Energy Scenarios

in support of the EN-H2

National Strategy for Hydrogen

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1. Introduction

This document provides a summary of energy-emissions BASE scenario that supported the Portuguese National Hydrogen Strategy (EN-H2), published as a Ministerial Resolution in August 14, 2020 (EN-H2, 2020). These scenarios were developed at the Division of Studies, Research and Renewables of the Portuguese Directorate-General for Energy and Geology (hereafter DGEG), using a proprietary national energy-emissions model, JANUS. This model is mounted over the LEAP platform - Long-range Energy Alternatives Planning System (Heaps, 2016). It is a bottom-up energy modelling tool, enabling the modelling of the various energy demand, transmission, and transformation technologies. Although LEAP can be run searching for cost-optimal solutions, it was found more useful to run it in a backcasting mode: starting from public policy targets such as renewable energy shares, GHG ceilings, energy efficiency obligations, and allowing only a certain set of technological value chains selected or indicated exogenously. Economical analysis is still performed but it is not exclusive in determining the more interesting scenarios.

JANUS 4.27 had already been used for developing scenarios this way in support of the National Energy and Climate Plan 2021-2030 (NECP, 2020), as described in the first issue of this same series of studies of the Portuguese energy system (DGEG, 2020).

JANUS 5.0 of the model was developed for the Project "Assessment of the Potential and Impact of Hydrogen in Portugal – Strategy for Sustainability" (DGEG, 2019 a), that was essentially a roadmap for selecting the best hydrogen value chains for the specific case of Portugal. The selected best new value chains were added to the JANUS previous versions, and the time horizon expanded to 2040. Six scenarios were built which are explained in DGEG (2019 b), regarding the original NECP, two updates of the NECP, and three disruptive visions for a new, more intense role of hydrogen in the Portuguese energy system. Innovative technologies were added, including most notably batteries, deep geothermal, advanced biofuels and hydrogen technologies, including production via natural gas reforming, electrolysis and biomass gasification.

At request of the Secretary of State for Energy, for supporting decisions regarding the assembling of the EN-H2, the same JANUS 5.0 version was used with some improvements. Three scenarios were built – LOW, BASE, and HIGH. The BASE scenario came to be the numerical basis for the energy-related forecasts supporting EN-H2 (obviously many other information sources were considered to assemble the strategy and define its goals).

2. Storyline of the EN-H2 BASE scenario

This section addresses in more detail the EN-H2 scenarios characteristics, in particular the BASE scenario. The scenarios update the NECP scenario and extend it to 2050. In addition to a review of the macro-economic outlook and end-use energy demand in the economic sectors, while maintaining the emphasis on renewable electricity production and its penetration in the energy end-use mix, hydrogen technologies are introduced along the strategic lines of EN-H2. The way this is done seeks to optimize the management of energy assets; decarbonize energy end-uses whose approach via electricity would be economically unfeasible (e.g. high range temperatures, but not only), either through the direct use of hydrogen or through the use of the increasingly renewable blend of gases circulating in the current natural gas network; provide great flexibility and security of supply at all time scales; and even decarbonize the use of certain raw materials.

The NECP national and sectoral targets for 2030 are maintained:

- 47% renewable fraction at gross final consumption of energy
- 80% renewable fraction at gross final consumption of electricity
- 20% renewable fraction at transportation (EU definition but without multipliers)
- 1% per year rise of the renewable share at heating and cooling processes,

as well as the carbon neutrality national objective in 2050, which translates in a reduction of at least 95% of GHG emissions of the energy sector by 2050 (relative to 2005).

However, with the introduction of hydrogen there are now more alternatives and more room for maneuver in choosing the solutions to be promoted in each decade until 2050.

Hereafter we review the major new features of the EN-H2 BASE scenario, contrasting when adequate with the NECP "With Additional Measures" scenario (WAM), that is described in detail at another report (DGEG, 2020).

2.1. Energy demand

The BASE scenario received:

i. A short-term update of the macroeconomic scenario with the impact of the Covid-19 pandemic, and in the long term, of the level of demand in the economic sectors as a result of increased use of Information and Communication Technologies; in particular, increased use of teleworking and teleconferencing, with some increase in household energy demand and reduction in commuting, but especially with significant reductions in domestic and international business travel, with particular impact on aviation and business tourism.

ii. Inclusion of the renewable contribution of heat pumps (heating and cooling of buildings), same as in the reviewed NECP WAM 2020 scenario but not included in the original NECP WAM scenario submitted to the European Commission in December 2019.

iii. Downscaling of the NECP electrification level in some sectors, with emphasis on some of the 15 industrial sub-sectors, and assuming less battery-based electrical propulsion in shipping and long distance aviation.

iv. Upward revisions of the outlook for the use of renewable fuels of non-biological origin (RFNBO), including but not only hydrogen, in the industry and transport sectors (in particular at road transportation of merchandise, transportation by rail, shipping, and aviation).

v. Inclusion of the needs and opportunities for the use of hydrogen in conventional refining and as a raw material at the industrial sub-sector of chemicals and plastics.

2.2. Energy transformation

Two differences of EN-H2 in relation to the NECP WAM scenario are that:

i. decommissioning of coal thermal power plants is expected to happen until 2022, not 2030;
ii. some planned reversible hydroelectric systems will not be built after all, simply because it seems that there is no unavoidable technical necessity to do it, or interesting business case exists.

Much more important is that, while the NECP WAM scenario already accommodated some hydrogen production after 2030, the new EN-H2 strategy increases this ambition enormously and takes much early action, starting operations by 2022. Large-scale hydrogen production by electrolysis is implemented, dimensioned to be supplied by renewable electricity from dedicated power plants, mainly solar photovoltaic, but also wind turbines (2:1 ratio). Also, when possible, electrolysis is to use excesses of national and international production potentially available from the grid at very low cost, avoiding wind and solar power curtailment in passing. In the central or BASE scenario, the total (generating) power considered in 2030 is 2.2 GW (at the LOW scenario it was 10% lower, viz. 2.0 GW; and in the HIGH scenario, about 15% higher, viz. 2.5 GW). By 2050 the installed power grows by about 8 times.

Additional value chains for hydrogen production are also considered, although with much less installed power than for electrolysis:

i. biomass gasification, redirecting part of the biomass resources allocated in the NECP to electricity production and advanced biofuels; and
ii. separation of water with thermo-electrochemical technologies; these are viewed as unicorn-type technologies, meaning that the respective value chains are considered with small installed power in the scenario, but if they turn out as successful as currently expected, they could change the panorama of hydrogen production, even overcoming "conventional" electrolysis.

The BASE scenario also considers small amounts of renewable fuels of biological origin other than biofuels for transportation. It is foreseen the use of hydrogen in methanation of biogas and gasified biomass, resulting in renewable methane which, accompanied by biomethane, will be injected into the gas network.

But the other major feature of EN-H2 that differs from the NECP views, other than the scale of hydrogen production, is the production of very significant amounts of RFNBO, such as methane, methanol, and jets, obtained by methanation of CO_2 streams from carbon capture (CCU processes). The capacity to be installed at the RFNBO production processes is about half the capacity at the large scale electrolysis plants for hydrogen production; their energy supply coming, again, mostly from dedicated solar PV power plants. By 2030 about 2/3 of the renewable hydrogen production is exported, the rest being used internally.

It is relevant to remark that 'blue hydrogen' – obtained by reforming natural gas and using CCS (carbon capture and geological storage) – is not considered in the EN-H2. Although for some countries this may be a technologic trajectory that makes sense at an initial stage of an hydrogen strategy, that is not the case for Portugal. On the one hand, a CCS infrastructure would need some years to develop; on the other hand, the very low prices of solar electricity in the country mean that obtaining renewable hydrogen by electrolysis already is cheaper than blue hydrogen. So, the opportunity window for blue hydrogen and the related CCS in Portugal is very narrow, if it exists at all. In contrast, renewable hydrogen is expected to be used at refineries to progressively replace hydrogen from natural gas reforming, as well as raw matter for the chemical and plastics industry, for instance at the fabrication of ammonia.

Navigation and aviation are to be decarbonized via the use of RFNBO fuels, namely hydrogen and methane. Methanol is seen as another one of those unicorn-type alternatives in the scenarios: technically possible and even able to dominate the panorama, but not favored at current technological and political views. In land transport, decarbonization is still viewed as being achieved via electric vehicles, but while the NECP considered only batteries except at very long range haul of merchandise, EN-H2 features a more widespread and stronger component of vehicles based on hydrogen fuel cells.

Electricity production based on hydrogen is of course also a possibility but must follow the "efficiency first" principle, and avoid important lost assets, namely at thermal power plants. Therefore, it is only foreseen to substitute current methane turbines for hydrogen turbines (or perhaps fuel cells) when the blend of hydrogen in the gas network reaches a maximum and the existing gas turbines reach their end of life (therefore around 2035-2040).

2.3. Decarbonizing the gas supply

The renewable hydrogen is to be used directly as fuel across all sectors in new equipment, although especially at transportation and industry, but it is also envisaged that it will be injected in the (current) natural gas network, thus allowing for utilization in existing equipment. The Portuguese gas network is relatively recent, so it enables for the transportation of hydrogen without significant leaks and corrosion effects. It is foreseen that the amounts of hydrogen injected into the gas network will grow until 2030 up to the level that requires no change in end-use equipment, viz. about 10% by volume. This will have an impact across all sectors of final demand, as mentioned, but also in gas-based power plants and cogeneration units, that no longer will be considered pure fossil fuel based installations (and will emit less harmful GHG and produce electricity with an implicit renewable fraction). From 2030 onwards, progressive adaptation of gas end-use equipment is considered, enabling even more blending of hydrogen, until the technical limit of the gas network is reached by 2040, i.e. about 20% by volume (ca. 8.5% in terms of energy) and then becomes stable.

Meanwhile, renewable methane will also be blended in the mixture of gases circulating in the network, in increasingly larger quantities. By 2045 the gas network will be almost completely decarbonized, containing a mixture of hydrogen and renewable methane from various sources.

It must be remarked that no similar strategy is adopted for LPG, seen as gases to be phased-out rapidly and thus presenting no business cases for decarbonization.

2.4. National energy dependence

Portugal has been very dependent on imported oil and natural gas, although in the case of oil, a large share is processed in refineries and secondary fossil fuels are exported (mostly gasoil). The general approach of EN-H2 is to reduce the need for combustion fuels by electrifying end uses, although with less extent than foreseen by the NECP, and supply the remainder fuel needs with RFNBO (and some biofuels). This way the national dependence on imported fossil oil and gas progressively disappears. Of course, refineries also make less and less secondary fuels for exporting, and by 2045 they should have stopped operations (this does not mean that the facilities are closed, as they are expected to have transformed meanwhile into biorefineries and/or RFNBO fabrication). So, the imports and exports of fuels contract together, towards near equilibrium by 2050. The BASE scenario expects that, at that horizon Portugal has no external dependence on fuels, and in fact becomes a net exporter of hydrogen (and biomass).

As regards electricity, Portugal has also been, in most years, a net importer. The EN-H2 scenarios specify, at long-term, a neutral performance in the export/import of electricity, as already did the NECP WAM scenarios.

The overall result of the EN-H2 approach is an energy system almost 100% renewable by 2050 and without external dependence, overcoming the hindrances that the NECP approach posed to make further progress after 2030, especially the slow pace and hurdles of electrifying all high temperature industrial processes, shipping, and aviation.

2.5. Security of supply

As Portugal could not find significant, economically viable, endogenous fossil fuel resources, security of supply has always been a major concern, and in fact one of the major drivers of the country towards developing its large renewable energy potential.

From the EN-H2 strategy outlined in sections 2.2 to 2.4 above, it is evident how security of supply of fuels is to be solved in the long term. However, how the issue of security of supply of electricity is handled is probably much less evident.

Some decades ago, the electricity system was based on thermal power plants and cogeneration, and on hydroelectric power plants – some run-of-river, others with dams. Short-term, seasonal and interannual variability of precipitation could always be compensated by the thermal power plants. Also, importing electricity (mainly from Spain) was always an option. However, in the last decades, and especially since 2010, introduction of more and more capacity from variable renewables – especially hydro, wind and solar – accompanied by the decommissioning of conventional thermal power plants, has been putting pressure on this strategy. It is remarkable that the utilities and technical system operator have been able to maintain quality of service without experiencing problems as serious as once feared, and in fact it was even possible at some strings of days to supply the country with renewable electricity only. Besides the technological improvements at control and scheduling, important contributors for this result were the geographical dispersion of wind turbines, their reaching at higher altitudes with more stable wind flows, and the large hydro storage capacity, including reversible hydro plants built meanwhile. More recently, the PV power plants have also shown a welcomed ability to produce some energy even during overcast and cloudy skies. Also, precipitation and solar radiation availability are mostly out of phase with each other, and this complementarity is beneficial at daily as well as at seasonal time scales. In summary, the combined supply of renewable energy from various sources was less variable than could be naively expected, and storage and imports were enough to ensure stability of supply.

Nevertheless, for very high levels of penetration of renewables, such as the 80% target in 2030 endorsed by the NECP and EN-H2 (the scenario value is even higher), additional options should be available. The NECP proposes several for the horizon 2030, but the most important are:

- wind and solar PV power plants with battery storage;
- concentrated solar power plants (with thermal storage);
- offshore wind parks;
- additional reversible hydro power plants.

An auction for renewable capacity at 24 august 2020 (MAAC, 2020) already selected solar PV projects with aggregated capacity of 483 MW installations, featuring on-site storage. CSP power plants are well developed in neighboring Spain, and Portugal also enjoys vast areas with high direct normal irradiation. The recent news about the Windfloat offshore wind project (EDP, 2021) are encouraging, with performance 45% above predictions, and much more stable production than expected. A study on storage commissioned by the Government (UL, 2020) indicated that the existing and under construction hydro storage is under-utilized (probably due to market failures) and can comply with daily and weekly weather variability under the NECP or EN-H2 scenarios. Therefore, it can be said that the NECP security of supply measures at all these four vectors, really seem feasible.

Still, the NECP approach does not solve the problem of interannual variability of the climate, it requires imports during years of lower level of the hydro, wind and/or solar renewable resources. In principle, these imports are available, especially from Spanish coal and nuclear power plants, but as Spain also accelerates the pace of decarbonization and decommissions part of its nuclear fleet, past 2030 this is not so sure.

More important yet, is that although the NECP strategy can lead the country to reach the desired national goals at 2030, it does not seem able to be pushed beyond this horizon to further increase renewable shares. In particular for electricity production, progress above around 85% renewable fraction would require the shutdown of all thermal power plants – endangering security of supply at all time scales.

The EN-H2 solves these drawbacks of NECP by considering further dispatchable capacity from other renewable energy technologies, such as enhanced geothermal, but mainly by using a different strategy for thermal power plants. As mentioned before, decarbonizing gas supply with renewable hydrogen and renewable methane means that the thermal power plants can produce renewable electricity and need not be taken out of the national electric system. Together with large scale hydrogen and methane storage (possibly in salt caverns as done today with natural gas) this will enable to handle the problems of weather variability, for intra-annual as well as inter-annual time scales.

The security of supply is further reinforced by considering more small scale PV systems with storage at buildings and energy communities, and by the possibility of, under exceptional circumstances, connecting to the national grid the PV and wind power plants dedicated to production of hydrogen and other RFNBO.

2.6. GHG emissions and CCUS

CO_2 emissions from the energy system in 2050 are projected to be less than 2% of 2005 emissions. This is achieved primarily through the combined effect of energy efficiency, renewable-based electrification, biofuel and hydrogen (that have no environmentally harmful GHG emissions), and of other RFNBO with low GHG emissions, mainly synthetic methane and jets.

The environmentally harmful GHG emissions of these RFNBO can be modulated by carefully selecting the CO_2 streams used in their manufacture. This CCU aspect stands more implicit than highlighted in EN-H2, nonetheless it is a technical necessity. In this context, capture of emissions from biomass based thermal power plants and boilers has the highest priority, as they have no implicit fossil content. Whereas emissions from fossil fuels or from non-energy processes (such as cement and lime manufacture) have the lowest ranking for CCU because they lead to just a transitory use of CO_2, which will end up in the atmosphere anyway. The modelling shows that by about 2040 CO_2 becomes more of an asset than a liability, because by that time there remain few large stationary sources of CO_2 that can offer CCU paths for RFNBO fabrication. However, the current scenarios need not consider direct air capture of CO_2 to achieve the desired reductions of GHG emissions from the energy system.

As a result of this approach of EN-H2, the need for using carbon sinks – geological sequestration (CCS) or biological sequestration – is very reduced and achieving the country goal of carbon neutrality by 2050 is facilitated. In conclusion, for Portugal, although some sectors like cement production may need to resort to CCS to reach their specific environmental targets (viz. under the ETS scheme), current national energy plans require CCU and possibly temporary storage of CO_2 (e.g. in salt caverns such as it is done today for natural gas), but not CCS.

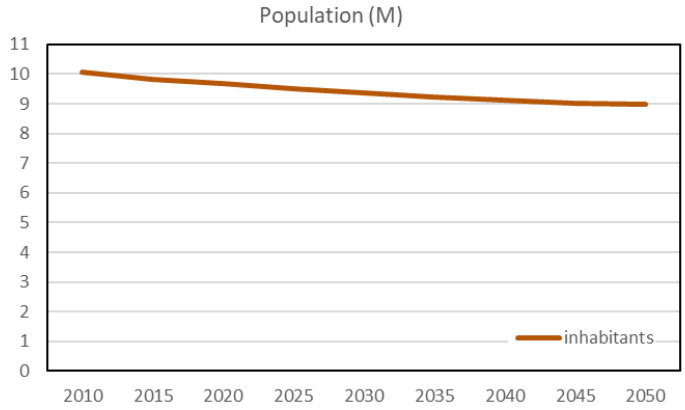
2.7. Refreshed BASE scenario

The first review of the present document follows an update of the BASE scenario with model JANUS 5.1, featuring a post-pandemic (Covid-19) refresh of economic perspectives, improvements to cogeneration approach, and a better detailing and accounting of biomass-related value chains. However, the differences to the original BASE scenario remained small at the level of national performance indicators.

In the following sections, we present the most important numerical data for the refreshed BASE scenario. It is never out of place to recall that these data are for a *scenario*, results of a modelling that simplifies several aspects of the actual energy system, and possessing large uncertainty in their economic, social, and technological assumptions. Therefore, data on demand, capacity, production, etc., cannot be viewed as official forecasts to comply with. Furthermore, the energy targets and other indicators of performance of public policies such as EN-H2 (and NECP) are inspired by, but almost never coincide with, the numerical outputs of modelling exercises such as presented hereafter.

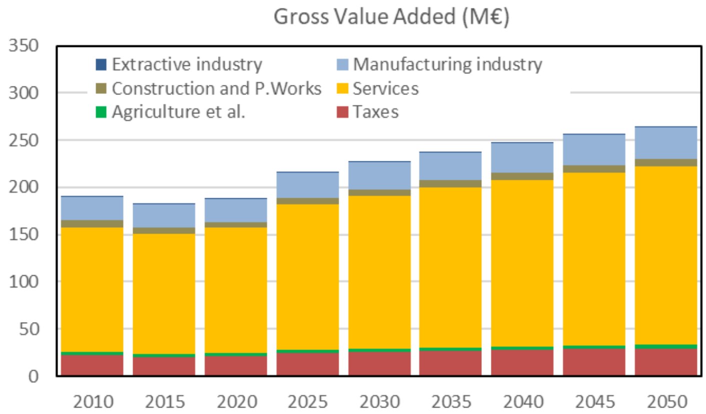
3. Main Drivers

3.1. Demography



		2010	2015	2020	2025	2030	2035	2040	2045	2050
Population	M	10,1	9,8	9,7	9,5	9,4	9,2	9,1	9,0	9,0

3.2. Macroeconomy



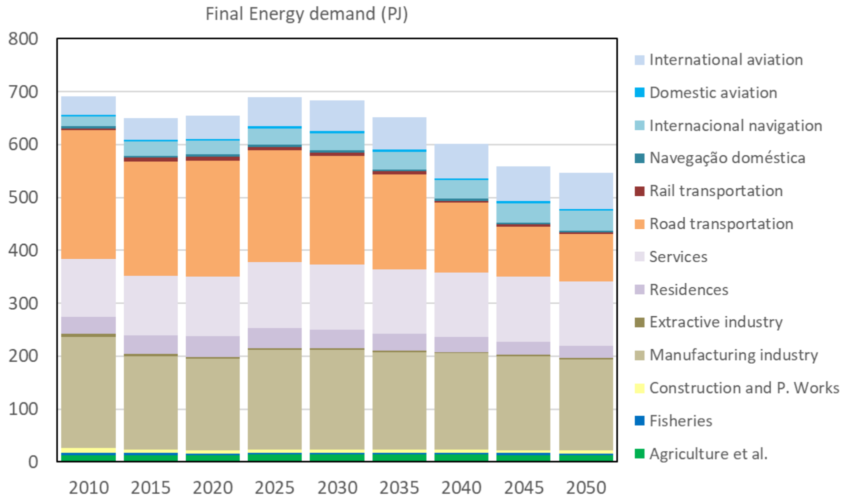
		2010	2015	2020	2025	2030	2035	2040	2045	2050
GDP change	%	1,7	1,8	-6,9	2,0	1,0	0,9	0,8	0,7	0,6
Nominal GDP	M€	191	183	188	216	227	238	247	256	264
GVA Construction and Public Wo	M€	9	7	6	7	7	8	8	8	8
GVA Agriculture etc.	M€	3	3	3	3	4	4	4	4	4
GVA Extractive industry	M€	1	1	1	1	1	1	1	1	1
GVA Manufacturing industry	M€	24	24	25	27	28	30	31	32	33
GVA Services	M€	132	128	133	154	162	169	176	183	189
Taxes	M€	22	20	21	24	25	27	28	29	29

3.3. *Elasticity at energy demand relative to GDP*

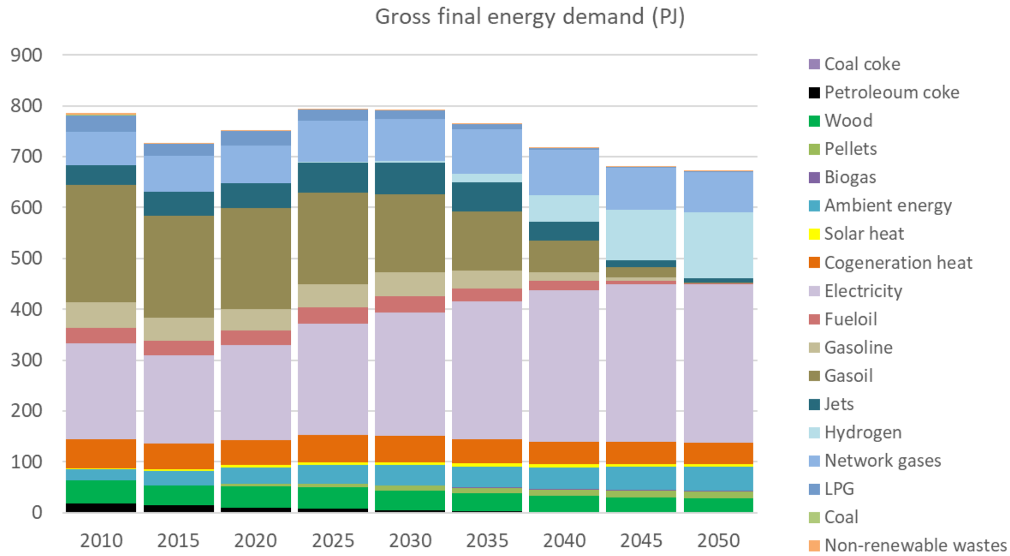
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Residences	0,8	0,8	-1,5	0,5	0,7	0,7	0,7	0,7	0,7
Services	1,1	1,1	1,0	0,8	0,8	0,8	0,8	0,8	0,8
Passenger transport - private	1,0	1,0	0,9	0,8	0,8	0,8	0,8	0,8	0,8
Passenger transport - public	0,6	0,6	0,6	0,5	0,5	0,5	0,5	0,5	0,5
Rail transportation	0,6	0,6	0,6	0,5	0,5	0,5	0,5	0,5	0,5
Merchandise transportation	1,0	1,0	0,9	0,9	0,9	0,9	0,9	0,9	0,9

4. Final energy demand

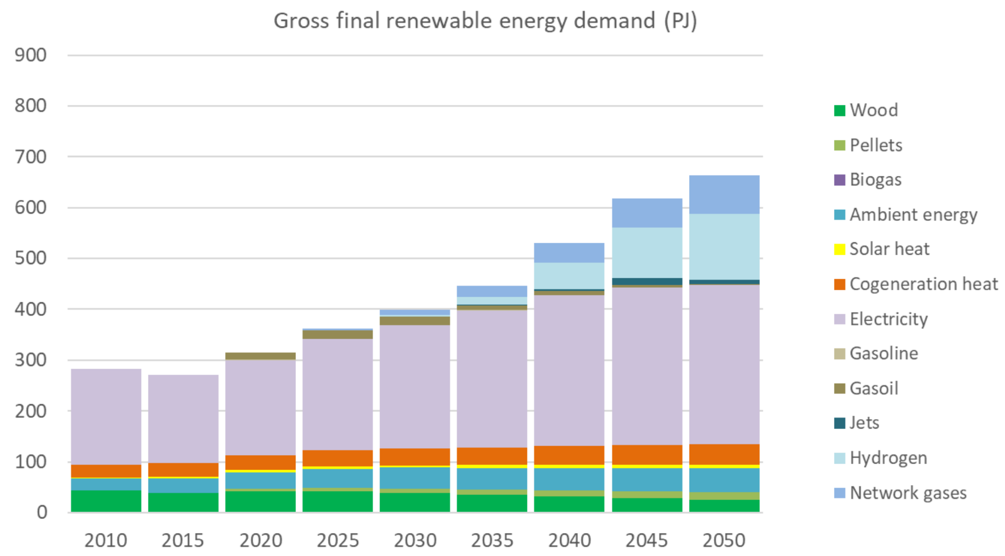
NB. Hydro and wind energy were not normalized by EU rules



by sector	PJ	2010	2015	2020	2025	2030	2035	2040	2045	2050
Agriculture, Forestry et al.		13.5	13.4	12.7	13.6	13.6	13.6	13.7	13.4	13.0
Fisheries		3.8	3.5	3.1	3.4	3.4	3.4	3.4	3.3	3.2
Construction and Public Works		9.5	5.9	5.5	6.1	6.1	6.1	6.1	6.0	5.8
Extractive Industry		5.6	4.4	2.8	3.0	3.0	3.0	3.0	3.0	3.0
Manufacturing industry		209.8	177.1	174.1	189.2	189.5	184.6	182.0	176.6	172.0
Residences		32.6	35.3	39.2	37.8	34.7	31.5	28.5	25.5	22.5
Services		109.6	113.0	113.5	124.4	123.8	122.6	122.0	122.0	122.0
Road transportation		242.9	214.9	218.1	211.2	205.3	179.4	131.0	95.5	89.1
Rail transportation		2.4	7.9	8.2	7.2	6.1	5.1	4.2	3.4	2.8
Domestic navigation		5.0	3.8	3.8	4.3	4.3	4.3	4.3	4.3	4.3
Internacional navigation		18.3	26.3	26.6	30.5	32.0	33.5	34.9	36.1	37.2
Domestic aviation		3.5	3.6	3.5	3.8	3.8	3.7	3.7	3.6	3.6
International aviation		34.7	41.4	44.2	54.7	58.1	61.3	64.2	66.8	68.8
Total		*691.2*	*650.4*	*655.3*	*689.2*	*683.6*	*652.0*	*601.0*	*559.6*	*547.5*
Non-energy products		69.8	56.5	29.8	23.7	20.2	18.4	17.4	16.9	16.1



	2010	2015	2020	2025	2030	2035	2040	2045	2050
Hydrogen				0,3	2,0	15,5	51,9	98,6	129,3
Wood	44,7	39,1	42,8	41,7	38,4	35,1	31,9	28,8	25,6
Pellets			4,4	6,8	9,1	10,5	12,0	13,5	15,0
Biogas	0,0	0,3	0,4	0,4	0,4	0,3	0,3	0,3	0,3
Ambient energy	22,2	28,1	32,6	37,9	40,7	41,9	43,5	45,2	47,1
Solar heat	2,2	3,7	4,5	4,9	5,0	5,8	5,8	5,7	5,6
Cogeneration heat	56,0	49,8	48,7	53,2	53,0	47,6	44,5	43,2	42,0
Electricity	189,4	174,1	186,5	218,3	242,0	270,3	297,7	309,8	312,5
Gasoline	50,8	45,2	41,3	46,1	46,8	35,2	17,1	7,0	0,2
Gasoil	230,2	200,8	199,2	180,0	153,2	115,2	62,0	19,1	3,1
Jets	39,4	46,1	48,4	59,2	62,5	58,6	37,5	14,3	8,0
Network gases	65,8	70,6	74,7	81,2	82,9	88,3	88,9	83,5	79,9
LPG	31,5	23,9	27,4	22,6	17,9	10,1	3,7	1,2	0,7
Fueloil	30,0	28,2	29,6	32,6	32,3	26,1	18,2	7,5	0,0
Coal	2,0	0,3	0,3						
Coal coke	0,1	0,2	0,1	0,1	0,1	0,0			
Petroleoum coke	18,5	14,6	9,3	7,5	5,3	3,4	1,9	1,9	1,8
Non-renewable wastes	2,3	2,3	2,4	2,0	1,6	1,3	1,1	1,1	1,1
Total	*785*	*727*	*752*	*795*	*793*	*765*	*718*	*681*	*672*



	2010	2015	2020	2025	2030	2035	2040	2045	2050
Hydrogen				0,3	2,0	15,5	51,9	98,6	129,3
Wood	44,7	39,1	42,8	41,7	38,4	35,1	31,9	28,8	25,6
Pellets			4,4	6,8	9,1	10,5	12,0	13,5	15,0
Biogas	0,0	0,3	0,4	0,4	0,4	0,3	0,3	0,3	0,3
Ambient energy	22,2	28,1	32,6	37,9	40,7	41,9	43,5	45,2	47,1
Solar heat	2,2	3,7	4,5	4,9	5,0	5,8	5,8	5,7	5,6
Cogeneration heat	25,0	25,8	28,5	31,3	32,7	34,2	37,0	40,1	41,7
Electricity	110,9	94,6	135,0	172,3	213,7	249,8	286,6	306,0	311,7
Gasoline	0,0	0,0	2,1	1,4	0,9	0,4	0,2	0,0	0,0
Gasoil	0,0	0,0	13,9	15,9	16,1	8,4	7,0	4,1	2,0
Jets	0,0	0,0	0,0	0,3	1,0	2,2	4,4	14,3	8,0
Network gases	0,0	0,0	0,0	3,1	11,0	20,9	38,9	57,6	76,9
Total	*205*	*192*	*264*	*316*	*371*	*425*	*520*	*614*	*663*

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Cogeneration heat	45%	52%	58%	59%	62%	72%	83%	93%	99%
Electricity	59%	54%	72%	79%	88%	92%	96%	99%	100%
Gasoline	0%	0%	5%	3%	2%	1%	1%	0%	0%
Gasoil	0%	0%	7%	9%	11%	7%	11%	21%	64%
Jets	0%	0%	0%	0%	2%	4%	12%	100%	100%
Network gas	0%	0%	0%	4%	13%	24%	44%	69%	96%
Lubrifiers, solvents, etc.	0%	0%	0%	0%	3%	8%	19%	45%	52%
Other chemical raw matter	0%	0%	0%	0%	2%	4%	15%	39%	67%

Non-energy materials

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Lubrifiers, solvents, etc.	15,8	11,3	9,6	8,3	7,1	6,1	5,2	4,5	3,9
Fueloil as raw matter	1,4	1,4	0,0	0,0					
LPG as raw matter	2,5	14,9	5,1	1,7	0,5	0,2	0,1	0,0	0,0
Other chemical raw matter	50,0	28,9	15,1	13,6	12,3	11,1	10,1	9,1	8,2
Hydrogen as raw matter				0,1	0,3	1,0	2,1	3,3	4,0
Total	*70*	*56*	*30*	*24*	*20*	*18*	*17*	*17*	*16*

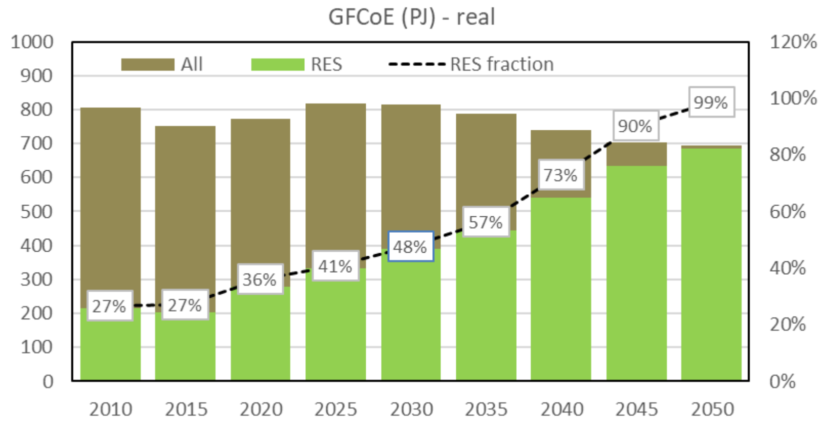
Losses

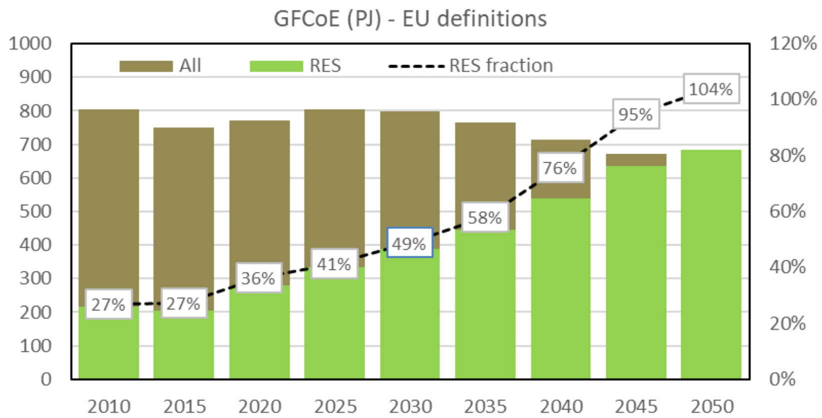
	2010	2015	2020	2025	2030	2035	2040	2045	2050
at electricity storage	0,4	1,1	1,7	1,7	1,7	1,7	1,7	1,7	1,7
at self-consumption of installations	4,1	4,2	3,3	3,6	3,4	3,4	3,4	3,3	3,1
at electricity transport	6,2	6,4	5,4	5,5	5,2	5,0	4,7	4,9	4,9
at electricity distribution	8,9	11,7	10,8	11,2	10,8	11,0	11,1	11,4	11,3
at pipelines	0,2	0,1	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Total	*20*	*24*	*21*	*22*	*21*	*21*	*21*	*21*	*21*

5. Country performance indicators

NB. Hydro and wind energy were *not* normalised by EU rules

5.1. *Gross final consumption of energy*





	2010	2015	2020	2025	2030	2035	2040	2045	2050
Gross consumption	805	751	774	817	815	787	740	702	693
- of which renewable	216	204	279	334	390	445	540	635	684
Renewable fraction	27%	27%	36%	41%	47,8%	57%	73%	90%	99%
EU international aviation correction *	0	1	4	12	16	21	27	32	35
EU definition of gross consumption	805	750	770	805	799	766	712	670	659
- of which renewable	27%	27%	36%	41%	**48,8%**	58%	76%	95%	104%
national target					47%				
(*) cap 6,18%									

5.2. *Electricity*

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Gross consumption	209	197	208	240	263	291	319	331	334
- of which renewable	122	107	150	190	232	269	307	327	333
Renewable fraction	59%	54%	72%	79%	88%	92%	96%	99%	100%
national target					80%				

5.3. *Transports*

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Consumption	307	291	298	306	305	284	240	209	205
- of which renewable	1	1	18	25	41	63	115	178	205
Renewable fraction (real)	0%	0%	6%	8%	13%	22%	48%	85%	100%
Consumption at land transportation	245	216	220	213	207	181	133	98	91
- of which renewable	1	1	18	25	39	49	66	79	92
Renewable fraction (real)	0%	0%	8%	12%	19%	27%	50%	81%	100%
EU rules viewpoint									
Renewables *without* multipliers	1	1	18	25	41	63	115	178	205
Renewable fraction *without* multipliers	0%	0%	8%	12%	19,7%	35%	86%	182%	225%
national target					20%				
Renewables *with* multipliers	8	5	25	44	83	131	205	278	309
Renewable fraction *with* multipliers	3%	2%	11%	21%	40%	72%	154%	284%	338%

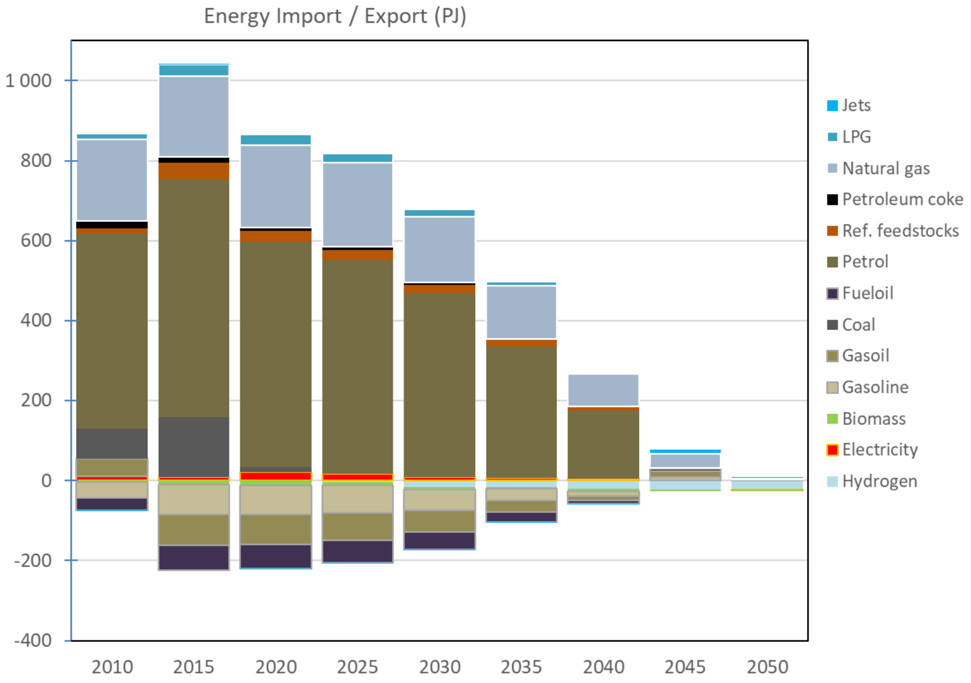
5.4. *Heating & Cooling*

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Consumption	290	263	270	277	267	249	234	226	221
- of which renewable	94	97	113	126	139	164	221	290	341
Renewable fraction	32%	37%	42%	46%	52,2%	66%	95%	128%	155%
mean annual variation				1,0% /year					
national target				1,0% /year					

5.5. *Non-energy products*

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Consumption	70	56	30	24	20	18	17	17	16
- of which renewable	0	0	0	0	1	2	5	9	12
Renewable fraction	0%	0%	0%	1%	4%	11%	26%	52%	72%

6. Import/Export



	2010	2015	2020	2025	2030	2035	2040	2045	2050
Hydrogen				-3,5	-15,7	-15,7	-21,2	-22,0	-23,2
Coal	75,2	149,0	10,7	0,0					
Natural gas	204,0	202,1	204,9	209,0	166,3	132,3	82,1	35,1	3,4
Petrol	488,3	596,3	564,2	534,8	459,4	329,2	170,3		
Gasoil	42,6	-75,2	-74,4	-68,5	-53,0	-29,2	-11,4	15,0	1,1
Gasoline	-39,5	-74,9	-73,5	-67,7	-52,4	-28,8	-11,2	7,0	0,2
Electricity	11,7	8,7	22,2	17,4	8,1	6,3	5,1	0,8	-0,4
Fueloil	-31,6	-62,3	-61,2	-56,3	-43,6	-24,0	-9,4	7,7	0,2
LPG	14,0	28,8	28,1	24,3	18,5	10,3	3,8	1,3	0,7
Jets	-2,4	0,1	-0,1	0,0	0,0	0,0	0,0	8,0	0,7
Refinery feedstocks	12,8	40,9	26,6	25,2	21,6	15,4	7,8		
Petroleum coke	18,5	14,6	9,3	7,5	5,3	3,4	1,9	1,9	1,8
Biomass (wood & pellets)	-3,9	-10,8	-11,5	-9,2	-7,0	-5,5	-5,6	-4,2	-3,8
Total	***790***	***817***	***645***	***613***	***507***	***394***	***212***	***51***	***-19***

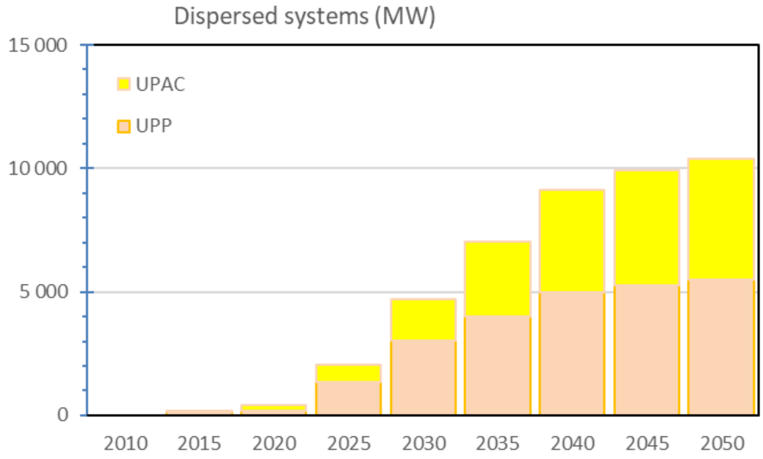
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Lubrifiers, solvents et al.	-14,8	-17,4	-17,1	-15,7	-12,2	-6,7	-2,6	1,2	0,2
Fueloil as raw matter	1,4	1,4	0,0						
LPG as raw matter	2,5	14,9	5,1	1,7	0,5	0,2	0,1	0,0	0,0
Naphtas as raw matter	-16,0	-18,0	-17,6	-16,2	-12,5	-6,9	-2,7	-0,9	-4,5
Hydrogen as raw matter				0,0	0,0	0,0	0,0	0,0	0,0
Total	***-27***	***-19***	***-30***	***-30***	***-24***	***-13***	***-5***	***0***	***-4***

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Energy balance *	790	817	645	613	507	394	212	51	-19
Country energy demand **	898	1066	938	909	798	626	414	191	156
Dependency index	*88%*	*77%*	*69%*	*67%*	*64%*	*63%*	*51%*	*27%*	*-12%*

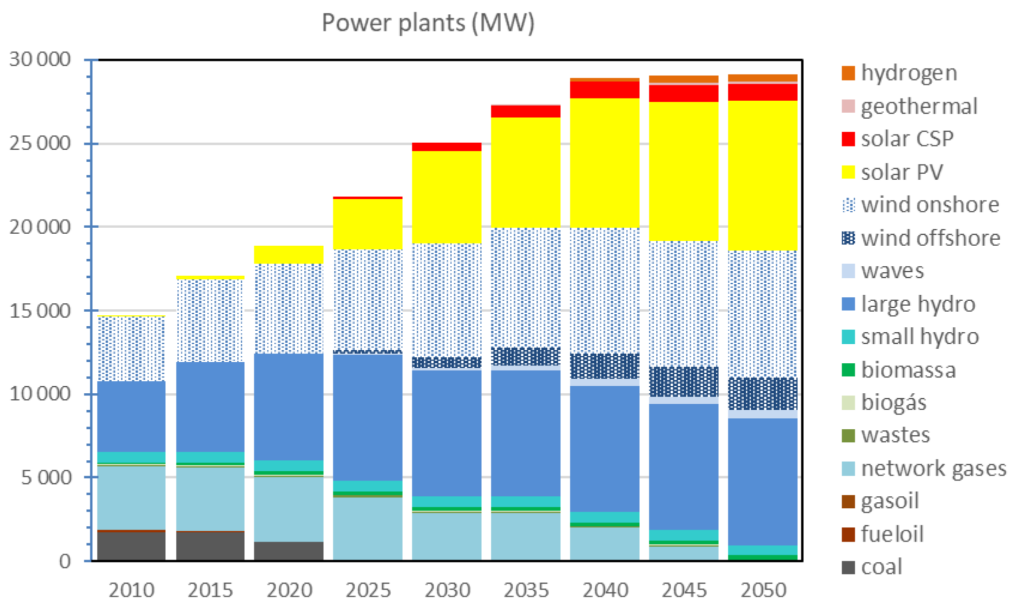
* except non-energy products; positive for imports

** has a specific calculation scope

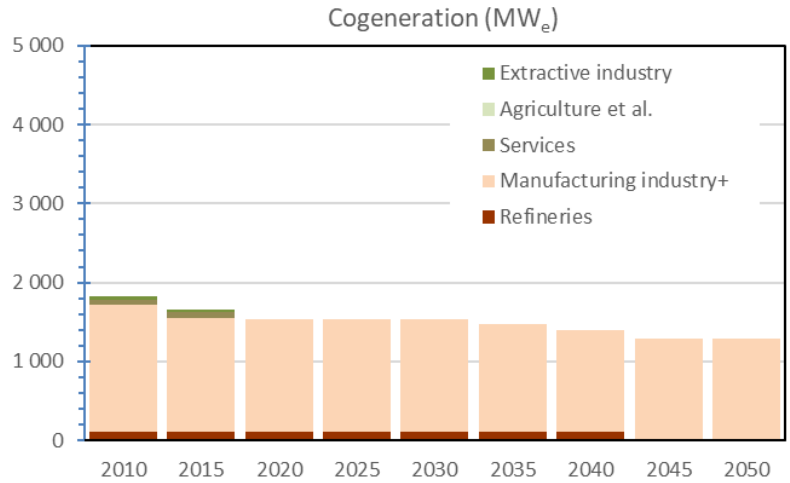
7. Installed electrical power



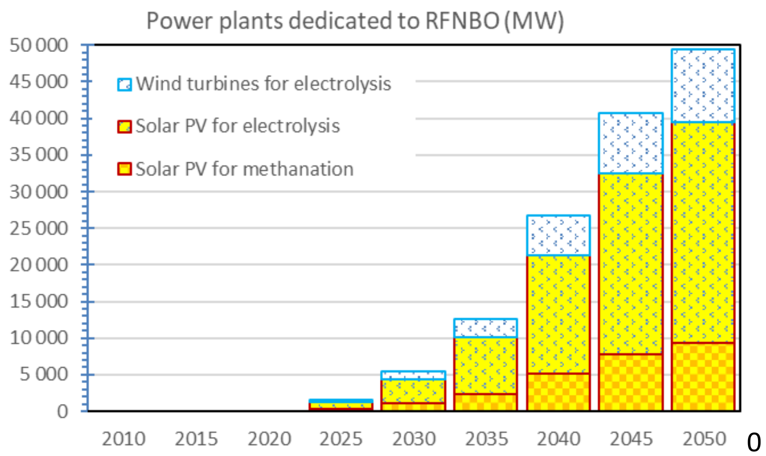
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Dispersed units									
UPAC (self-consumption)		**17**	**264**	**724**	**1 697**	**3 046**	**4 127**	**4 674**	**4 888**
solar PV		17	264	724	1 697	3 046	4 127	4 674	4 888
UPP (small units)		**153**	**163**	**1 326**	**3 001**	**4 001**	**5 001**	**5 251**	**5 501**
micro wind turbines		0	1	1	1	1	1	1	1
mictro-hydro		0	0	0	0	0	0	0	0
solar PV		153	163	1 325	3 000	4 000	5 000	5 250	5 500
Total		**170**	**428**	**2 050**	**4 698**	**7 047**	**9 128**	**9 925**	**10 389**



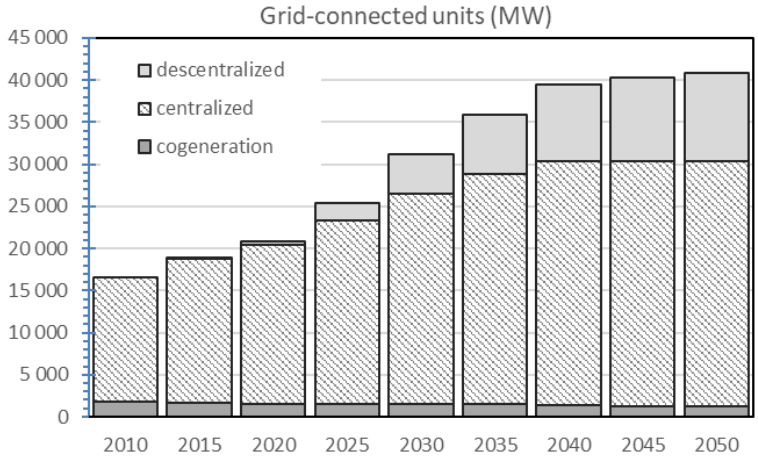
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Coal	1 756	1 756	1 180						
Gasoil	17	17							
Fueloil	100	18	18	18					
Wastes	78	78	78	78	77	77	77	77	77
Network gases	3 829	3 829	3 829	3 829	2 900	2 900	2 000	900	
Hydrogen							200	400	400
Wind onshore	3 865	4 957	5 370	6 031	6 842	7 171	7 500	7 550	7 600
Wind offshore			25	207	600	1 050	1 500	1 750	2 000
Solar PV	125	259	1 078	2 988	5 500	6 625	7 750	8 325	8 900
Concentrated solar power				188	500	750	1 000	1 000	1 000
Large hydro	4 234	5 389	6 388	7 542	7 542	7 542	7 542	7 542	7 542
Small hydro	600	605	619	619	635	635	635	635	635
Waves and currents			1	58	150	275	400	450	500
Biomass (woody)	116	123	226	244	250	250	250	250	250
Biogas	31	85	85	24	16	16	16	16	16
Geothermal (enhanced)						22	50	125	200
Total	**14 751**	**17 116**	**18 897**	**21 827**	**25 012**	**27 313**	**28 920**	**29 020**	**29 120**

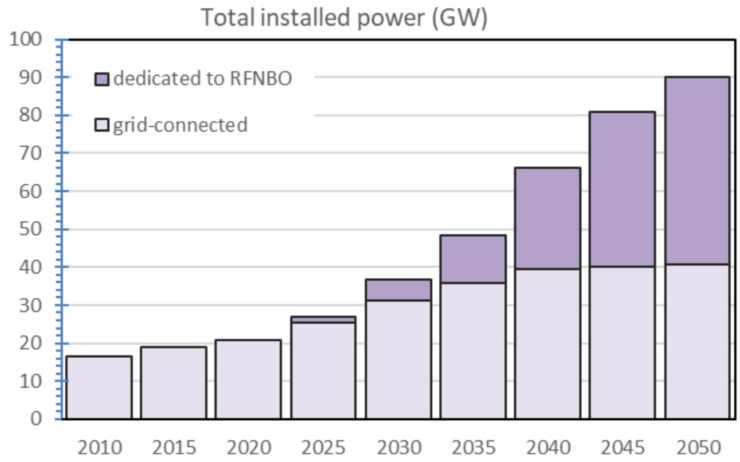


	2010	2015	2020	2025	2030	2035	2040	2045	2050
Refineries	106	106	106	106	106	106	106		
Services	63	82	0	0	0				
Manufacturing industry	1 604	1 437	1 435	1 425	1 432	1 359	1 295	1 295	1 295
Extractive industry	48	17	0	0	0	0			
Agriculture et al.	10	7	0	0	0	0			
Total	**1 831**	**1 649**	**1 541**	**1 531**	**1 538**	**1 466**	**1 401**	**1 295**	**1 295**



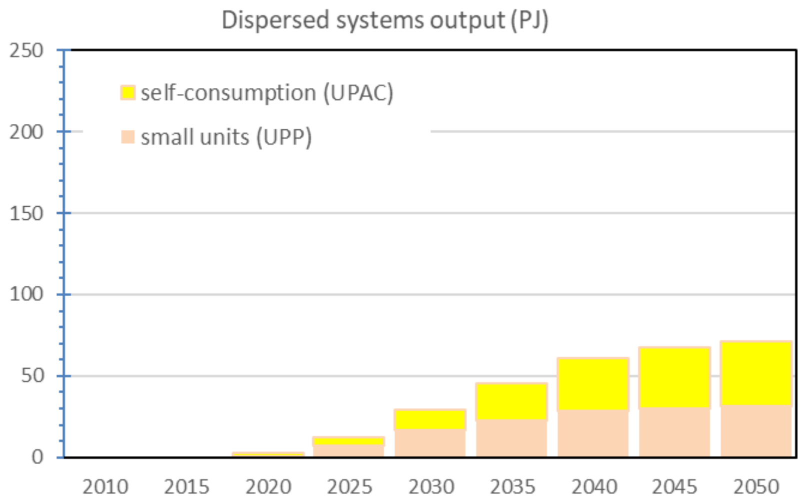
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Wind turbines for electrolysis				318	1 100	2 550	5 400	8 250	10 000
Solar PV for electrolysis				954	3 300	7 650	16 200	24 750	30 000
Solar PV for methanation				299	1 034	2 397	5 076	7 755	9 400
Total				**1 570**	**5 434**	**12 597**	**26 676**	**40 755**	**49 400**



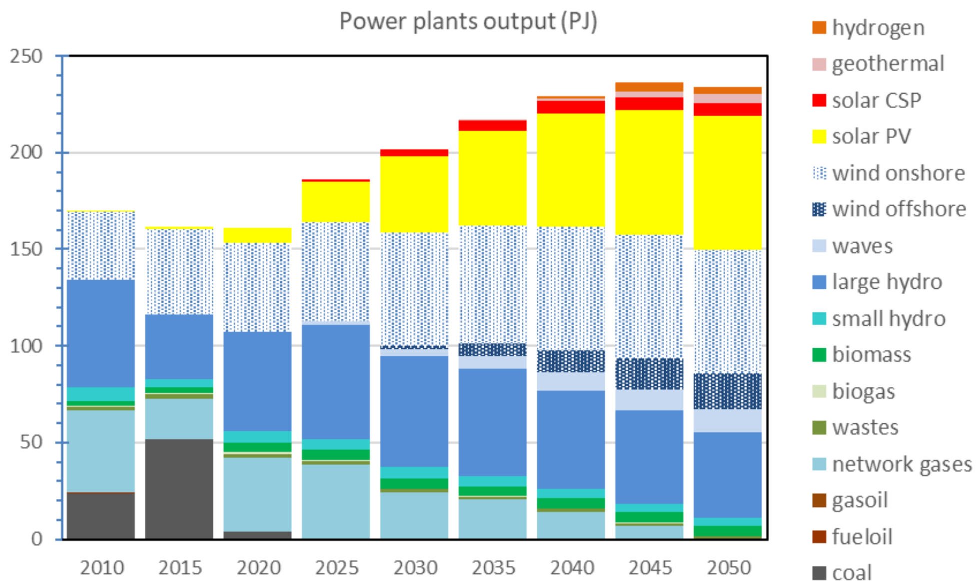


	2010	2015	2020	2025	2030	2035	2040	2045	2050
grid-connected	16,6	18,9	20,9	25	31	36	39	40	41
dedicated to RFNBO				2	5	13	27	41	49
Total				**27**	**37**	**48**	**66**	**81**	**90**

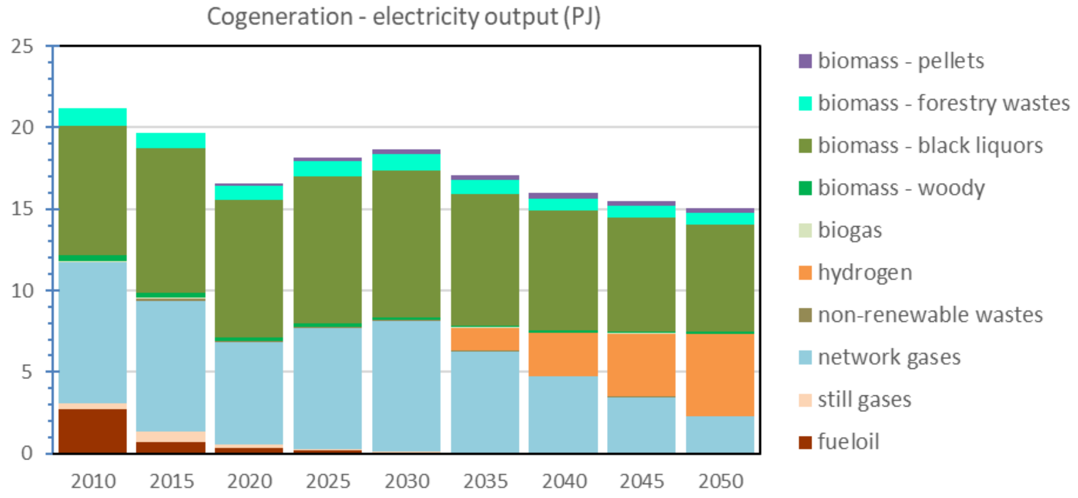
8. Electricity production



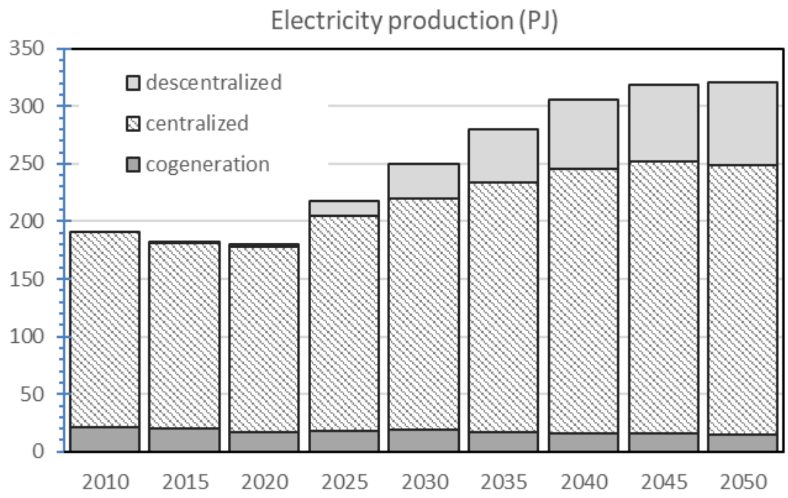
	2010	2015	2020	2025	2030	2035	2040	2045	2050
UPAC	0.0	0.0	1.8	5.2	12.5	23.0	32.1	37.3	40.1
UPP	0.0	0.9	0.9	7.6	17.1	22.8	28.5	29.9	31.4
Total	***0***	***1***	***3***	***13***	***30***	***46***	***61***	***67***	***71***
N.B. renewable fraction	100%	100%	100%	100%	100%	100%	100%	100%	100%

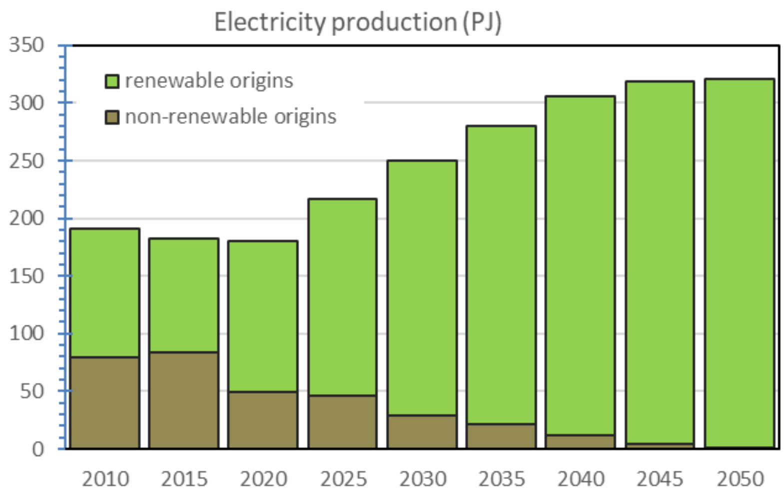


	2010	2015	2020	2025	2030	2035	2040	2045	2050
Coal	23.9	51.7	3.6						
Gasoil	0.0	0.0	0.0						
Fueloil	0.6	0.1	0.0	0.0					
Wastes	1.9	1.9	1.9	1.8	1.7	1.6	1.5	1.4	1.4
Network gases	42.1	21.0	38.3	38.8	24.4	20.4	14.3	7.0	
Hydrogen							1.4	4.5	3.8
Wind onshore	35.0	44.2	45.9	51.5	58.3	61.1	63.9	64.0	63.8
Wind offshore			0.0	0.3	2.2	6.5	11.4	16.3	18.9
Solar PV	0.7	1.7	7.4	20.8	39.4	48.9	58.6	64.2	69.2
Concentrated solar power				1.3	3.4	5.1	6.8	6.7	6.5
Large hydro	55.7	33.4	51.6	59.1	57.3	55.5	50.4	48.4	44.4
Small hydro	7.4	4.0	6.2	5.9	5.7	5.4	5.0	4.7	4.3
Waves and currents			0.0	1.4	3.5	6.5	9.4	10.6	11.6
Biomass (woody)	2.3	2.8	4.8	5.1	5.3	5.3	5.3	5.3	5.3
Biogas	0.4	1.0	1.0	0.3	0.2	0.2	0.2	0.2	0.2
Geothermal (enhanced)						0.5	1.2	3.0	4.8
Total	***170***	***162***	***161***	***186***	***202***	***217***	***229***	***236***	***234***
N.B. renewable fraction	60%	54%	73%	79%	89%	92%	96%	99%	100%



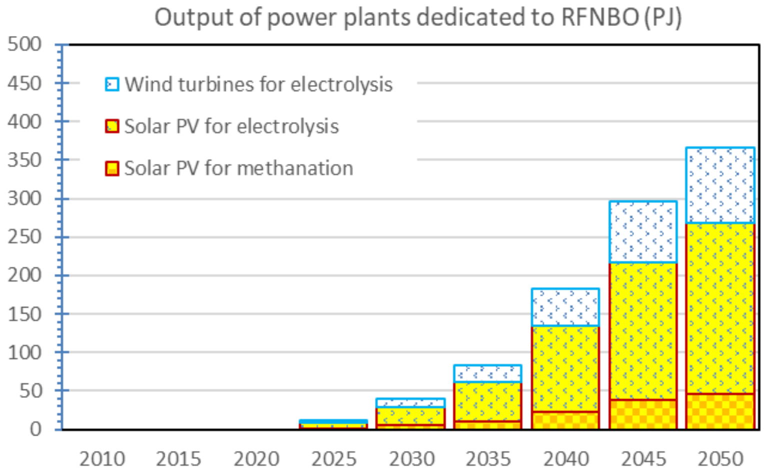
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Fueloil	2.7	0.7	0.3	0.2	0.1	0.0	0.0	0.0	0.0
Wastes (non- renewable)	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Still gas	0.3	0.7	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Network gases	8.7	8.0	6.2	7.4	8.0	6.2	4.7	3.4	2.3
Biogas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass - black liquors	8.0	8.9	8.4	9.0	9.0	8.1	7.4	7.0	6.6
Biomass - woody	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Biomass - forestry wastes	1.1	0.9	0.9	1.0	1.0	0.8	0.7	0.7	0.7
Biomass - pellets	0.0	0.0	0.1	0.2	0.3	0.3	0.3	0.3	0.3
Hydrogen	0.0	0.0	0.0	0.0	0.0	1.4	2.7	3.9	5.0
Total	***21***	***20***	***17***	***18***	***19***	***17***	***16***	***15***	***15***
N.B. renewable fraction	45%	52%	58%	59%	62%	72%	83%	93%	99%



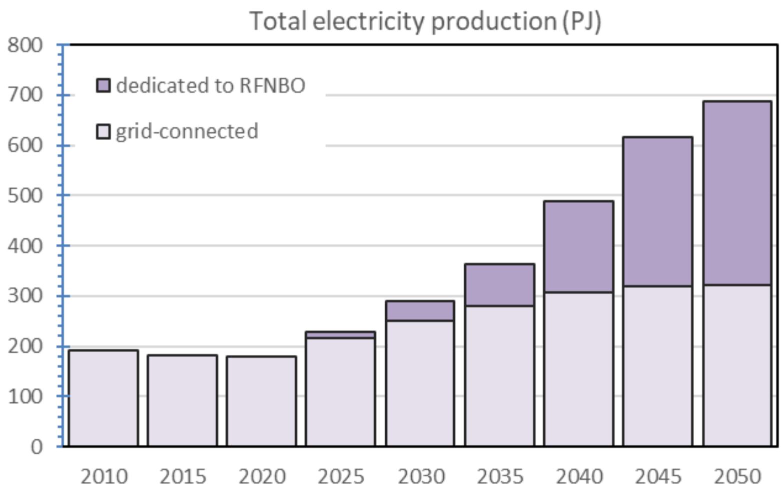


	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total	***191***	***182***	***180***	***217***	***250***	***280***	***306***	***319***	***321***
fossil sources	79	83	50	46	29	21	11	4	1
renewable sources	112	99	130	171	221	259	294	315	320
N.B. renewable fraction	59%	54%	72%	79%	88%	92%	96%	99%	99.8%

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total production [GWh]	53 102	50 691	50 054	60 336	69 380	77 761	84 980	88 554	89 070
Total emissions [M ton CO_2]	14.77	18.93	7.22	6.16	4.28	2.95	1.55	0.36	0.03
GHG emissions [g/kWh]	278	374	144	102	62	38	18	4	0



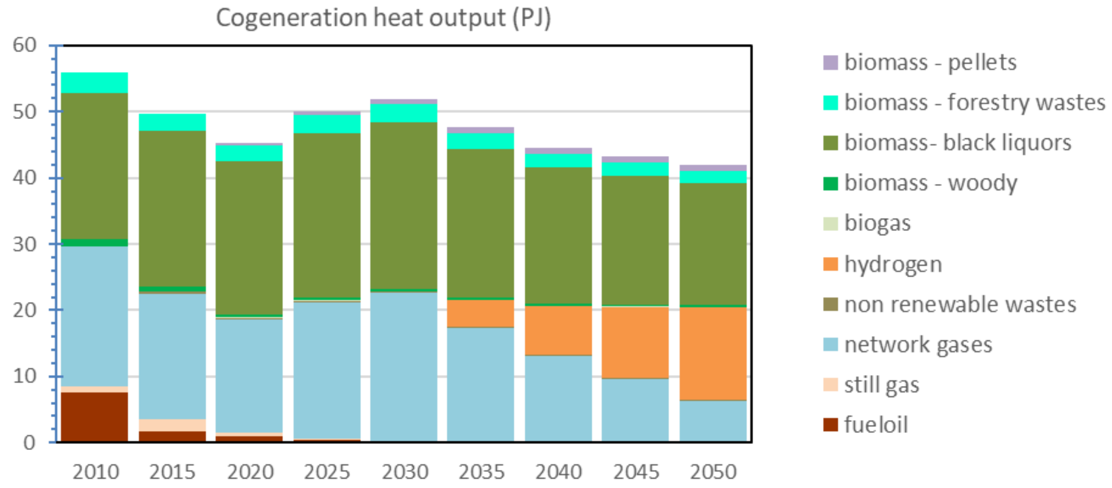
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Wind turbines for electrolysis				2.9	10.4	22.1	48.3	78.8	97.6
Solar PV for electrolysis				6.8	24.2	51.0	110.8	179.8	221.6
Solar PV for methanation				1.4	5.1	10.7	23.3	37.7	46.5
Total				***11***	***40***	***84***	***182***	***296***	***366***



	2010	2015	2020	2025	2030	2035	2040	2045	2050
Grid-connected				191.2	182.5	180.2	217.2	249.8	279.9
Dedicated to RFNBO				11.1	39.8	83.8	182.3	296.3	365.7
Total				***202***	***222***	***264***	***400***	***546***	***646***

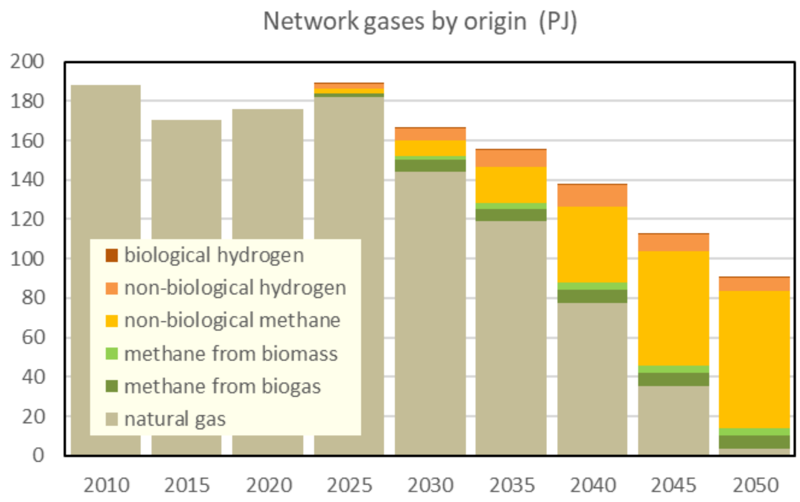
	2010	2015	2020	2025	2030	2035	2040	2045	2050
System services	(not additional production)								
H2 fuel cells				0.01	0.01	0.03	0.04	0.05	0.06
Batteries				0.00	0.02	0.05	0.05	0.06	0.06
Total				*0.0*	*0.0*	*0.1*	*0.1*	*0.1*	*0.1*
Energy storage	(not additional production)								
at wind parks onshore				1.7	5.8	5.8	5.8	6.2	6.6
at solar PV plants				3.1	6.6	8.8	11.1	12.3	13.4
at concentrated solar power plants				1.3	3.4	5.1	6.8	6.7	6.5
at hydroelectric dams	1.3	1.4	4.1	6.8	6.8	6.8	6.8	6.8	6.8
Total	*1*	*1*	*4*	*13*	*23*	*27*	*31*	*32*	*33*
– as a percentage of production for each technology									
at wind parks onshore				3%	10%	10%	9%	10%	10%
at solar PV plants				15%	17%	18%	19%	19%	19%
at concentrated solar power plants				100%	100%	100%	100%	100%	100%
at hydroelectric dams				11%	12%	12%	13%	14%	15%

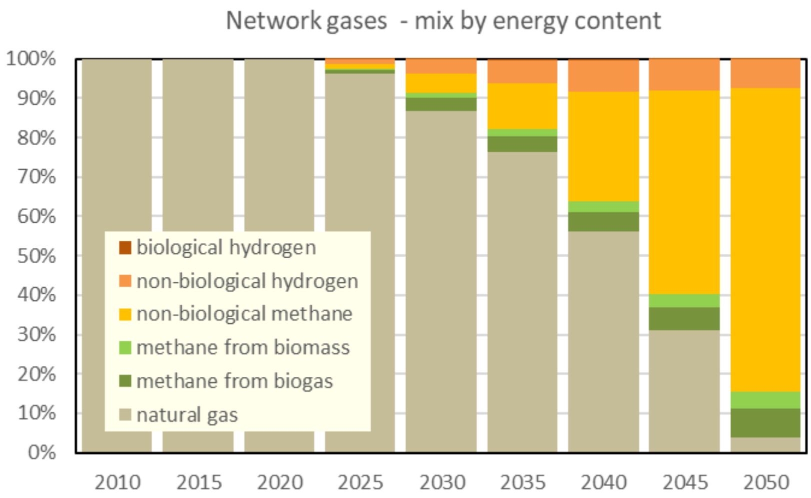
9. Cogeneration heat



	2010	2015	2020	2025	2030	2035	2040	2045	2050
Fueloil	7.6	1.8	0.9	0.5	0.2	0.1	0.0	0.0	0.0
Wastes (non- renewable)	0.0	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1
Still gas	0.9	1.7	0.6	0.2	0.1	0.0	0.0	0.0	0.0
Network gases	21.0	18.9	17.0	20.5	22.3	17.3	13.1	9.6	6.3
Biogas	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Biomass - black liquors	22.2	23.4	23.0	24.9	25.1	22.5	20.5	19.4	18.4
Biomass - woody	1.0	0.8	0.5	0.5	0.4	0.4	0.3	0.3	0.3
Biomass - forestry wastes	3.0	2.5	2.5	2.7	2.7	2.4	2.1	2.0	1.9
Biomass - pellets	0.0	0.0	0.3	0.6	0.8	0.9	0.9	0.9	0.9
Hydrogen	0.0	0.0	0.0	0.0	0.0	4.0	7.4	10.8	14.0
Total	***56***	***50***	***45***	***50***	***52***	***48***	***45***	***43***	***42***
N.B. renewable fraction	47%	54%	58%	59%	62%	72%	83%	93%	99%

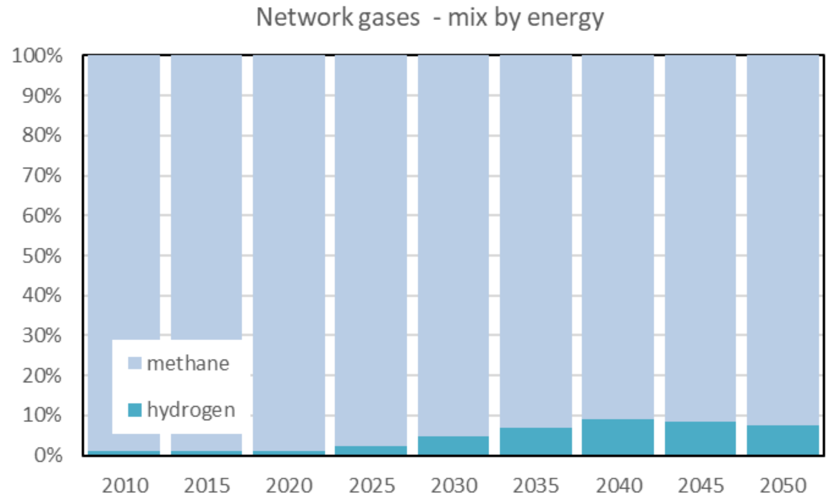
10. Network gases



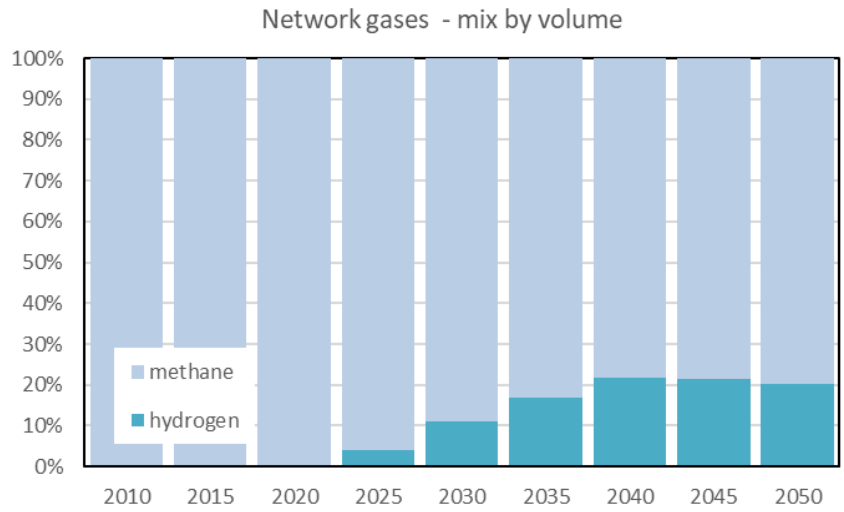


	2010	2015	2020	2025	2030	2035	2040	2045	2050
natural gas	188.4	170.3	175.9	181.9	144.4	118.9	77.6	35.1	3.4
methane from biomass				0.5	1.9	2.8	3.8	3.8	3.8
methane from biogas				1.7	5.8	6.3	6.7	6.7	6.7
methane non-biological				2.3	8.0	18.3	38.3	58.1	69.9
hydrogen non-biological				2.5	5.9	9.1	11.1	8.9	6.7
hydrogen biological				0.1	0.5	0.5	0.4	0.3	0.2
Total	**188**	**170**	**176**	**189**	**166**	**156**	**138**	**113**	**91**

	2010	2015	2020	2025	2030	2035	2040	2045	2050
natural gas	100%	100%	100%	96%	87%	76%	56%	31%	4%
methane from biomass				0%	1%	2%	3%	3%	4%
methane from biogas				1%	4%	4%	5%	6%	7%
methane non-biological				1%	5%	12%	28%	51%	77%
hydrogen non-biological				1%	4%	6%	8%	8%	7%
hydrogen biological				0.0%	0.3%	0.3%	0.3%	0.3%	0.2%



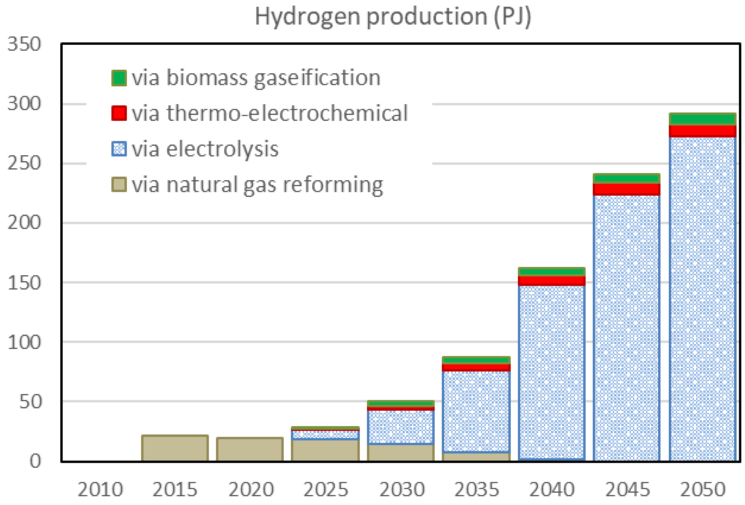
	2010	2015	2020	2025	2030	2035	2040	2045	2050
methane and traces of other gases	99.8%	99.8%	99.8%	98.4%	96.0%	93.7%	91.6%	91.8%	92.4%
hydrogen	0.2%	0.2%	0.2%	1.6%	4.0%	6.3%	8.4%	8.2%	7.6%



	2010	2015	2020	2025	2030	2035	2040	2045	2050
methane and traces of other gases	99.8%	99.8%	99.8%	95.9%	89%	83%	78%	79%	80%
hydrogen	0.2%	0.2%	0.2%	4.1%	11%	17%	22%	21%	20%

	2010	2015	2020	2025	2030	2035	2040	2045	2050
mass (Mton CO_2e)	10.6	9.6	9.9	10.2	8.1	6.7	4.4	2.0	0.2
emission factor (g CO_2e/kWh)	202	202	202	195	176	154	114	63	8

11. Hydrogen



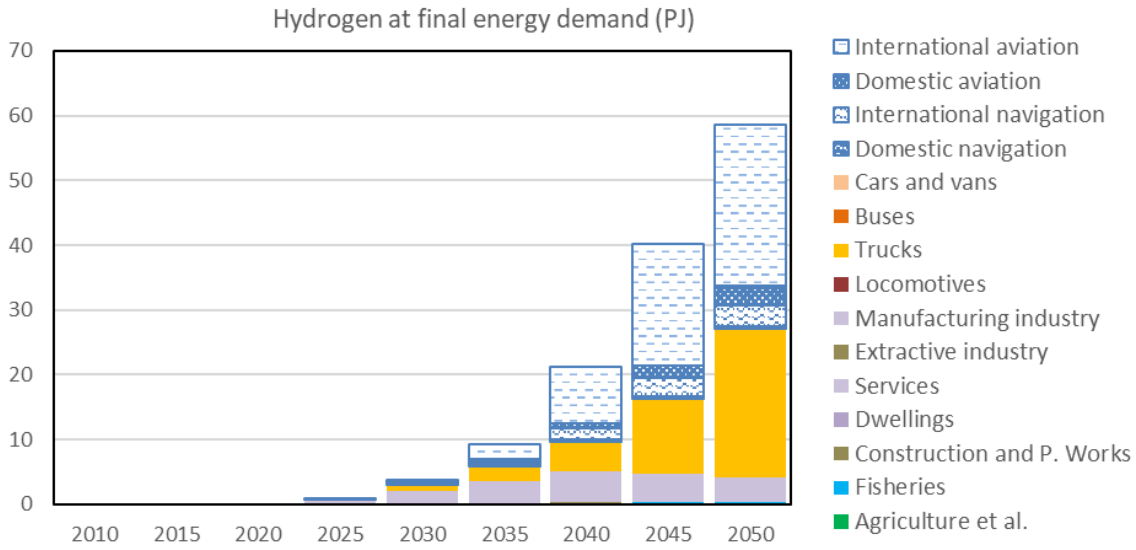
	2010	2015	2020	2025	2030	2035	2040	2045	2050
via natural gas reforming *		21.9	19.6	18.2	14.3	7.9	1.7		
via electrolysis				8.5	29.5	68.6	145.9	223.8	272.5
via thermo-electrochemical				1.11	2.95	5.8	8.7	9.5	10.4
via biomass gaseification				0.99	3.65	4.8	6.0	7.4	8.8
Total		*22*	*20*	*29*	*50*	*87*	*162*	*241*	*292*
renewable total				*11*	*36*	*79*	*161*	*241*	*292*
mix of production %									
non--biological		*100%*	*100%*	*97%*	*93%*	*94%*	*96%*	*97%*	*97%*
biological		*0%*	*0%*	*3%*	*7%*	*6%*	*4%*	*3%*	*3%*
*fossil **		*100%*	*100%*	*63%*	*28%*	*9%*	*1%*	*0%*	*0%*
renewable		*0%*	*0%*	*37%*	*72%*	*91%*	*99%*	*100%*	*100%*

(*) completely consumed within refineries

		2010	2015	2020	2025	2030	2035	2040	2045	2050
electrolyzers										
efficiency relative to HHV	%				78	78	79	79	80	80
efficiency relative to LHV	%				66	66	67	67	67	68
average load factor	%				42	42	43	43	43	43
running hours	h/year				3 703	3 719	3 735	3 752	3 768	3 784
nominal power	GW				0.6	2.2	5.1	11	17	20
dedicated solar PV power	GW				1.0	3.3	7.7	16	25	30
dedicated wind power	GW				0.3	1.1	2.6	5	8	10
rario P solar / P electrolyser	GW/GW				1.5	1.5	1.5	1.5	1.5	1.5
rario P wind / P electrolyser	GW/GW				0.5	0.5	0.5	0.5	0.5	0.5

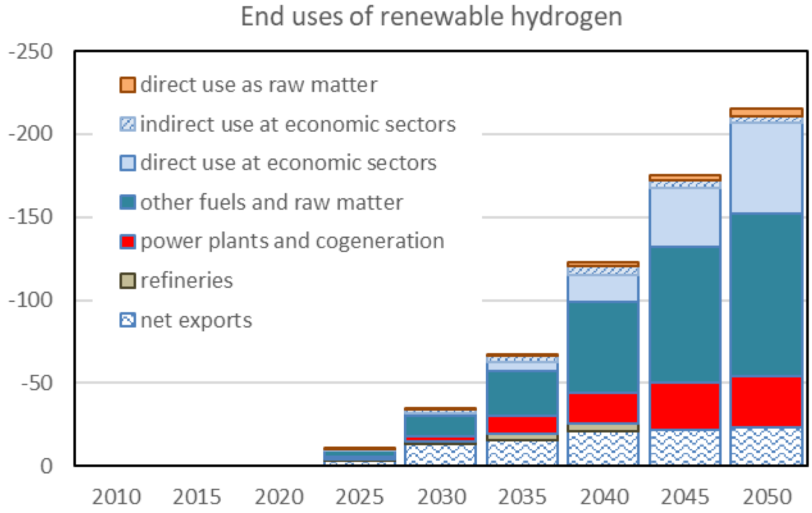
Intermediate consumption

	2010	2015	2020	2025	2030	2035	2040	2045	2050
non-biological fuels and raw matter				3.0	10.4	24.1	51.1	78.1	94.7
methanation of gasified biomass				0.37	1.30	2.0	2.6	2.6	2.6
methanation of biogas				0.30	1.05	1.2	1.3	1.3	1.3
refineries		21.9	19.6	18.5	15.9	11.3	5.8		
hydrogen power plants						0.0	2.3	7.6	6.5
network gas power plants				1.0	1.8	2.4	2.3	1.1	0.0
cogeneration with hydrogen					0.0	6.6	12.4	18.0	23.3
cogeration with network gases				0.5	1.4	1.8	1.8	1.3	0.8
system services (power grid)				0.03	0.05	0.1	0.1	0.1	0.1
Total				***24***	***32***	***49***	***80***	***110***	***129***



PJ

		2010	2015	2020	2025	2030	2035	2040	2045	2050
Final energy demand										
Agriculture et al.	[1]				0.004	0.02	0.1	0.2	0.2	0.3
Fisheries	[1]				0.001	0.01	0.02	0.0	0.1	0.1
Construction and Public Works	[1]				0.010	0.0	0.1	0.1	0.1	0.1
Extractive industry	[1]				0.002	0.01	0.02	0.04	0.04	0.04
Manufacturing industry					0.7	2.0	3.4	4.8	4.3	3.6
at specific equipment					0.00	0.00	0.0	0.0	0.0	0.0
via network gases	[1]				0.73	2.02	3.4	4.8	4.3	3.6
Transportation					0.1	1.6	5.8	16.2	35.5	54.5
Trucks and tractors					0.00	0.93	2.2	4.6	11.5	23.0
Buses					0.00	0.00	0.0	0.0	0.0	0.0
Cars and vans					0.00	0.00	0.0	0.0	0.0	0.0
Locomotives					0.00	0.00	0.0	0.0	0.0	0.0
Domestic navigation					0.000	0.12	0.2	0.4	0.4	0.4
fuel cells					*0.000*	*0.12*	*0.2*	*0.4*	*0.4*	*0.4*
gases	[1]				*0.000*	*0.00*	*0.0*	*0.0*	*0.0*	*0.0*
Navegação internacional					0.000	0.00	0.4	1.7	2.9	3.2
células de combustível					*0.00*	*0.00*	*0.4*	*1.7*	*2.9*	*3.2*
gases	[1]				*0.00*	*0.00*	*0.0*	*0.0*	*0.0*	*0.0*
Domestic aviation					0.11	0.22	0.5	0.9	1.9	3.0
International aviation					0.00	0.32	2.3	8.7	18.8	24.9
Dwellings	[1]				0.0	0.0	0.0	0.0	0.0	0.0
Services	[1]				0.0	0.0	0.0	0.0	0.0	0.0
Total					***0.9***	***3.7***	***9.3***	***21.3***	***40.2***	***58.6***
[1] via network gases										
used as raw matter										
chemical industry					0.12	0.30	1.0	2.1	3.3	4.0
net exports										
Total					***3.5***	***12.9***	***15.7***	***21.2***	***22.0***	***23.2***
% of the renewable H2 production					33%	36%	20%	13%	9%	8%



PJ

	2010	2015	2020	2025	2030	2035	2040	2045	2050
production				10.6	36.1	79.2	160.6	240.8	291.7
direct consumption at economic sectors				-0.1	-1.6	-5.8	-16.2	-35.5	-54.5
indirect consumption at economic sectors				-0.7	-2.1	-3.6	-5.1	-4.7	-4.1
used at electricity production (inc. cogeneration)				-1.5	-3.3	-10.8	-18.8	-28.0	-30.6
production of other fuels and raw matter				-3.7	-12.8	-27.3	-55.1	-82.0	-98.6
used as raw matter at the chemical industry				-0.1	-0.3	-1.0	-2.1	-3.3	-4.0
used at fossil fuel refineries				-0.4	-1.6	-3.4	-4.0		
net export				-3.5	-12.9	-15.7	-21.2	-22.0	-23.2

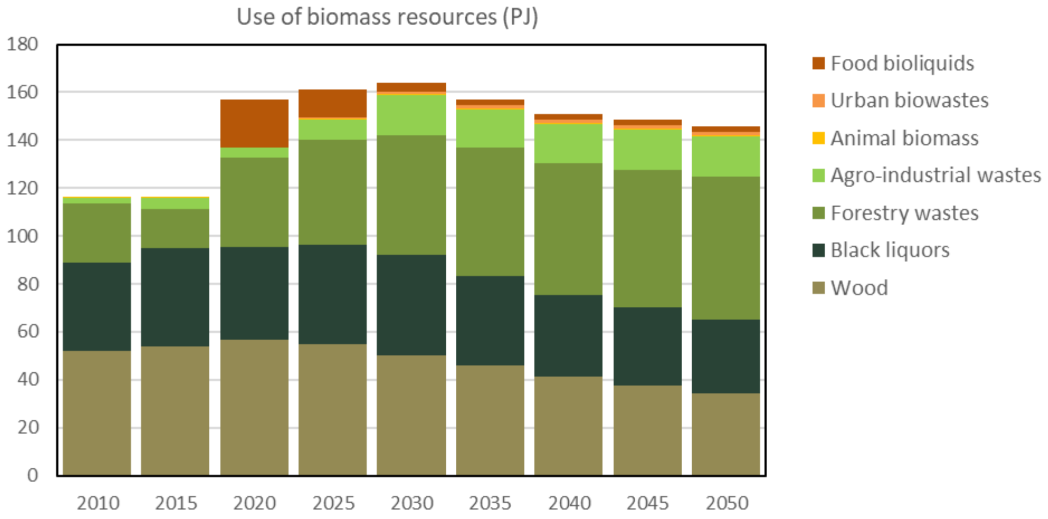
TWh

	2010	2015	2020	2025	2030	2035	2040	2045	2050
production				2.9	10.0	22.0	44.6	66.9	81.0
direct consumption at economic sectors				0.0	-0.4	-1.6	-4.5	-9.9	-15.1
indirect consumption at economic sectors				-0.2	-0.6	-1.0	-1.4	-1.3	-1.1
used at electricity production (inc. cogeneration)				-0.4	-0.9	-3.0	-5.2	-7.8	-8.5
production of other fuels and raw matter				-1.0	-3.5	-7.6	-15.3	-22.8	-27.4
used as raw matter at the chemical industry				0.0	-0.1	-0.3	-0.6	-0.9	-1.1
used at fossil fuel refineries				-0.1	-0.4	-0.9	-1.1		
net export				-1.0	-3.6	-4.4	-5.9	-6.1	-6.4

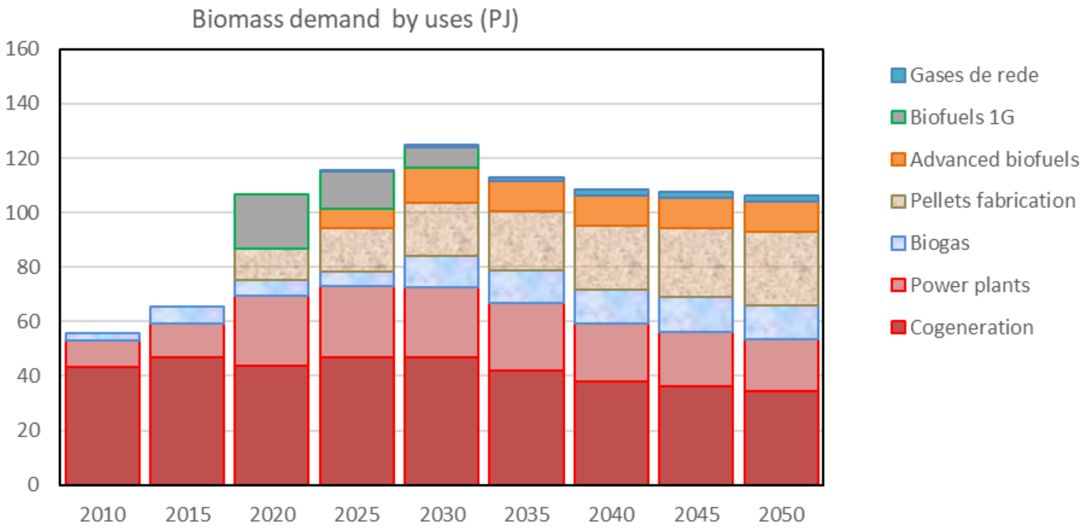
k ton PCS (HHV = 142 ton/GJ)

	2010	2015	2020	2025	2030	2035	2040	2045	2050
production				74.4	253.9	557.7	1 130.9	1 695.4	2 054.3
direct consumption at economic sectors				-0.8	-11.2	-40.6	-114.1	-250.2	-384.1
indirect consumption at economic sectors				-5.3	-14.7	-25.1	-35.9	-33.0	-28.5
used at electricity production (inc. cogeneration)				-10.6	-22.9	-76.2	-132.6	-197.2	-215.8
production of other fuels and raw matter				-25.9	-89.9	-192.1	-387.7	-577.7	-694.4
used as raw matter at the chemical industry				-0.9	-2.1	-7.0	-14.8	-23.2	-28.2
used at fossil fuel refineries				-2.6	-11.2	-24.0	-28.4		
net export				-24.3	-90.9	-110.8	-149.6	-154.9	-163.0

12. Biomass



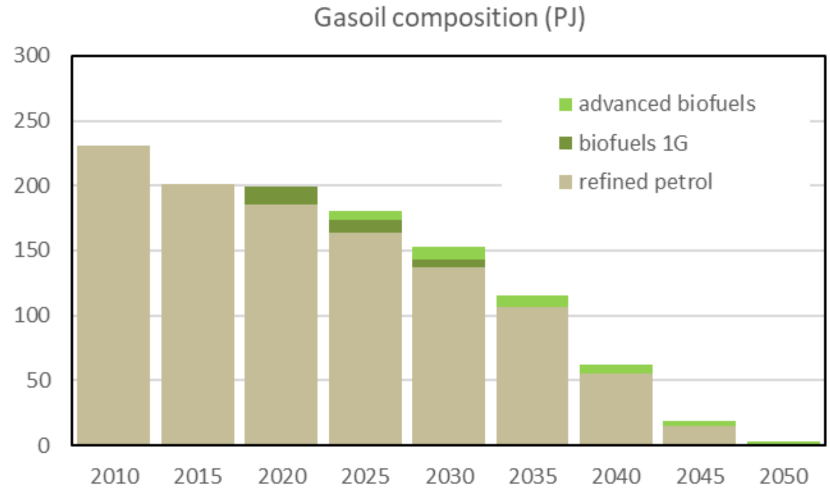
	2010	2015	2020	2025	2030	2035	2040	2045	2050
black liquors	36.8	41.2	38.7	41.6	41.8	37.4	34.1	32.3	30.6
wood	52.2	53.8	56.7	54.8	50.3	45.8	41.2	37.7	34.2
agro-industrial wastes	1.9	4.4	4.1	8.3	16.5	16.0	16.5	16.6	16.7
forestry wastes	24.8	16.4	37.4	44.0	50.0	53.8	54.9	57.6	60.0
animal biomass	0.1	0.1	0.1	0.3	0.5	0.5	0.5	0.5	0.5
urban biowastes				0.4	1.0	1.1	1.2	1.4	1.5
wastewaters	0.7	1.7	1.7	1.4	3.3	3.5	3.7	3.7	3.7
food bioliquids	0.0	0.0	19.9	12.0	4.0	2.4	2.3	2.3	2.2
	116	**118**	**159**	**163**	**167**	**160**	**155**	**152**	**149**
resources in mass units (kton)									
black liquors	3 101	3 472	3 265	3 506	3 527	3 155	2 878	2 722	2 583
wood	4 988	5 142	5 415	5 237	4 804	4 371	3 939	3 602	3 270
agro-industrial wastes	189	439	406	828	1 650	1 597	1 653	1 662	1 672
forestry wastes	3 117	2 055	4 701	5 525	6 281	6 753	6 899	7 231	7 533
animal biomass	1	3	3	6	11	11	11	12	12
urban biowastes				32	85	89	105	115	124
wastewaters	108	287	276	239	550	581	613	612	611
food bioliquids			4 332	2 609	870	519	507	495	483



	2010	2015	2020	2025	2030	2035	2040	2045	2050
biogas	2.6	6.2	5.8	5.1	11.5	12.1	12.7	12.7	12.6
pellets			11.7	15.9	19.6	21.6	23.7	25.3	27.0
advanced biofuels				7.2	12.7	11.1	11.1	11.1	11.1
biofuels 1G			19.9	13.5	7.7				
network gases				0.3	1.1	1.6	2.1	2.1	2.1
power plants	9.7	12.3	25.6	26.3	25.4	24.7	20.9	20.2	19.0
cogeneration	43.4	47.0	43.8	46.9	47.0	41.9	38.1	36.1	34.3
	56	**66**	**107**	**115**	**125**	**113**	**109**	**108**	**106**

	2010	2015	2020	2025	2030	2035	2040	2045	2050
at the economic sectors	**61**	**52**	**52**	**47**	**42**	**47**	**46**	**44**	**43**

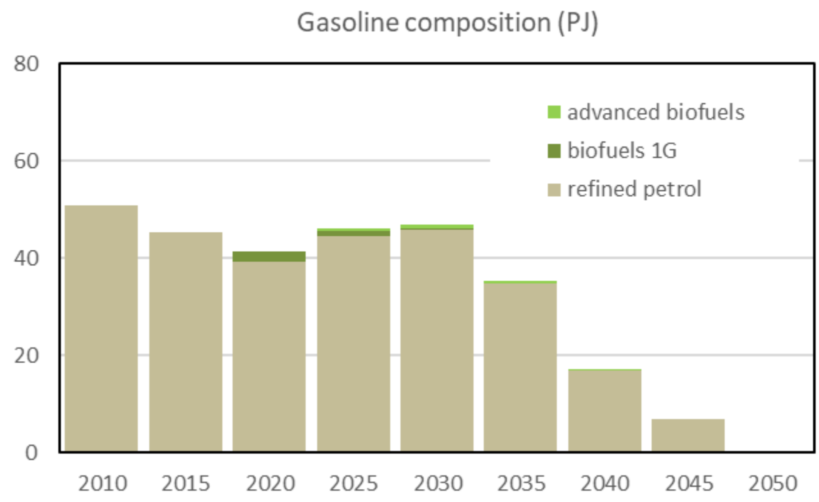
13. Gasoil and Gasoline



	2010	2015	2020	2025	2030	2035	2040	2045	2050
Production (national)									
fossil fuels	187.8	276.0	259.8	232.7	190.1	135.9	66.4	0.0	0.0
biofuels 1G	0.0	0.0	13.9	9.9	5.8	0.0			
advanced biofuels			0.0	6.0	10.2	8.4	7.0	4.1	2.0
total	**188**	**276**	**274**	**249**	**206**	**144**	**73**	**4**	**2**
Net imports									
fossil fuels	42.6	-75.2	-74.4	-68.5	-53.0	-29.2	-11.4	15.0	1.1
biofuels 1G									
advanced biofuels									
total	**43**	**-75**	**-74**	**-68**	**-53**	**-29**	**-11**	**15**	**1**
Total supply									
fossil fuels	230.4	200.8	185.4	164.2	137.1	106.8	55.0	15.0	1.1
biofuels 1G	0.0	0.0	13.9	9.9	5.8	0.0			
advanced biofuels			0.0	6.0	10.2	8.4	7.0	4.1	2.0
total	**230**	**201**	**199**	**180**	**153**	**115**	**62**	**19**	**3**
Demand									
global (check)	**230**	**201**	**199**	**180**	**153**	**115**	**62**	**19**	**3**
road transportation	191	167	173	154	130	98	52	14	1
Renewable fractions									
global (1)	0%	0%	7%	9%	11%	7%	11%	21%	64%
at road transportation (1)	0%	0%	8%	10%	12%	9%	13%	30%	185%

(*) imported raw matter, but finalproduct is produced internally (National Energy Balance criterium)

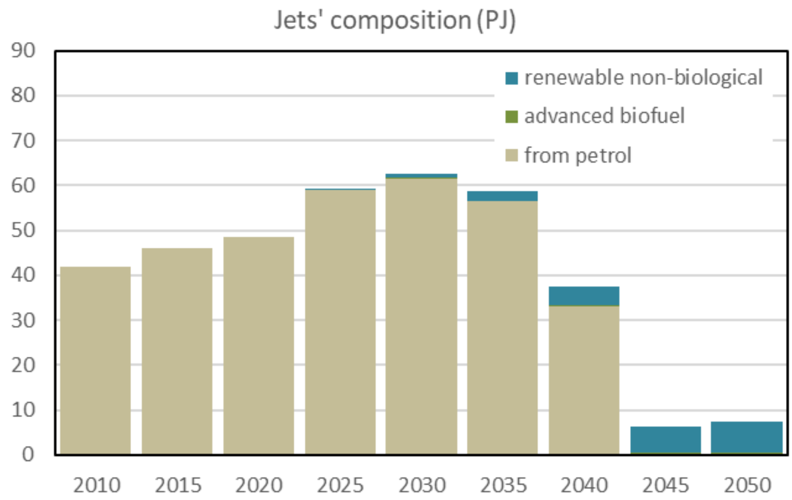
(1) assuming the same proportion of imported fuels



	2010	2015	2020	2025	2030	2035	2040	2045	2050
Production (national)									
fossil fuels	90.3	120.1	112.8	112.3	98.3	63.7	28.2	0.0	0.0
biofuels 1G	0.0	0.0	2.1	1.0	0.3	0.0			
advanced biofuels			0.0	0.5	0.6	0.4	0.2	0.0	0.0
total	**90**	**120**	**115**	**114**	**99**	**64**	**28**	**0**	**0**
Net imports									
fossil fuels	-39.5	-74.9	-73.5	-67.7	-52.4	-28.8	-11.2	7.0	0.2
biofuels 1G									
advanced biofuels									
total	**-39**	**-75**	**-74**	**-68**	**-52**	**-29**	**-11**	**7**	**0**
Total supply									
fossil fuels	50.8	45.2	39.2	44.7	45.9	34.9	16.9	7.0	0.2
biofuels 1G	0.0	0.0	2.1	1.0	0.3	0.0			
advanced biofuels			0.0	0.5	0.6	0.4	0.2	0.0	0.0
total	**51**	**45**	**41**	**46**	**47**	**35**	**17**	**7**	**0**
Demand									
global (check)	**51**	**45**	**41**	**46**	**47**	**35**	**17**	**7**	**0**
road transportation	50	45	41	46	47	35	17	7	0
Renewable fractions									
global [1]	0%	0%	5%	3%	2%	1%	1%	0%	0%
at road transportation [1]	0%	0%	5%	3%	2%	1%	1%	0%	0%

(1) assuming the same proportion of imported fuels

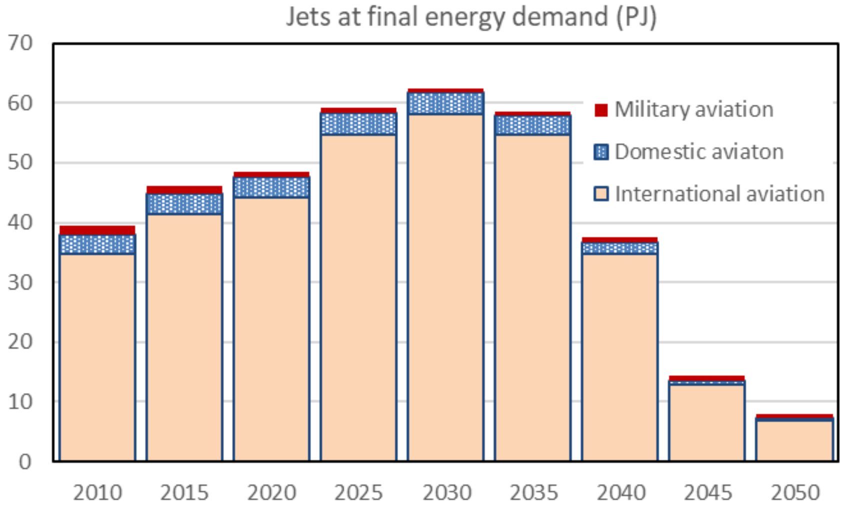
14. Jets



	2010	2015	2020	2025	2030	2035	2040	2045	2050
from petrol	41.8	46.0	48.4	59.0	61.6	56.4	33.1	0.0	0.0
advanced biofuel				0.00	0.1	0.2	0.3	0.4	0.5
non-biological synthesis				0.27	0.9	2.0	4.1	6.0	6.8
Total	***41.8***	***46.0***	***48.4***	***59.2***	***62.6***	***58.6***	***37.6***	***6.4***	***7.3***
fossil	*100%*	*100%*	*100%*	*100%*	*98%*	*96%*	*88%*	*0%*	*0%*
biological	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*1%*	*6%*	*7%*
renewable non-biological	*0%*	*0%*	*0%*	*0%*	*1%*	*3%*	*11%*	*94%*	*93%*

Net exports

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total	***2.4***	***-0.1***	***0.1***	***0.0***	***0.0***	***0.0***	***0.0***	***-8.0***	***-0.7***



	2010	2015	2020	2025	2030	2035	2040	2045	2050
Military aviation (services sector)	1.3	1.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8
Domestic aviation	3.3	3.5	3.5	3.7	3.7	3.2	2.0	0.7	0.4
International aviation	34.7	41.4	44.2	54.7	58.1	54.6	34.8	12.9	6.9
Total	***39.4***	***46.1***	***48.4***	***59.2***	***62.5***	***58.6***	***37.5***	***14.3***	***8.0***

15. Primary Energy Factors

15.1. Electricity

Dispersed systems (based on renewables)	2010	2015	2020	2025	2030	2035	2040	2045	2050
UPAC (self-consumption)	0.0	0.0	1.8	5.2	12.5	23.0	32.1	37.3	40.1
UPP (small units)	0.0	0.9	0.9	7.6	17.1	22.8	28.5	29.9	31.4

Power plants	2010	2015	2020	2025	2030	2035	2040	2045	2050
electricity production based on:									
coal	23.9	51.7	3.6						
gasoil	0.0	0.0	0.0						
fueloil	0.6	0.1	0.0						
wastes	1.9	1.9	1.9	1.8	1.7	1.6	1.5	1.4	1.4
network gases	42.1	21.0	38.3	38.8	24.4	20.4	14.3	7.0	
hydrogen							1.4	4.5	3.8
wind onshore	35.0	44.2	45.9	51.5	58.3	61.1	63.9	64.0	63.8
wind offshore			0.0	0.3	2.2	6.5	11.4	16.3	18.9
solar PV	0.7	1.7	7.4	20.8	39.4	48.9	58.6	64.2	69.2
concentrated solar power				1.3	3.4	5.1	6.8	6.7	6.5
large hydro	55.7	33.4	51.6	59.1	57.3	55.5	50.4	48.4	44.4
small hydro	7.4	4.0	6.2	5.9	5.7	5.4	5.0	4.7	4.3
waves and currents			0.0	1.4	3.5	6.5	9.4	10.6	11.6
biomass	2.3	2.8	4.8	5.1	5.3	5.3	5.3	5.3	5.3
biogas	0.4	1.0	1.0	0.3	0.2	0.2	0.2	0.2	0.2
geothermal (enhanced)						0.5	1.2	3.0	4.8
from fossil inputs	*68*	*74*	*43*	*38*	*22*	*16*	*9*	*3*	*0.7*
from renewable inputs	*101*	*87*	*117*	*147*	*179*	*200*	*220*	*232*	*233*

primary energy inputs (statistical convention)	2010	2015	2020	2025	2030	2035	2040	2045	2050
fossil	148	185	83	71	41	30	16	5	1.3
renewable	101	87	117	147	179	200	220	232	233

Losses	2010	2015	2020	2025	2030	2035	2040	2045	2050
self-consumption	4.1	4.2	3.3	3.6	3.4	3.4	3.4	3.3	3.1
at storage	0.4	1.1	1.7	1.7	1.7	1.7	1.7	1.7	1.7
at transportation	6.2	6.4	5.4	5.5	5.2	5.0	4.7	4.9	4.9
subtotal	*11*	*12*	*11*	*11*	*10*	*10*	*10*	*10*	*10*
at distribution	9	12	11	11	11	11	11	11	11

Allocation of prod., storage and transp. losses	2010	2015	2020	2025	2030	2035	2040	2045	2050
Final Área do Gráfico									
from fossil fuels	79	83	50	46	29	21	11	4	1
from renewables	111	97	127	158	190	212	233	247	248
total	190	181	176	204	219	233	245	251	249
from fossil fuels	42%	46%	28%	22%	13%	9%	5%	2%	0%
from renewables	58%	54%	72%	78%	87%	91%	95%	98%	100%
Primary energy inputs + losses	2010	2015	2020	2025	2030	2035	2040	2045	2050
from fossil fuels	198	227	112	102	70	50	27	10	2
from renewables	117	104	134	166	199	221	242	257	257

Allocation of distribution losses	2010	2015	2020	2025	2030	2035	2040	2045	2050
Final energy outputs									
from fossil fuels	79	83	50	46	29	21	11	4	1
from renewables	111	98	128	165	207	235	262	277	279
total	190	182	177	211	236	256	273	281	280
from fossil fuels	42%	46%	28%	22%	12%	8%	4%	1%	0%
from renewables	58%	54%	72%	78%	88%	92%	96%	99%	100%
Área do Gráfico									
Primary energy inputs + losses	2010	2015	2020	2025	2030	2035	2040	2045	2050
from fossil fuels	197	227	112	102	70	50	27	10	2
from renewables	116	105	135	174	217	245	272	288	290
total	313	331	248	276	286	295	299	298	292

Primary energy factors	2010	2015	2020	2025	2030	2035	2040	2045	2050
Fossil electricity	2.48	2.72	2.26	2.23	2.39	2.35	2.36	2.44	2.16
Renewable electricity	1.05	1.06	1.06	1.05	1.05	1.04	1.04	1.04	1.04
Electricity from the grid	1.65	1.82	1.40	1.31	1.21	1.15	1.10	1.06	1.04
					2021-30 average		2021-40 average		2021-50 average
Fossil electricity					2.29		2.32		2.31
Renewable electricity					1.05		1.05		1.05
Electricity from the grid					**1.31**		**1.23**		**1.18**
EPBD II interpretation	2010	2015	2020	2025	2030	2035	2040	2045	2050
Fossil electricity	*0.69*	*0.84*	*0.39*	*0.28*	*0.15*	*0.10*	*0.05*	*0.02*	*0.00*
Renewable electricity	*0.96*	*0.99*	*1.00*	*1.02*	*1.06*	*1.06*	*1.05*	*1.05*	*1.04*
Electricity from the grid	*1.65*	*1.82*	*1.40*	*1.31*	*1.21*	*1.15*	*1.10*	*1.06*	*1.04*
					2021-30 average		*2021-40 average*		*2021-50 average*
Fossil electricity					*0.27*		*0.19*		*0.14*
Renewable electricity					*1.03*		*1.04*		*1.04*
Electricity from the grid					*1.31*		*1.23*		*1.18*

15.2. Network gases

Electricity used at preparing:	2010	2015	2020	2025	2030	2035	2040	2045	2050
methane from biomass				0.0	0.1	0.2	0.2	0.2	0.2
methane from biogas				0.2	0.6	0.6	0.7	0.7	0.7
methane non-biological				1.2	4.0	9.1	19.2	29.0	34.9
hydrogen non-biological				2.7	6.7	10.6	13.2	10.8	8.1
hydrogen biological				0.0	0.1	0.1	0.1	0.0	0.0

Hydrogen used at preparing:	2010	2015	2020	2025	2030	2035	2040	2045	2050
methane from biomass				0.4	1.3	2.0	2.6	2.6	2.6
methane from biogas				0.3	1.1	1.2	1.3	1.3	1.3
methane non-biological				0.7	8.9	2.9	42.6	64.6	77.7

Electricity used at gas network	2010	2015	2020	2025	2030	2035	2040	2045	2050
related to renewable gases				0.03	0.06	0.10	0.12	0.09	0.07

Overall ancillary energy	2010	2015	2020	2025	2030	2035	2040	2045	2050
total				5.5	22.7	26.8	80.0	109.4	125.6

Outputs:	2010	2015	2020	2025	2030	2035	2040	2045	2050
natural gas (fossil)	188	170	176	182	144	119	78	35	3
renewable gases				7	22	37	60	78	87
total	188	170	176	189	166	156	138	113	91
fossil energy	100%	100%	100%	96%	87%	76%	56%	31%	4%
renewable energy				4%	13%	24%	44%	69%	96%

Losses at transport and distribution:	2010	2015	2020	2025	2030	2035	2040	2045	2050
in pipelines	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Inputs + ancillary energy + losses:	2010	2015	2020	2025	2030	2035	2040	2045	2050
fossil energy	189	170	176	182	145	119	78	35	3
renewable energy				13	45	64	140	187	213
total	189	170	176	195	189	183	218	222	217

Primary energy factors	2010	2015	2020	2025	2030	2035	2040	2045	2050
fossil gases	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
renewable gases				1.78	2.03	1.73	2.33	2.41	2.44
network gases	1.00	1.00	1.00	1.03	1.14	1.17	1.58	1.97	2.39

	2021-30 average	2021-40 average	2021-50 average
fossil gases	1.00	1.00	1.00
renewable gases	1.90	1.97	2.12
network gases	**1.06**	**1.18**	**1.47**

EPBD II interpretation	2010	2015	2020	2025	2030	2035	2040	2045	2050
fossil gases	*1.00*	*1.00*	*1.00*	*0.99*	*0.99*	*0.89*	*0.89*	*0.61*	*0.09*
renewable gases	*0.00*	*0.00*	*0.00*	*0.04*	*0.15*	*0.28*	*0.69*	*1.36*	*2.30*
network gases	*1.00*	*1.00*	*1.00*	*1.03*	*1.14*	*1.17*	*1.58*	*1.97*	*2.39*

	2021-30 average	*2021-40 average*	*2021-50 average*
fossil gases	*0.99*	*0.95*	*0.78*
renewable gases	*0.06*	*0.23*	*0.69*
network gases	*1.06*	*1.18*	*1.47*

15.3. Hydrogen

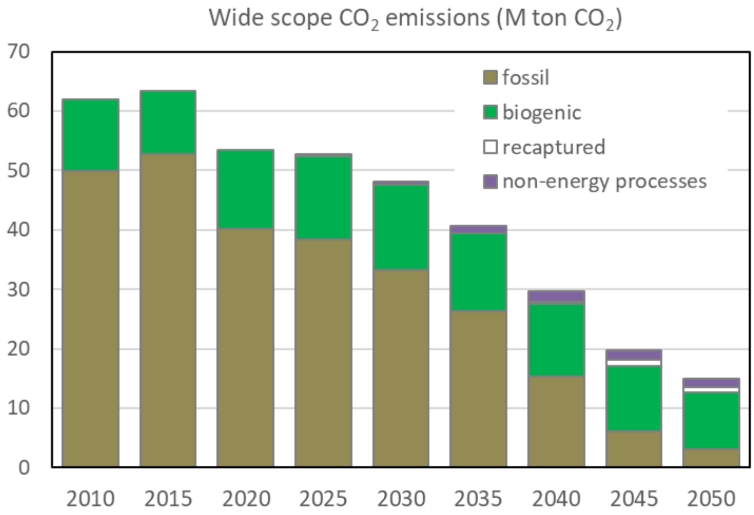
Electricity used at preparing:	2010	2015	2020	2025	2030	2035	2040	2045	2050
hydrogen non-biological				10.9	37.7	87.2	184.4	281.4	340.6
hydrogen biological				0.2	0.6	0.8	1.0	1.2	1.5
total				11.1	38.3	88.0	185.4	282.6	342.1
Solar radiation used at preparing:	2010	2015	2020	2025	2030	2035	2040	2045	2050
hydrogen non-biological				1.1	2.9	5.8	8.7	9.5	10.4
Biomass used at preparing:	2010	2015	2020	2025	2030	2035	2040	2045	2050
hydrogen non-biological				1.4	5.2	6.8	8.6	10.5	12.5
Outputs	2010	2015	2020	2025	2030	2035	2040	2045	2050
hydrogen				10.6	33.1	79.2	160.6	240.8	291.7
Primary energy factor	2010	2015	2020	2025	2030	2035	2040	2045	2050
hydrogen				1.28	1.40	1.27	1.26	1.26	1.25
					2021-30 average		*2021-40 average*		*2021-50 average*
					1.34		*1.30*		*1.29*

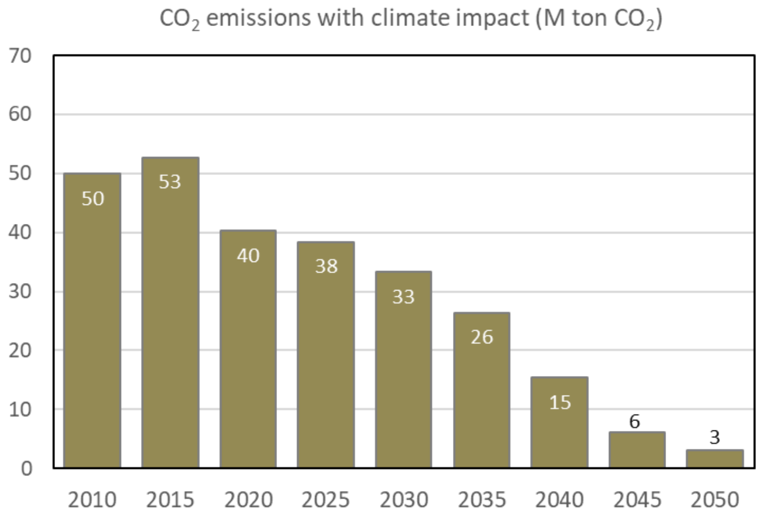
15.4. Pellets & Briquettes

Pellets & Briquettes									
Production	2010	2015	2020	2025	2030	2035	2040	2045	2050
pellets & briquettes			11	14	18	19	21	23	24
Energy used in the fabrication:	2010	2015	2020	2025	2030	2035	2040	2045	2050
total			0.3	0.4	0.5	0.6	0.6	0.7	0.7
Primary energy factor	2010	2015	2020	2025	2030	2035	2040	2045	2050
pellets & briquettes			1.03	1.03	1.03	1.03	1.03	1.03	1.03
					2021-30 average		*2021-40 average*		*2021-50 average*
					1.03		*1.03*		*1.03*

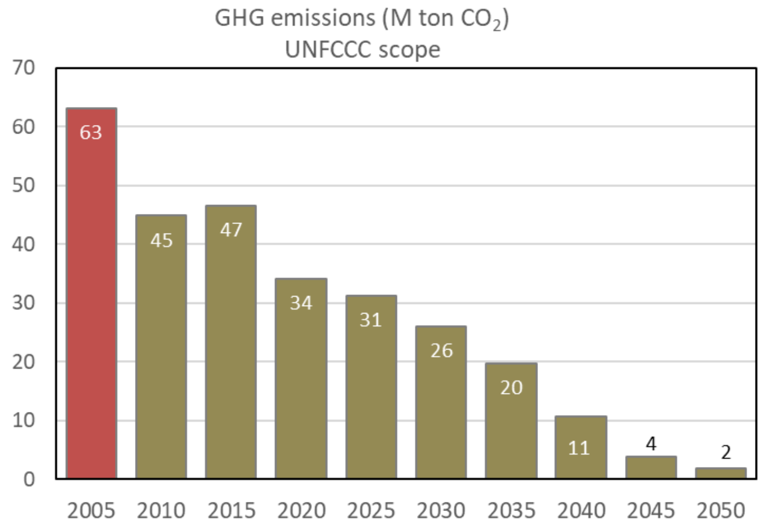
N.B. for LPG only refination losses are assumed (1%), thus primary energy factor = 1,01

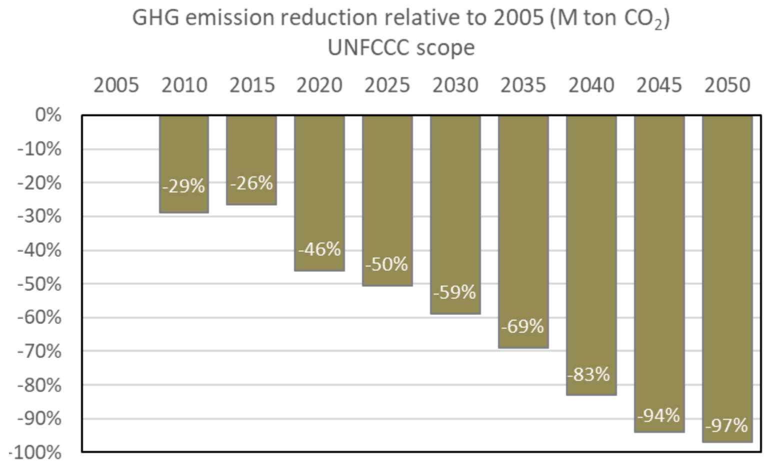
16. Greenhouse Gas Emissions





Total CO_2 emissions	2010	2015	2020	2025	2030	2035	2040	2045	2050
by origin:									
- biogenic	12.1	10.7	13.2	14.0	14.3	13.0	12.1	11.1	9.5
- recaptured				0.00	0.00	0.08	0.4	0.9	0.9
- fossil	49.9	52.7	40.2	38.4	33.3	26.4	15.4	6.0	3.1
- non-energy processes				0.44	0.7	1.1	1.7	1.7	1.5
total	62.0	63.4	53.4	52.8	48.2	40.6	29.6	19.7	14.9
with climate change impact:									
including non-energy processes	49.9	52.7	40.2	38.8	33.9	27.5	17.1	7.7	4.6
energy sector	49.9	52.7	40.2	38.4	33.3	26.4	15.4	6.0	3.1
estimate of reduction relative to 2005	*-23%*	*-19%*	*-38%*	*-41%*	*-49%*	*-59%*	*-76%*	*-91%*	*-95%*





GHG emissions - UNFCCC scope	2010	2015	2020	2025	2030	2035	2040	2045	2050
total CO_2 + other GHG	50.4	53.2	40.6	38.7	33.6	26.7	15.5	6.1	3.2
recalibration / UNFCCC scope	44.9	46.5	34.1	31.3	26.0	19.7	10.8	3.9	1.9
estimate of reduction relative to 2005	-29%	-26%	-46%	-50%	-59%	-69%	-83%	-94%	-97%
energy sector goal			-18% to-23%		-45% to -55%				-98%

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