Erwin Schmid, The impact of the EU car CO regulation on the energy system and the role of electro-mobility to achieve transport decarbonisation, Energy Policy, Volume 96, 2016, Pages 153-166, ISSN 0301-4215, http://dx.doi.org/10.1016/j.enpol.2016.05.043.
[9] https://about.bnef.com/new-energy-outlook/

3.6. Representation of nuclear energy in JRC-EU-TIMES

Representation of nuclear power plants in the model

Each individual existing and planned nuclear power plant in Europe is modelled at reactor level, considering its technological characteristics. The exact start and decommissioning dates are considered.

Investments are possible (depending on the scenario) in specific projects or generic projects. Specific projects are modelled one by one and have specific technology data (earliest commission date, installed capacity, efficiency, etc.), whereas the generic projects are modelled on the country level, have a total possible capacity and common technology data.

This approach differs from conventional power plants, which are always represented in blocks of plants (like the generic nuclear plants). Each block has performance factors averaged within a certain region and vintage block (decade) and a life dependent degradation of efficiency and life fixed operation and maintenance costs.

The nuclear fleet, including the replacement of plants due for retirement, is modelled on its economic merit and in competition with other energy sources for power generation except for Member States with legislative provisions on nuclear phase out. Several constraints are put on the model such as decisions of Member States not to use nuclear at all (Austria, Cyprus, Denmark, Estonia, Greece, Ireland, Latvia, Luxembourg, Malta and Portugal) and closure of existing plants in some Member States according to agreed schedules (e.g. Germany). Nuclear investments are possible in all the other countries.

Existing nuclear fleet representation

The nuclear data for each power plant covers the net installed capacity in MW, the thermal efficiency and the date of beginning commercial operation. The data is taken from the PRIS database of IAEA[10], plant operators, Member State nuclear regulators and industry organisations such as the World Nuclear Association.

Lifetime assumptions for the existing nuclear park

The model 'operates' nuclear power plants as long as (i) this is economically favourable compared to closing and investing in alternative supply technologies and (ii) the nuclear plant does not reach the end of its lifetime. The JRC-EU-TIMES implements scenarios based on technical and political assumptions for the maximum plant lifetimes. These vary depending on the Member State:

- **Explicit end of operation dates** are used for member States in which a phase out policy is in place (BE, DE and, to a degree, CH) or that explicitly state the end of a license (NL). Fixed closure dates are also applied to selected power plants in other Member States in which operators have indicated to close nuclear power plants for economic reasons (reactors Ringhals 1,2 and Oskarshamm 1,2 in Sweden). According to the goal to limit the French nuclear capacity at 63.2 MW[11], it is assumed that the two units at Fessenheim

[10] https://www.iaea.org/pris/
[11] http://www.developpement-durable.gouv.fr/Renforcer-la-surete-nucleaire-et-l,41397.html

cease operation in 2017. End of life dates for the existing UK fleet have been taken from the operator's (EDF ENERGY) publication as these exceed the current regulatory period. Finally, this option has been applied to power plants which have been decommissioned in the time period between the base year for the model calibration and today.

- **Generic reactor lifetimes** are used in all other cases assuming that the operators of existing reactors will be able to renew their operating licenses. Technical lifetimes of up to 60 years are envisaged by most nuclear operators and possible in the most ambitious scenario. Taking into account that licenses might not be prolonged for political reasons, scenarios with shorter reactor lifetimes have been prepared.

Figure 11 shows the installed capacity of the current nuclear fleet as a function of time for three different scenarios, differentiated by the maximum lifetime of the existing nuclear power plants. Fixed closure dates remain the same in all scenarios.

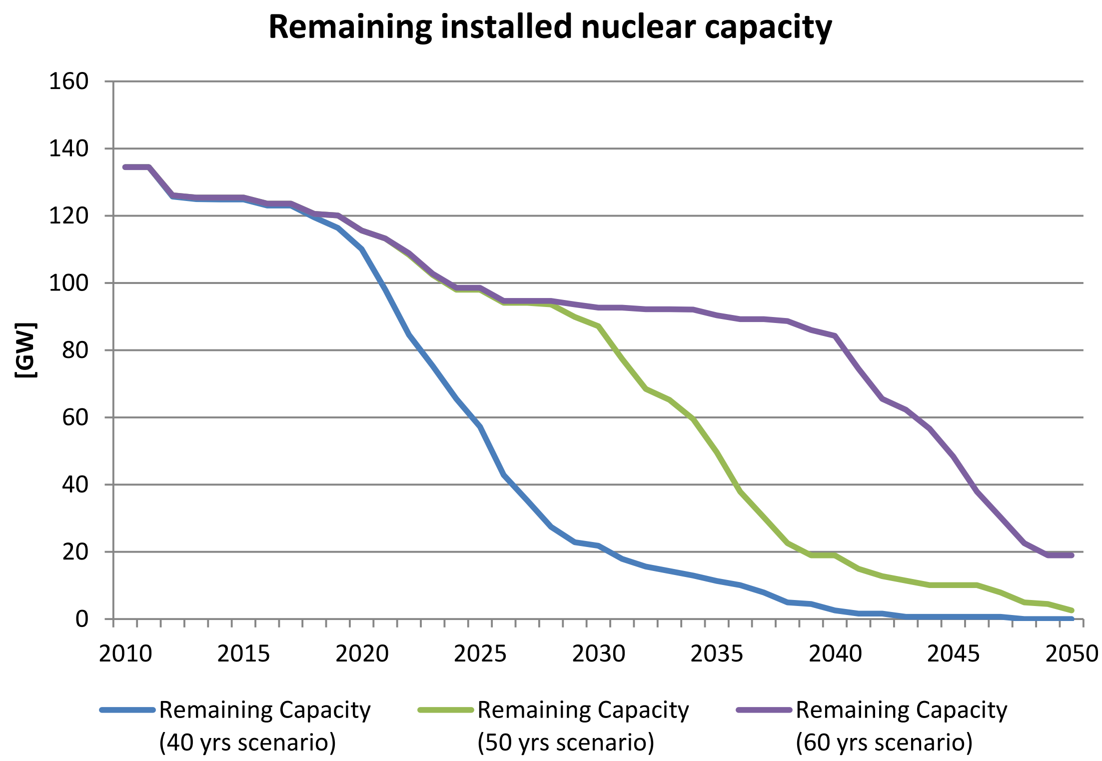


Figure 11 - Development of the capacity of the currently installed nuclear power fleet in the EU

Within the baseline for HRE4, 40 years scenario is used including the option of reinvestment for a 20 years plant lifetime extension to bring this life to 60 years.

3.7. Renewable resources

RES maximum potentials are defined for the HRE4 baseline as in the JRC-EU-TIMES report[12] including the following updates:

1. Wind 2050 potentials have been updated based on wind-water-solar report[13] from the Standford University[14], which considers a maximum of 6.5% of the land for onshore wind, a function of population density and minimum operating hours. For offshore potentials, the assumptions included 5% of usable coastline, distances between 10-100 km from the shore, mostly based on NREL[15]. For both technologies, a power density of 7.2 MW/km^2 was used.
2. Forestry biomass potentials[16] have been updated following the results of a JRC Biomass internal project[17] A high mobilization scenario (HM) has been used. The forestry biomass availability in this scenario has been formulated assuming that "the full forest harvest potential is exploited for material and/or energy purposes, under equilibrium conditions for the forest, i.e. the forest exploitation will result CO_2 neutral, not being a sink nor a source of carbon". In this way, the forest biomass availability shown in Table 6 will be over the reference levels considered in the proposal for a LULUFC directive (COM/2016/0479 final - 2016/0230 (COD)), if historical reference levels based on increasing sinks would be adopted. The potential debit CO_2 resulting from fully using these potentials can be compensated by other LULUCF sectors (such as afforestation) or by other finally approved flexibility mechanisms. Secondly, wood pellets apparent consumption for the whole of EU as modelled by GFTM[18] is forced to double between 2015 and 2030, reaching a level of 40 million tons by 2030. We deem this increase, though steep, as being plausible. In GFTM, for all other wood-based commodities within the EU and for all commodities outside the EU, projections of production, trade and apparent consumption are derived as solutions to the welfare-optimization problem under resource, technology and equilibrium constraints, without the addition of any further exogenous assumption. Table 6 illustrates de total maximum energy potential available from forestry products for 2050, as considered for the HRE4 baseline.

[12] Simoes, Nijs, Ruiz, Sgobbi, Radu, Bolat, Thiel, Peteves (2013), The JRC-EU-TIMES model. Assessing the long-term role of the SET Plan Energy technologies. JRC Scientific and Policy Reports. Luxemburg. doi: 10.2790/97596.
[13] Jacobson et al., 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World, Joule (2017), http://dx.doi.org/10.1016/j.joule.2017.07.005
[14] https://web.stanford.edu/group/efmh/jacobson/Articles/I/CountriesWWS.pdf
[15] http://www.nrel.gov/docs/fy13osti/55049.pdf
[16] Ruiz Castello Pablo; Sgobbi Alessandra; Nijs Wouter; Thiel Christian;et al (2015). The JRC-EU-TIMES model. Bioenergy potentials for EU and neighbouring countries. . JRC Scientific and Policy Reports. Luxemburg. doi: 10.2790/39014
[17] Public version of internal work to be released.
[18] https://ec.europa.eu/jrc/en/publication/global-forest-trade-model-gftm

Table 6 Potential (PJ) for wood-based forestry commodities (excluding pellets) for 2050

Country	Potential		Country	Potential		Country	Potential
Austria	34		France	177		Netherland	2
Belgium	6		Greece	5		Norway	25
Bulgaria	11		Croatia	9		Poland	23
Switzerland	14		Hungary	19		Portugal	15
Cyprus	0		Ireland	1		Romania	30
Czech Republic	11		Iceland	0		Sweden	75
Germany	93		Italy	58		Slovenia	12
Denmark	6		Lithuania	14		Slovakia	4
Estonia	11		Luxembourg	0		United Kingdom	8
Spain	22		Latvia	20			
Finland	37		Malta	0			

3.8. Fossil indigenous resources

For the HRE4 baseline, indigenous fossil resources for crude oil, natural gas and coal have been kept as in the JRC-EU-TIMES report[19]. Originally they were defined by national expert modellers within the NEEDS and RES2020 EU projects, and later updated within the REACCESS research project.

[19] Simoes, Nijs, Ruiz, Sgobbi, Radu, Bolat, Thiel, Peteves (2013), The JRC-EU-TIMES model. Assessing the long-term role of the SET Plan Energy technologies. JRC Scientific and Policy Reports. Luxemburg. doi: 10.2790/97596.

4. Baseline EU28 results

In this section, HRE4 baseline results[20] for the EU28 are shown to illustrate the main average trends. In "Annex 1: MS baseline results", more detailed results are presented for the 14 HRE4 target MS.

4.1. Energy consumption

Energy consumption in the HRE4 baseline follows the evolution depicted in Figure 12. Driven by the policy targets considered in the baseline scenario, from 2010 to 2030 the gross energy consumption[21] is reduced for the whole EU28. In the 2010-2050 period, the contribution of fossil fuel to the energy mix is reduced by 29% from 15264 to 10745 TWh, while the nuclear contribution remains pretty stable, with an 8% increase. On the renewable side, biomass will still be the main contributor, reaching 1556 TWh by 2050, and followed by the 1061 TWh coming from wind sources.

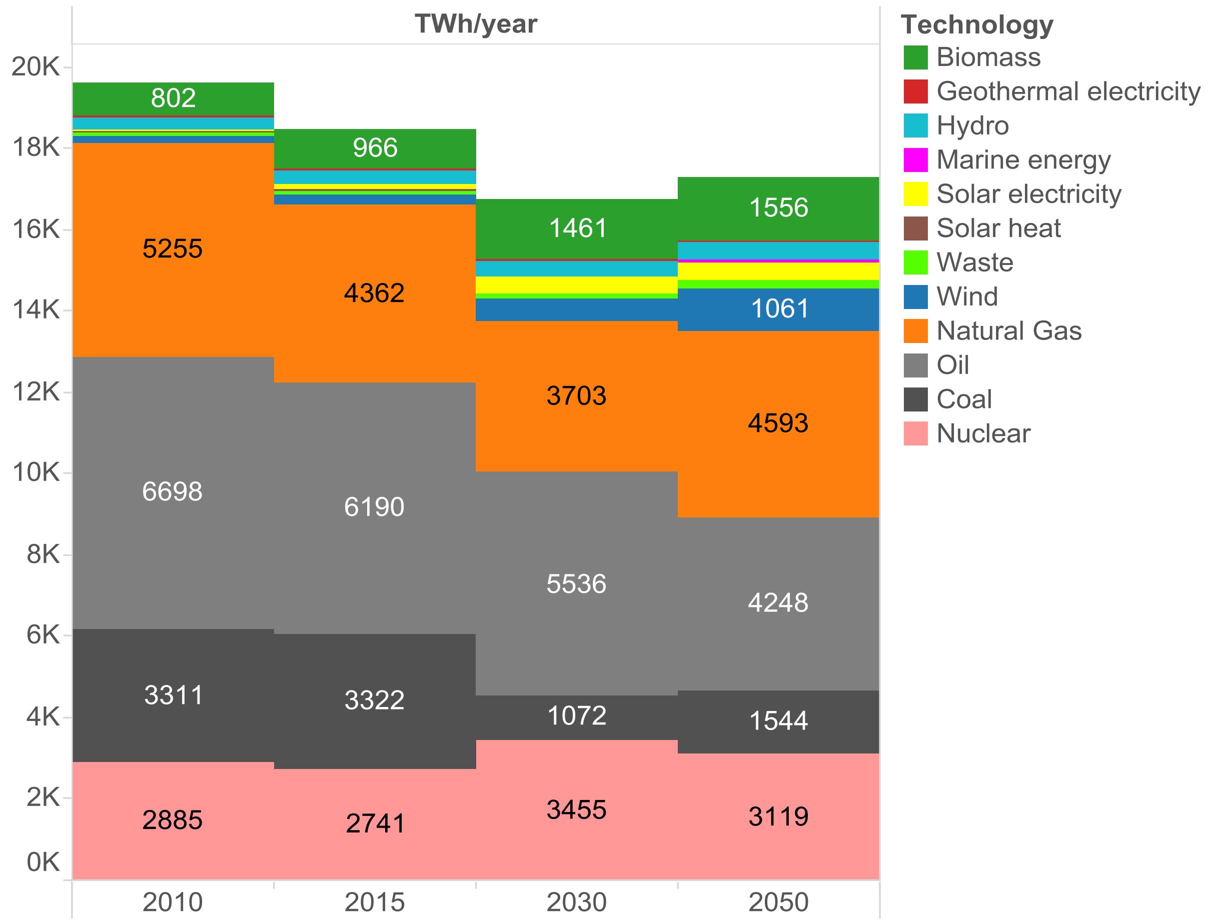


Figure 12 HRE4 Baseline total gross energy consumption for EU28, 2010-2050 (TWh/year)

[20] Disclaimer: 2015 is a model output and although close to Eurostat, there might be deviations. For that reason, we also added the year 2010 which is the calibration year of JRC-EU-TIMES.
[21] Gross energy consumption includes primary energy consumption plus non-energy uses.

4.2. Sectoral energy consumption

Focusing on end use-sectors for EU-28 in the HRE4 baseline, buildings (especially residential dwellings) will concentrate most of the reductions in consumption. Electrification of transport will cover most of its future consumption increase, with a limited role of hydrogen by 2050. Industry will have a small increase since 2015 onwards, keeping a mostly stable energy mix where biomass gradually replaces natural gas. Agriculture is anticipated to have stable consumption and mix, while the transformation sector will experience a slight decrease in its consumption, more and more dominated by petroleum.

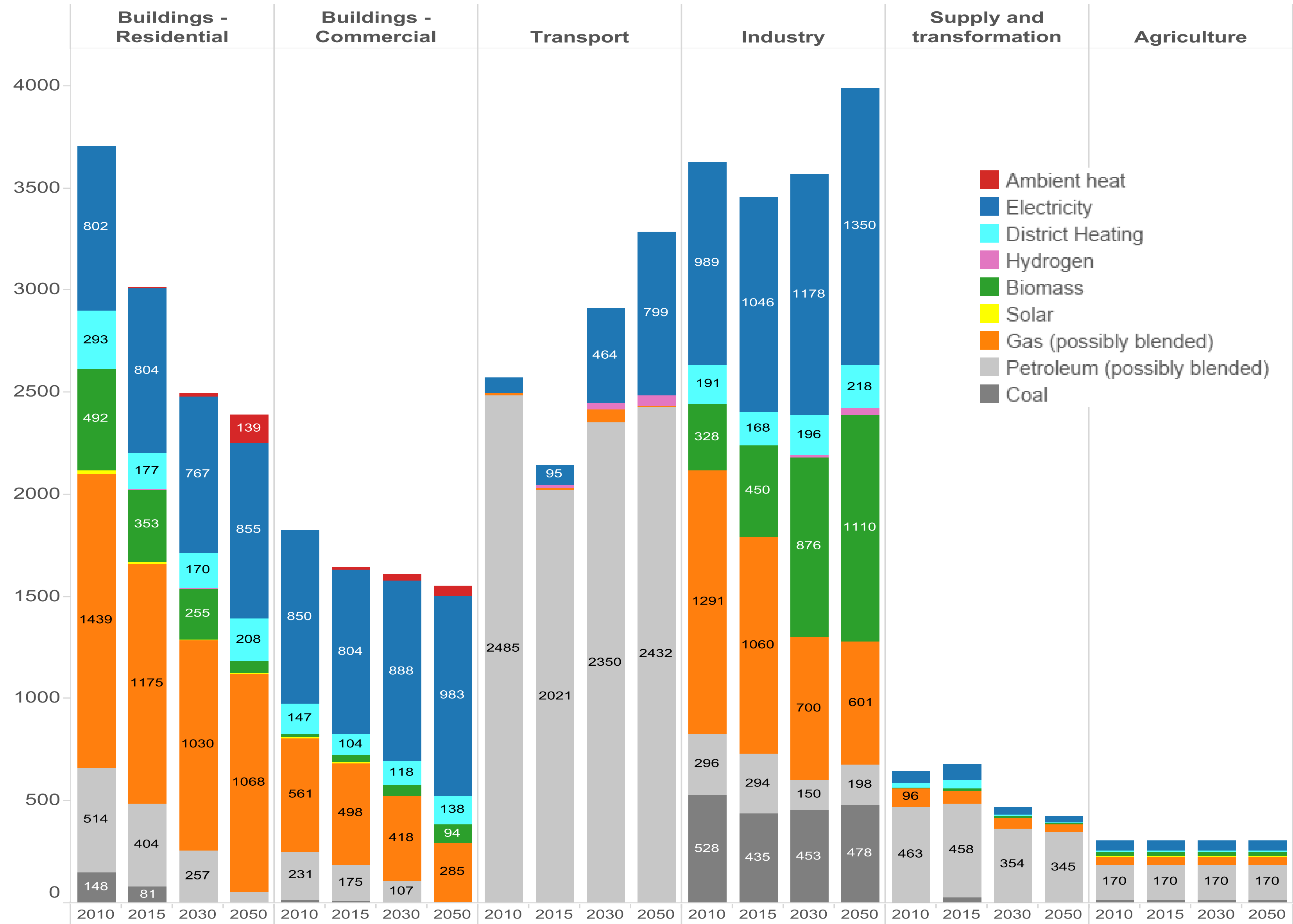


Figure 13 HRE4 baseline sectoral energy consumption for EU28, 2010-2050 (TWh/year) – industry CHP reported with fuel inputs.

4.3. Heating and cooling

As one of the key sub-sectors for the HRE4, heating and cooling are considered in the baseline with a high technology detail level in JRC-EU-TIMES. As shown in Figure 14, both residential and commercial buildings are expected to concentrate a very significant part of the consumptions reductions due to energy efficiency targets. Figure 14 and Figure 15 illustrates how these reductions will be distributed among the heating and cooling technologies.

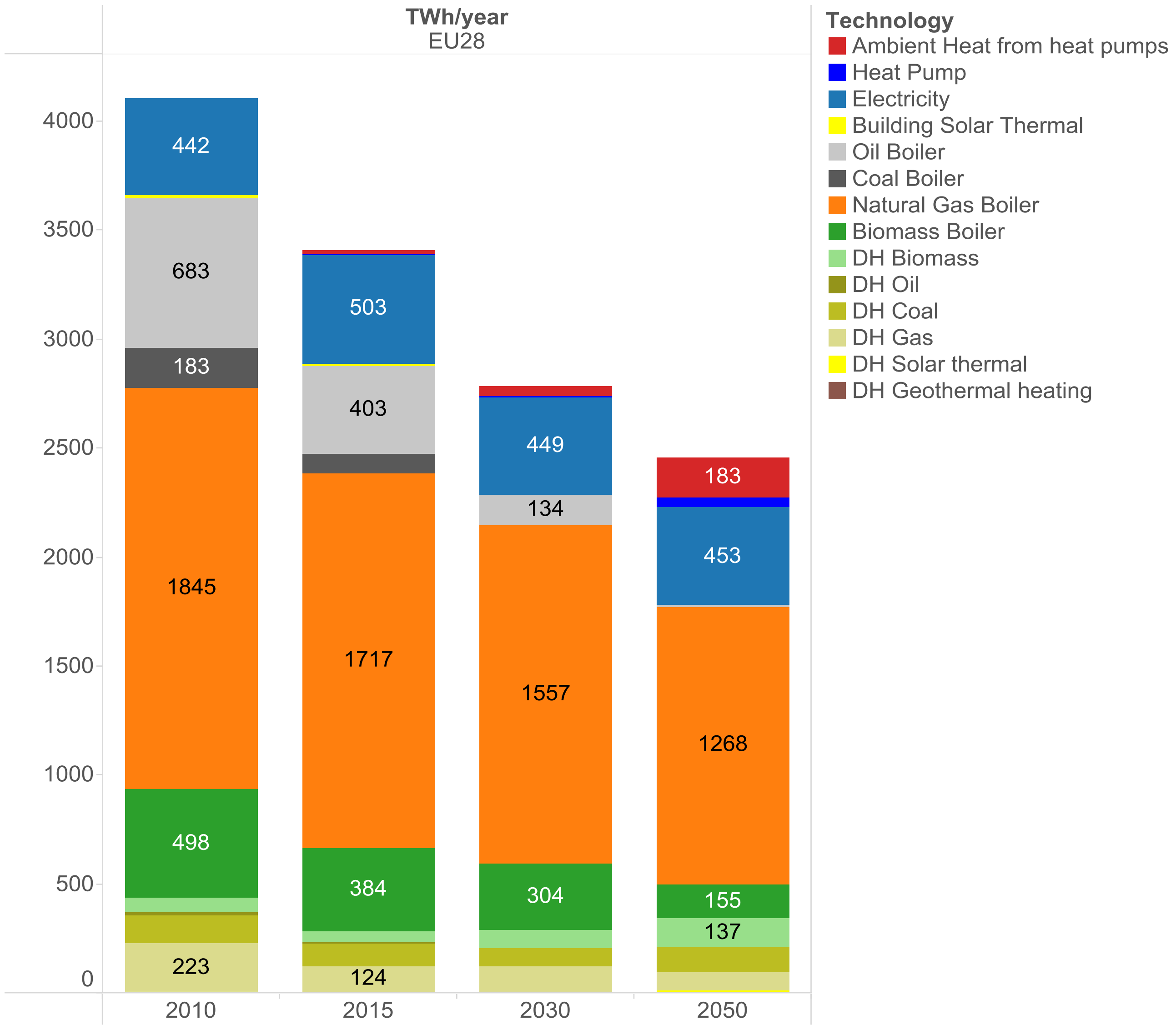


Figure 14 HRE4 baseline Heating and Hot water final energy for buildings sector, EU28, 2010-2050 (TWh/year) For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.

Coal and oil boilers experience a dramatic reduction from 2010 to 2030, virtually disappearing by 2050, because of their CO_2 emissions. Natural gas boilers will reduce their contribution by 30% from 1845 to 1268 TWh. A remarkable increase in DH fuelled by biomass is expected to reach 263 TWh by 2050, when heat pumps will also contribute to the supply mostly with ambient heat.

In industry, while heating and cooling keep a similar level of consumption from 2010 to 2050, some remarkable changes can be expected in the energy mix, as Figure 15 depicts. Biomass fuelled systems will gradually displace gas based systems, while oil and coal will keep their shares in key industries.

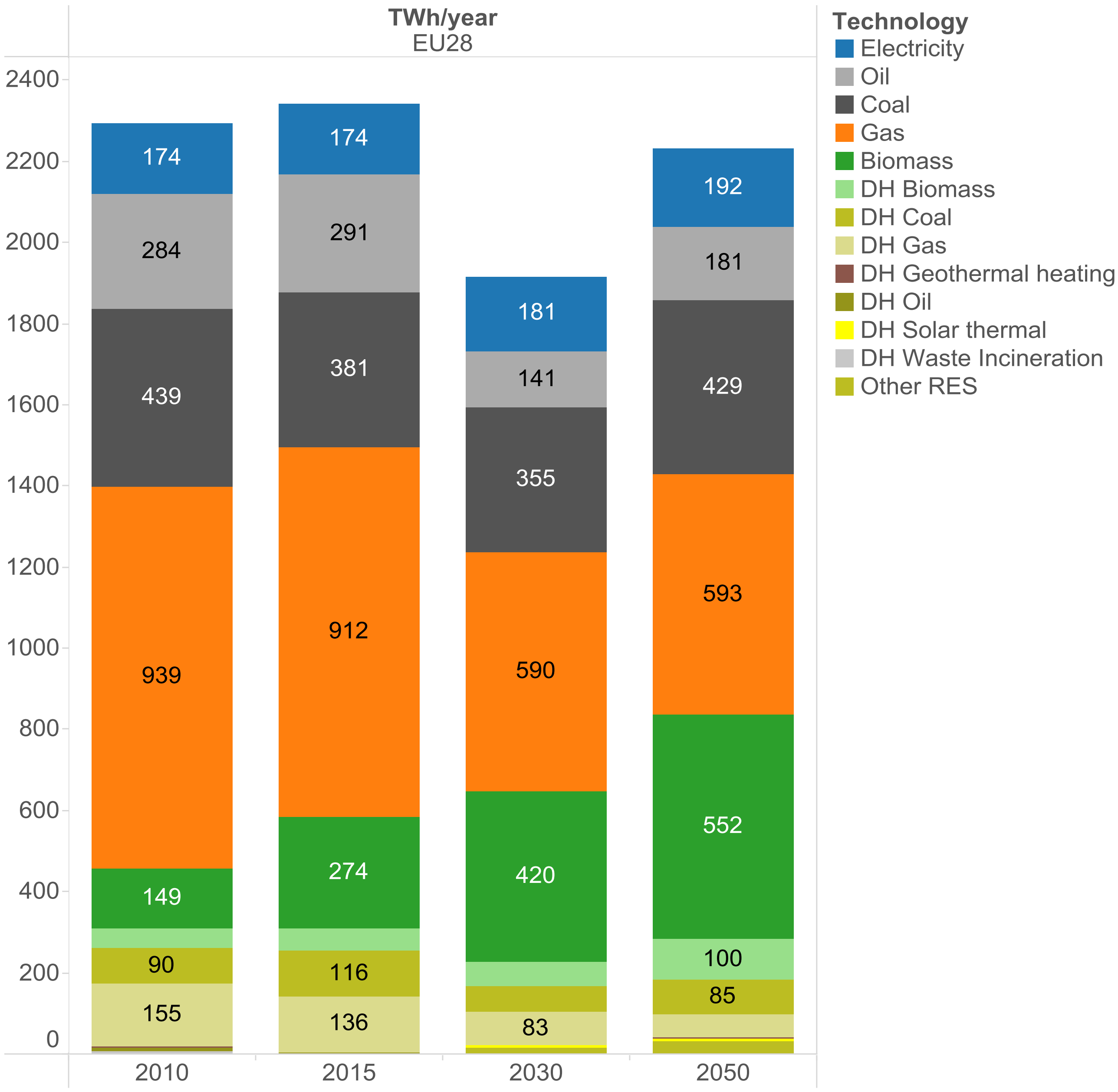


Figure 15 HRE4 baseline H&C for Industry sector, EU28, 2010-2050 (TWh/year)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.

4.4. Power generation

The power sector will steadily increase its production, driven by the electrification of the transport sector. From 2010 to 2050, the amount of installed generation capacity will almost double, increasing from almost 800 GWe to more than 14000 GWe. Most of this increase can be explained by newly installed PV and wind capacity. PV grows from below 50GWe to almost 400 GWe, while wind installed power increases from 80 GWe to 470 GWe, including 81 GWe of offshore wind. Biomass-fired capacity reaches almost 70 GWe by 2050 in the HRE4 baseline, while coal and oil will be marginal by 2050.

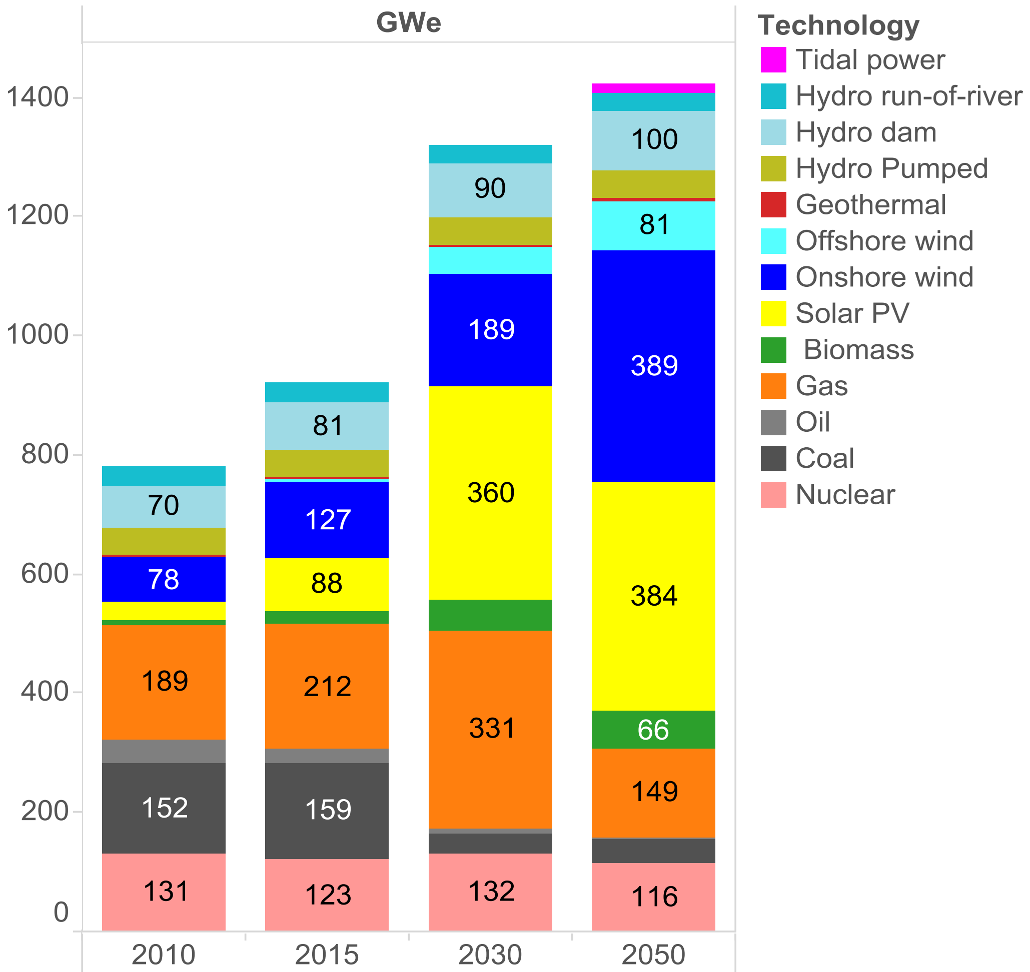


Figure 16 HRE4 baseline power sector, installed capacities, EU28, 2010-2050 (GWe)

Given the described evolution of the energy mix, electricity generation will reflect the corresponding changes. While nuclear generation stays pretty stable, showing even a slight increase by 2030 and 2050, coal generation is almost phased out by 2030. Natural Gas based generation is reduced by 638 TWh/year from 2010 to 2050, falling down to 1338 TWh. This energy is below the total RES based generation, where 920 TWh from biomass, 448 TWh from PV and 766 TWh from wind onshore are the main contributors.

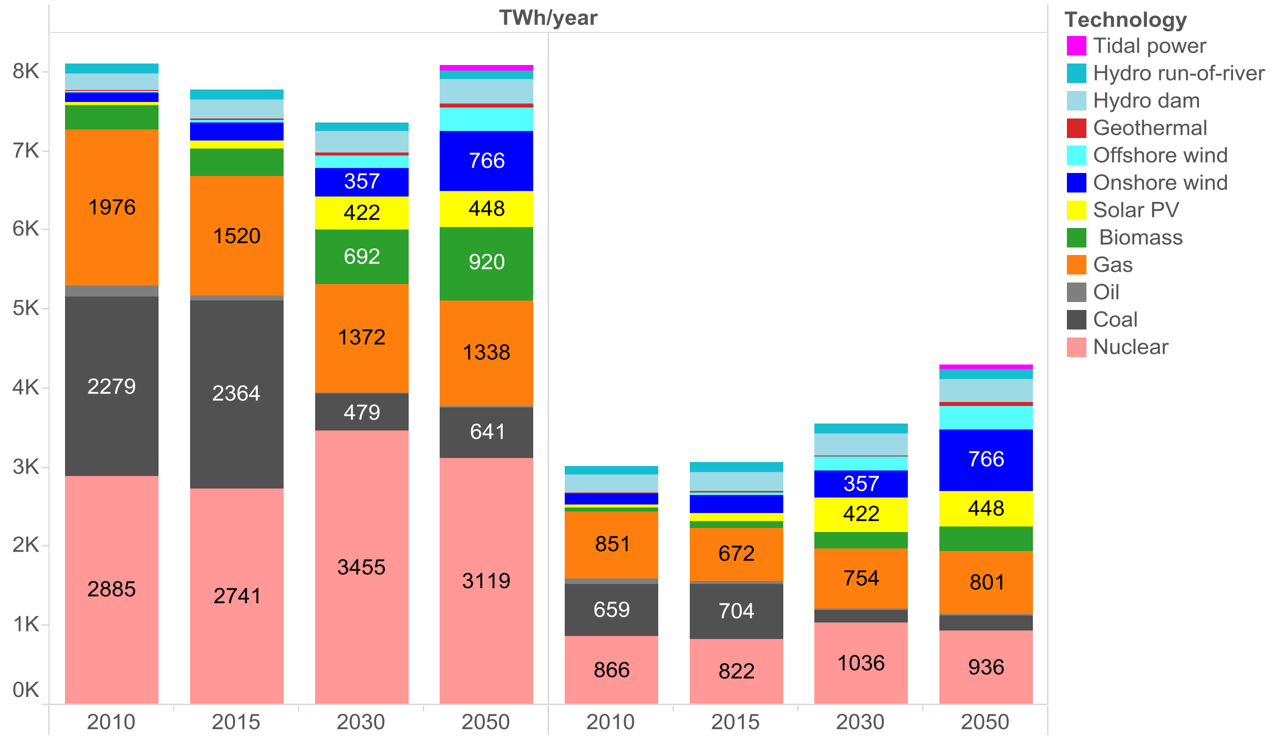


Figure 17 HRE4 baseline power sector, generated electricity by technology, EU28, 2010-2050 (TWh/year)

The JRC-EU-TIMES model considers variable generation balance through the method described in section 2.2. Figure 18 shows a bench marking of the output resulting from the JRC-EU-TIMES approach. The graph compares the share of VRES, other RES and fossil and nuclear generation in a selected key foresight exercises. As it can be seen, HRE4 baseline VRES balance results pretty close to one on EU Reference Scenario from the European Commission, turning out more conservative than the IEA ETP.

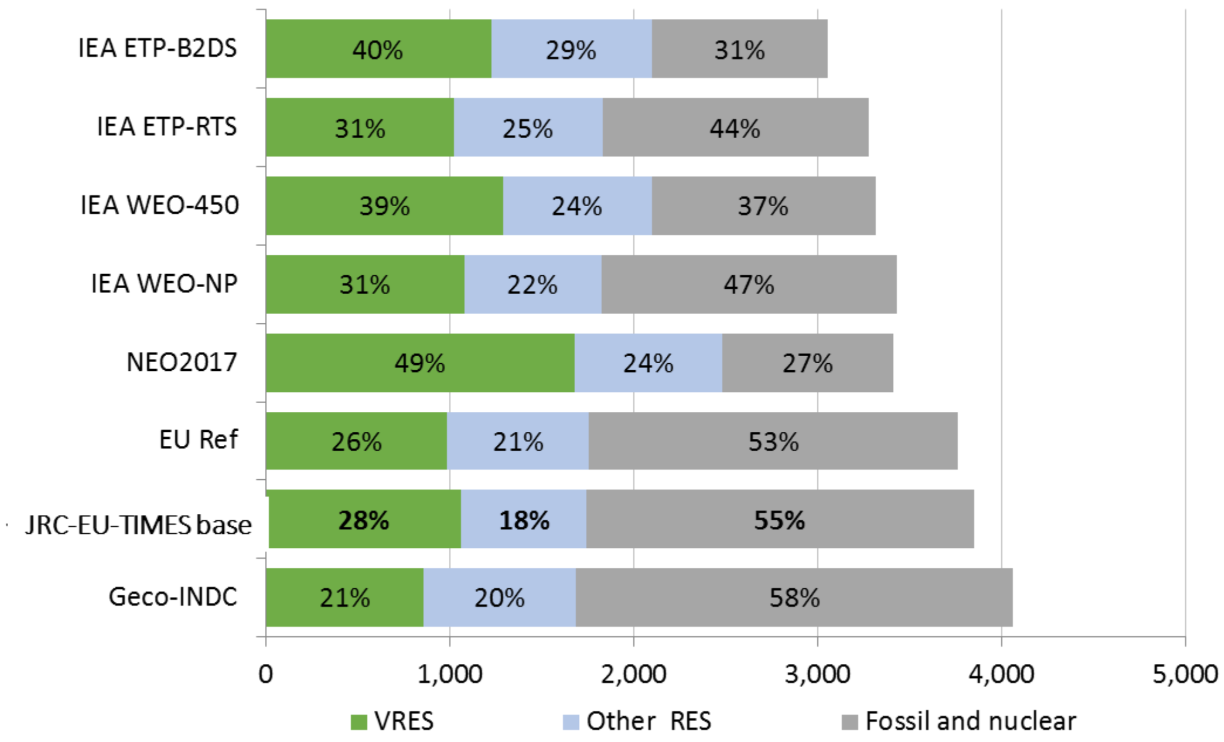


Figure 18 HRE4 baseline power sector. VRES balance across different key EU28 scenarios for 2040

4.5. Transport

Figure 19 shows the number of vehicles in the EU28 energy system. The uptake of electric vehicles is modelled as described in Figure 10. Following this approach, the remarkable deployment of EVs starts by 2030. Between 2015 and 2030, 55 millions of electric cars break into the market. By 2050, electric cars will represent more than 60% of the total car fleet.

On energy terms, Figure 20 illustrates the referred transformation, were the biofuel used in flexible vehicles keeps some relevance until 2030. The decarbonisation of the transport sector is mainly driven by the penetration of electric vehicles. Decarbonisation takes place first in the car fleet, followed to a lesser degree by trucks.

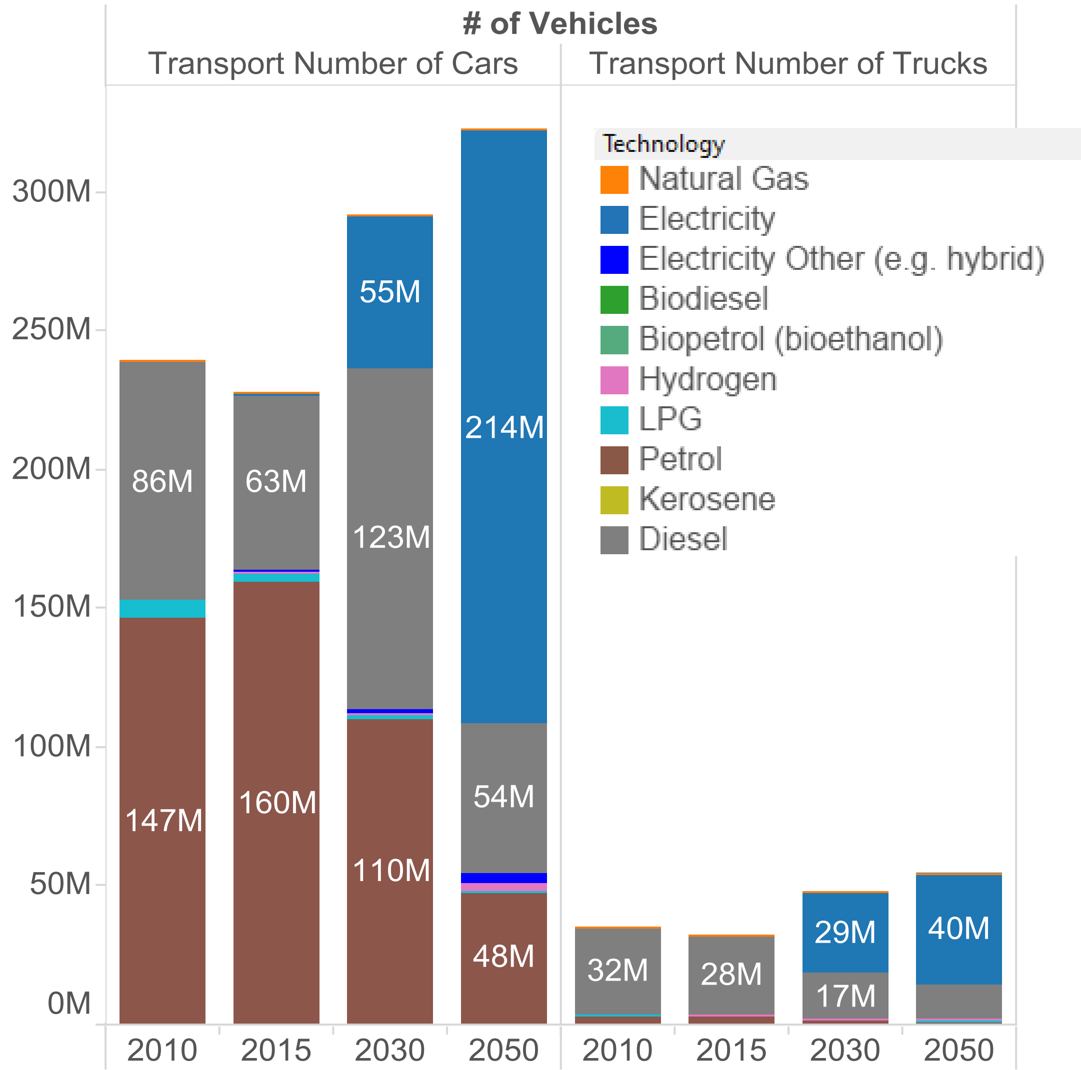


Figure 19 HRE4 baseline transport sector, millions of cars & trucks by fuel, EU28, 2010-2050

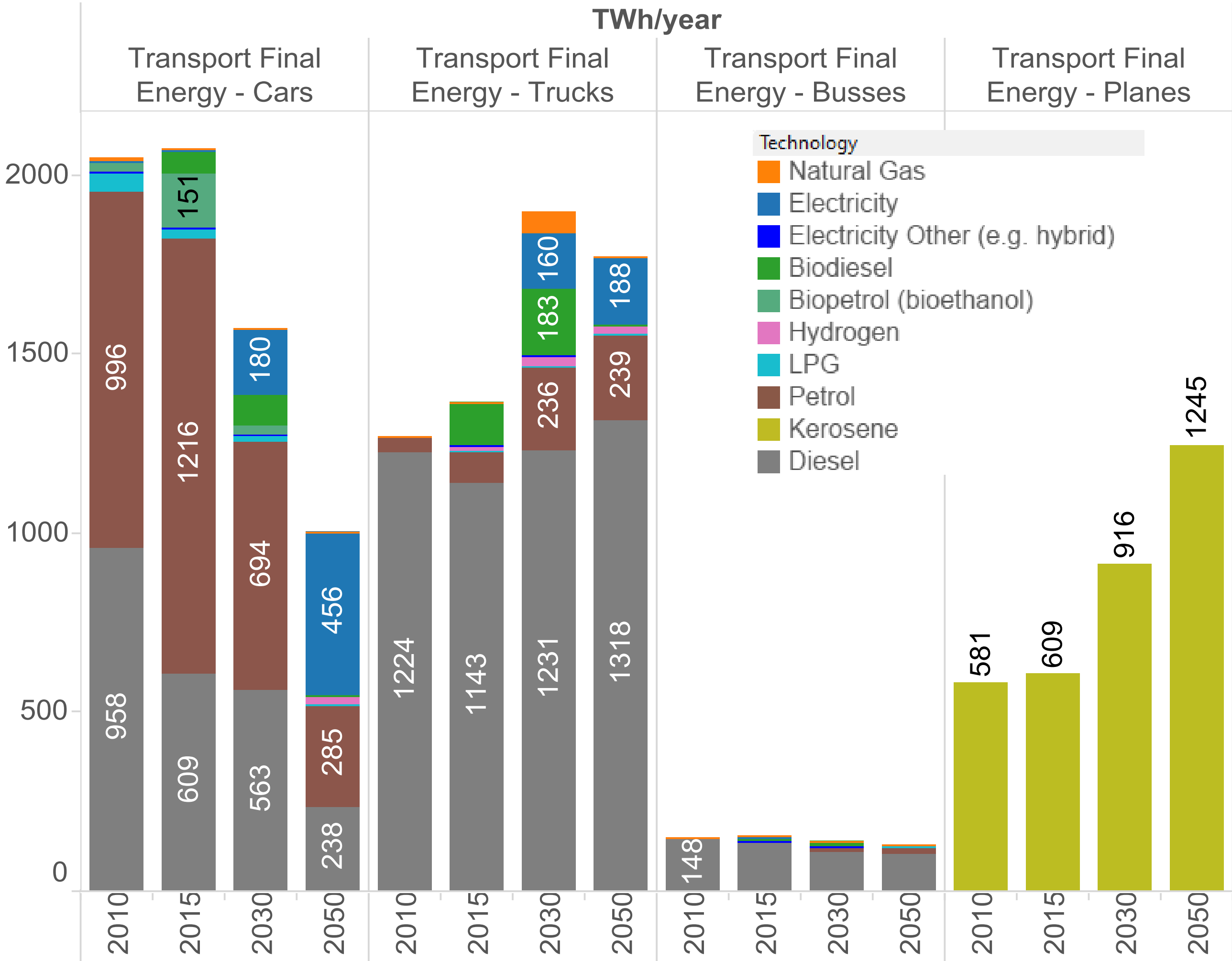


Figure 20 HRE4 baseline transport sector, energy consumption (TWh/year) by vehicle type and fuel, EU28, 2010-2050

4.6. CO_2 emissions

Energy related CO_2 emissions in the HRE4 baseline follow the pathways resulting from the policy target as described in section 3.3. Figure 21 illustrates how the effort of the referred policies model results distribute across the efforts needed to meet the referred targets. The main reductions come from the decarbonisation of the power sector, followed by reductions in emissions from buildings and transport. Renewable production in the power sector contributes to decarbonisation of transport through its electrification while, as seen in section 4.3, buildings reduce emissions through investment in energy efficiency measures to reduce the required energy consumption. The industry also contributes to the reduction by almost halving its emissions from 2010 to 2050.

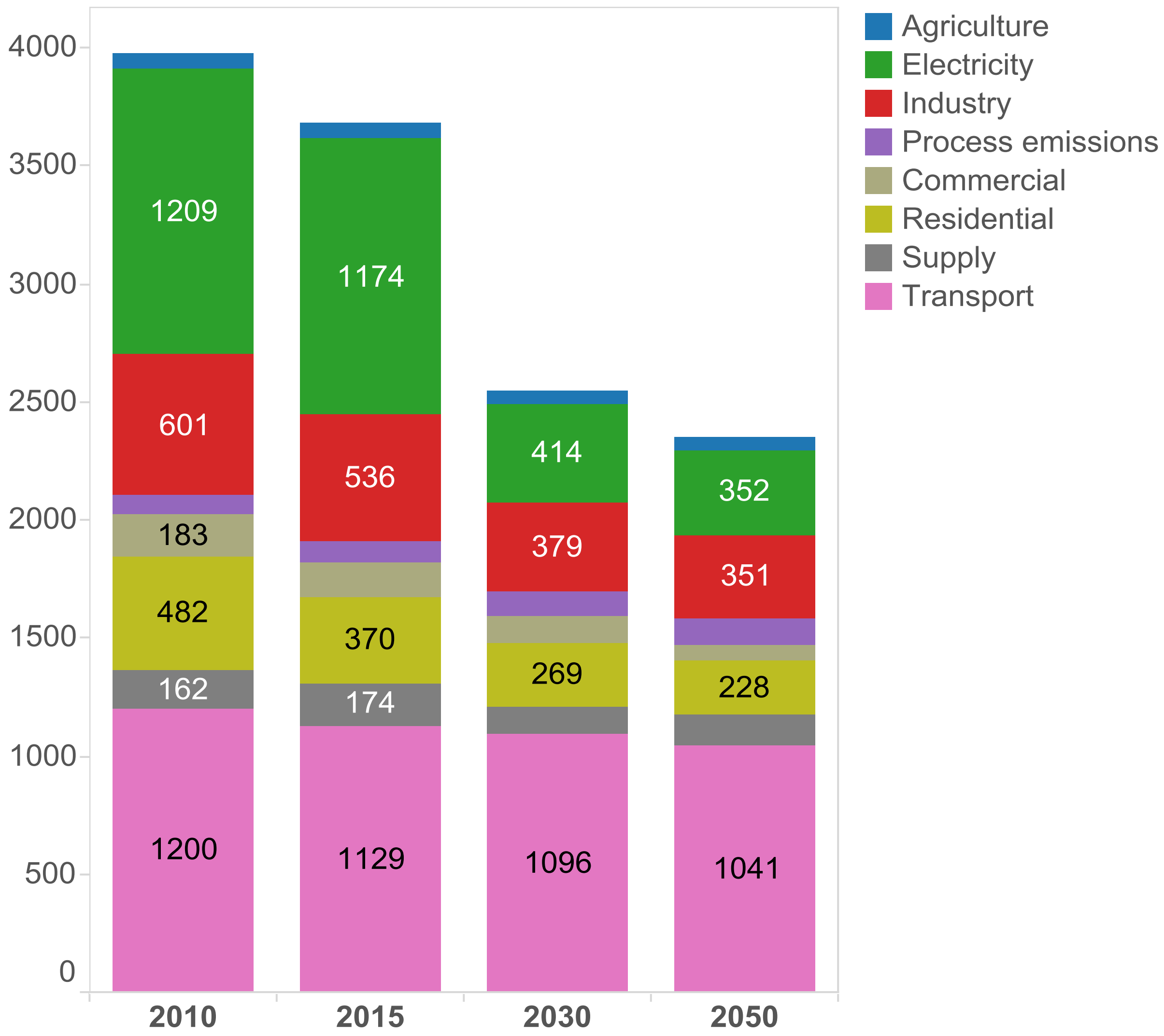


Figure 21 HRE4 baseline CO_2 emissions ($ktCO_2$) by sector, EU28, 2010-2050

4.7. Investments in the residential sector

Figure 22 shows which investments are needed along 2020 to 2050 to materialize the described reduction of emissions and energy consumption in the residential sector. While main investments will remain centred in gas to supply heat, insulation will become close to halve of such amount. There is an initial DH potential investment of 206 BEUR in the residential sector.

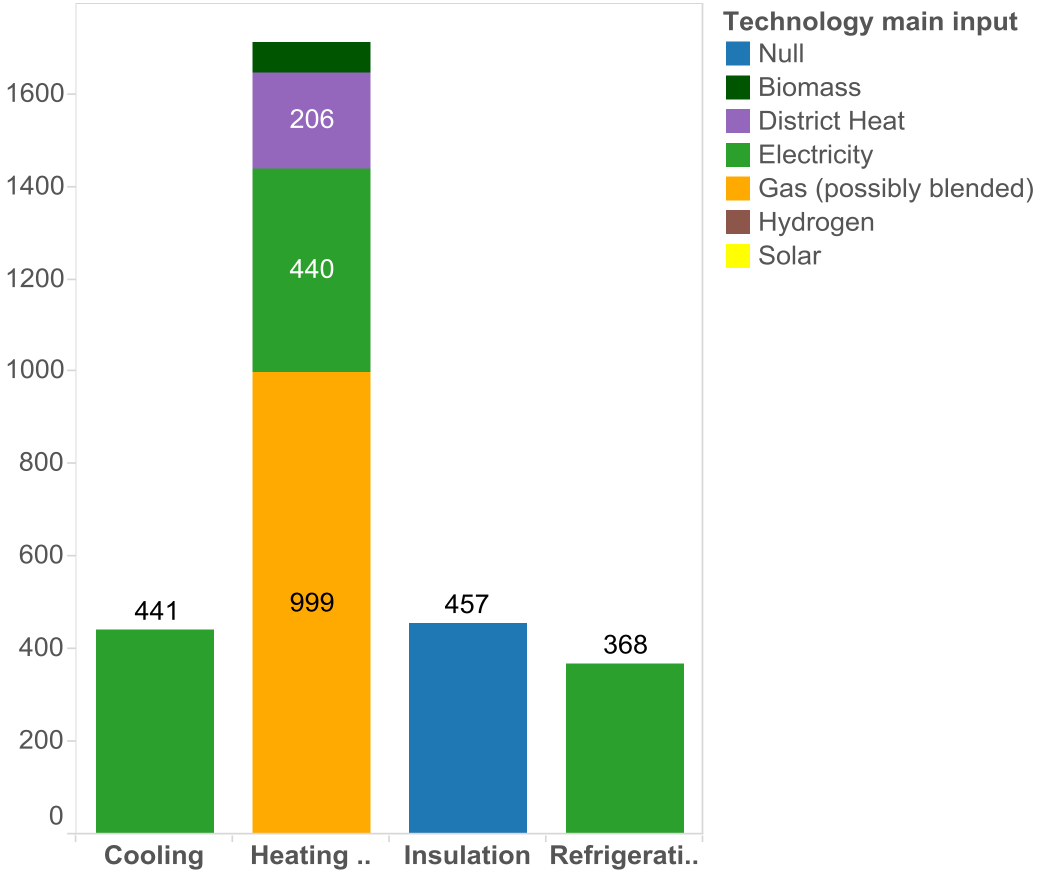


Figure 22 HRE4 baseline 2020-2050 Investments (BEUR) in the residential sector, EU28. Legend abbreviations: Heating and Hot water - Refrigeration

4.8. Investments in the electricity sector

Decarbonisation of the power sector is reached through the investments shown in Figure 23. Nuclear and wind result to be the two main invested technologies.

Investments are expressed in billion EUR (BEUR) for each period. The biggest investments are on wind and nuclear generation capacity, followed by solar. By 2050, 376 BEUR and 363 BEUR are invested in wind and nuclear respectively, while PV follows with 127 BEUR. The key investment cycle should begin by 2025, while the investments are remarkably concentrated in the 2030-2050 period.

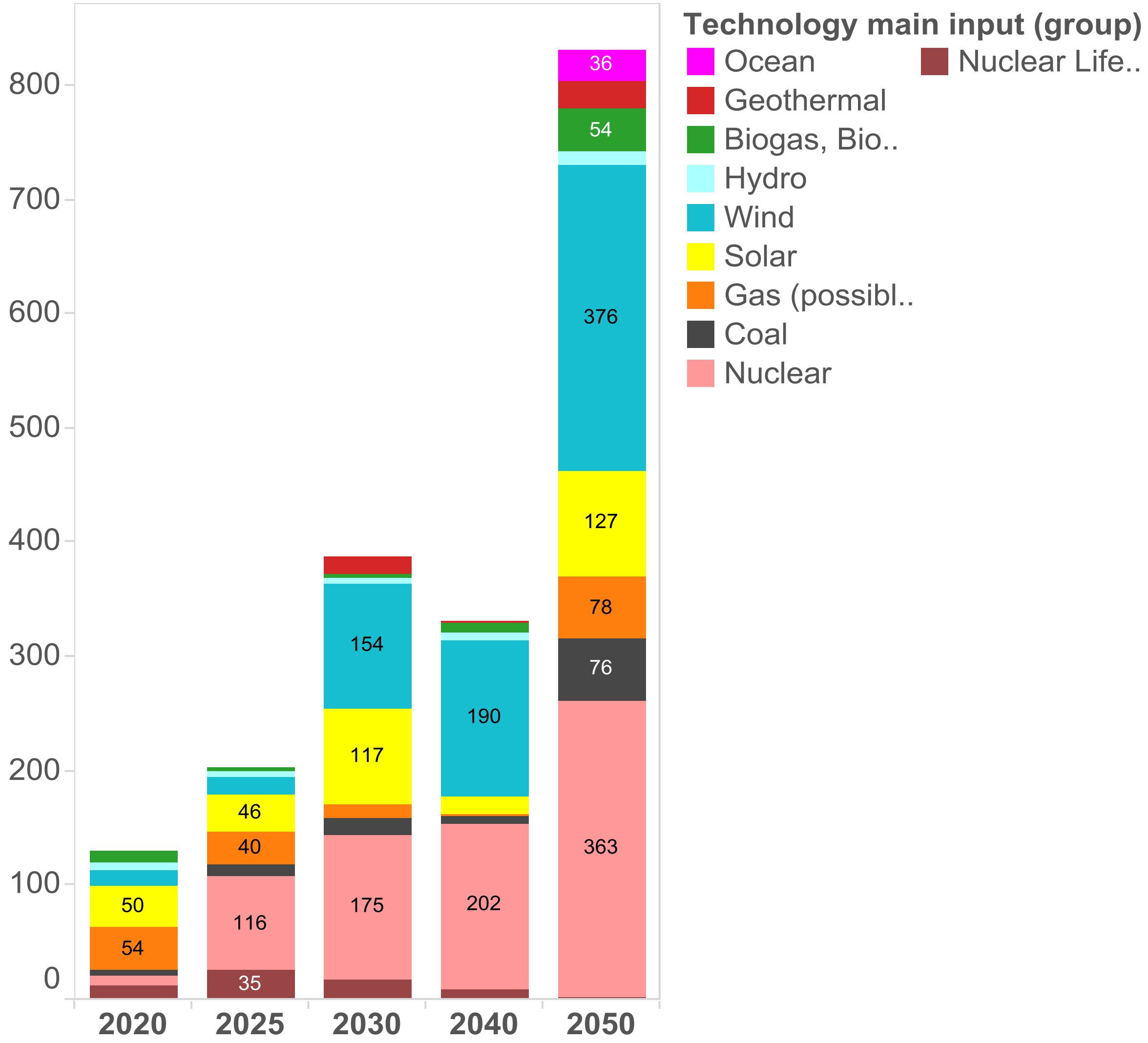


Figure 23 HRE4 baseline 2020-2050 Investments (BEUR) per period in the power sector, EU28. Legend abbreviations: Biogas, Biomass - Gas (possibly blended) - Nuclear Lifetime Extensions

5. Impacts of energy and climate targets

All the energy and climate related targets interact with each other and there can also be interaction between the modelling periods. These interactions result in different technology choices. All targets contribute to the reduction of CO_2 emissions, however some work at the EU level and some at MS level. As the energy and climate targets are a key driver of the baseline solution, in this section its impact on the HRE4 baseline is analysed.

For 2030, the combined impact of renewable energy and primary energy targets drives the overall CO_2 emissions below the CO_2 target (resulting in a 37% reduction, compared with targeted -36%, when referred to 2005). The non-ETS CO_2 emissions target has a very high price, reflecting the additional costs for electric light trucks and for improved fossil internal combustion engine cars. EVs are cost-efficient and could lower this price, if new electric cars entering the market were not restricted as described in Figure 10.

For 2050, the most stringent constraints are the overall CO_2 and the primary energy target, while the renewable energy target is not binding. This means that reducing CO_2 and primary energy requires efforts while, once CO_2 emissions and primary energy consumption are reduced, the renewable production will be already over its target.

Table 7 Individual prices of the most important energy policy constraints in JRC-EU-TIMES, HRE4 baseline

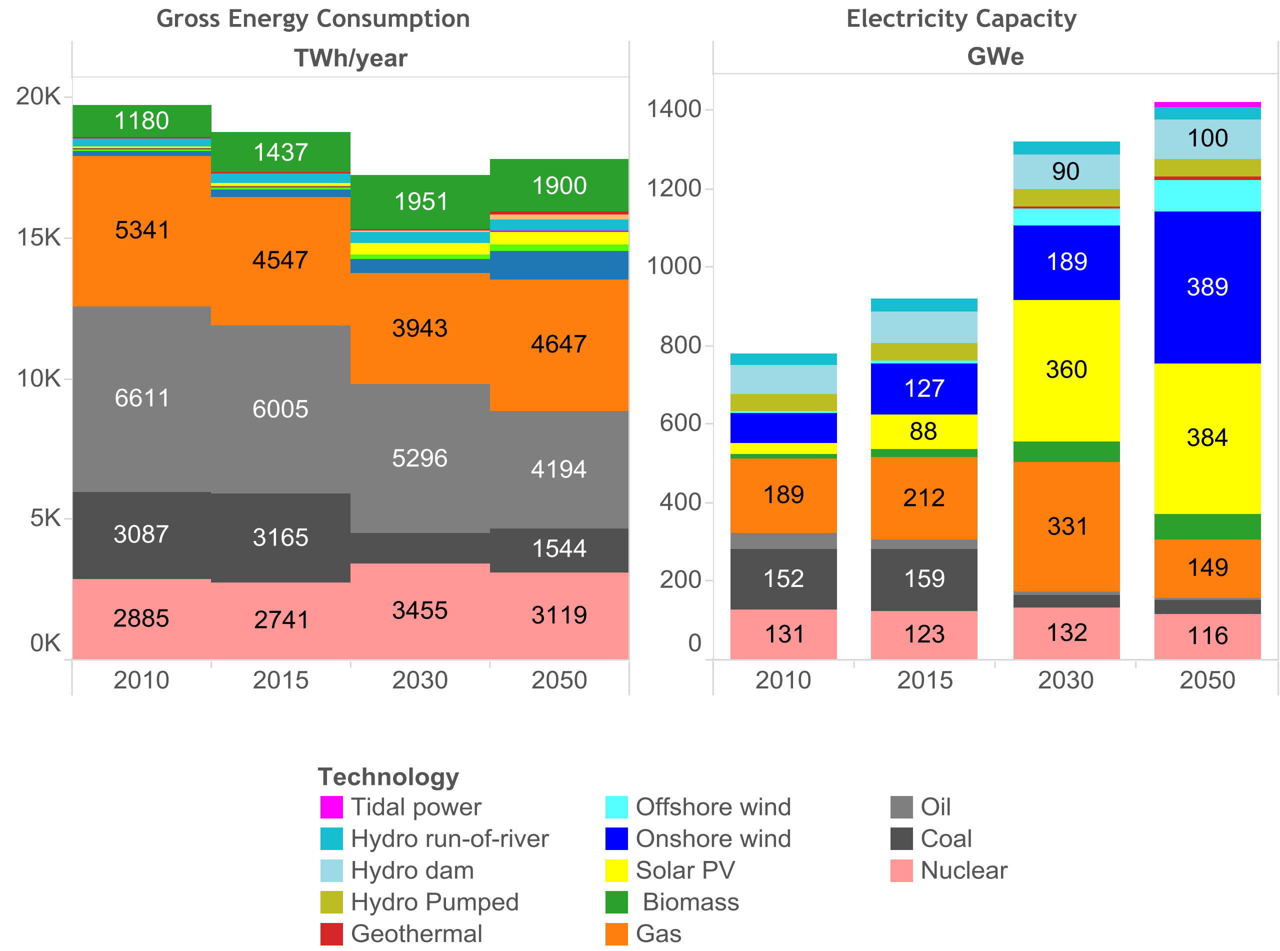
	2030	2050	Unit	
Renewable Energy	27	0	EUR/BOE	(a)
Primary Energy	91	20	EUR/BOE	(b)
CO_2 overall	0	86	EUR/ton	(c)
CO_2 ETS	0	0	EUR/ton	(d)
CO_2 ESR (MS non-ETS)	up to 350	up to 53	EUR/ton	(e)

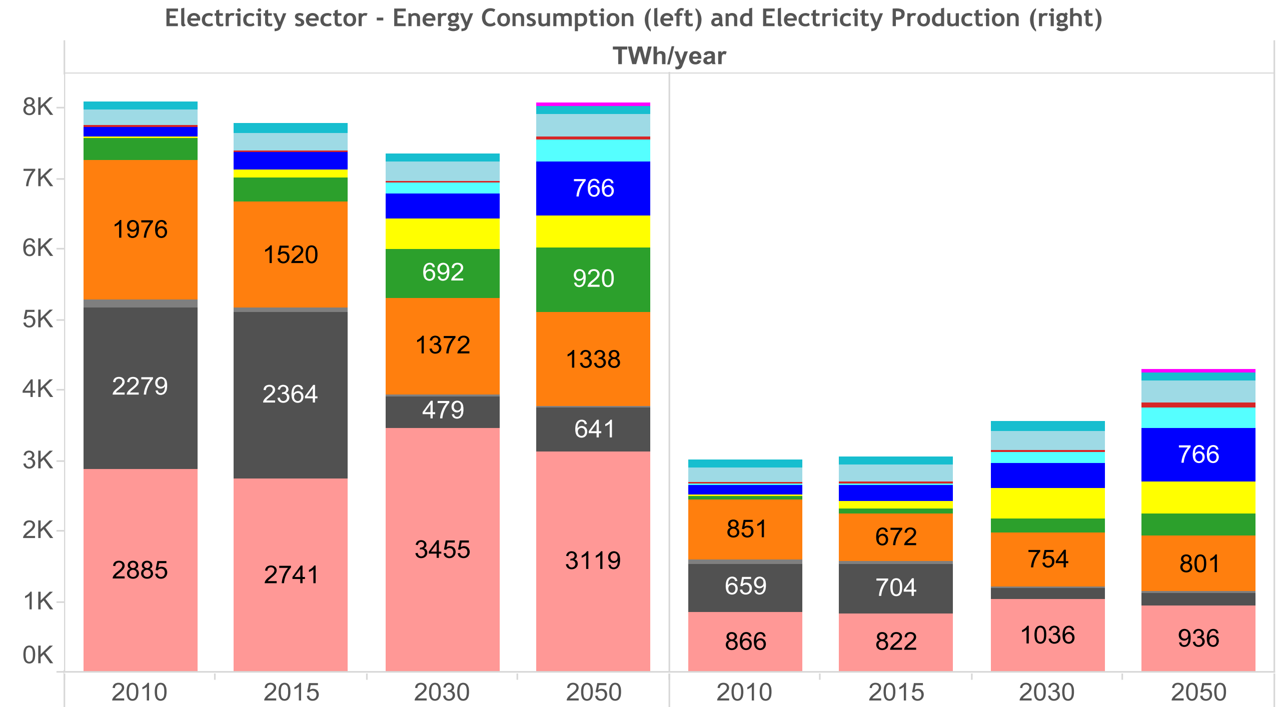
Table 8 Combined prices of emitting CO_2 in JRC-EU-TIMES, HRE4 Baseline

	2030	2050	Unit	
CO_2 ETS	0	86	EUR/ton	(c) + (d)
CO_2 ESR (MS non-ETS)	up to 350	86-139	EUR/ton	(c) + (e)

Annex 1: EU28 and MS baseline results

EU 28

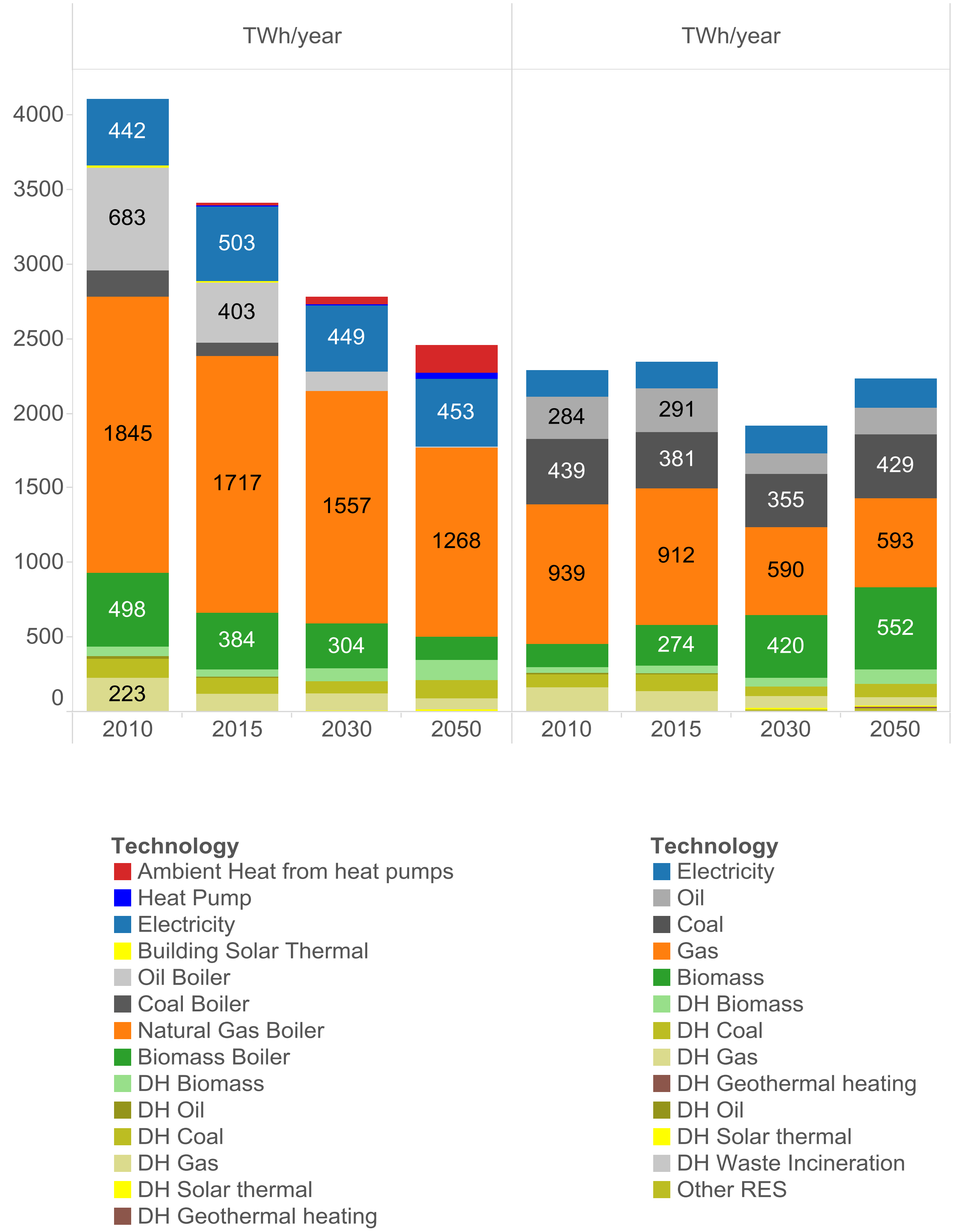

Gross Energy Consumption
TWh/year
20K
15K
10K
5K
0K
1180
5341
6611
3087
2885
1437
4547
6005
3165
2741
1951
3943
5296
3455
1900
4647
4194
1544
3119
2010
2015
2030
2050
Electricity Capacity
GWe
1400
1200
1000
800
600
400
200
0
189
152
131
127
88
212
159
123
90
189
360
331
132
100
389
384
149
116
2010
2015
2030
2050
Technology
Tidal power
Hydro run-of-river
Hydro dam
Hydro Pumped
Geothermal
Offshore wind
Onshore wind
Solar PV
Biomass
Gas
Oil
Coal
Nuclear


Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
8K
7K
6K
5K
4K
3K
2K
1K
0K
1976
2279
2885
1520
2364
2741
692
1372
479
3455
766
920
1338
641
3119
851
659
866
672
704
822
754
1036
766
801
936
2010
2015
2030
2050
2010
2015
2030
2050

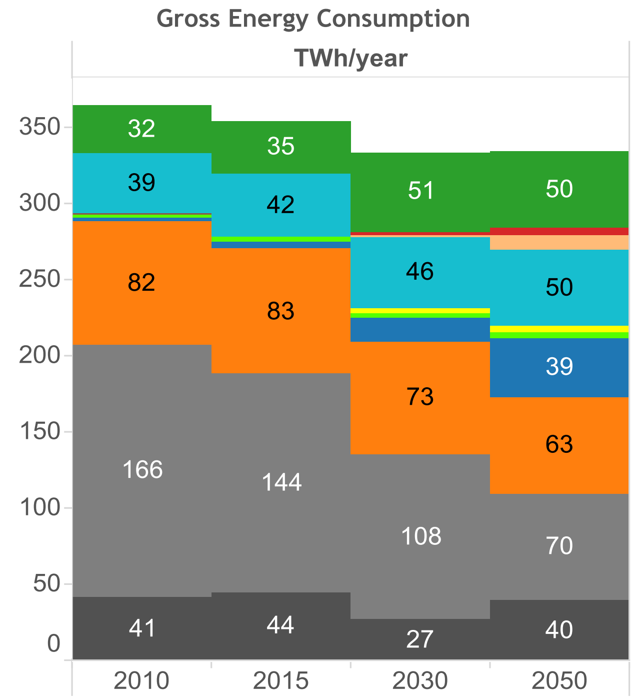
EU28

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

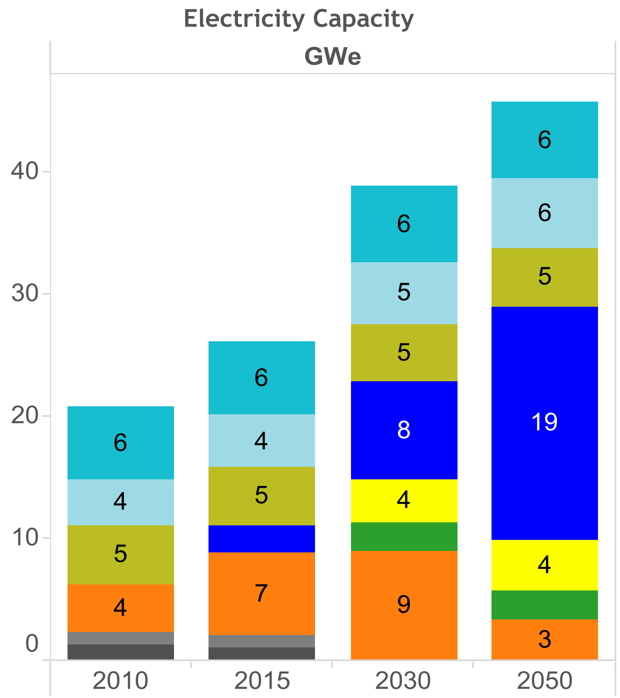
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.



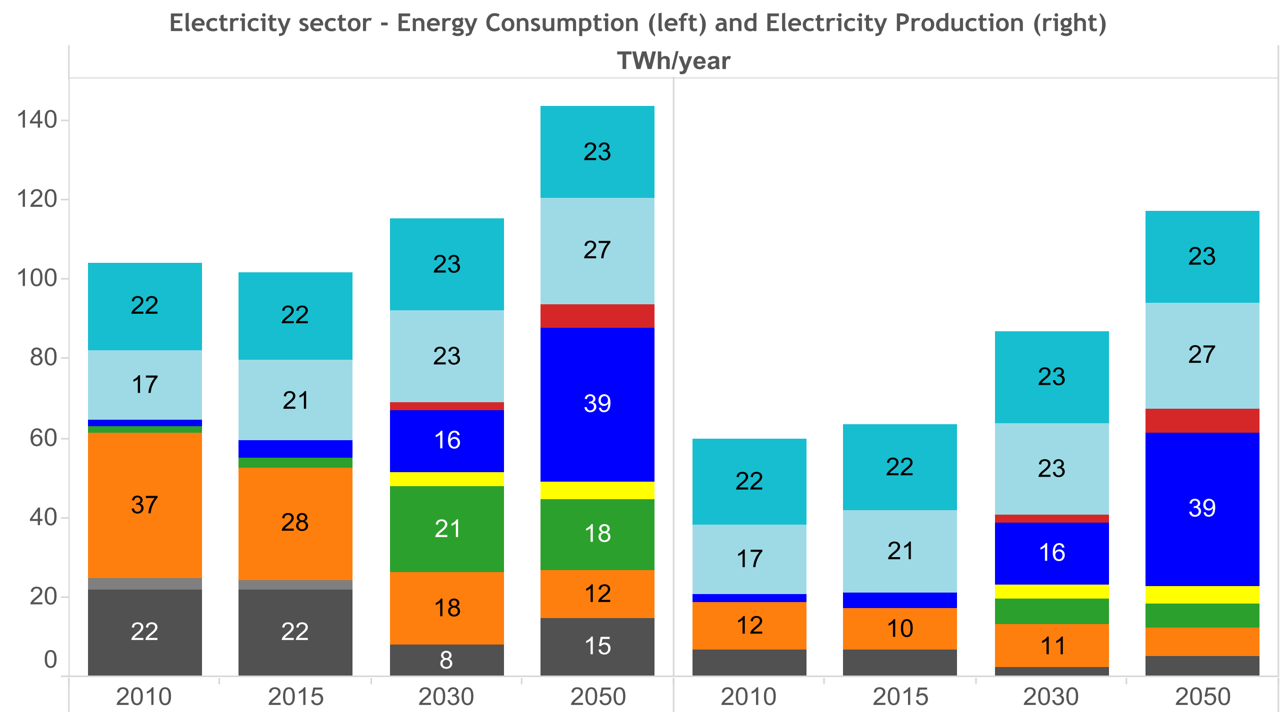
Austria



Gross Energy Consumption
TWh/year
350
300
250
200
150
100
50
0
32
39
82
166
41
35
42
83
144
44
51
46
73
108
27
50
50
39
63
70
40
2010
2015
2030
2050

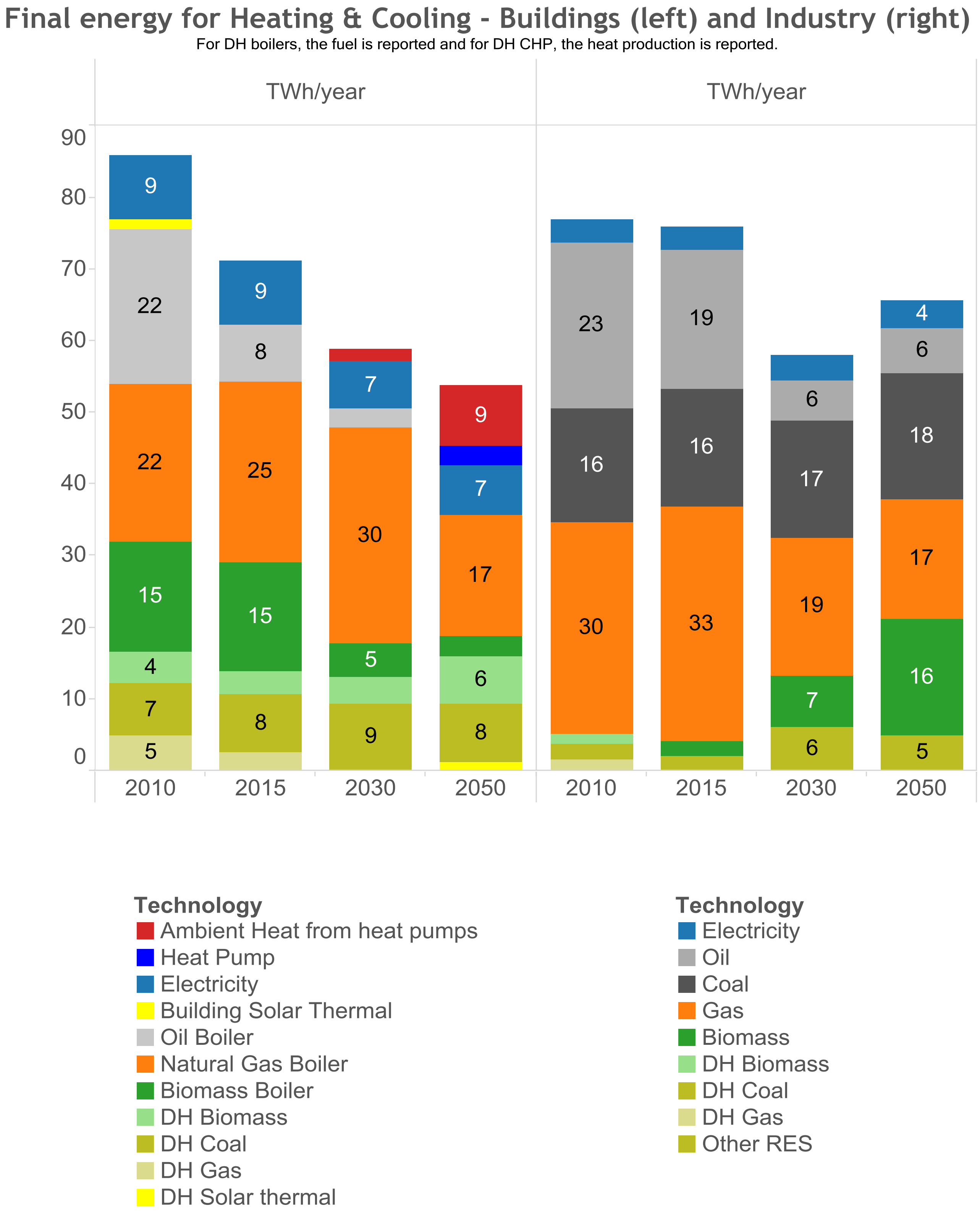


Electricity Capacity
GWe
40
30
20
10
0
6
4
5
4
6
4
5
7
6
5
5
8
4
9
6
6
5
19
4
3
2010
2015
2030
2050
Technology
Hydro run-of-river
Hydro dam
Hydro Pumped
Onshore wind
Solar PV
Biomass
Gas
Oil
Coal

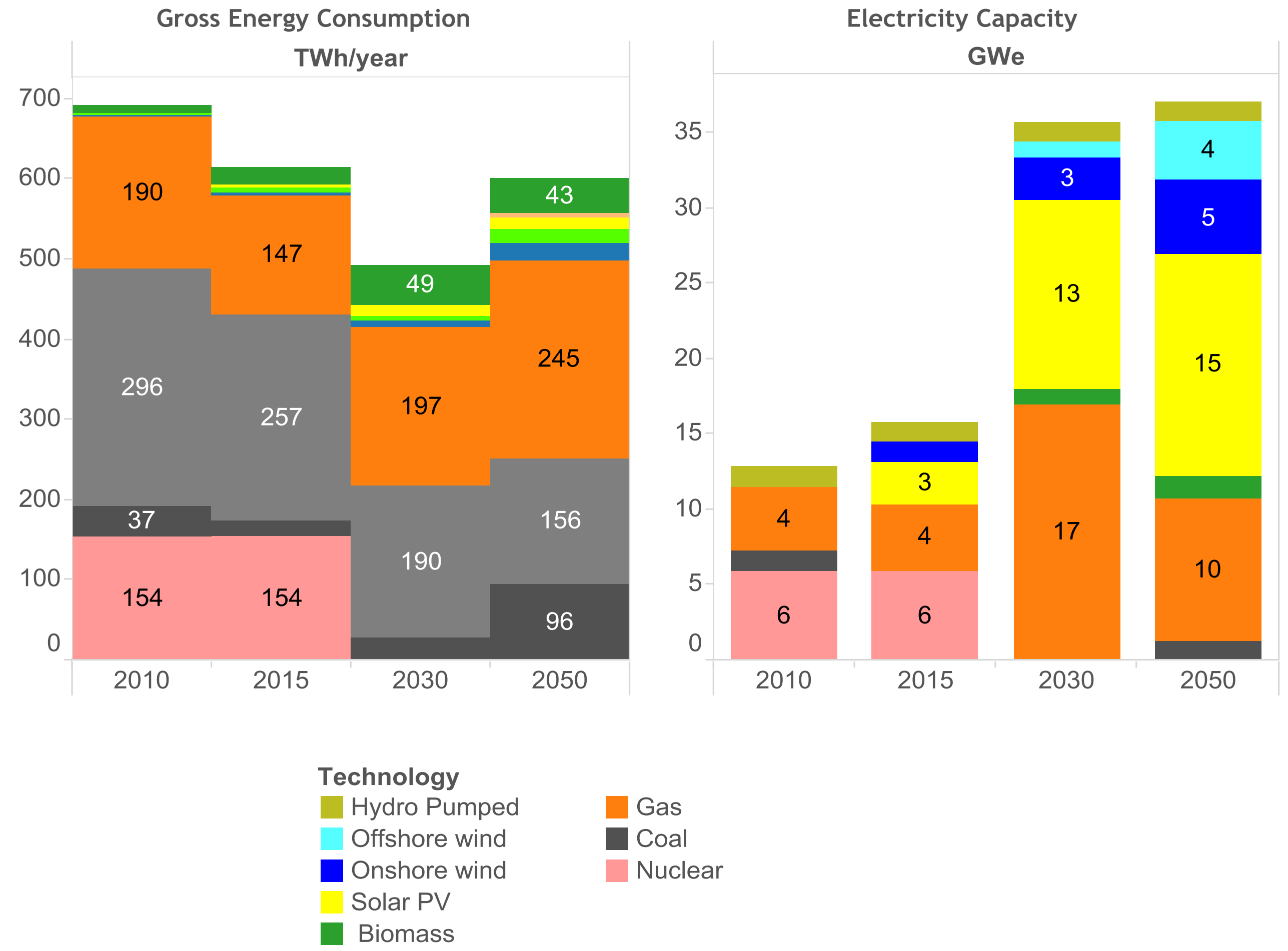


Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
140
120
100
80
60
40
20
0
22
17
37
22
22
21
28
22
23
23
16
21
18
8
23
27
39
18
12
15
22
17
12
22
21
10
23
23
16
11
23
27
39
2010
2015
2030
2050
2010
2015
2030
2050

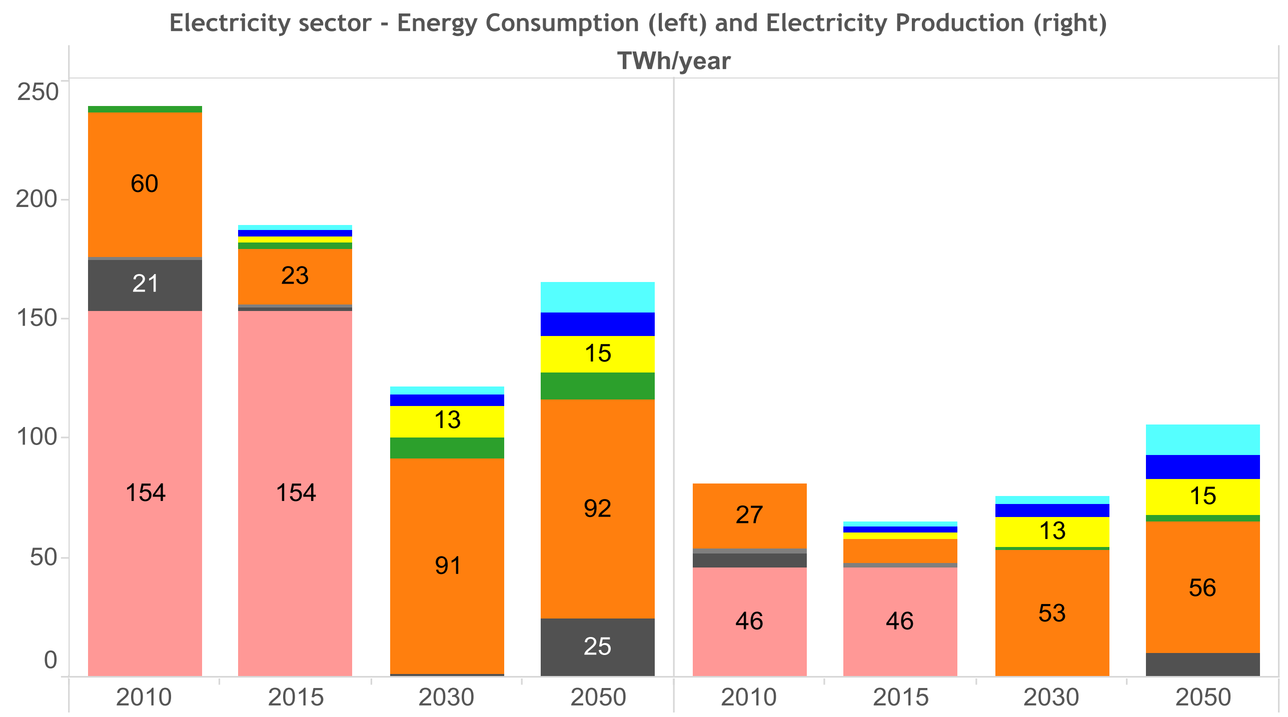
Austria


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.
TWh/year
TWh/year
90
80
70
60
50
40
30
20
10
0
2010
2015
2030
2050
2010
2015
2030
2050
9
22
22
15
4
7
5
9
8
25
15
8
7
30
5
9
9
7
17
6
8
23
16
30
19
16
33
6
17
19
7
6
4
6
18
17
16
5
Technology
Ambient Heat from heat pumps
Heat Pump
Electricity
Building Solar Thermal
Oil Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
DH Coal
DH Gas
DH Solar thermal
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass
DH Coal
DH Gas
Other RES

Belgium

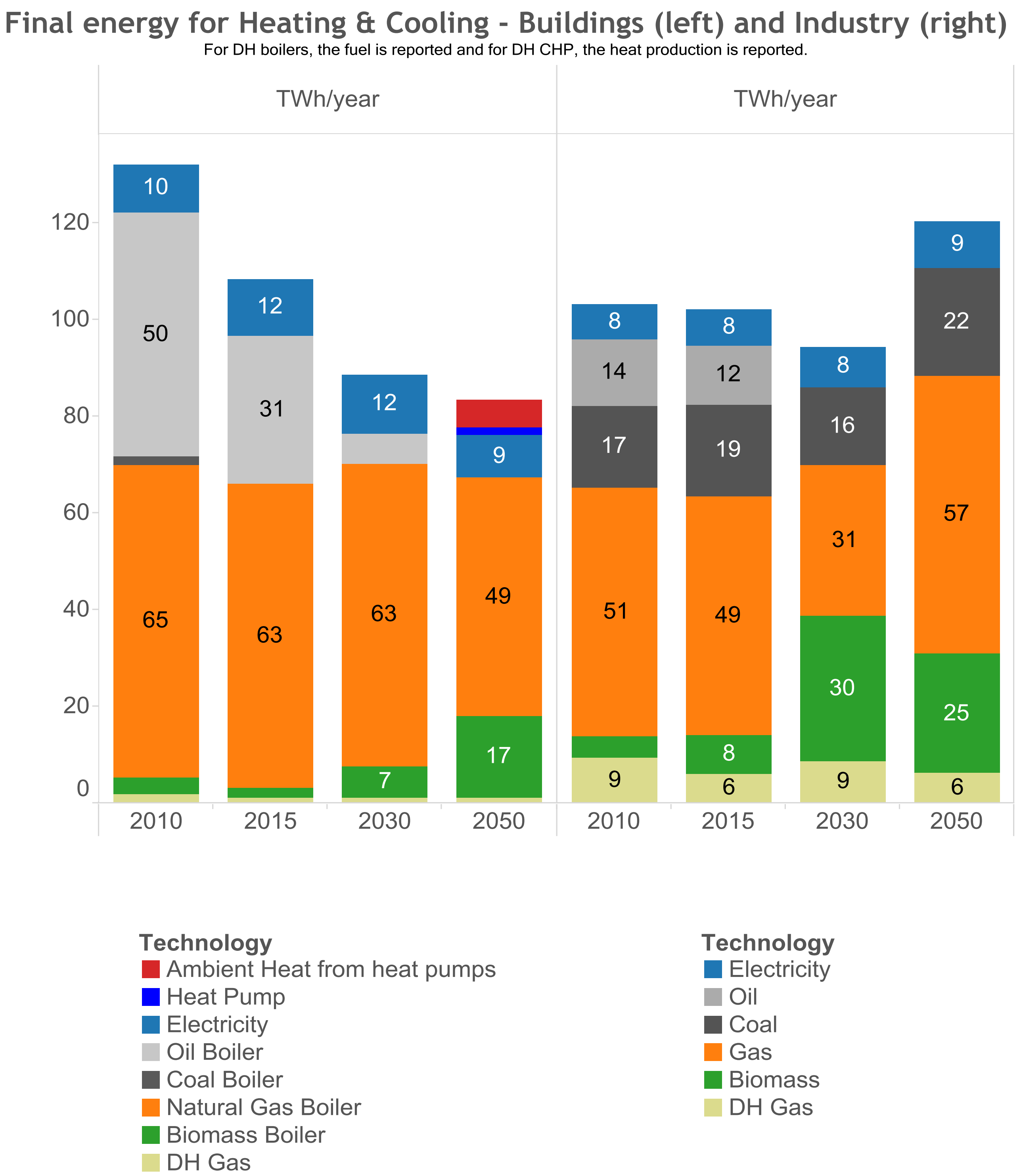


Gross Energy Consumption
TWh/year
700
600
500
400
300
200
100
0
190
296
37
154
147
257
154
49
197
190
43
245
156
96
2010
2015
2030
2050
Electricity Capacity
GWe
35
30
25
20
15
10
5
0
4
6
3
4
6
3
13
17
4
5
15
10
2010
2015
2030
2050
Technology
Hydro Pumped
Offshore wind
Onshore wind
Solar PV
Biomass
Gas
Coal
Nuclear



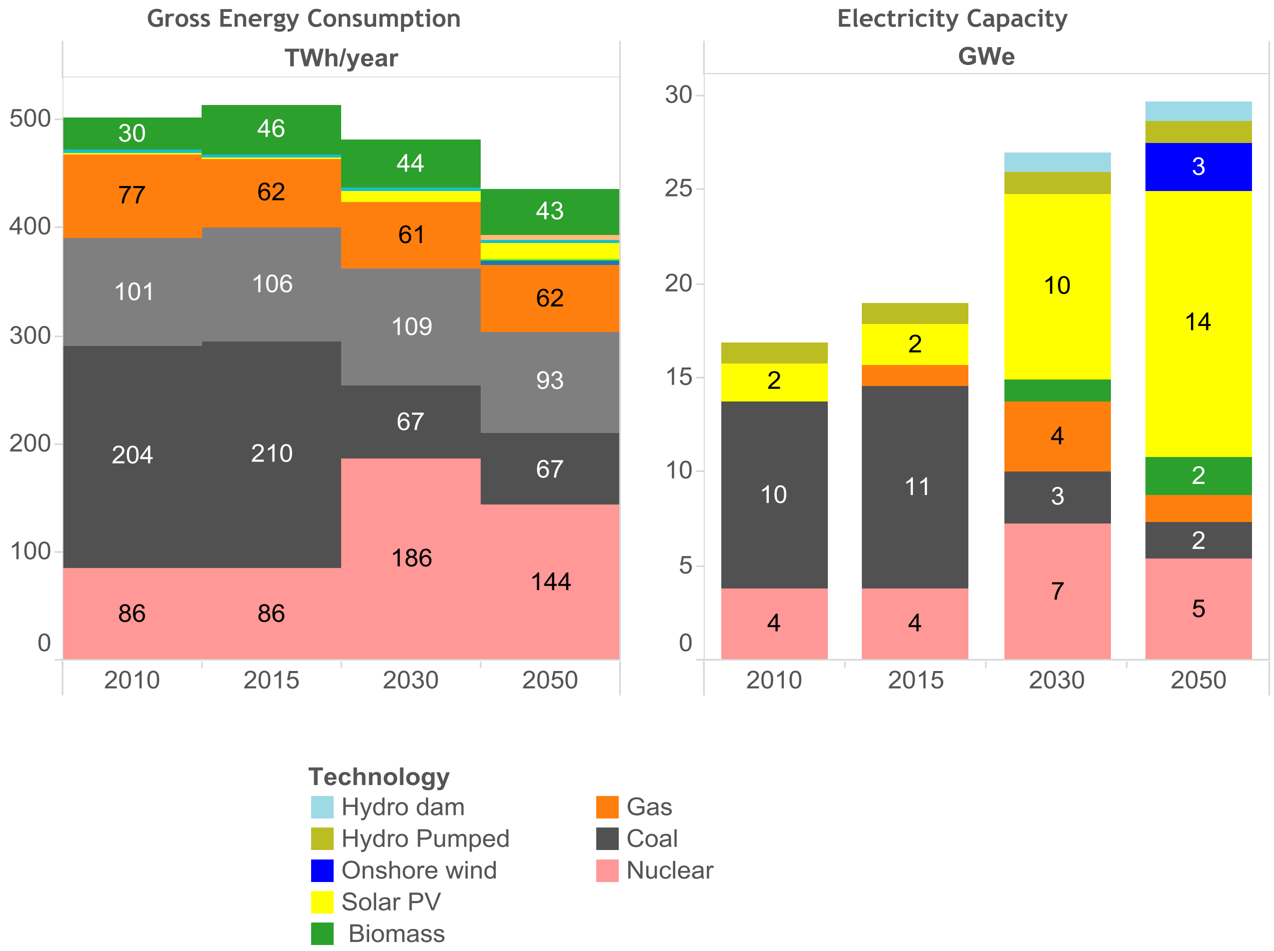
Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
250
200
150
100
50
0
60
21
154
23
154
13
91
15
92
25
27
46
46
13
53
15
56
2010
2015
2030
2050
2010
2015
2030
2050

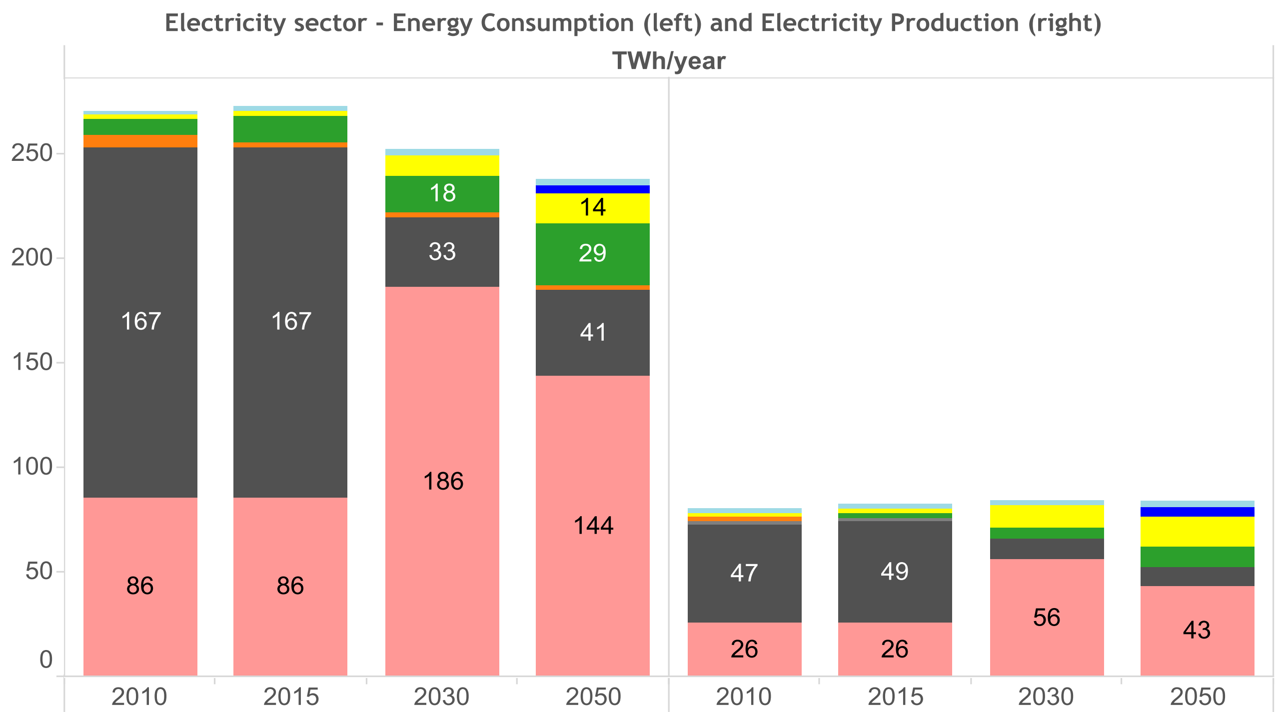
Belgium



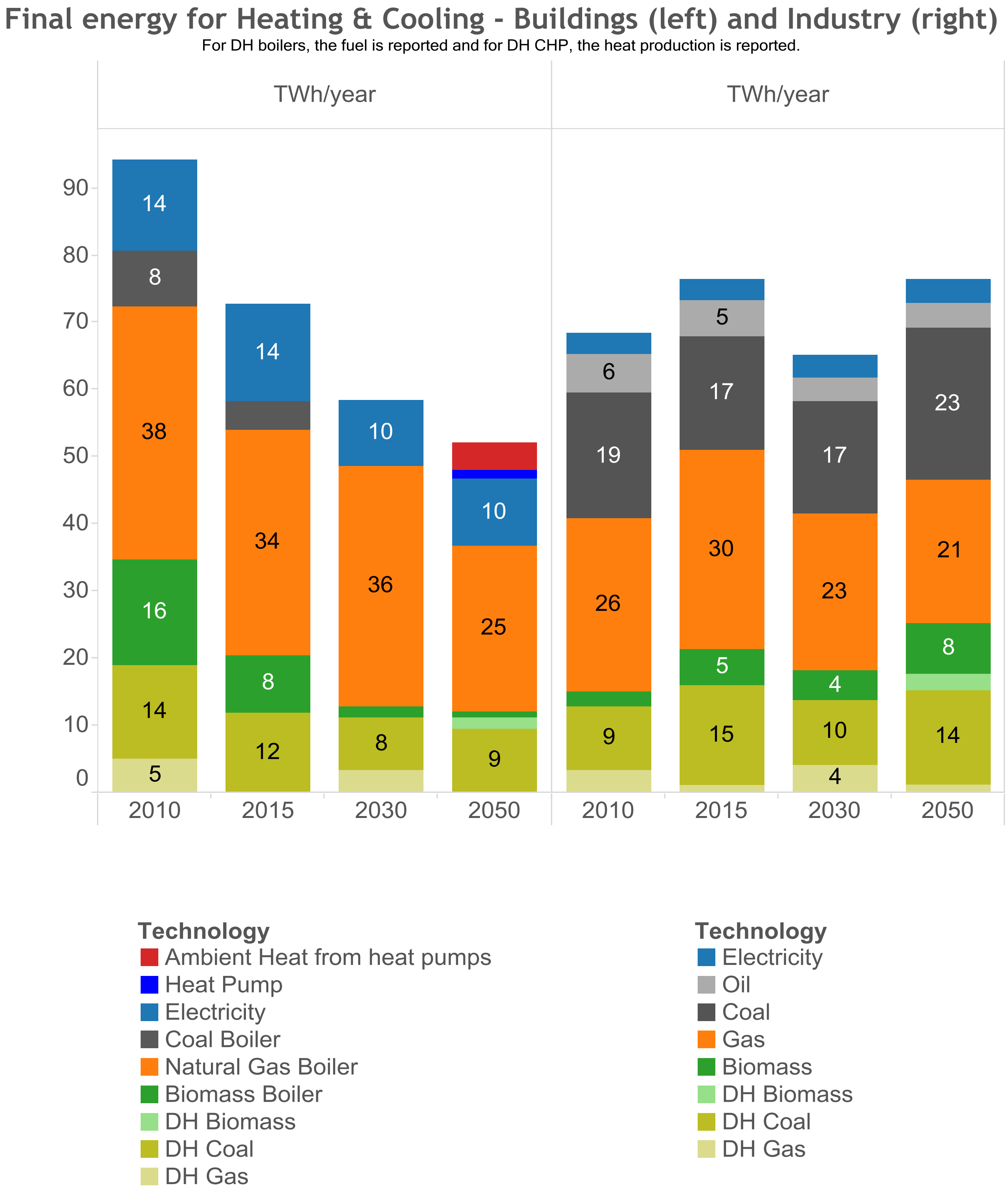
Final energy for Heating & Cooling - Buildings (left) and Industry (right)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.
TWh/year
TWh/year
120
100
80
60
40
20
0
10
50
65
12
31
63
12
63
7
9
49
17
8
14
17
51
9
8
12
19
49
8
6
8
16
31
30
9
9
22
57
25
6
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Ambient Heat from heat pumps
Heat Pump
Electricity
Oil Boiler
Coal Boiler
Natural Gas Boiler
Biomass Boiler
DH Gas
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Gas

Czech Republic

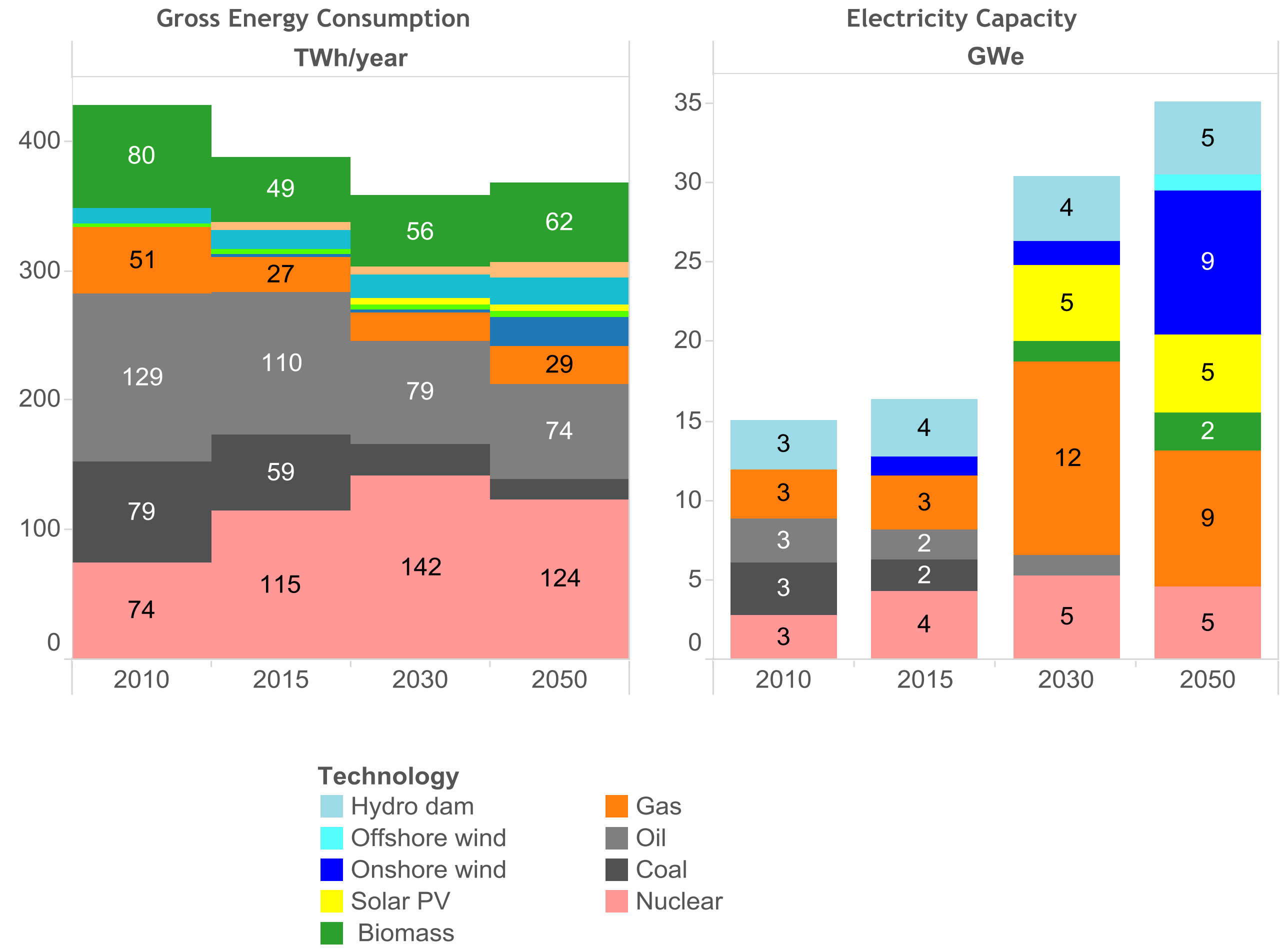




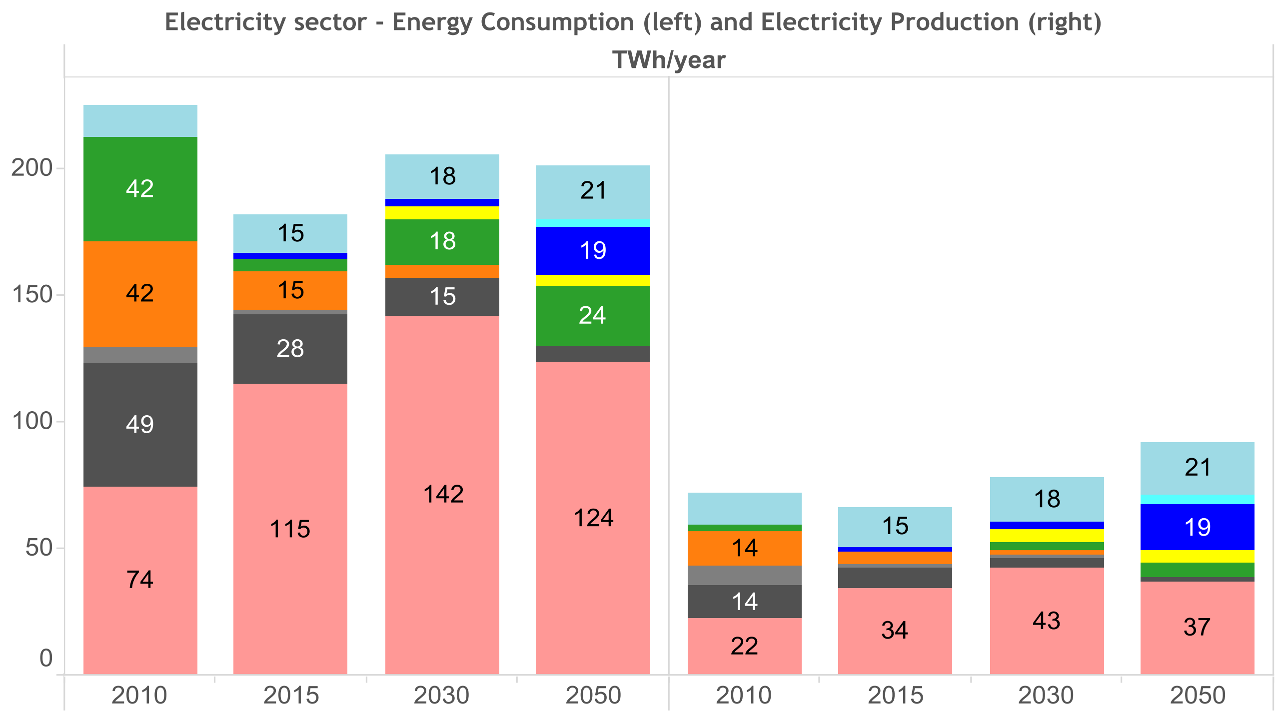
Czech Republic



Finland



Gross Energy Consumption
TWh/year
400
300
200
100
0
80
51
129
79
74
49
27
110
59
115
56
79
142
62
29
74
124
2010
2015
2030
2050
Electricity Capacity
GWe
35
30
25
20
15
10
5
0
3
3
3
3
3
4
3
2
2
4
4
5
12
5
5
9
5
2
9
5
2010
2015
2030
2050
Technology
Hydro dam
Offshore wind
Onshore wind
Solar PV
Biomass
Gas
Oil
Coal
Nuclear

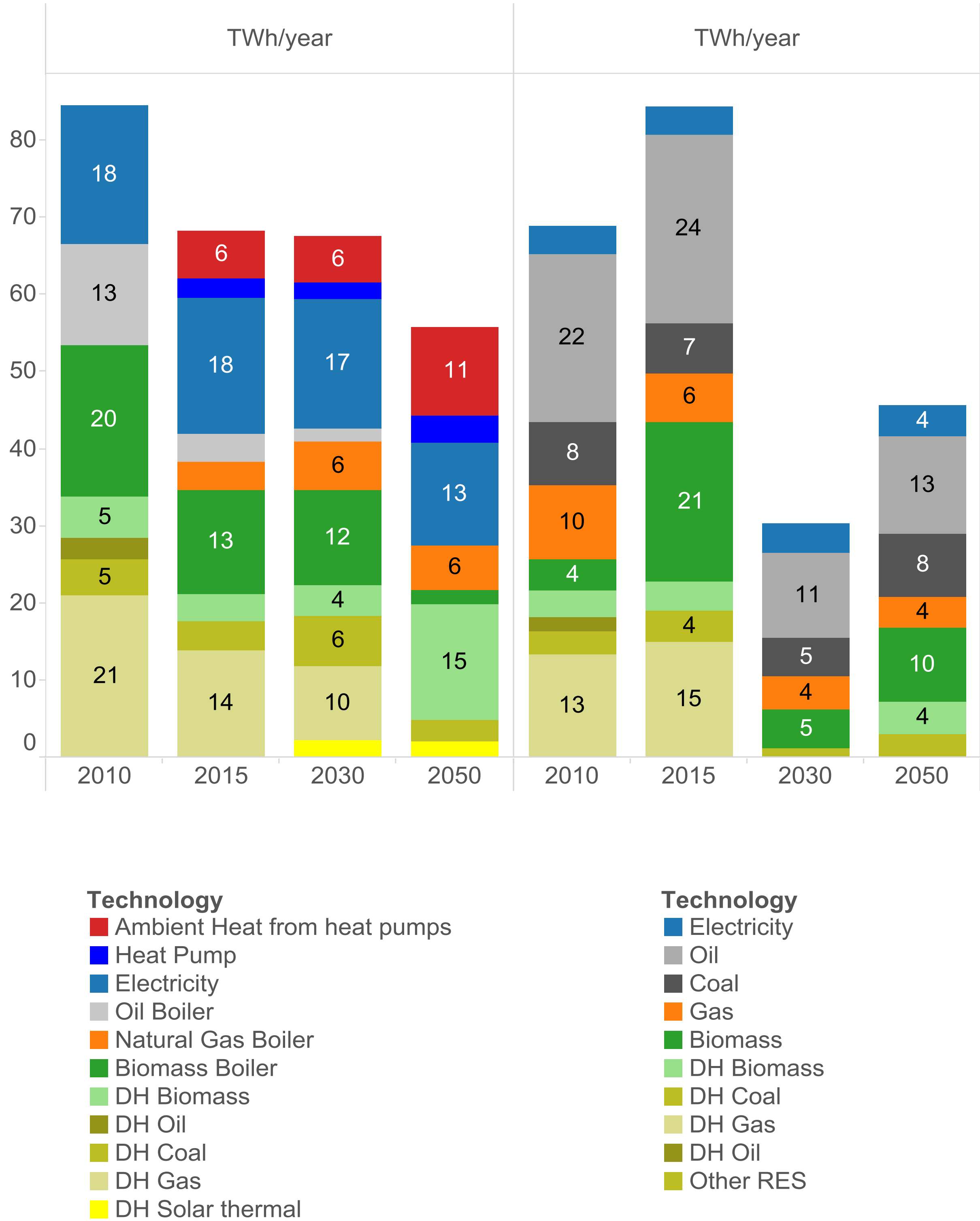


Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
200
150
100
50
0
42
42
49
74
15
15
28
115
18
18
15
142
21
19
24
124
14
14
22
15
34
18
43
21
19
37
2010
2015
2030
2050
2010
2015
2030
2050

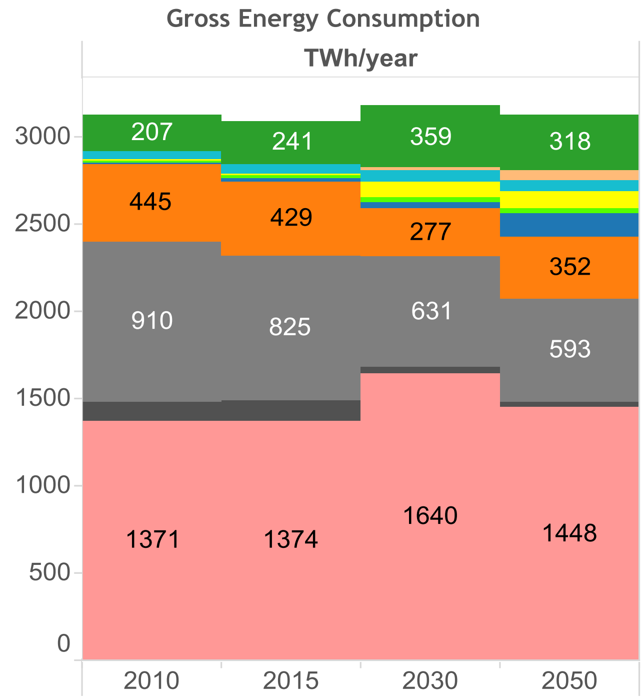
Finland

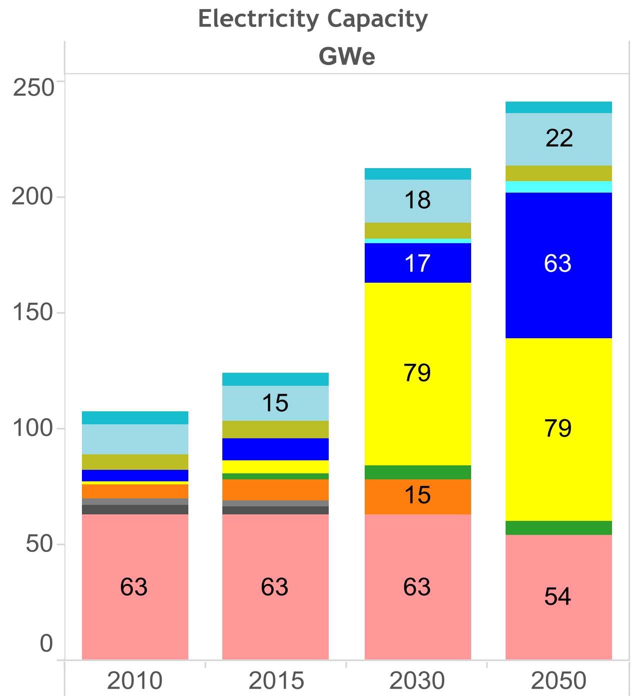
Final energy for Heating & Cooling - Buildings (left) and Industry (right)

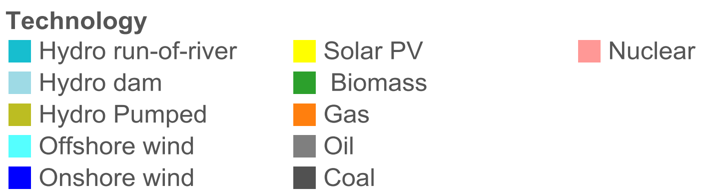
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.

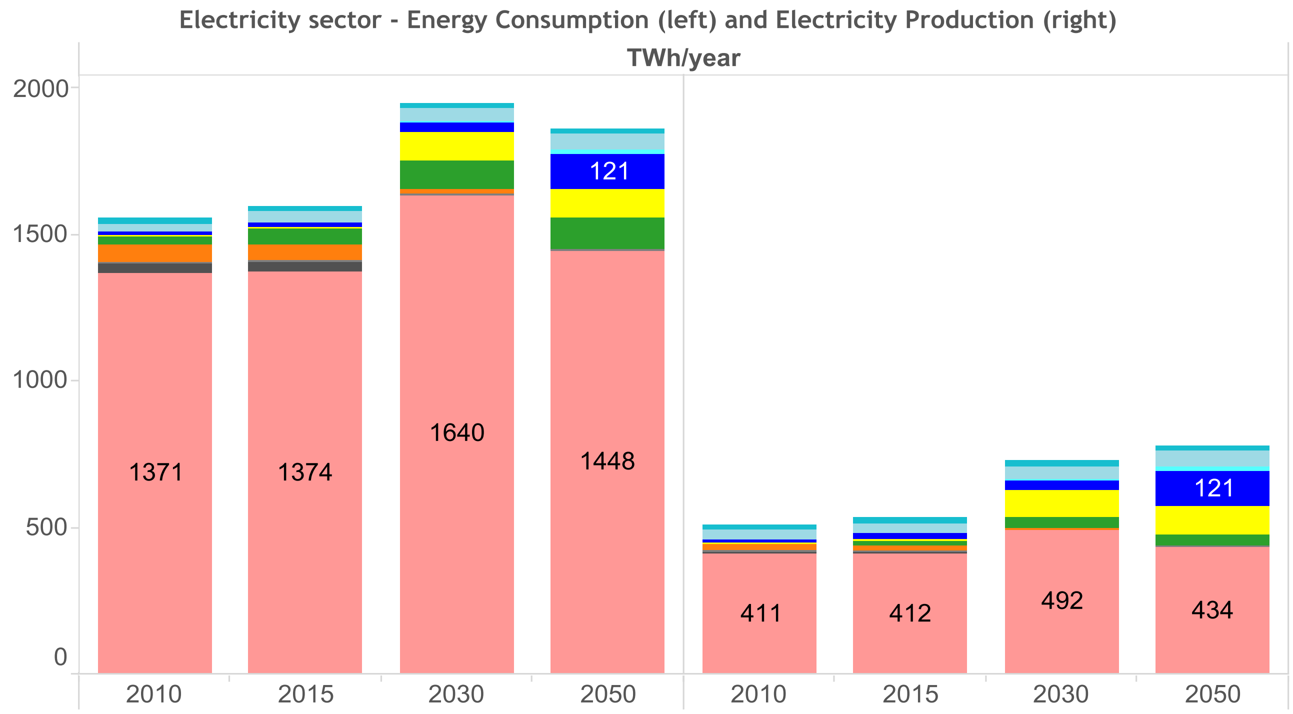


France

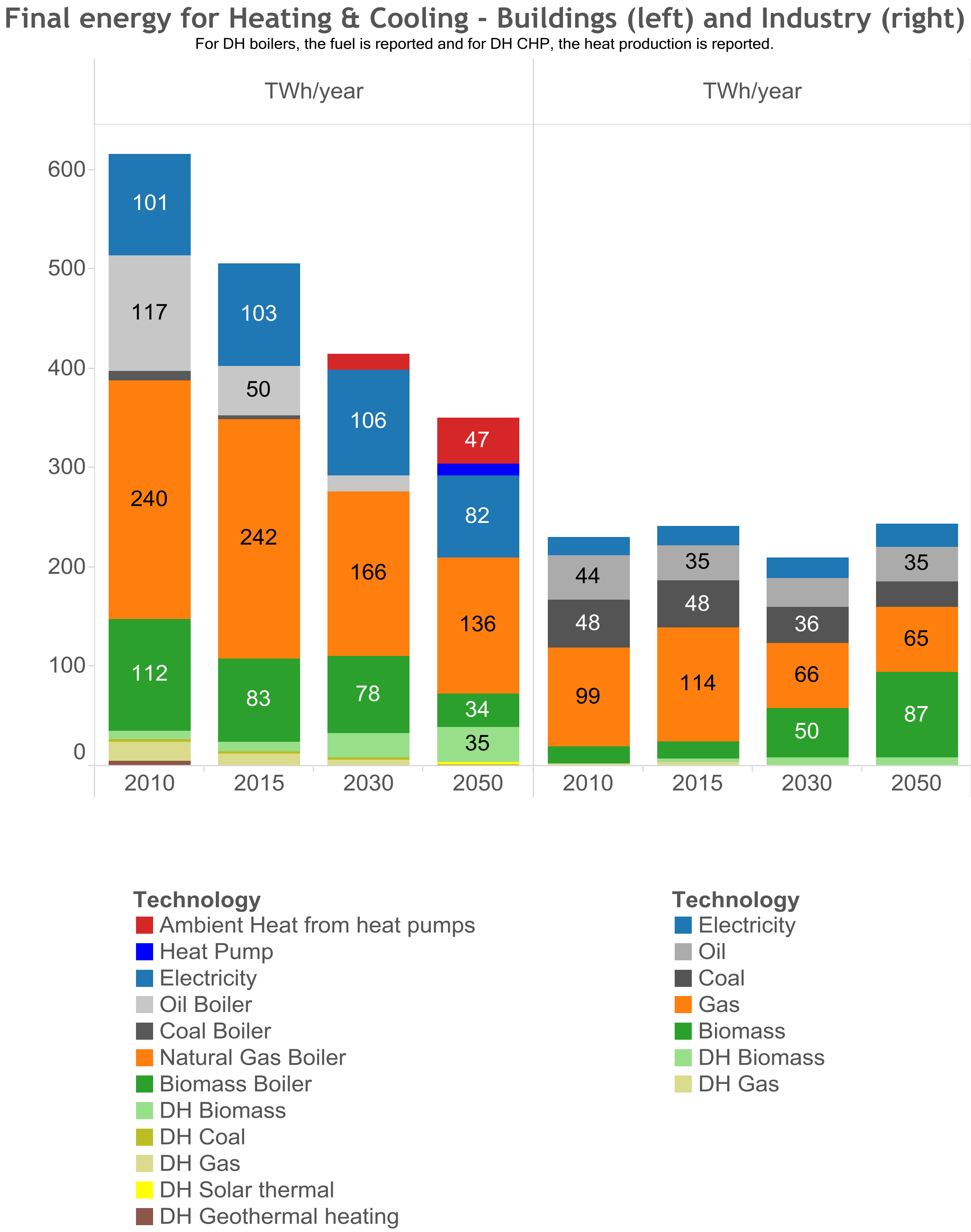

Gross Energy Consumption
TWh/year
3000
2500
2000
1500
1000
500
0
207
241
359
318
445
429
277
352
910
825
631
593
1371
1374
1640
1448
2010
2015
2030
2050


Electricity Capacity
GWe
250
200
150
100
50
0
22
18
15
17
63
79
79
15
63
63
63
54
2010
2015
2030
2050


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

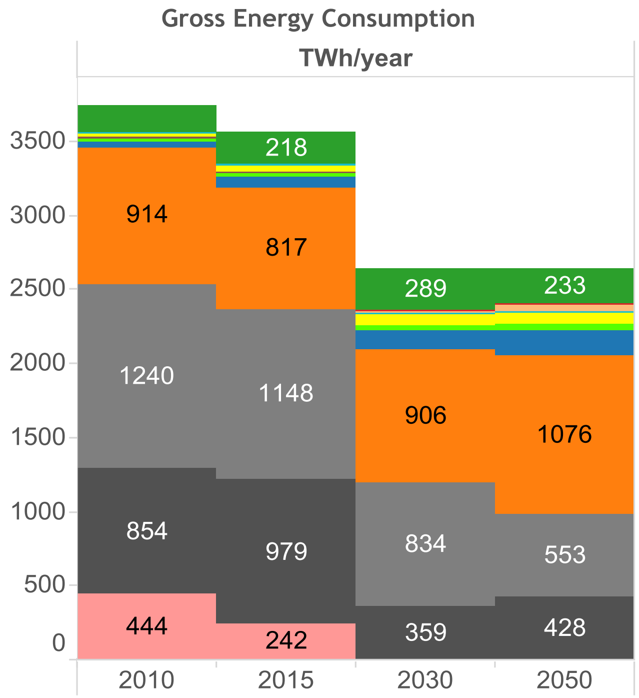

Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
2000
1500
1000
500
0
121
1371
1374
1640
1448
121
411
412
492
434
2010
2015
2030
2050
2010
2015
2030
2050

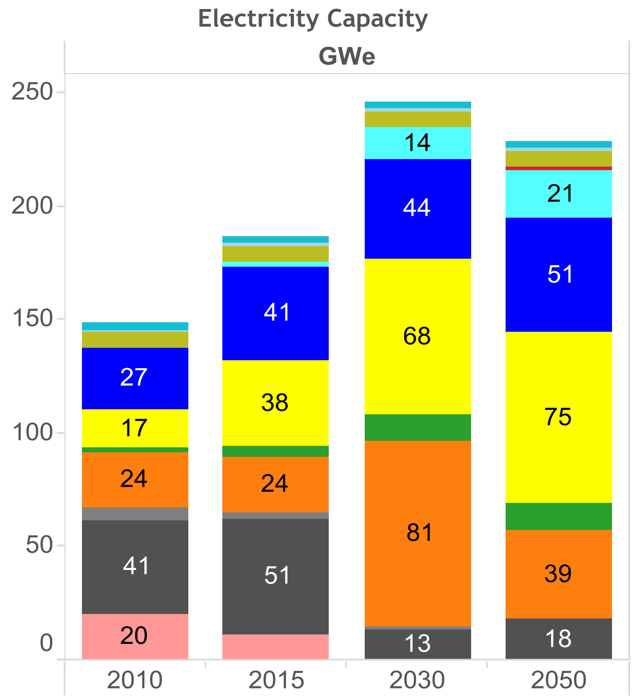
France

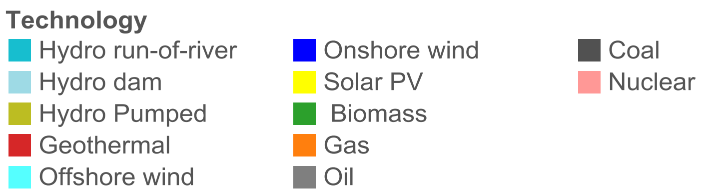


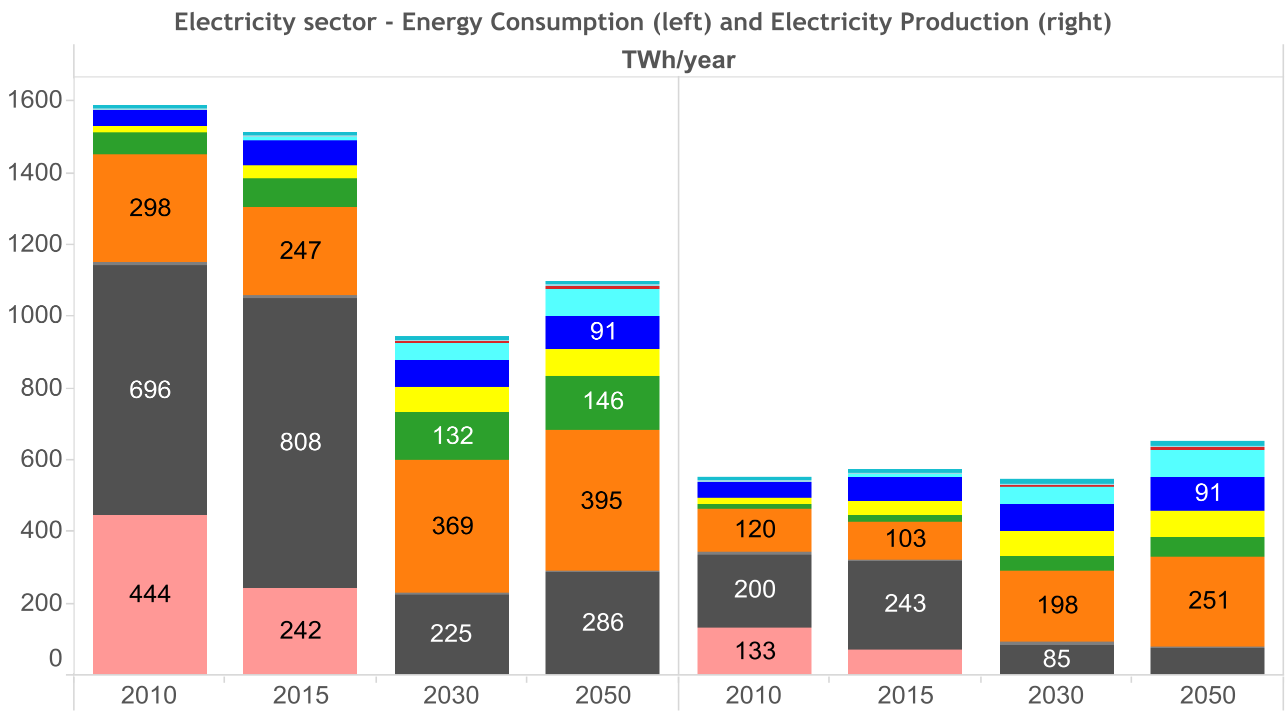
Final energy for Heating & Cooling - Buildings (left) and Industry (right)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.
TWh/year
TWh/year
600
500
400
300
200
100
0
101
117
240
112
103
50
242
83
106
166
78
47
82
136
34
35
44
48
99
35
48
114
36
66
50
35
65
87
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Ambient Heat from heat pumps
Heat Pump
Electricity
Oil Boiler
Coal Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
DH Coal
DH Gas
DH Solar thermal
DH Geothermal heating
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass
DH Gas

Germany

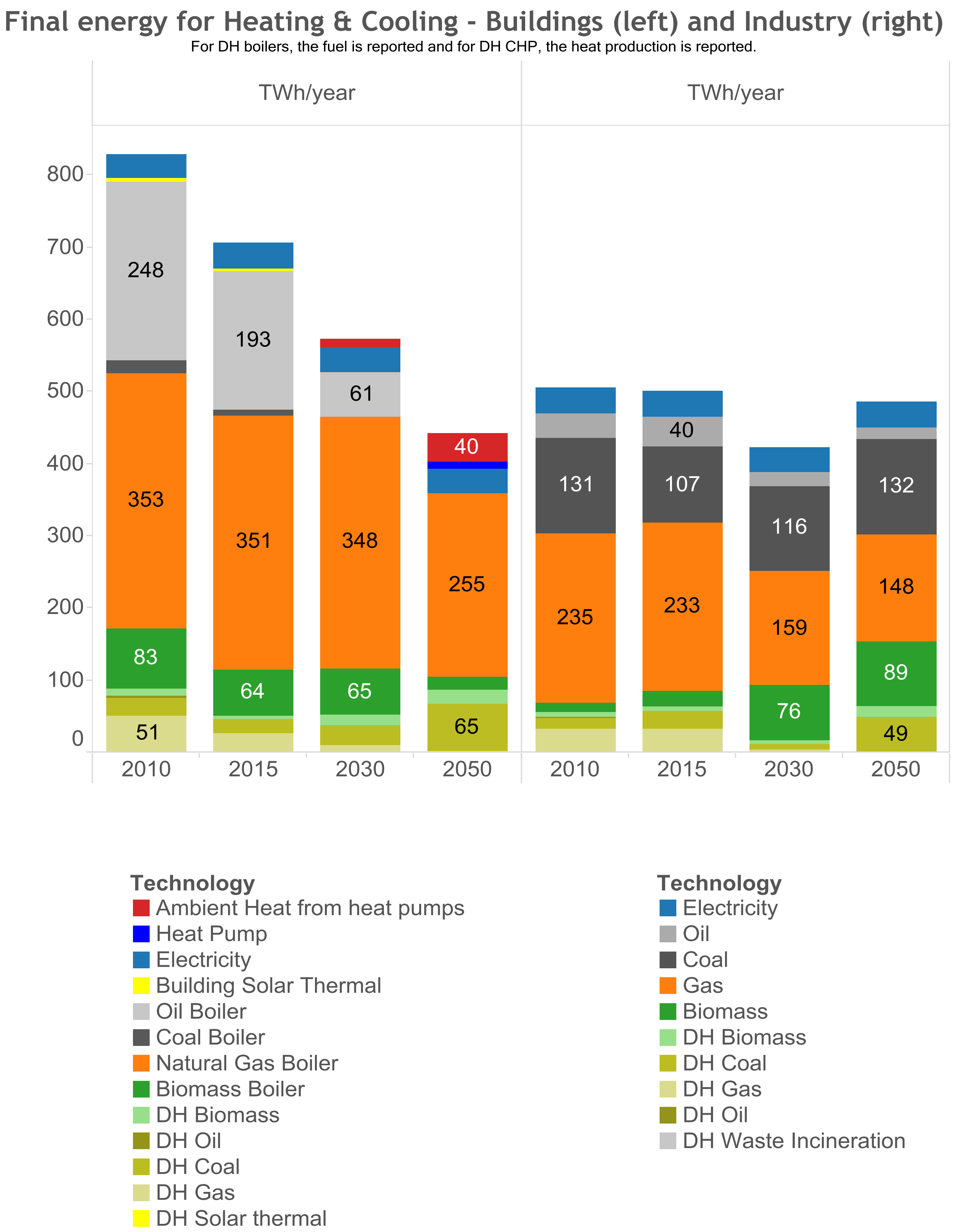

Gross Energy Consumption
TWh/year
3500
3000
2500
2000
1500
1000
500
0
218
914
817
289
233
1240
1148
906
1076
854
979
834
553
444
242
359
428
2010
2015
2030
2050


Electricity Capacity
GWe
250
200
150
100
50
0
14
21
44
51
41
27
68
75
17
38
24
24
81
39
41
51
20
13
18
2010
2015
2030
2050


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

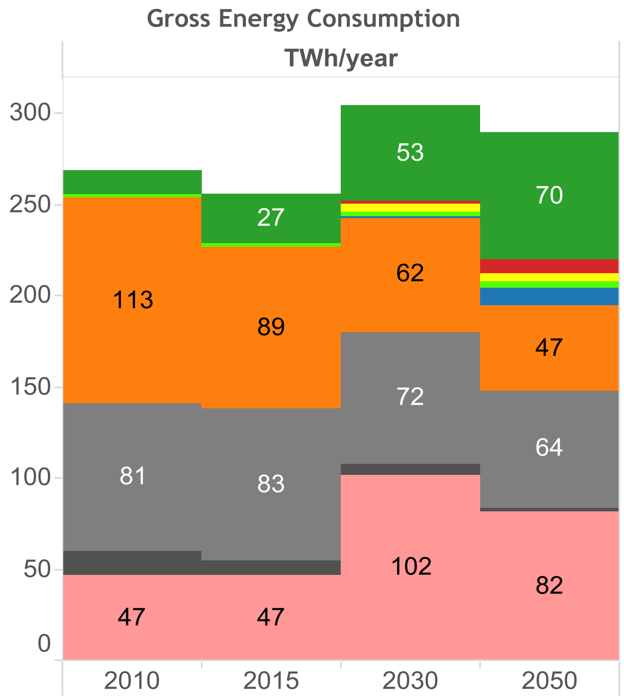

Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
1600
1400
1200
1000
800
600
400
200
0
298
247
91
146
132
369
395
696
808
225
286
444
242
91
120
103
198
251
200
243
133
85
2010
2015
2030
2050
2010
2015
2030
2050

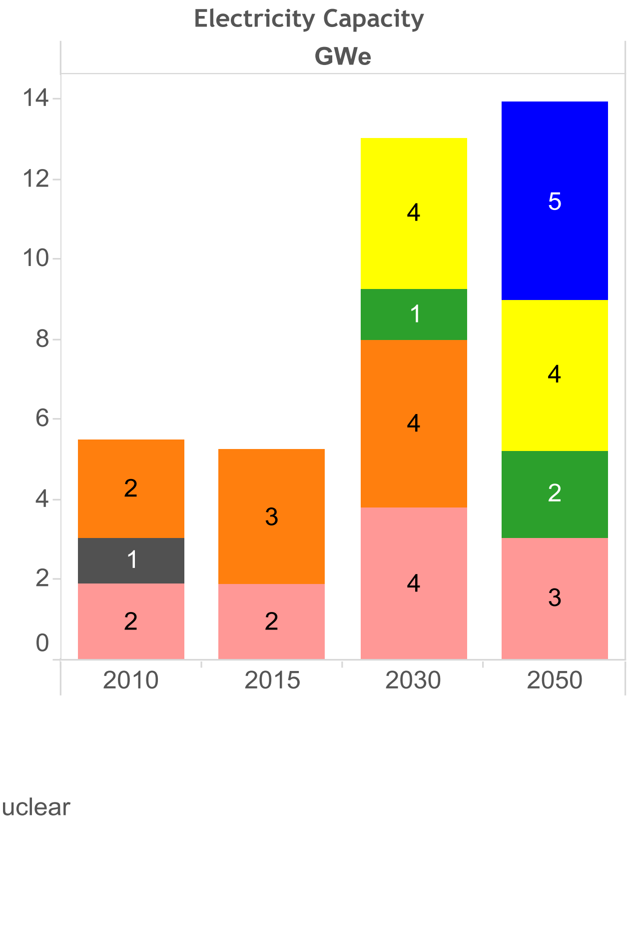
Germany

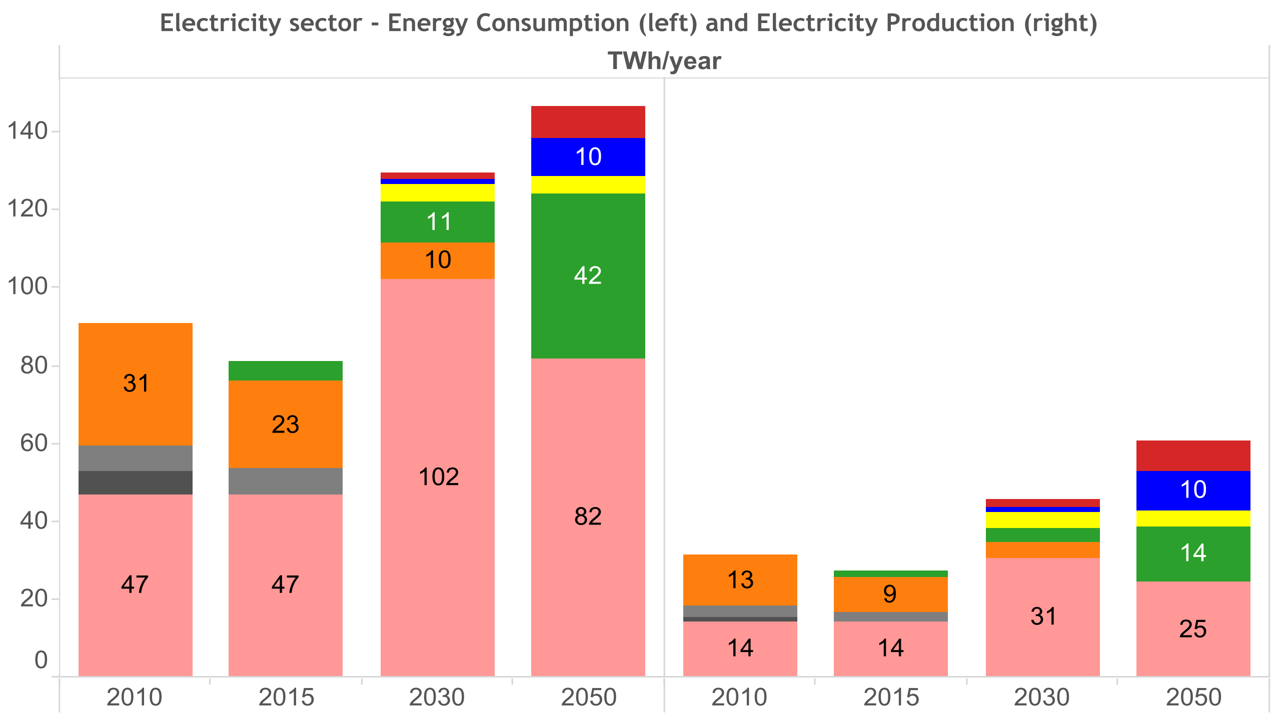


Final energy for Heating & Cooling - Buildings (left) and Industry (right)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.
TWh/year
TWh/year
800
700
600
500
400
300
200
100
0
248
193
61
40
353
351
348
255
83
64
65
65
51
131
107
116
132
40
235
233
159
148
89
76
49
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Ambient Heat from heat pumps
Heat Pump
Electricity
Building Solar Thermal
Oil Boiler
Coal Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
DH Oil
DH Coal
DH Gas
DH Solar thermal
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass
DH Coal
DH Gas
DH Oil
DH Waste Incineration

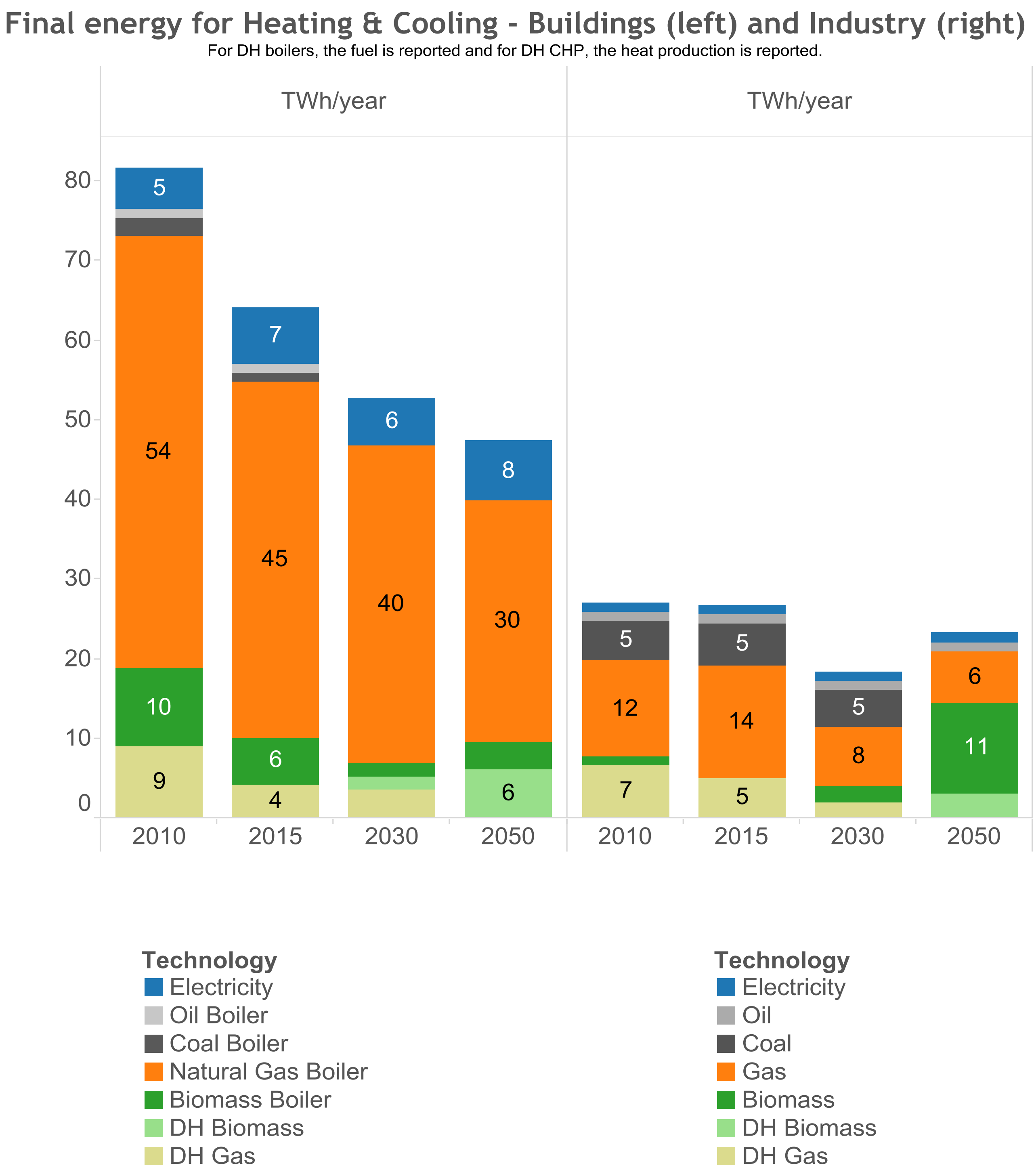
Hungary


Gross Energy Consumption
TWh/year
300
250
200
150
100
50
0
2010
2015
2030
2050
113
81
47
27
89
83
47
53
62
72
102
70
47
64
82


Electricity Capacity
GWe
14
12
10
8
6
4
2
0
2010
2015
2030
2050
2
1
2
3
2
4
1
4
4
5
4
2
3
Technology
Onshore wind
Solar PV
Biomass
Gas
Coal
Nuclear

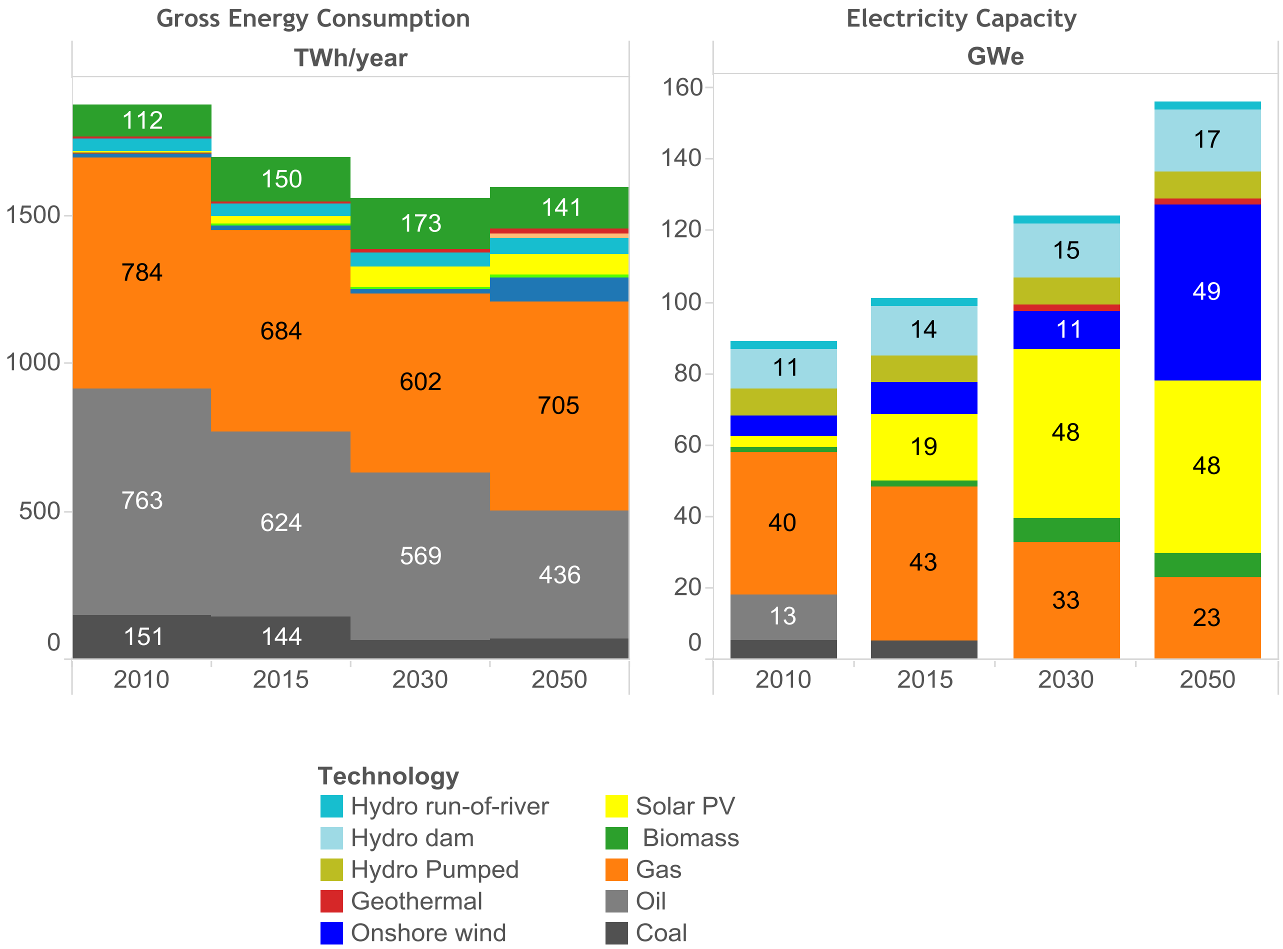

Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
140
120
100
80
60
40
20
0
2010
2015
2030
2050
2010
2015
2030
2050
31
47
23
47
11
10
102
10
42
82
13
14
9
14
31
10
14
25

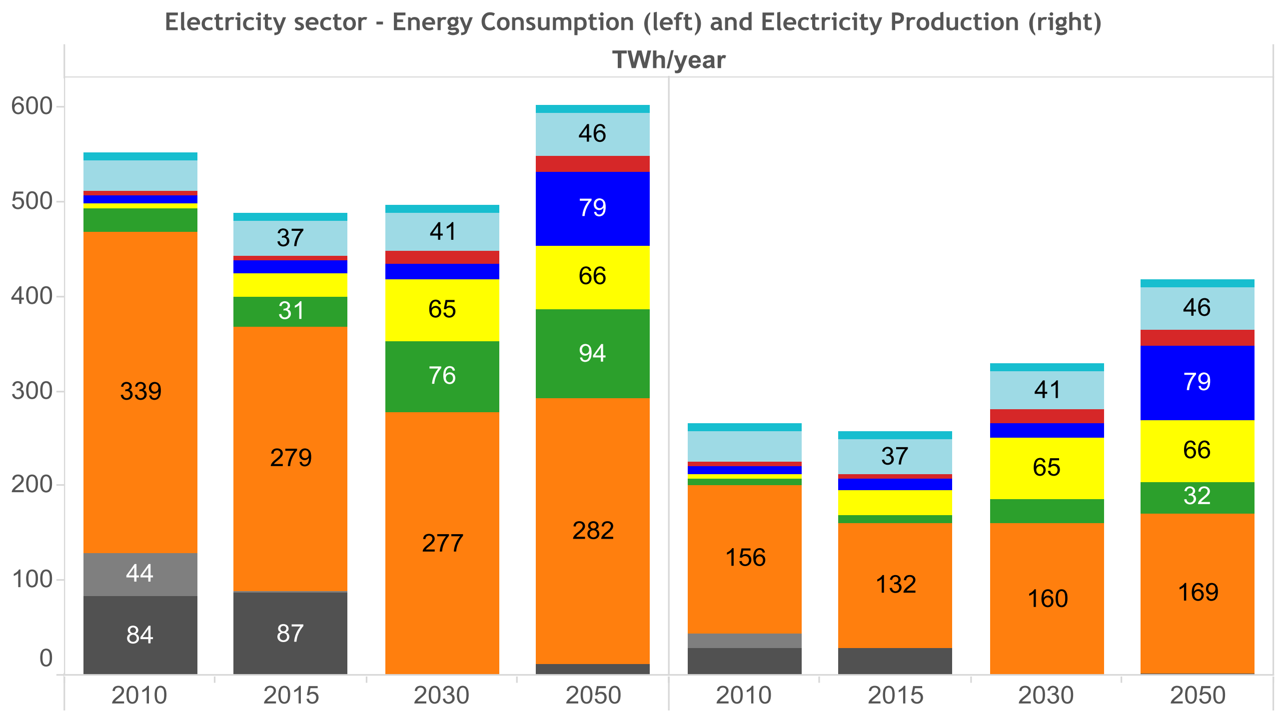
Hungary



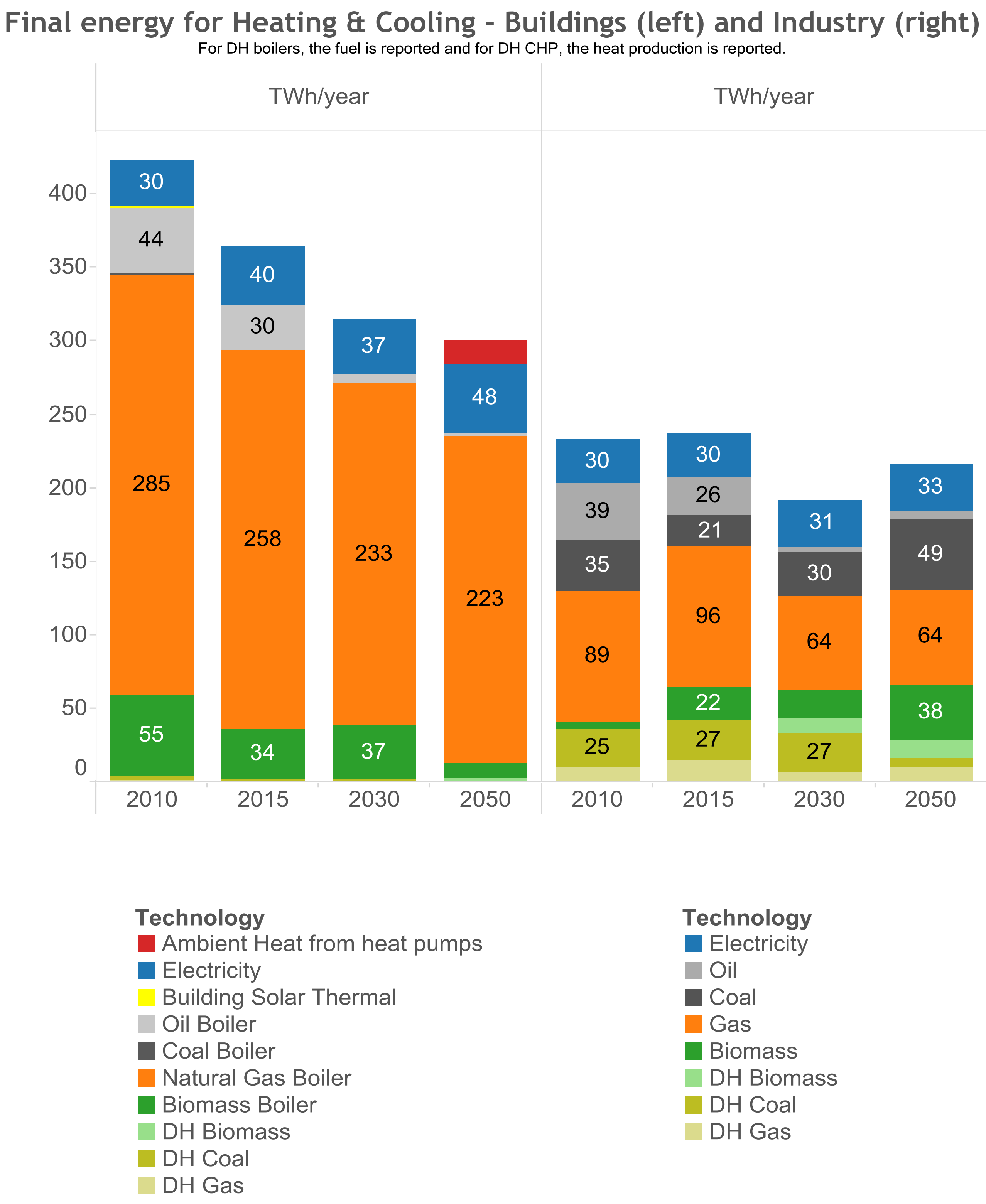
Final energy for Heating & Cooling - Buildings (left) and Industry (right)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.
TWh/year
TWh/year
80
70
60
50
40
30
20
10
0
5
54
10
9
7
45
6
4
6
40
8
30
6
5
12
7
5
14
5
5
8
6
11
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Electricity
Oil Boiler
Coal Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
DH Gas
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass
DH Gas

Italy

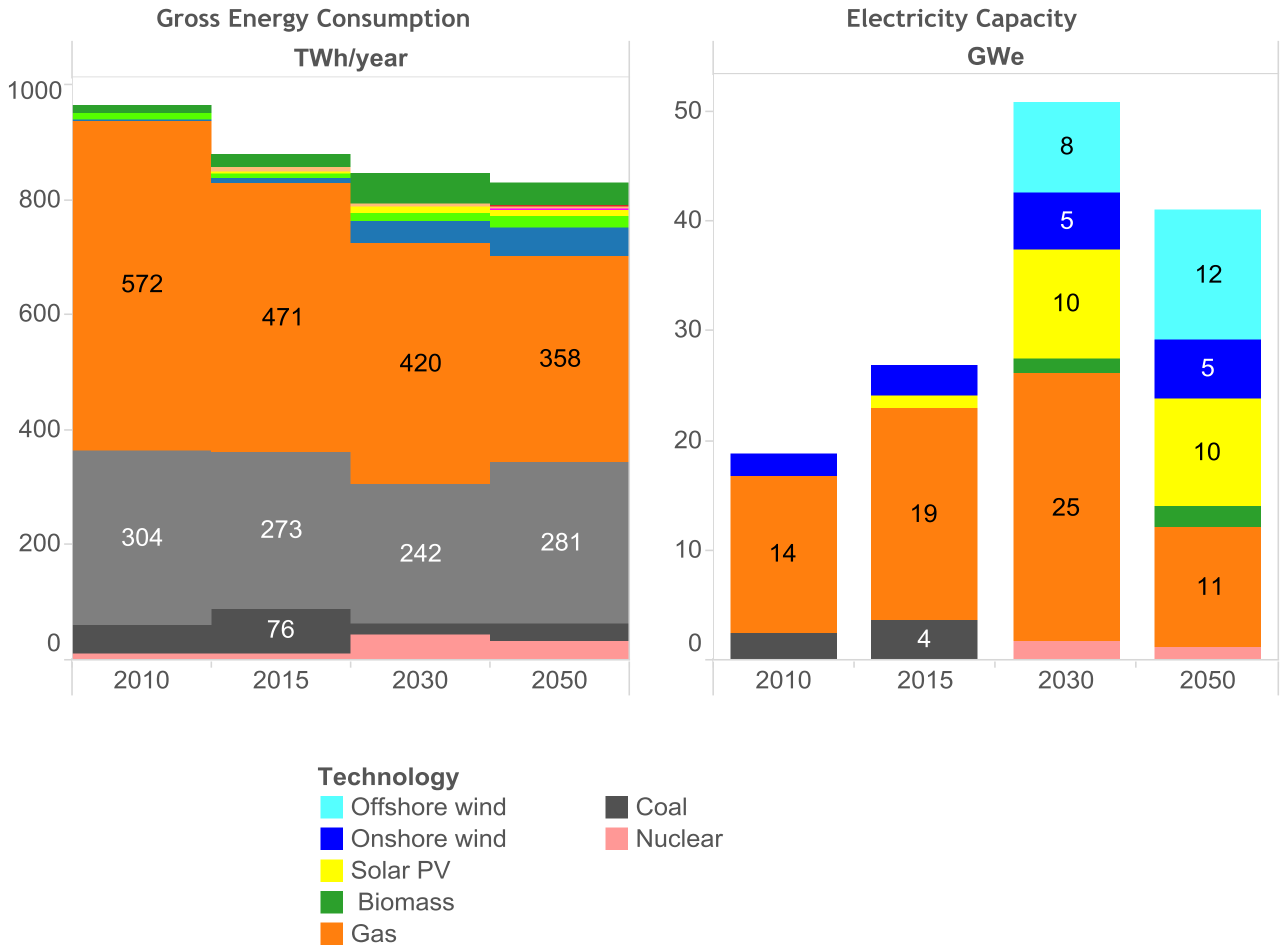

Gross Energy Consumption
TWh/year
1500
1000
500
0
112
150
173
141
784
684
602
705
763
624
569
436
151
144
2010
2015
2030
2050
Electricity Capacity
GWe
160
140
120
100
80
60
40
20
0
17
49
48
23
15
11
48
33
14
19
43
11
40
13
2010
2015
2030
2050
Technology
Hydro run-of-river
Hydro dam
Hydro Pumped
Geothermal
Onshore wind
Solar PV
Biomass
Gas
Oil
Coal

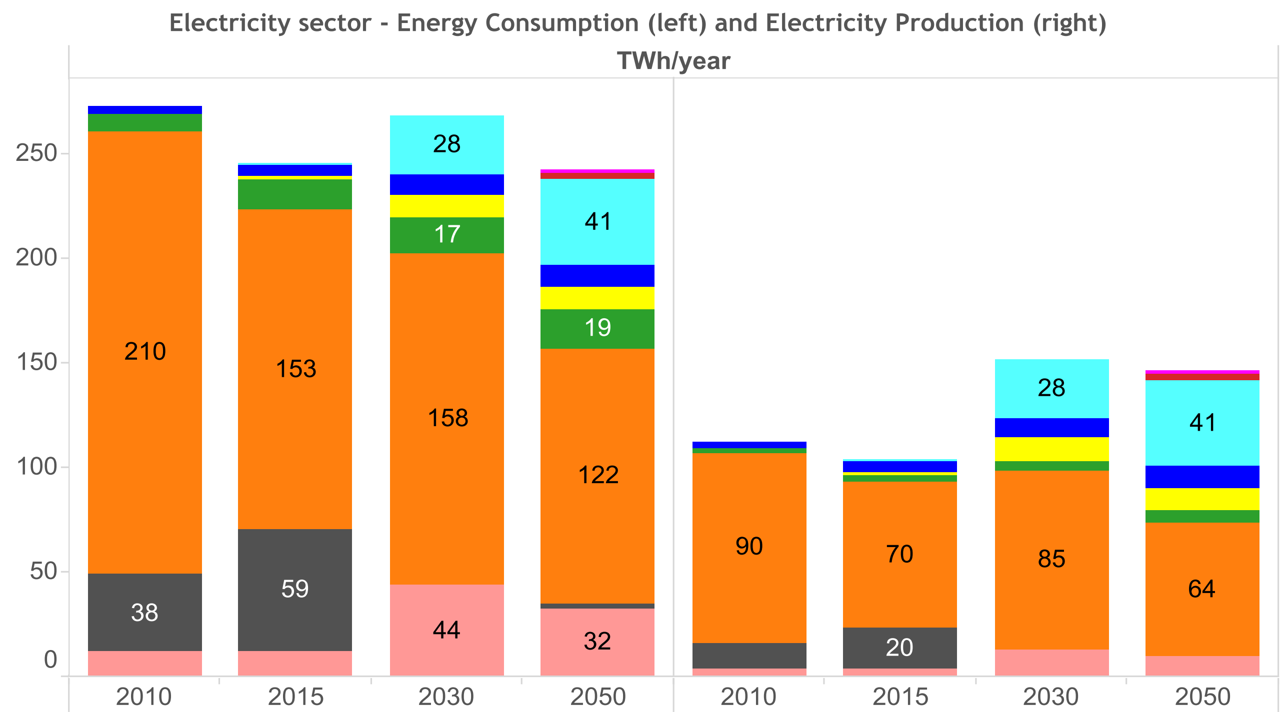

Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
600
500
400
300
200
100
0
339
44
84
37
31
279
87
41
65
76
277
46
79
66
94
282
156
37
132
41
65
160
46
79
66
32
169
2010
2015
2030
2050
2010
2015
2030
2050

Italy

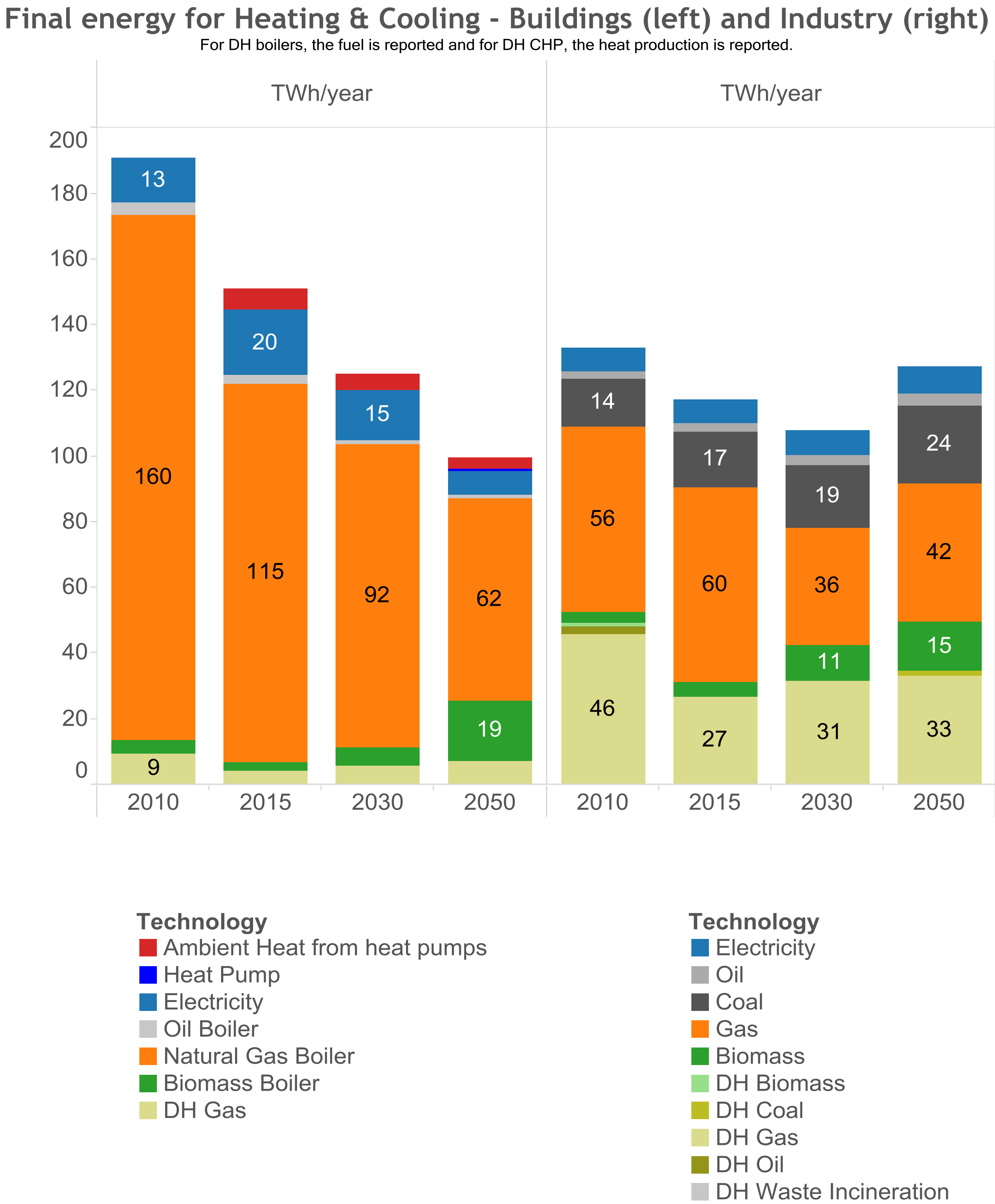

Final energy for Heating & Cooling - Buildings (left) and Industry (right)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.
TWh/year
TWh/year
400
350
300
250
200
150
100
50
0
30
44
285
55
40
30
258
34
37
233
37
48
223
30
39
35
89
25
30
26
21
96
22
27
31
30
64
27
33
49
64
38
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Ambient Heat from heat pumps
Electricity
Building Solar Thermal
Oil Boiler
Coal Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
DH Coal
DH Gas
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass
DH Coal
DH Gas

Netherlands

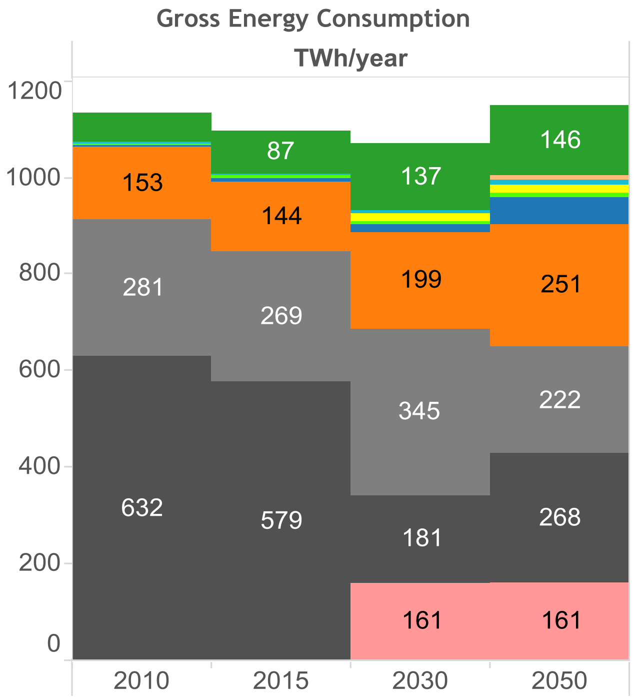


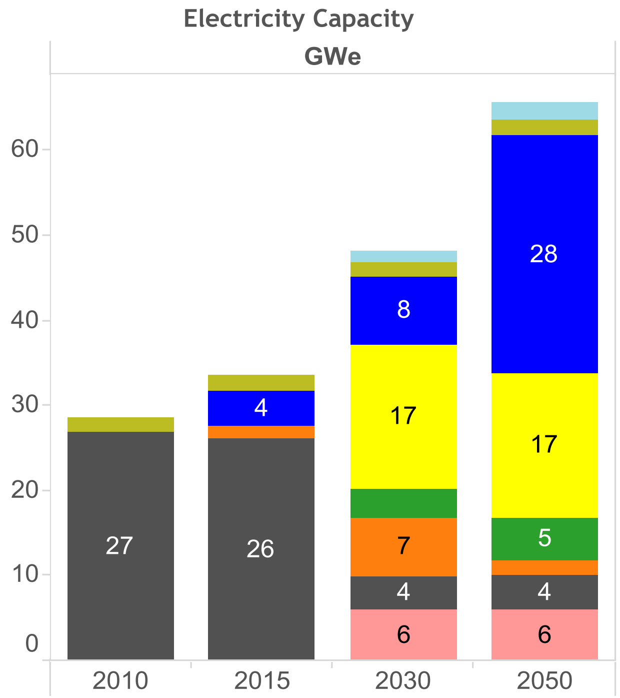


Netherlands

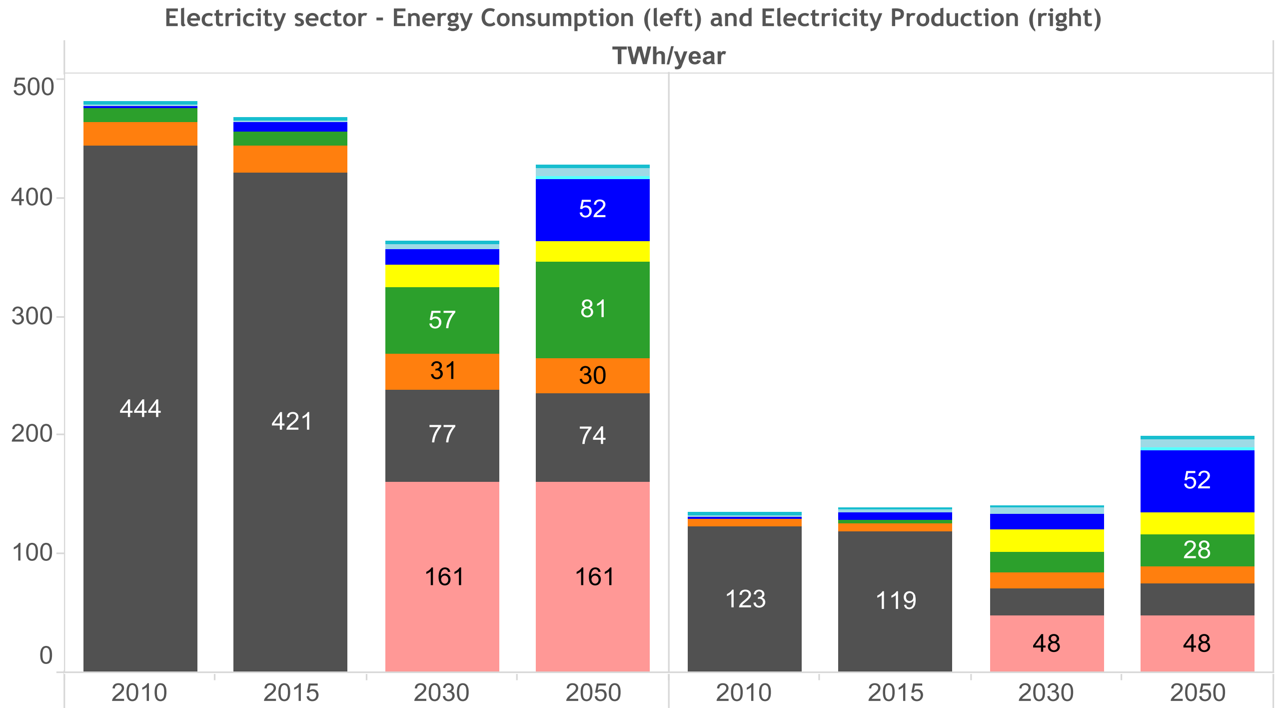


Poland

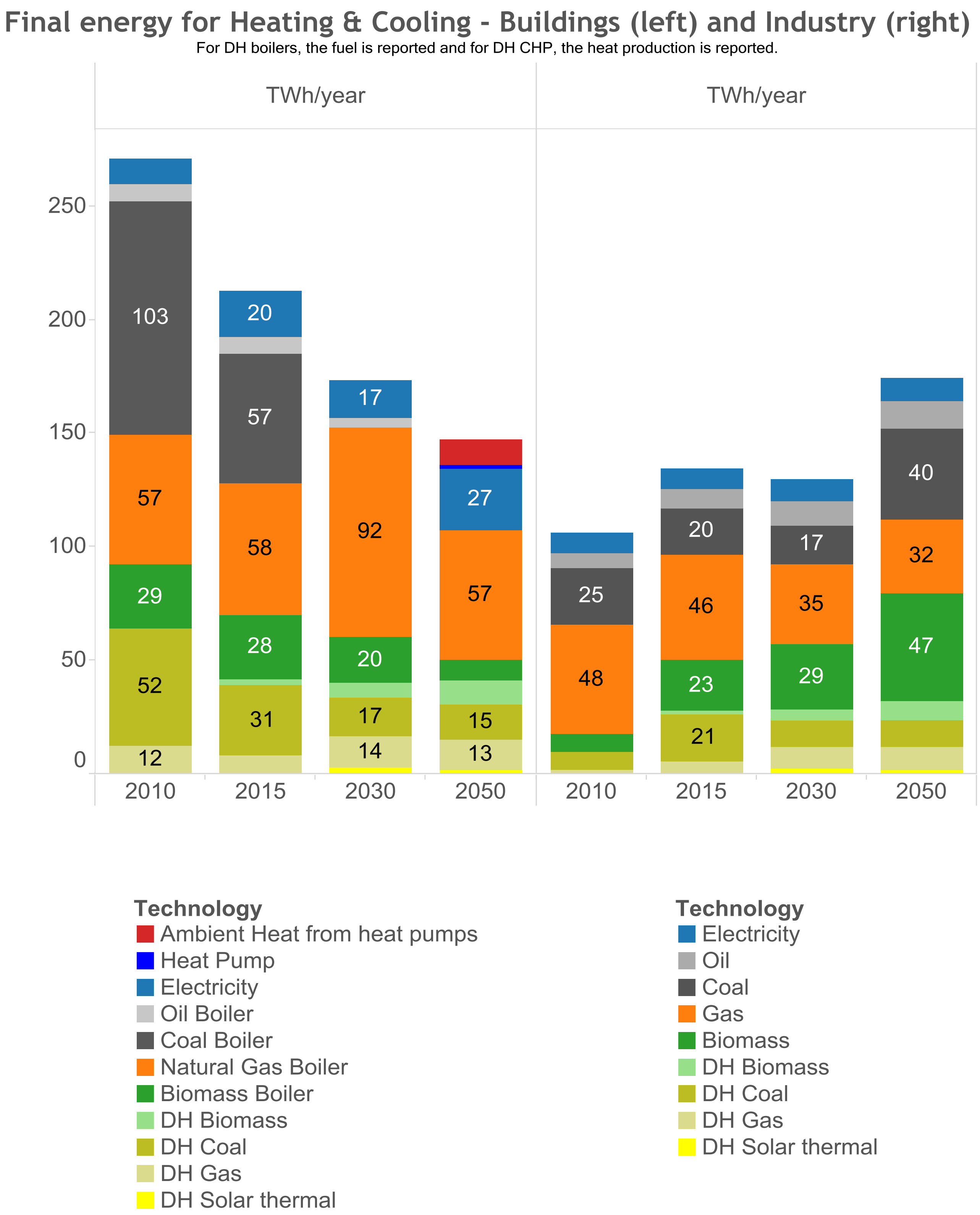




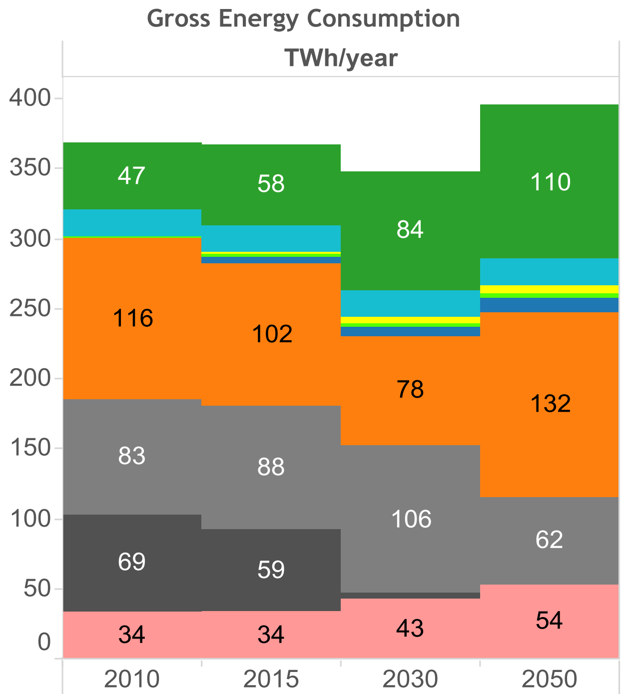
Technology
- Hydro dam
- Hydro Pumped
- Onshore wind
- Solar PV
- Biomass
- Gas
- Coal
- Nuclear

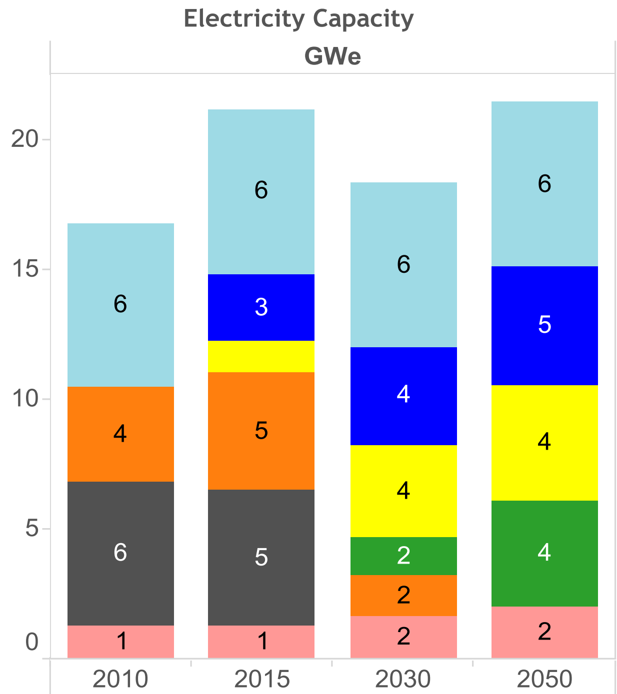


Poland

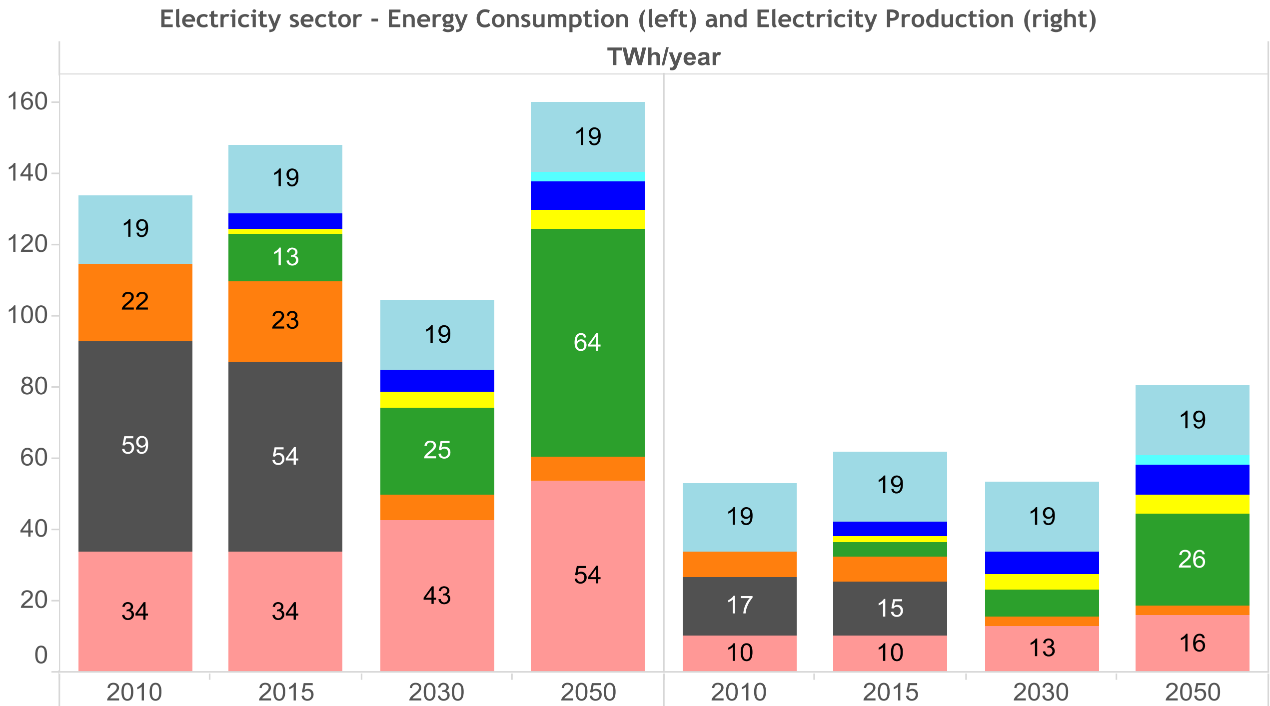

Final energy for Heating & Cooling - Buildings (left) and Industry (right)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.
TWh/year
TWh/year
250
200
150
100
50
0
103
57
29
52
12
20
57
58
28
31
17
92
20
17
14
27
57
15
13
25
48
20
46
23
21
17
35
29
40
32
47
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Ambient Heat from heat pumps
Heat Pump
Electricity
Oil Boiler
Coal Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
DH Coal
DH Gas
DH Solar thermal
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass
DH Coal
DH Gas
DH Solar thermal

Romania

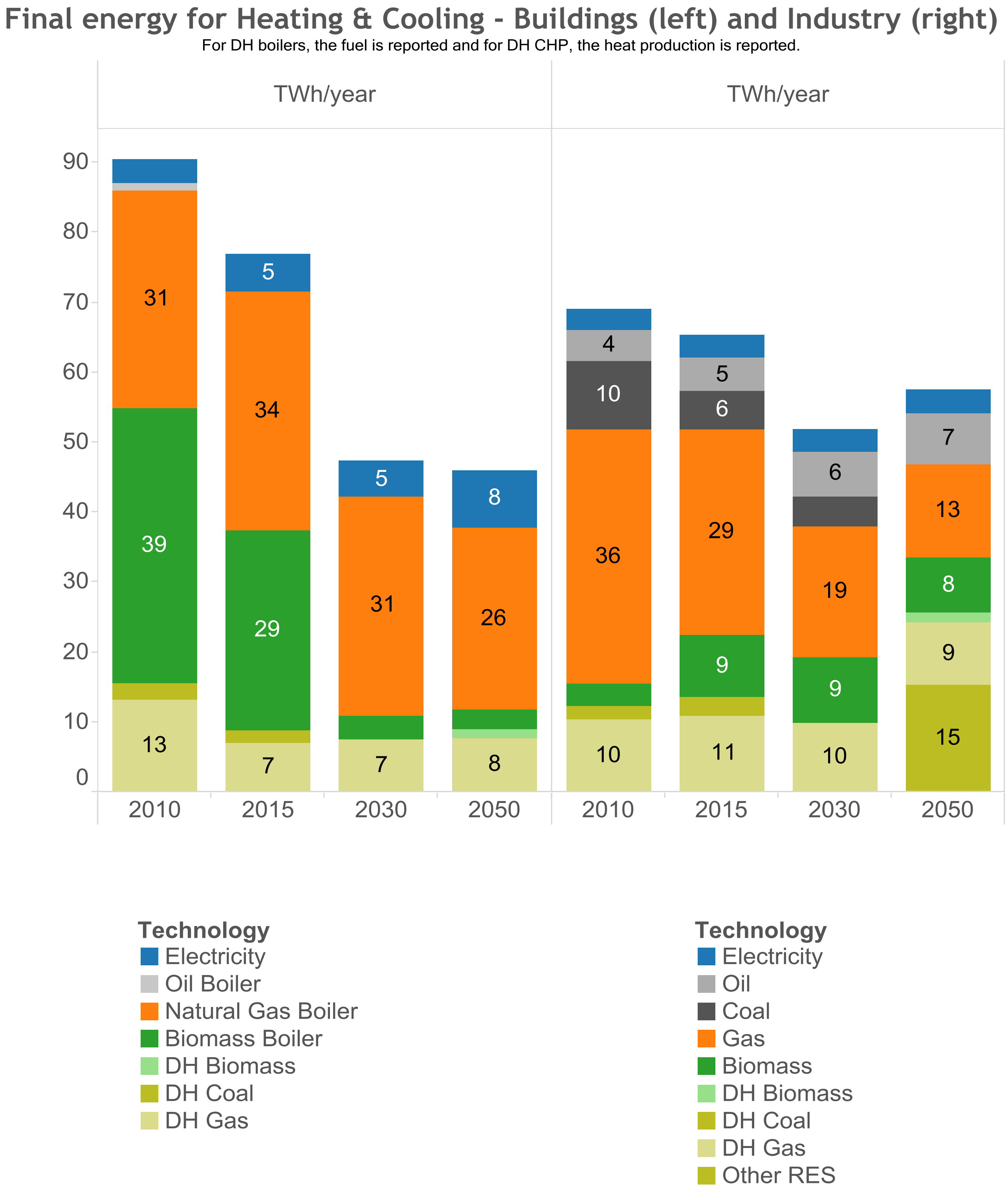




Technology
- Hydro dam
- Onshore wind
- Solar PV
- Biomass
- Gas
- Coal
- Nuclear

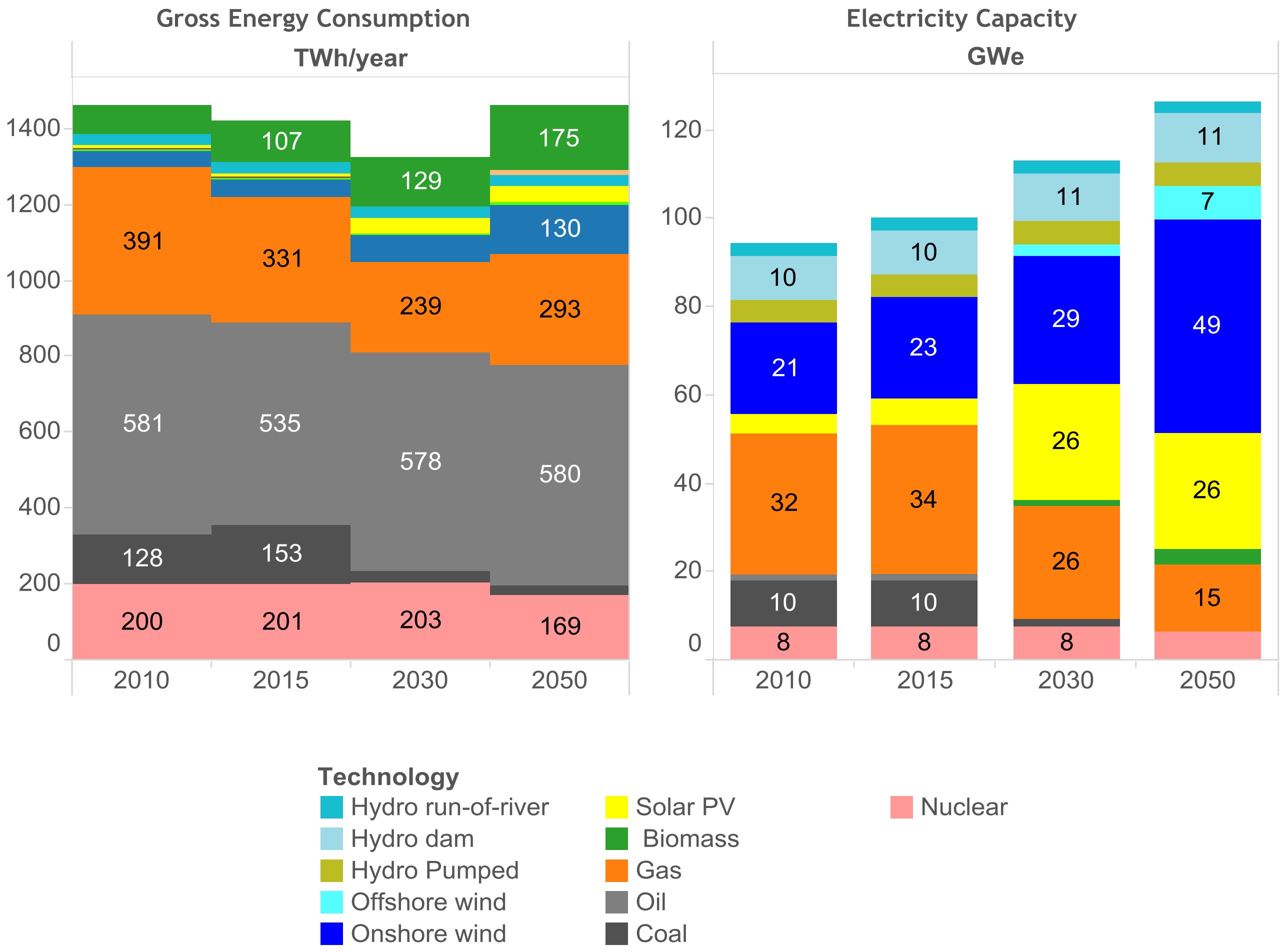


Romania

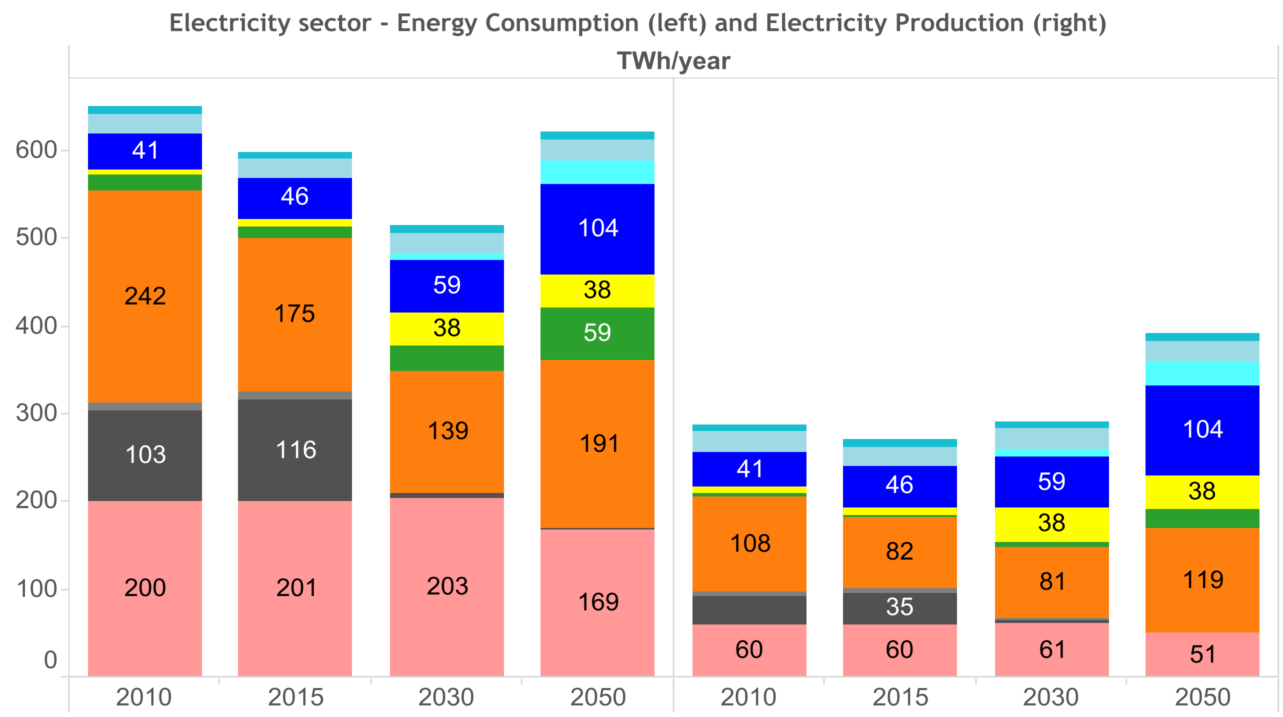


Final energy for Heating & Cooling - Buildings (left) and Industry (right)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.
TWh/year
TWh/year
90
80
70
60
50
40
30
20
10
0
31
39
13
5
34
29
7
5
31
7
8
26
8
4
10
36
10
5
6
29
9
11
6
19
9
10
7
13
8
9
15
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Electricity
Oil Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
DH Coal
DH Gas
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass
DH Coal
DH Gas
Other RES

Spain

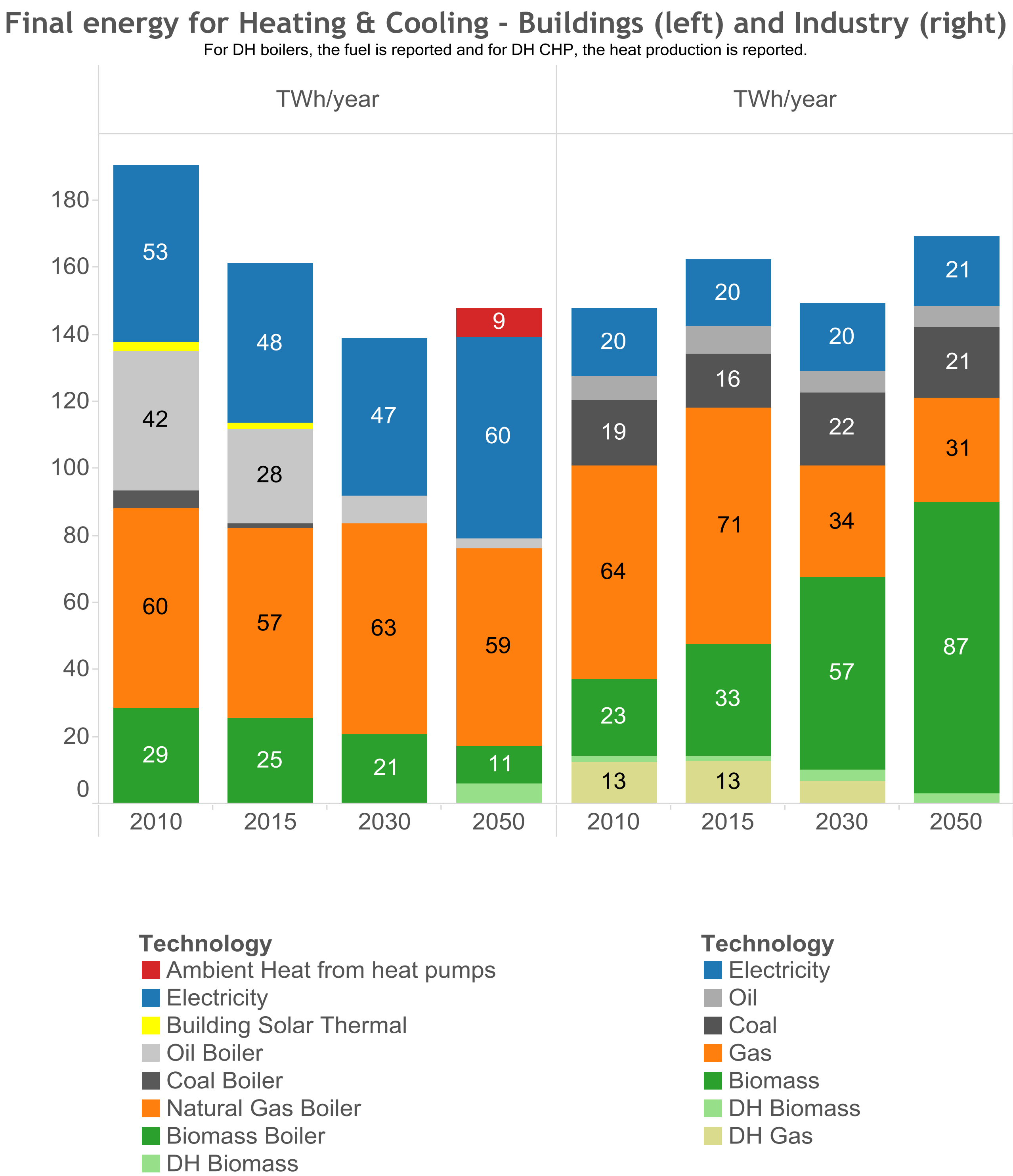


Gross Energy Consumption
TWh/year
1400
1200
1000
800
600
400
200
0
107
175
129
130
391
331
239
293
581
535
578
580
128
153
200
201
203
169
2010
2015
2030
2050
Electricity Capacity
GWe
120
100
80
60
40
20
0
11
11
10
10
7
21
23
29
49
26
26
32
34
26
15
10
10
8
8
8
2010
2015
2030
2050
Technology
Hydro run-of-river
Hydro dam
Hydro Pumped
Offshore wind
Onshore wind
Solar PV
Biomass
Gas
Oil
Coal
Nuclear



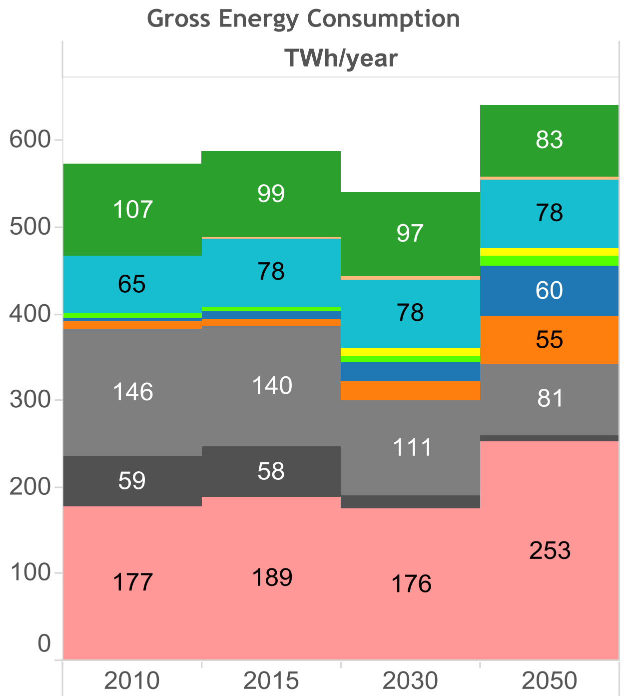
Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
600
500
400
300
200
100
0
41
46
59
104
38
38
59
242
175
139
191
103
116
200
201
203
169
41
46
59
104
38
38
108
82
81
119
35
60
60
61
51
2010
2015
2030
2050
2010
2015
2030
2050

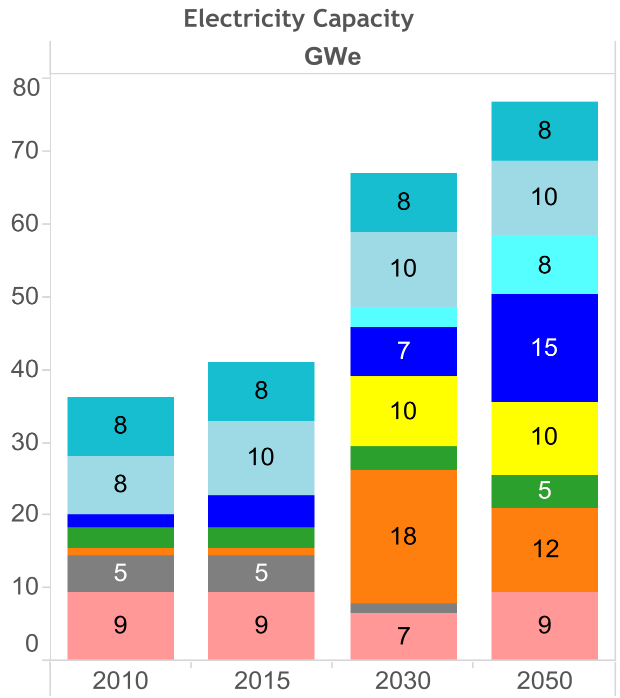
Spain

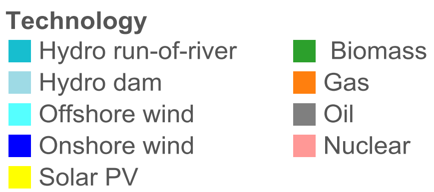


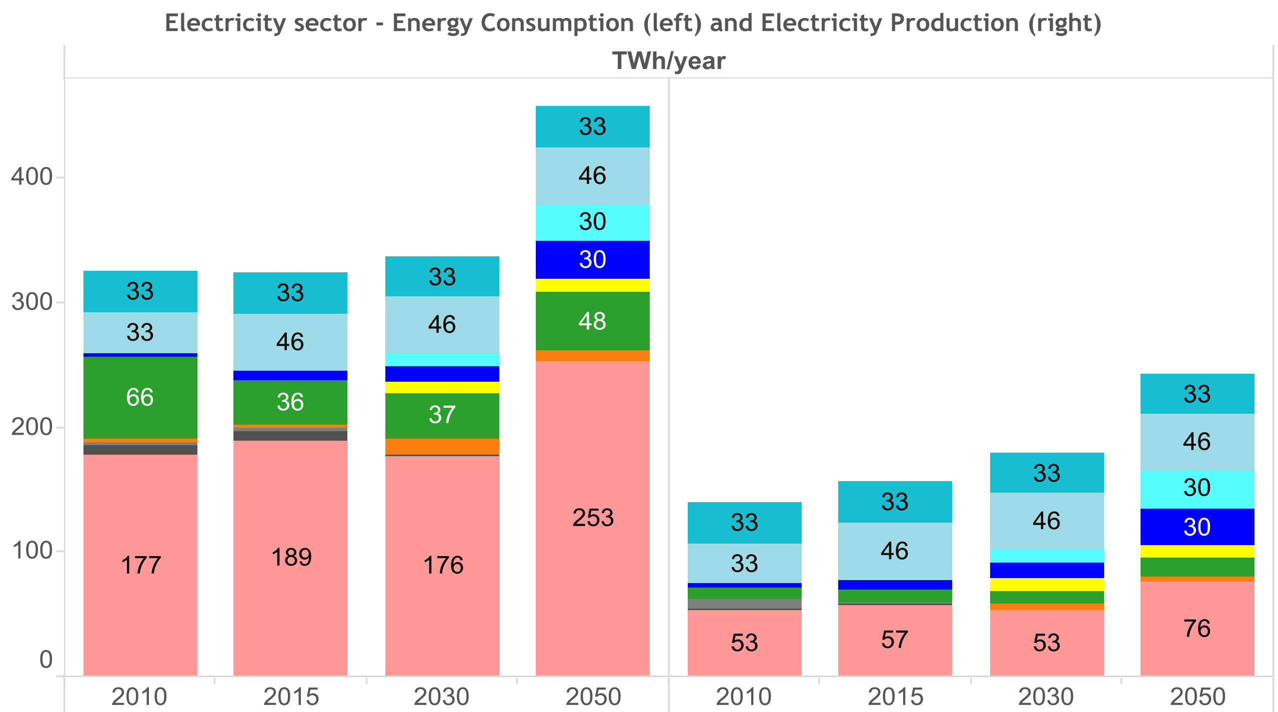
Final energy for Heating & Cooling - Buildings (left) and Industry (right)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.
TWh/year
TWh/year
180
160
140
120
100
80
60
40
20
0
53
48
42
28
47
9
60
60
57
63
59
29
25
21
11
20
20
20
21
19
16
22
21
64
71
34
31
23
33
57
87
13
13
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Ambient Heat from heat pumps
Electricity
Building Solar Thermal
Oil Boiler
Coal Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass
DH Gas

Sweden

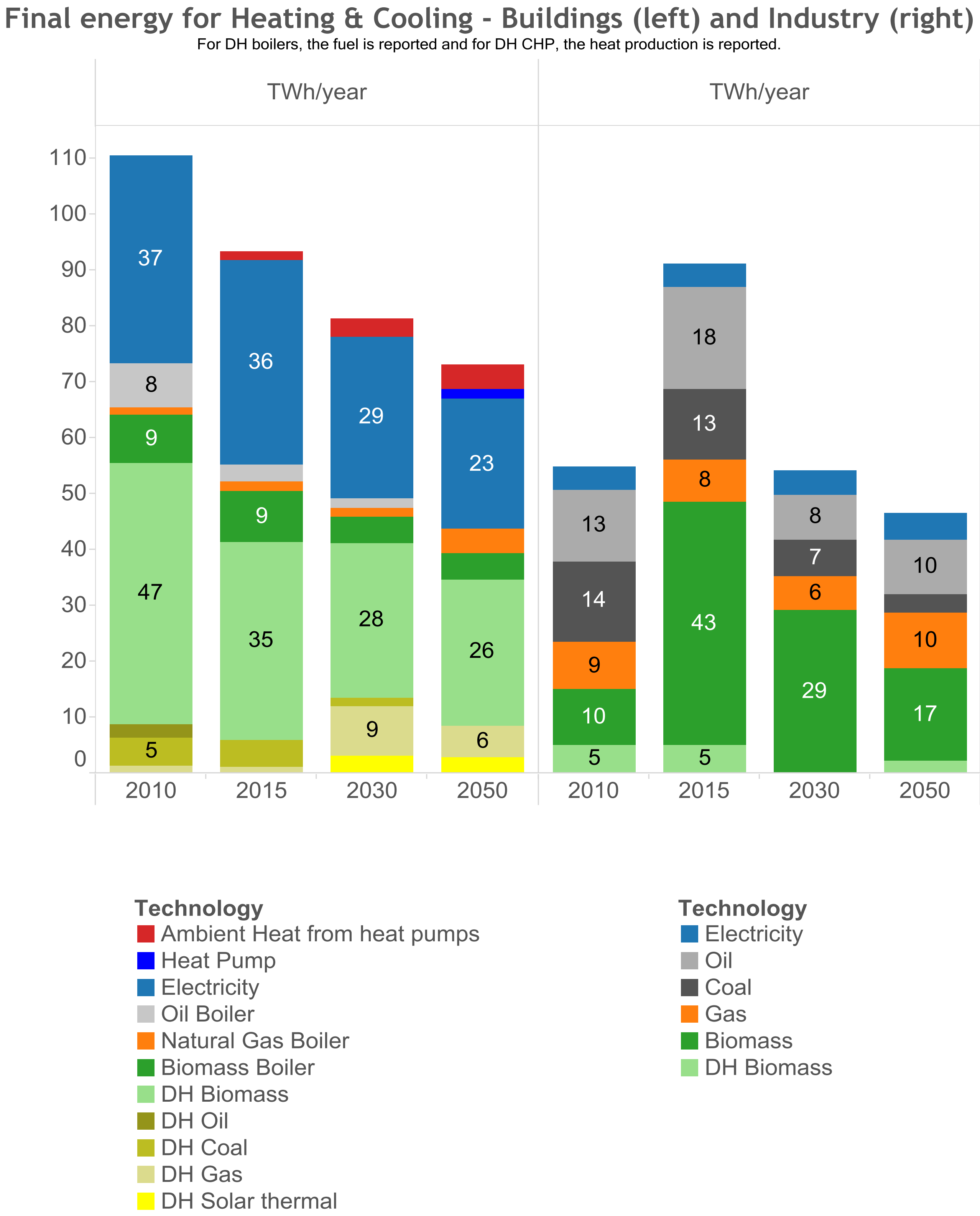

Gross Energy Consumption
TWh/year
600
500
400
300
200
100
0
107
65
146
59
177
99
78
140
58
189
97
78
111
176
83
78
60
55
81
253
2010
2015
2030
2050


Electricity Capacity
GWe
80
70
60
50
40
30
20
10
0
8
8
5
9
8
10
5
9
8
10
7
10
18
7
8
10
8
15
10
5
12
9
2010
2015
2030
2050


Technology
Hydro run-of-river
Hydro dam
Offshore wind
Onshore wind
Solar PV
Biomass
Gas
Oil
Nuclear

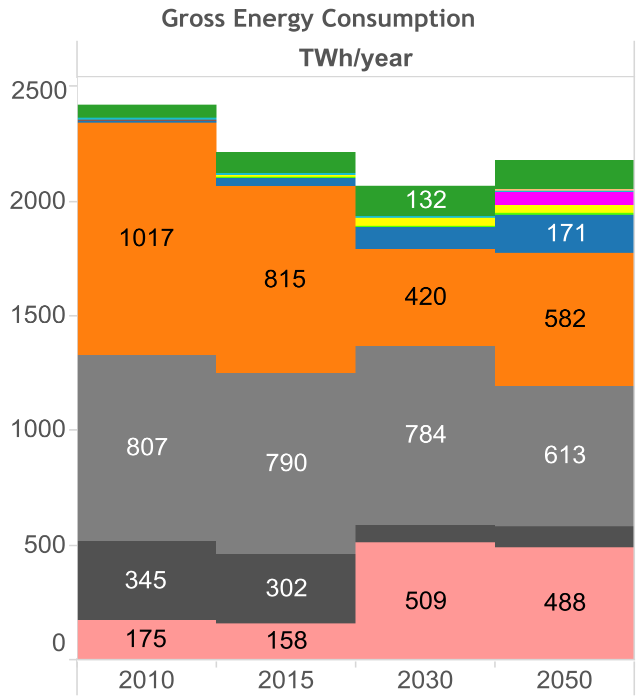

Electricity sector - Energy Consumption (left) and Electricity Production (right)
TWh/year
400
300
200
100
0
33
33
66
177
33
46
36
189
33
46
37
176
33
46
30
30
48
253
33
33
53
33
46
57
33
46
53
33
46
30
30
76
2010
2015
2030
2050
2010
2015
2030
2050

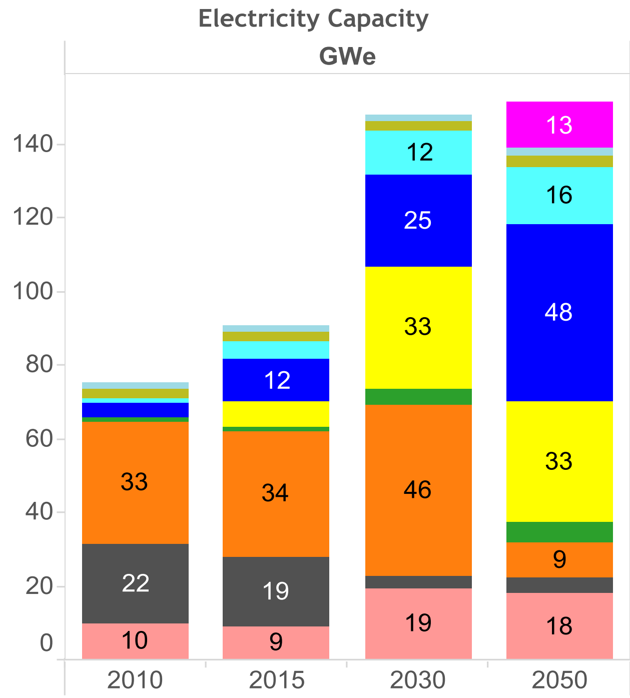
Sweden

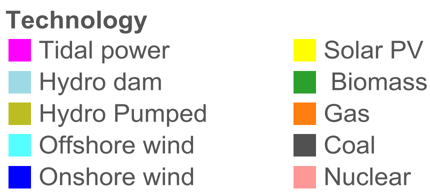


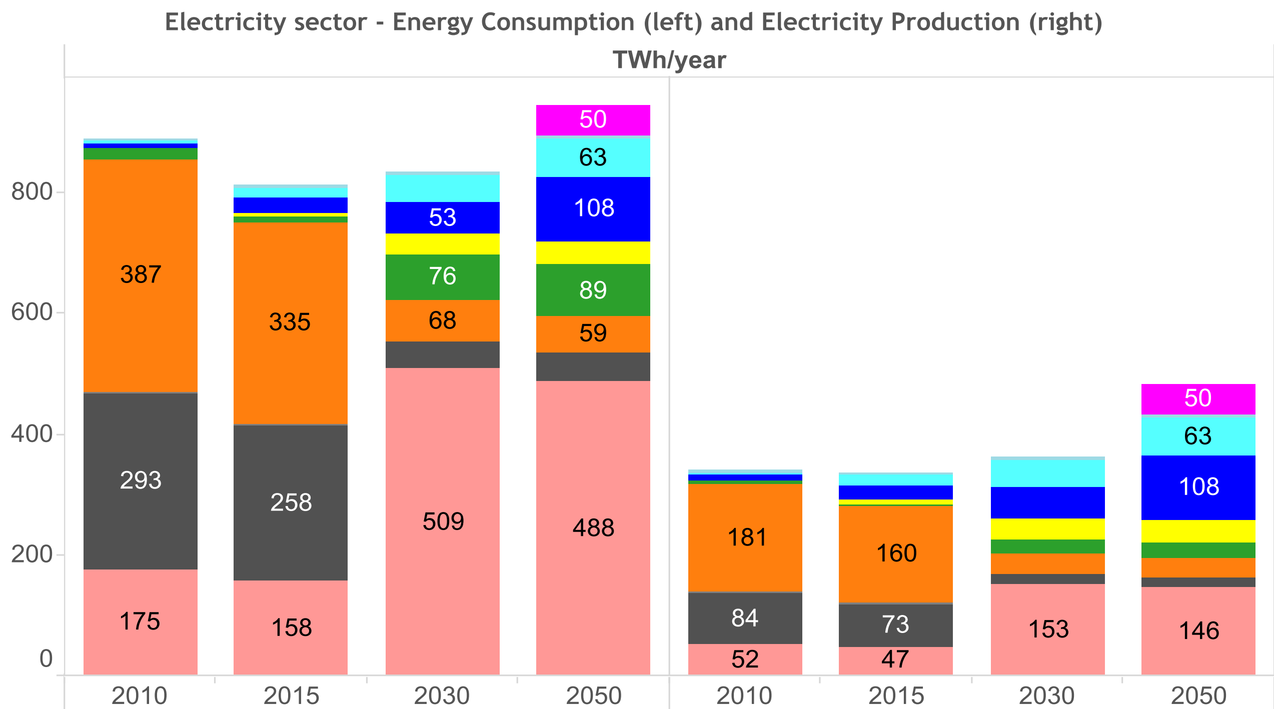
Final energy for Heating & Cooling - Buildings (left) and Industry (right)
For DH boilers, the fuel is reported and for DH CHP, the heat production is reported.
TWh/year
TWh/year
110
100
90
80
70
60
50
40
30
20
10
0
37
8
9
47
5
36
9
35
29
28
9
23
26
6
13
14
9
10
5
18
13
8
43
5
8
7
6
29
10
10
17
2010
2015
2030
2050
2010
2015
2030
2050
Technology
Ambient Heat from heat pumps
Heat Pump
Electricity
Oil Boiler
Natural Gas Boiler
Biomass Boiler
DH Biomass
DH Oil
DH Coal
DH Gas
DH Solar thermal
Technology
Electricity
Oil
Coal
Gas
Biomass
DH Biomass

United Kingdom

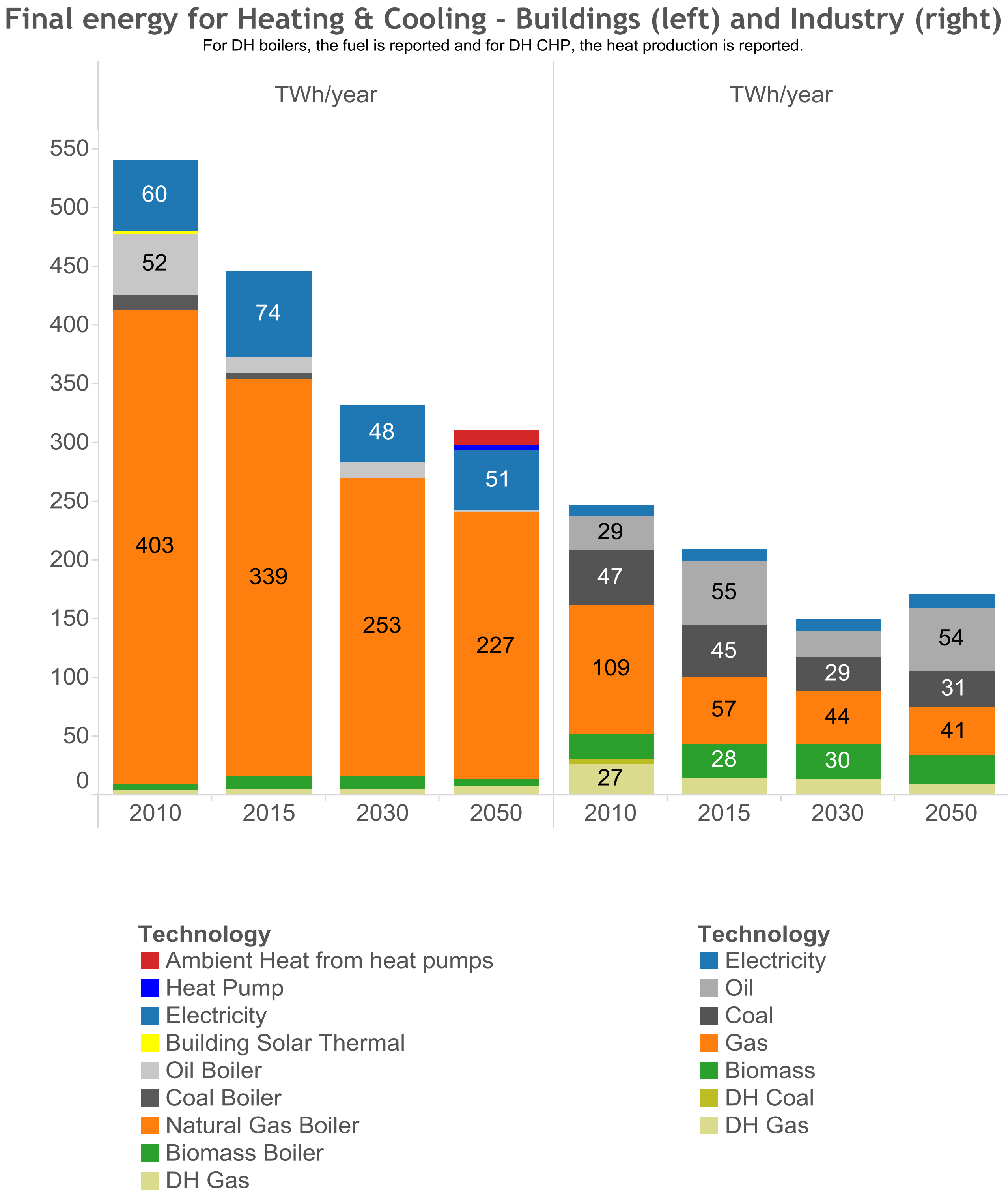








United Kingdom



Annex 2: current energy system, calibration and key sources

To ensure an adequate and accurate representation of the current energy system, the JRC-EU-TIMES is calibrated to 2010 as its base year 2010. The energy supply and demand technologies in 2010 are characterised considering the energy consumption data available from Eurostat. Sector specific energy balances to which the technologies profiles must comply are set also using Eurostat data. Technology information on installed capacity, efficiency, availability factor, and input/output ratio were introduced using diverse national sources. Afterwards, a final bottom-up calibration approach adjusted the technologies specifications to achieve coherence with official national energy statistics. This final adjustment has been especially relevant for the residential and commercial sectors, for which there is less detailed information available on existing technologies. The sections below describe how JRC-EU-TIMES has been calibrated and what sources have been used for it.

Calibration of the residential sector

The heating requirements for the residential sector are calibrated by merging a bottom-up method with a more traditional top-down approach via the following sequential procedure:

1. **Bottom-up geometrical analysis:** The calibration starts with the calculation of the thermal requirements (kWh/m^2) based on technical characteristics of the building. By using nominal U-values (thermal transmittance expressed in W/m^2K by country, period of construction and building component) and average heating degree-days (HDDs), the thermal requirements are calculated for three types of buildings (detached, semidetached and flats), per each period of construction (six periods), as well as for the entire stock (weighted average). The ENTRANZE[22] database has been used as the main reference for this calculation. Behavioural parameters such as fuel poverty that can drive differences between **theoretical** (design) and **real** thermal requirements have been taken into account through a logarithmic-like curve based on Hens et al.[23] The most relevant assumptions in this step are related with the building geometries, the glazed areas, the number of dwellings per each semidetached building, and the correction factors (including ventilation losses and gains from sun).
2. **Top-down actual thermal requirements:** The **actual** thermal requirements (i.e. the weighted average across the period of construction) for the three types of buildings have been estimated on the basis of the breakdown of the residential consumption as it appears in the national energy balances by service and fuel and by assuming efficiencies of the heating systems. National energy balances have been extracted from JRC-IDEES (JRC Integrated Database on the European Energy Sector), which is a "top-down" calculation of the thermal requirements (kWh/m^2) based on the breakdown of the balance item (residential sector) from Eurostat.

[22] Available online at: http://www.entranze.enerdata.eu/

[23] Hens H., Parijs W., Deurinck M. (2010). Energy consumption for heating and rebound effects. Energy and Buildings 42, 105–110

3. **Tuning:** Differences between the bottom-up and the top-down approaches have been calculated. These differences may be driven by a number of factors, which include historical temperature trends (i.e. **cold/warm** winters), behaviour, fuel poverty, partial heating and other factors.

Historical temperature trends have been explicitly represented in the model by virtual processes which convert the building's **standard** heating requirement (based on average Heating Degree Days (HDD)) to **specific** year requirements. Over the short term historical HDDs from Eurostat have been used, while over the long term horizon assumptions are aligned with PRIMES.

All the remaining factors have been explicitly represented in the model by two **virtual** correction factors, named the **Actual to Theoretical Demand Factors** (ATDF). The first one refers to a stock component, captures the share of the stock that is not heated, i.e. due to families that have multiple houses. The second one models the heating intensity component, to include the difference in actual heating intensity due to, for example, different temperature preferences or insufficient resources to heat to a standard comfort level (fuel poverty).

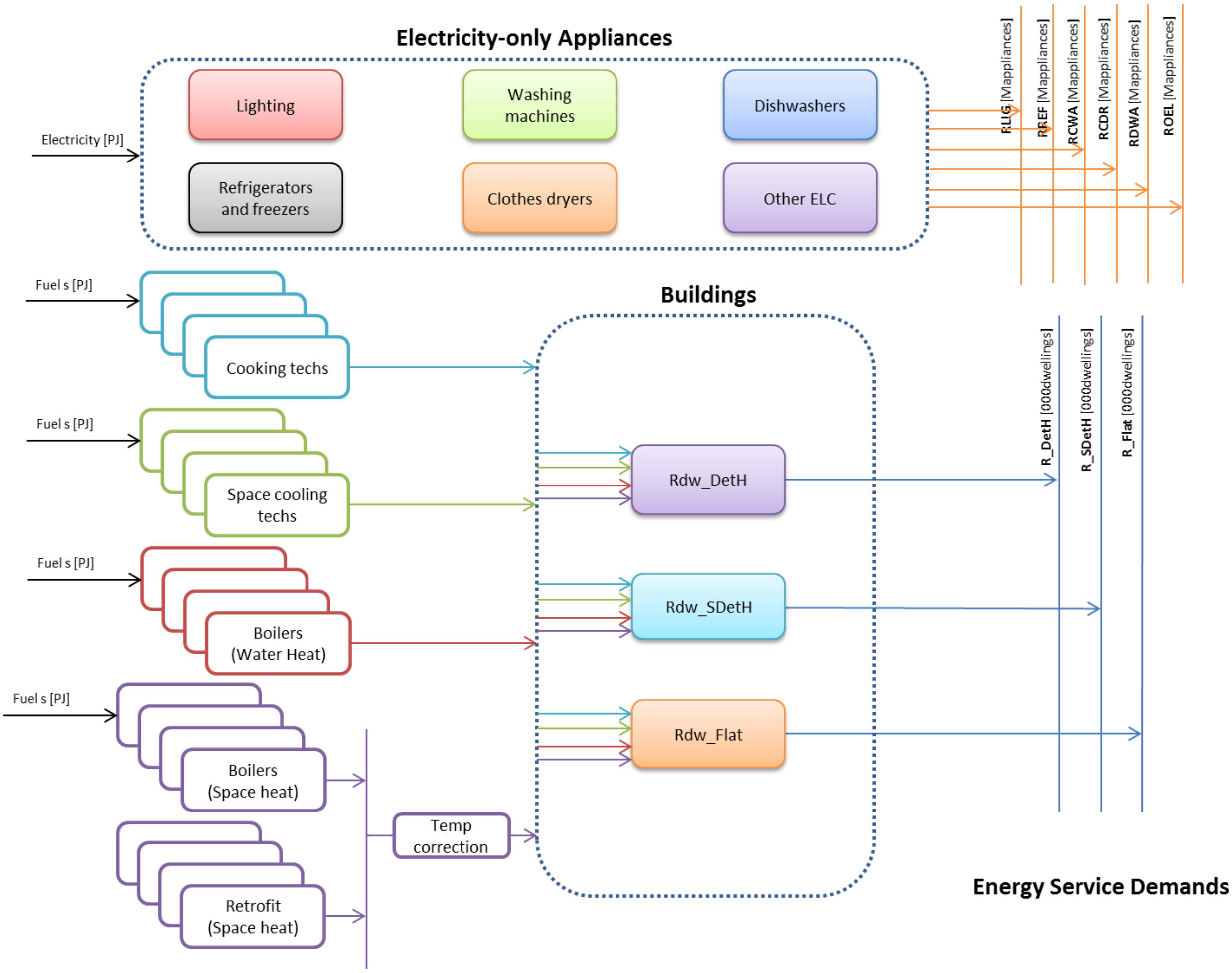


Figure 24. Residential structure in JRC-EU-TIMES

The calibration of the other energy services, namely water heating, cooling cooking and all the electric appliances, followed a more "standard" approach, making use only of the top-down step described in 2). The JRC-IDEES database is the main source used to characterize these residential technologies, i.e. efficiencies, availability factors, etc. The most relevant assumptions concern the nominal capacities of appliances for heating, water heating, cooling and cooking technologies, which are based on own estimates.

Key data sources

The calibration implemented in the JRC-EU-TIMES makes use of the latest available information and statistics about the EU residential sector and in particular the building stock. Where information for some model regions was missing, data was estimated on the basis of neighbouring or similarly economically developed countries. The key input sources are summarized in Table 9.

Table 9. List of key sources used for calibrating the residential sector

Component	Source	Type of data
Building stocks	ENTRANZE	Dwelling stock by construction period, Stock of dwelling per type, Average size of dwelling by type, Average number of dwellings per building, U-values.
	Eurostat	Distribution of population by dwelling type, Population, Heating Degree Days (HDD).
	Own assumptions	Building geometries, the glazed areas, the number of dwellings per semidetached building, correction factors for ventilation losses and gains from sun.
Retrofit	ENTRANZE	Costs and technical characteristics of passive retrofit measures for selected MS.
Energy balances	JRC-IDEES	Disaggregated energy balances for EU-28.
	Eurostat	Sectoral energy balance for IS, ME, MK, NO, RS.
	IEA	Sectoral energy balance for CH, AL, BA, KS.
End-use technologies	JRC-IDEES	Efficiencies of heating, water heating, cooking and cooling technologies, number of electric appliances.
	Own assumptions	Nominal capacities for heating, water heating, cooling and cooking technologies

Calibration of the tertiary sector

The breakdown of the "thermal" energy requirements (i.e. space heating, water heating, cooling and cooking) for each of the commercial activities is provided. For the base year it has been estimated on the basis of the breakdown of the commercial sector consumption (item of the national energy balance) by service and fuel; and by assuming a further split into single activities. National energy balances have been extracted from the JRC-IDEES (JRC Integrated Database on the European Energy Sector), which is a "top-down" calculation of the energy requirements based on the breakdown of the balance item (commercial sector) from Eurostat. The further breakdown of energy by activity is based on the analysis developed by JRC experts on a number of target countries (Spain, Germany, UK, Sweden, France). Assumptions for other MS have been done on the basis of similar climate and similar economic development.

The calibration of the other energy services, namely lighting, building technologies, ICT and multimedia, refrigeration, street lighting and ventilation, followed a more “standard” approach, making use only of the breakdown of the commercial sector consumption (item of the national energy balance) based on the JRC-IDEES database estimates.

Were information were missing energy balance items for Eurostat or IEA were used. The most relevant assumptions regard the nominal capacities of appliances for heating, water heating, cooling and cooking technologies, which are based on own estimates.

Key data sources

The JRC-IDEES database has been used as main source for the disaggregation of consumption by fuel and services. Where information was missing, Eurostat and IEA energy balances have been used as main source and the breakdown was estimated on the basis of neighbour or similar economic development countries. The breakdown between different activities (e.g. hotels, hospitals, etc.) is based on surveys for some key MS which has been provided by JRC. The estimates of heated and cooled areas are based on ENTRANZE online database[24] (which collects information from a number of other sources, mostly from BPIE). The key input sources are summarized in Table 10.

Table 10. List of key sources used for calibrating the tertiary sector

Component	Source	Type of data
Building stocks	ENTRANZE JRC	Breakdown of floor areas by non-residential sub-sector. Breakdown of consumption by building type (for selected countries).
Energy balances	JRC-IDEES Eurostat IEA	Disaggregated energy balances for EU-28. Sectoral energy balance for IS, ME, MK, NO, RS. Sectoral energy balance for CH, AL, BA, KS.
Retrofit	ENTRANZE RSD Retrofit SubRes	Costs and technical characteristics of passive retrofit measures. Savings assumed as the ones for the residential Flats
End-use technologies	JRC-IDEES Own assumptions JRC-EU-TIMES 2013 model	Efficiencies of heating, water heating, cooking and cooling technologies, number of electric appliances. Nominal capacities for heating, water heating, cooling and cooking technologies Availability factors, Technical life

24 Available online at: http://www.entranze.enerdata.eu/

Calibration of the transport sector

The JRC-EU-TIMES model provides the breakdown of the energy requirements and demands for each relevant transport mode. Namely the demand modelling covers private transport (cars, mopeds and motorcycles), public road transport (urban buses and coaches), road freight (trucks and light commercial vehicles), rail (metro, standard passenger trains, high speed trains and freight), navigation, and aviation (passenger and freight). For road transport the breakdown of the base year has been estimated on the basis of the technical details provided by the TRACCS[25] database by type of vehicle and fuel. For all the other transport modes the breakdown is provided by the JRC-IDEES (JRC Integrated Database on the European Energy Sector). JRC-IDESS provides a "top-down" calculation of the energy requirements based on the breakdown of the balance item (transport sector) from Eurostat. Where information for some regions of the JRC-EU-TIMES was missing, the available energy balances have been used and its corresponding breakdown was estimated on the basis of neighbour or economically similarly developed countries.

Key data sources

The template makes use of the latest available information and statistics about the EU transport sector. For each section of the template, the following key data sources have been used.

- The latest TRACCS datasets for calibrating fuel uses, efficiency, occupancy and demands in road transport (private transport, public buses, freight).
- The JRC-IDEES datasets for calibrating EU-28 aviation, navigation, rail and bunkers fuel uses and energy service demands.
- Where country specific information was missing from TRACCS and JRC-IDEES, the Eurostat and IEA energy balances have been used as main source. The breakdown of the energy balance item was estimated on the basis of neighbour or similar economic development countries.

The key input sources are summarized in Table 11.

[25] Available online at: http://traccs.emisia.com/

Table 11. List of key sources used for calibrating the transport sector

Sector	Source	Type of data
Road transport	TRACCS Eurostat IEA	Vehicle stocks, Fuel consumption, Average occupancy/tonnage, Average Efficiency for EU-28, CH, NO, IS and MK. Sectoral energy balance for ME and RS. Sectoral energy balance for AL, BA, KS.
Aviation	JRC-IDEES Eurostat IEA	Disaggregated energy balances and activity for the EU-28. Sectoral energy balance for IS, ME, MK, NO, RS. Sectoral energy balance for CH, AL, BA, KS.
Navigation	JRC-IDEES Eurostat IEA	Disaggregated energy balances and activity for the EU-28. Sectoral energy balance for IS, ME, MK, NO, RS. Sectoral energy balance for CH, AL, BA, KS.
Rail	JRC-IDEES Eurostat IEA	Disaggregated energy balances and activity for the EU-28. Sectoral energy balance for IS, ME, MK, NO, RS. Sectoral energy balance for CH, AL, BA, KS.
Bunkers	JRC-IDEES Eurostat IEA	Disaggregated energy balances and activity for the EU-28. Sectoral energy balance for IS, ME, MK, NO, RS. Sectoral energy balance for CH, AL, BA, KS.

Calibration of the industrial sector

The industrial sector has been recalibrated maintaining the technology-explicit detail of the previous JRC-EU-TIMES model version and when possible, adjustments and updates on data assumptions were made based on more recent indicators available from the IDEES database and other sources. The key features of this database are the following:

- The sector has been calibrated based on 2010 Eurostat energy balance data. Where information was not available, IEA energy balances have been used.
- The number and the definition of the following industrial sub-sectors have been maintained as in the previous JRC-EU-TIMES model version; namely Iron and Steel (IIS), Non-Metallic Minerals (ICM, ILM, IGF, IGH, INM), Pulp and Paper (IPP), Chemical Industry (IAM, ICL, ICH), Non-Ferrous Metals (IAL, ICU, INF), Other (IOI).
- The new Non-Energy Use in Industry Sectors (NEU), has replaced the Non-Energy Consumption Chemicals (NEC) and Non-Energy Consumption as in the Eurostat statistics.

- The assumptions on all the key energy service demands have been updated based on latest EU Energy Reference Scenario available.

For a more complete overview of the sector structure and details please refer to the JRC-EU-TIMES model documentation[26].

Key data sources

The template uses a number of sources to provide a calibrated industry sector for 2010. All key input data and assumptions have been explicitly referenced and indicated. The following table summarizes the key input sources used.

[26] Simoes, Nijs, Ruiz, Sgobbi, Radu, Bolat, Thiel, Peteves (2013), The JRC-EU-TIMES model. Assessing the long-term role of the SET Plan Energy technologies. JRC Scientific and Policy Reports. Luxemburg. doi: 10.2790/97596.

Table 12. List of key sources used in the IND template

Component	Source	Type of data
Energy balances	Eurostat	Sectoral energy balance for EU-28, IS, ME, MK, NO, RS. Transformation input in autoproducers for EU-28, IS, ME, MK, NO, RS. Electricity generation autoproducer electricity only, CHP plants and main activity (Eurostat table nrg105a) for EU-28, IS, ME, MK, NO, RS.
	IEA	Sectoral energy balance for CH, AL, BA, KS.
Demands	JRC-IDEES	Demands for Iron and Steel, Aluminium, Cement and Lime, Glass, Pulp Paper and Printing for EU-28.
	USGS Mineral Yearbook	Demands for Copper for all countries; demands for Iron and Steel, Aluminium, Cement and Lime for missing countries in JRC-IDEES.
	JRC-EU-TIMES 2013 model	Production shares for Cement and Lime, Glass. Demands for Pulp Paper and Printing for missing countries in JRC-IDEES. Demands for Ammonia and Chlorine for selected countries.
	JRC	Demands for Ammonia for EU-28 for selected EU countries.
	EuroChlor	Demands for Chlorine for selected EU countries.
Technologies	JRC-EU-TIMES 2013 model	Default technological assumptions for EU-28+.
	The Balkan countries Final Report[27]	Default technological assumptions for Balkan countries.
	Own assumptions (starting from old JRC-EU-TIMES assumptions)	User input data for calibration, Fractional shares.

Calibration power generation

The EU power plants are grouped by fuel type, but vintages have been defined. The power plant capacities have been calibrated based on Platts Powervision[28] 2014 data. For all technologies coming from Platts (except solar and wind) endogenous retirement is allowed starting from 2020. No minimum or maximum retirement has been imposed.

For the year 2015, solar PV capacities are aligned with Eurostat data and wind capacities are aligned with the JRC wind database.

[27] Tender JRC/PTT/2012/F06/063/NC – B110513 Extension of the JRC-EU-TIMES energy systems model geographical coverage to include Balkan countries

[28] S&P Global. Platts PowerVision data base.

Key data sources

Table 13 summarizes the key data sources used for calibrating the power sector.

Table 13. List of key sources used in the ELC template

Component	Source	Type of data
Generation portfolio	Platts Powervision JRC-EU-TIMES 2013 model JRC-IDEES Eurostat	EU power plants capacities (by installation period). Efficiencies, Operation costs Availability factors for dispatchable generation CHP Heat to Power Ratios (CHPR)