ASSOCIATION négaWatt

ANALYSIS NOTE

May 2025

Balancing ambition and feasibility: **Comparison of major EU energy and climate scenarios for 2040**

Many EU scenarios have been published around the European Commission 2040 climate target communication in 2024, as well as several reports from the European Scientific Advisory Board on Climate Change (ESABCC). The comparison of these scenarios and analyses can provide **important information for the discussion around 2040 objectives** and more broadly to future EU scenario modelling.

- **Most scenarios reach in 2040 at least 88% net GHG reduction** relative to 1990 and highlight the importance **by 2040** to **reduce energy consumption** (at least -30%), to **develop electric renewables** (at least 3900TWh) and **to electrify an important share of final energy consumption** (at least 45% in 2040 compared with 21% today).
- Several scenarios do not comply with 2030-2050 GHG budgets defined by the ESABCC. **The scenarios with the least ambition in terms of GHG budgets for 2030-2050 and the lowest contribution to Europe's energy security are also the ones with the most use of levers with high feasibility or environmental concerns** according to ESABCC thresholds, and **with the least ambition on energy savings**.
- **Energy savings have the potential to both help achieve ambitious climate objectives and energy security, and to reduce feasibility concerns and environmental risks. Applying only half of the ambition gap between CLEVER and the EC-S3 on only half a dozen energy savings indicators could enable the EU to save more than 500 TWh, thus greatly contributing to filling the gap left by the most unfeasible assumptions (e.g. on CCUS).**

Table of contents

–

1. Context, objectives and scenarios selection ... 4
- 1.1 Context and objectives ... 4
- 1.2 Selection of major scenarios and scope of the analysis ... 4
- 1.3 The ESABCC and its contribution to scenarios analyses ... 5

2. Scenarios’ analysis regarding feasibility and 2040 ambition ... 6
- 2.1 Quantitative analysis on major indicators for 2040 ... 7
- 2.2 Conclusions shared by most scenarios ... 8
- 2.3 Four categories of scenarios according to feasibility and ambition ... 8
- 2.4 Scenarios with the lowest ambition have more feasibility issues ... 9

3. Energy savings can reconcile ambition and feasibility ... 10
- 3.1 Lower demand facilitates higher ambition on climate and energy security and brings important co-benefits ... 10
- 3.2 The feasibility of energy savings ... 11
- 3.3 A short comparison of energy savings assumptions ... 12

ANNEX 1 – Extensive description of indicators used for the quantitative analysis ... 14
- Definitions, scopes, and adaptations of scenarios’ original data ... 14

ANNEX 2 – Main sources for scenarios and ESABCC comparison ... 19
- Main sources used to compile data from scenarios ... 19
- ESABCC resources used in this note ... 20

List of Abbreviations ... 21

References ... 22

1. Context, objectives and scenarios selection

1.1 Context and objectives

In 2023 and 2024, a lot of scenarios have been published by different stakeholders: NGOs, think tanks, European Commission, TSOs, academics…

This profusion of scenario modelling from organisations with sometimes very different approaches and objectives can bring important insights for future modelling exercises and discussions on 2040 objectives[1]. Indeed, the convergence between scenarios highlighted what should be the absolute minimum ambition. In the present study, we identified major differences between these scenarios and analysed the impacts of these differences (in terms of feasibility, GHG emissions, energy imports, environmental risks, cobenefits…) to fuel an informed discussion on the desired level of ambition.

The analysis mostly focused on 2040 which will be the next important milestone for climate action.

1.2 Selection of major scenarios and scope of the analysis

Among the scenarios published in 2023-2024, we selected the ones with:

- a substantial contribution to the EU debates around 2040 objectives
- a complete modelling of the energy system (e.g. not only the electricity) and an inclusion of all GHG
- results and assumptions sufficiently detailed to enable a comparison and mostly defined in accordance to definitions and scopes usually considered in publications from EUROSTAT and the European Commission.
- reaches at least 88% GHG emissions reduction by 2040 compared to 1990, which is the minimum ambition in 1.5 compatible scenarios analysed in (ESABCC, 2023). TYNDPs, which reach a lower ambition have been included given their importance in the EU debate

In the end, this selection included most scenarios identified in Table 1 of the Annex 13 of the impact assessment of the European Commission relative to 2040 climate targets. The PIK analysis is more a sensibility analysis than a proper scenario and the lack of data complicated its inclusion in this analysis. The PAC2.0 and the TYNDPs which were published later were included as raising from major stakeholders. We identified scenarios from EURELECTRIC which could be relevant for this analysis, but we could not include them at this stage because of the lack of data on certain indicators and the difference on the geographical perimeter (EU27+UK).

The comparison thus included 8 scenarios, one from an NGO, three from think tanks, 2 from the European Commission and 2 from TSOs. Here below the list of these scenarios. Further details are provided in the section "ANNEX 2"

- The PAC 2.0 scenario from CAN Europe, published in September 2024, abbreviated "PAC"
- The CLEVER scenario produced by a network of national partners led by négaWatt, released in June 2023, abbreviated "CLEVER"
- The "Visionary scenario[2]: -90% net" from the report "Choices for a more strategic Europe" from Strategic Perspectives, published in July 2023, abbreviated "SP90"
- "Breaking free from fossil gas" from AGORA Energiewende, published in May 2023, abbreviated AGORA

[1] For some of the scenarios analysed, the modelling work began before 2022 and relied on historical data from 2019, then some conclusions for the short term might soon necessitate some revision, but most of the conclusions for 2040 remain valid and the comparison can also inform future prospective studies.

[2] Only the scenario privileged by Strategic Perspectives among their 3 scenarios was analysed. "Strategic Perspectives considers the Visionary Scenario a feasible pathway that provides a strong contribution by the European Union to the global effort to fight climate change"

- The S2 and S3 scenarios from the 2040 Climate Target Impact Assessment of the European Commission, published in February 2024, abbreviated EC-S2 and EC-S3. The S1 scenario was not analysed because of its serious lack of ambition (-78% GHG in 2040)
- Scenarios from the "Ten-year development plans 2024" from ENTSO-E and ENTSOG, published in June 2024. We selected the 2 main variants "Distributed Energy" and "Global Ambition", respectively abbreviated "TYNDP-DE" and "TYNDP-GA"

The comparison mainly focuses on the levels of ambition, relating mostly to GHG emissions, but also to energy security, and feasibility and uses the ESABCC's recommendations as benchmark.

1.3 The ESABCC and its contribution to scenarios analyses

The European Scientific Advisory Board on Climate Change (ESABCC) "is an independent body providing the European Union (EU) with scientific knowledge, expertise and advice relating to climate change". "It was established in 2021 by the European Climate Law and consists of 15 independent senior scientific experts covering a broad range of relevant disciplines."[3]

1.3.1 Recommendations for EU-wide 2040 climate target

Their report "Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050", published in June 2023, recommended:

- "keeping the EU's greenhouse gas emissions budget (i.e. cumulative emissions) for the period 2030 to 2050 within a limit of 11-14 Gt CO_2e"
- "[striving] for net emissions reductions of 90-95% by 2040, relative to 1990 levels"

These recommendations stemmed from considerations of **fairness and feasibility**. "Under all assumptions assessed, the Advisory Board identified a shortfall between the feasible pathways for domestic emissions, and fair share estimates based on different equity principles." **"To address this shortfall, the EU should aim for the upper limit of feasible reductions in domestic emissions."**

The definition of feasible assumptions therefore becomes essential to assess scenarios the EU should aim for. For a certain number of assumptions (natural carbon sinks, demand reduction, CCUS, renewables…), **the ESABCC defined feasibility concern thresholds**, **including environmental risks and technology scale-up challenges**.

1.3.2 Methodology to assess TYNDPs' feasibility and ambition

In June 2024, the ESABCC published "Towards climate neutral and resilient energy networks across Europe - advice on draft scenarios under the EU regulation on trans-European energy networks" (ESABCC, 2024). This report included analyses of the TYNDPs with regards to ambition (2030-2050 GHG budgets and compliance with EU objectives) and feasibility.

To assess the feasibility, they compared TYNDPs' assumptions with thresholds defined in (ESABCC, 2023), "the European Commission's modelling results (scenario S3) and the collection of scenarios used by the [ESABCC] to determine fair and feasible climate neutrality pathways for the EU hereinafter 'the benchmark scenarios')[4]".

[3] https://climate-advisory-board.europa.eu/about

[4] In line with the advisory board's recommended GHG budget for 2030–2050, these include six filtered scenarios that achieve at least a 90 % reduction in net GHG emissions by 2040 and that do not exceed the environmental risk thresholds identified by the ESABCC (2023)

2. Scenarios’ analysis regarding feasibility and 2040 ambition

As a first step, the analysis focuses on major results and assumptions for 2040. We also included GHG emissions in 2030 as it can be considered as an important element to understand differences on GHG budgets for 2030-2050.

The table below includes, for the 8 scenarios, the figures for major indicators selected. Each result and assumption have been analysed in terms of respectively ambition and feasibility. This assessment was carried by comparison to ESABCC recommendations on GHG and feasibility thresholds from (ESABCC, 2023) and to the benchmark scenarios from (ESABCC, 2024).

Further details are provided in ANNEX 1 regarding:

- The definition and scope of each indicator
- Adaptations of original scenarios’ data to indicators’ scope
- Values used to assess the ambition of results and the feasibility of assumptions

2.1 Quantitative analysis on major indicators for 2040

2040		PAC2.0	CLEVER	SP90	AGORA	EC-S3	EC-S2	TYNDP24-DE	TYNDP24-GA
Results / ambition	GHG budget 2030-2050 ($GtCO_{2e}$)	3.35	10.5	12.9	14.2	16	18	16	15.8
	Net GHG reduction (2040/1990)	-102%	-92%	-90%	-89%	-92%	-88%	-86%	-86%
	Net GHG reduction (2030/1990)	*-72%*	*-65%*	*at least -55%*	*-60%*	*-58%*	*-58%*	*-59%*	*-59%*
	Primary fossil (TWh)	971	1689	2520	3414	3203	3617	2875	3323
	Net imports w/o nuclear (TWh)	1225	1474	2313	3293	3056	3421	3309	3922
Assumptions / feasibility	LULUCF (MtCO2)	-519	-351	-412	-361	-317	-316	-317	-317
	CCUS (MtCO2)	60	55	127	77	344	222	370	444
	Wind solar and hydro (TWh)	4143	3873	3158	4090	4409	4045	4604	4803
	Primary biomass (TWh)	703	1919	994	1418	2434	2430	1750	2049
	H2/e-fuels imports	539	70	78	164	15	15	658	823
	H2 production (TWh)	320	614	221	520	1163	884	959	1163
	Nuclear (TWh)	0	137	652	626	495	495	247	508
	FEC (% reduction /2019)	-56%	-48%	-46%	-30%	-38%	-37%	-31%	-25%
	Electrification (of FEC)	70%	51%	57%	46%	48%	47%	46%	38%

Results / Ambition

-102%	Beyond what is assumed feasible by ESABCC
-92%	In line with ESABCC benchmark and recommendations
-88%	Close to the limit of ambition of the ESABCC benchmark and recommendations
-85%	No compliance with ESABCC recommendations
12.9	Estimation of négaWatt with little confidence

Assumptions / Feasibility

703	Cautious assumption, below values in ESABCC benchmark. Might reflect a lack of ambition
4143	Good balance between feasibility and ambition. In line with ESABCC benchmark values
971	Raise some feasibility concerns. Close to the limit defined by the ESABCC benchmark
539	High feasibility or environmental concern. Largely beyond ESABCC benchmark
12.9	Estimation of négaWatt with little confidence

2.2 Conclusions shared by most scenarios

These scenarios, elaborated by diverse organisations, have a lot in common. Indeed, most of the scenarios (at least 6 scenarios out of 8) converged on:

- The feasibility of **a reduction of at least -88% GHG by 2040** compared to 1990 and carbon neutrality by 2050 at the latest (except TYNDPs with -86%)
- **A major role for electric renewables**[5], with at least 3900 TWh by 2040 (except SP90 with 3160TWh)
- **A demand reduction of at least 30% in 2040** compared to 2019 (except TYNDP-GA with -25%)
- **A strong electrification of FEC from 22% today to at least 45% in 2040** (except TYNDP24-GA with 38%)
- An important development of green H2 production: at least 500TWh (except SP90 and PAC2.0 with 220TWh and 320TWh)
- The critical role of natural carbon sinks with at least 315MtCO2
- At least 1400TWh of primary biomass, (except PAC2.0 and SP90)
- A limited role for nuclear in 2050 at EU level, representing 0% to 10% of electricity production (except SP90 and AGORA with 13% and 16%)
- A reduction of energy imports by at least 69% in comparison to 2019 (except TYNDP-GA with a 63% reduction)
- Some forms of carbon capture and use, at least for e-fuels production, but the sources of carbon capture (biogas coproduct, biomass combustion, cement production, direct air capture, …) and uses (e-fuels, materials, geological storage) strongly vary from one scenario to another

2.3 Four categories of scenarios according to feasibility and ambition

But these scenarios also presented important differences, which were **analysed through indicators of feasibility and ambition** mainly based on ESABCC recommendations from (ESABCC, 2023) and the benchmark scenarios from (ESABCC, 2024)

The evaluation of feasibility or ambition for each indicator is presented in section 2.1. The analysis of these indicators highlighted 3 to 4 categories of scenarios

- 1 scenario (PAC2.0) with very ambitious results related to climate. This high level of ambition raises some feasibility concerns with regards to its implementation as it relies on: very high natural carbon sinks, very high H2/e-fuels imports, and a very fast evolution of energy demand both in terms of energy savings (sufficiency and efficiency) and electrification (renewal of heating systems, vehicles and industrial processes). Its implementation would require a structural rupture with current policy trajectories.
- **3 scenarios (CLEVER, SP90 and AGORA) with a good balance between ambition and feasibility**, respecting most of the ESABCC recommendations. The CLEVER scenario reaches the higher ambition on GHG budget and fossil fuel reduction and the smaller amount of energy imports. This is achieved mainly thanks to ambition both on demand and renewable energies (electric and biomass).
- 2 scenarios from the European Commission. The EC-S3 reaches an ambitious GHG reduction (-92% in 2040) while failing to fully comply with GHG budget recommendation, and keeps a high level of energy imports. More energy savings could improve ambition and reduce the need for uncertain levers (primary biomass, H2 production, CCUS and nuclear). The EC-S2 has similar issues in terms of feasibility and lower ambition on GHG and imports' reductions.
- **TYNDP scenarios lack of ambition and feasibility** on most of the indicators considered. High FEC and low electrification rates, especially for GA, brings lower climate ambition and the **necessity to compensate with some levers beyond feasibility threshold (e.g. H2 production and imports, CCUS).**

[5] Solar, wind and hydro

2.4 Scenarios with the lowest ambition have more feasibility issues

The scenarios with lower ambition on GHG emissions (EC-S2 and TYNDPs) are also those with the highest energy dependence, and they present more feasibility issues than scenarios with higher ambition (SP90, AGORA and CLEVER). We can highlight that:

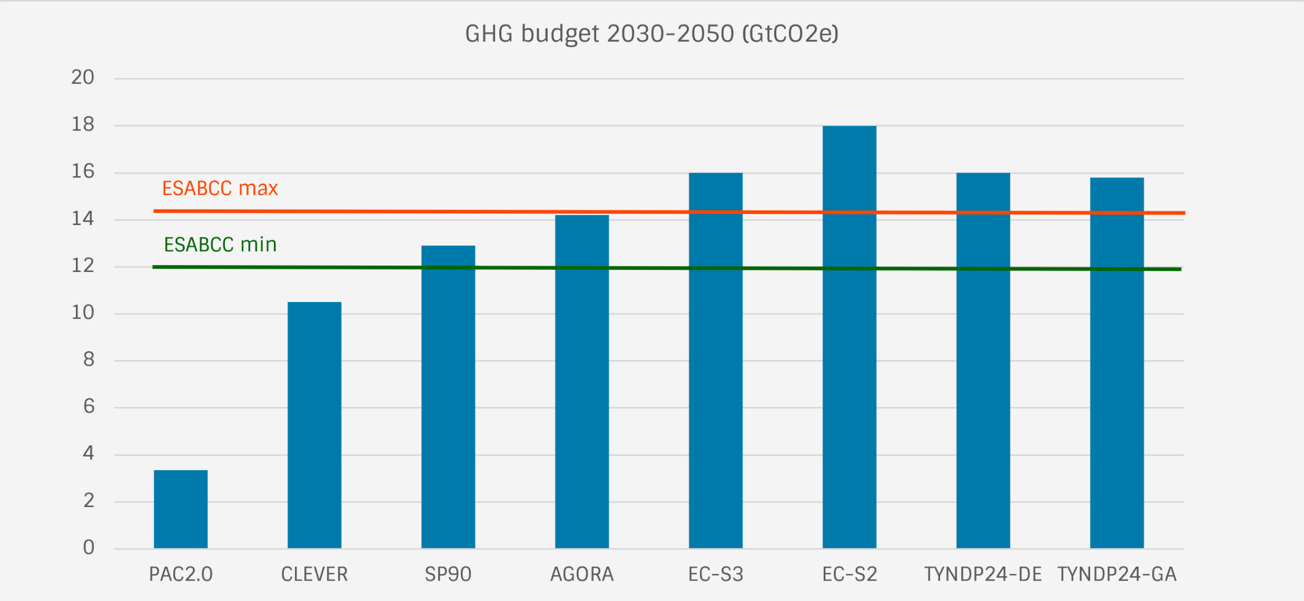
- **CCUS deployment** in 2040 is beyond the upper value of the ESABCC benchmark (233MtCO2). TYNDP-GA and EC-S3 go even beyond the ESABCC feasibility threshold for 2050 (425MtCO2).
- **Green hydrogen production** reaches 880 to 1160 TWh in 2040, well beyond the upper limit of ESABCC benchmark (430 to 600TWh depending on scope considered).
- In addition, TYNDP scenarios assume a "very high reliance on hydrogen imports in 2030-2050"[6] (658 to 823TWh in 2040).
- Nuclear production and primary biomass in TYNDP-GA and in EC scenarios are close to the upper boundary of the benchmark scenarios from ESABCC.
- TYNDPs scenarios are the most ambitious on electric renewables (solar, wind and hydro) with 4600 to 4800TWh.

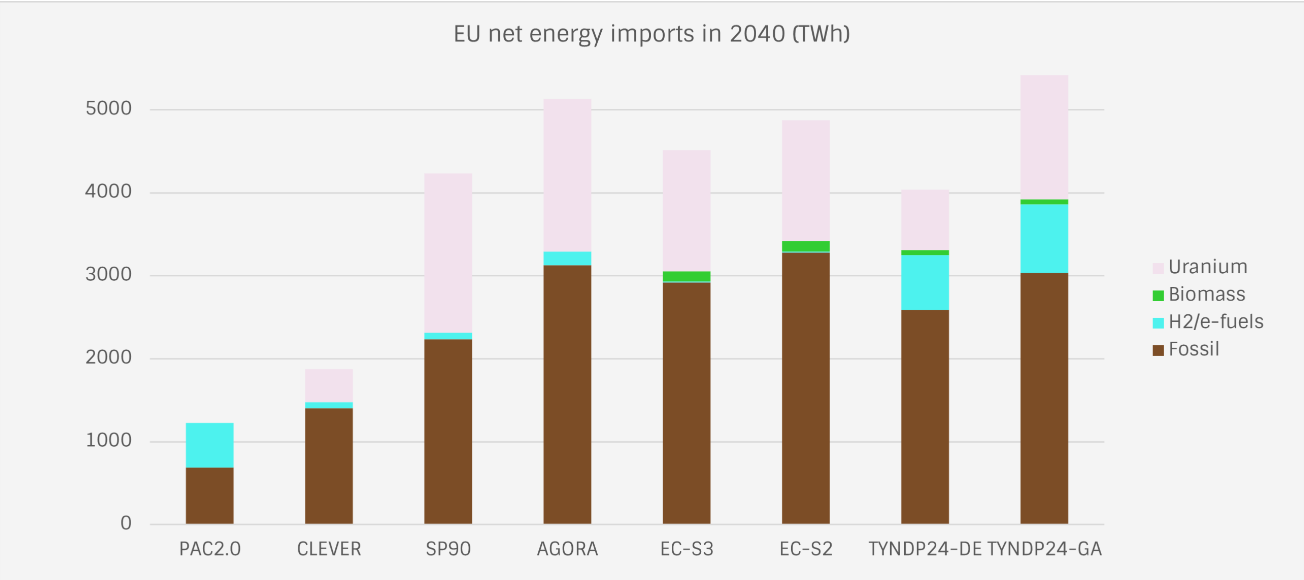
[6] (ESABCC, 2023), p.6

3. Energy savings can reconcile ambition and feasibility

3.1 Lower demand facilitates higher ambition on climate and energy security and brings important co-benefits

In our analysis, **the scenarios which reduce the most final energy consumption (PAC2.0, CLEVER and SP90) are also the ones the most ambitious on climate** (lowest GHG budgets). These scenarios also **reduce most importantly the EU's dependence on energy imports**.





Beyond energy and climate, **energy savings and sufficiency bring important co-benefits**: "contribution to sustainable development goals; mitigation of material-related environmental impacts; resilience to exogenous risks; reduction of health, environment and socio-economic impacts; reduction of the energy system costs"[7].

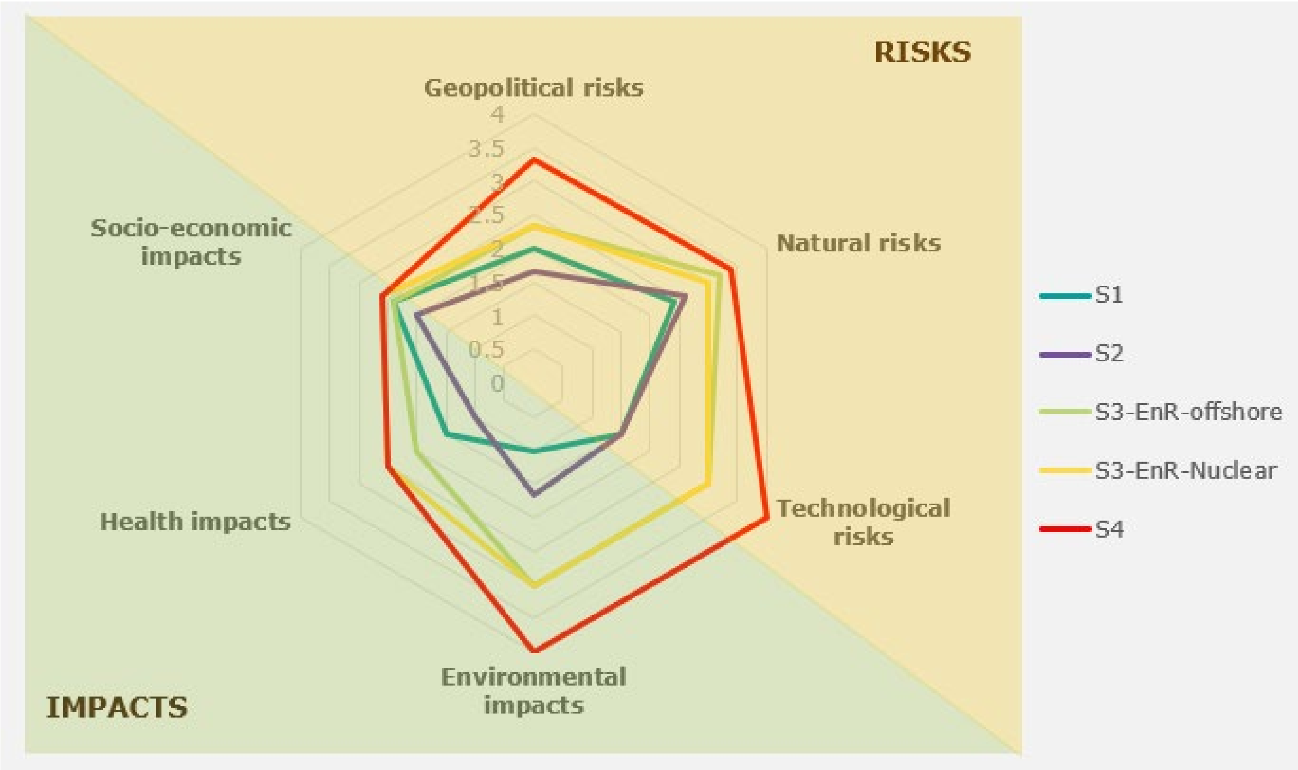


Figure 1: Risk and impact ratings by sub-category in the 4 scenarios for France by ADEME (2021). This figure has been extracted from page 43 ADEME (2024)8, translated and reproduced. The scenarios with higher energy savings (S1 and S2) reduce impacts and risks in comparison to other scenarios.

3.2 The feasibility of energy savings

The scenarios which reduce the most final energy consumption (CLEVER, SP90, and PAC in particular) are slightly more ambitious than the ESABCC's feasibility threshold for demand reduction (at most "a 20% decline between 2020 and 2030")[9]. But the scope of this indicator is different from the EED definition of final energy consumption (scope used for FEC comparison in the table in section 2.1) and is only provided for 2020-2030.

Reducing FEC by 45% or more within 20 years – as in PAC2.0, CLEVER and SP90 – has sometimes been considered as "unrealistic" or not "politically acceptable". But most of the time, there is no discussion of the underlying assumptions. It thus seems crucial for the public debate to explicit the assumptions which influence the most FEC reduction and compare the levels of ambition considered in major scenarios.

For the CLEVER scenario, most of these major assumptions, supported by policy proposals, can be found in sectoral notes available here as well as in the Excel file with major assumptions by country. Assumptions have been chosen in a technical and policy dialogue with national partners because they were deemed feasible and could be supported by appropriate policies and infrastructure, and did not rely on individual behavioural changes.

[7] (négaWatt, 2024)

[8] (ADEME, 2024)

[9] At the scope of ESABCC values, final energy demand in the CLEVER scenario is reduced by 22% and 42% by 2030 and 2040. Final energy demand in the CLEVER scenario in 2040 is 3.5% lower than the ESABCC benchmark (ESABCC, 2024)

An analysis of the level of ambition for a selection of assumptions was carried by (Wiese et al, 2024a), but only for sufficiency scenarios.

The following section is an extract of a detailed analysis and comparison of major energy savings assumptions currently being prepared by négaWatt.

3.3 A short comparison of energy savings assumptions

Our preliminary analysis is limited to a comparison between S3 and CLEVER. It finds that assumptions on a number of energy efficiency indicators are similar[10], but differ greatly on energy sufficiency indicators, which are detailed in the following table:

Assumption	2015 Value	S3 (Change to 2040)[11]	CLEVER (Change to 2040)	S3 2040 Value	CLEVER 2040 Value	Relative Gap (S3 vs CLEVER)[12]
Housing floor area (m²/person)	40	+21%	+6%	49[13]	42	≈14% ≈160TWh
Residential appliances	(Base 2015)	+86% (black) / +65% (white)	Other modelling categorisation	—	—	≈120 TWh
Passenger mobility[14] (km/person/year)	11 700	+24%	-1%	14 500	11 600	≈20% ≈160TWh (cars)
Carpooling (persons/vehicle)	≈1.5–1.7 (2019)	Assumed constant?[15]	1.9 in most countries by 2040	unchanged?	1.9	≈16% ≈130TWh (cars)[16]
International aviation (km/person/year)	2 250	+59%	-29%	≈3 575	1 580	≈56% ≈300TWh
Freight transport (Ttkm)	2.32	+44%	+3%	3.33	2.42	≈27% ≈100TWh
International maritime (Ttkm)	12.2	+34%	-19%	16.3	9.9	≈40% ≈200TWh

[10] The level of electrification of transports in the EC-S3 might be lower than in CLEVER, but further analysis must be carried out

[11] European Commission (2024, Part 3, pp. 4-100

[12] The energy values are rough estimations of the impact on S3 consumptions in 2040 if an assumption similar to CLEVER was considered

[13] Recalculated by négaWatt

[14] Soft mobility and aviation are not included

[15] No information retrieved in the Impact assessment

[16] Provided the value remains constant in S3

The Commission's assumptions, which seem to be a continuation of trends in the past 15 years, appear very conservative: eg for maritime transport 35% of tons are linked to fossil fuels and energy imports diminish by 70% between 2019 et 2040 in S3; the growth of 60% in the aviation sector does not seem to take into account the Green Deal's objectives relating to modal shift; the distance travelled by cars has already been stabilising in large Western EU countries (e.g. (FR, DE, NL, ES). In the CLEVER scenario, the "catching-up" of CEE countries, e.g. on buildings floor area and mobility, enabling them to increase their living standards is compensated by a stabilisation in Western EU countries. Similarly, socially just policies such as a frequent flyer levy could further keep such a growth on check.

Overall, energy savings assumptions have the potential to fill the ambition gap left by unfeasible assumptions (e.g. on CCUS). Applying half the ambition gap between CLEVER and the EC-S3 on the above listed demand indicators could enable the EU to save more than 530 TWh.

For aviation only, half the ambition gap between CLEVER and the EC-S3, i.e. an increase of 14% from 2015 to 2040, corresponds to 1% of 1990 GHG emissions.[17]

[17] Assuming an emission factor of 0.32MtCO2/TWh

ANNEX 1 – Extensive description of indicators used for the quantitative analysis

This section provides further details concerning the methodology behind the quantitative analysis presented in section 2.1 :

- More information about indicators' definitions and scope
- Scenarios' data processing when needed (e.g. to adjust the scope)
- Values considered to assess the ambition of results and the feasibility of assumptions

GHG budget 2030-2050 (GtCO2eq) and net GHG reduction

Definition, scope and ESABCC values used to assess the ambition

The GHG budget for 2030-2050 includes net emissions from 2030 to 2050 (2030 and 2050 are included[18]).

For both GHG budget and GHG reduction, the net emissions include all greenhouse gases (i.e. not only CO2) and land sinks are included following GHG inventories approach[19].

The ESABCC recommends a EU's 2030-2050 GHG budget within **11 to 14 Gt CO2e** and emission reductions of **90–95% by 2040**, relative to 1990. "This ESABCC report's recommendations for a 2040 target and accompanying budget include emissions from international aviation and maritime transport between EU destinations."[20]. The 2030-2050 GHG budget under the scope of the European Climate Law[21] includes intra-EU bunkers and 50% of international extra-EU maritime under the MRV. According to (ESABCC, 2023, p.50), the recommendation of GHG budget at the same scope would be between **11.3 and 14.5$GtCO_{2e}$.**

Comments on scenario data

PAC2.0

- GHG budgets recalculated from Pathways explorer data: might not include bunkers at all according to the detail of emissions in the section «Transports»
- GHG reduction: scope unclear for 2040; includes all international transports for 2030

CLEVER

- GHG budget: 11.8$GtCO_{2e}$ with all bunkers. 1.9 $GtCO_{2e}$ for all bunkers. Then 10.5 $GtCO_{2e}$ including only intra-EU bunkers assuming that intra-EU bunkers represent about ⅓ of bunkers as in (ESABCC, 2023, p. 109)
- GHG reduction: includes all international transports

SP90

- GHG budget: Recalculated by négaWatt from annual emissions with an estimation of intra-EU bunkers

AGORA

- GHG budget and GHG reduction are at the scope referred as "domestic" in the report. According to AGORA modellers, it includes intra-EU bunkers

[18] (ESABCC, 2023), p. 23 and 25

[19] (ESABCC, 2023), p.46

[20] (ESABCC, 2023), p.50

[21] (European Commission, 2024, Part 5/5, p.5)

EC-S2 and EC-S3

- GHG budget and GHG reduction include intra-EU international transports and 50% of international maritime. "The difference in scope between the indicative budget (European Climate Law scope) and the ESABCC budget (intra-EU emissions) is quantified to around 0.5 GtCO2-eq[22]"

Primary fossil and net imports

Definition, scope and ESABCC values used to assess the ambition

Primary energy corresponds to Gross available energy (as defined in EUROSTAT) for EC-S2, EC-S3 AND TYNDPs. It includes international bunkers.

"Primary fossil" is the sum of primary energy from oil, gas and coal.

Net fossil imports are calculated by withdrawing EU fossil production from primary fossil consumption. EU fossil production for EC-S2 and EC-S3 is respectively 285TWh and 338TWh). For other scenarios, it is assumed to be equal to EC-S3.

"Net imports w/o nuclear" is the sum of net imports of fossil energy, biomass, H2 and e-fuels.

Primary energy varies from 2013 to 2723 TWh in the scenario benchmark (ESABCC, 2024).

Adaptation of scenario data

AGORA – primary fossil recalculation: the report mentions on page 64 primary energy consumption for "Coal", "Oil" and "Fossil gas incl. feedstocks" in 2018, 2030 and 2040 and 2050. Then fossil primary energy is estimated at 1923TWh in 2040 in AGORA's report. However, historical values (2018) for primary oil in AGORA's report (3800TWh) is very low in comparison to EUROSTAT's gross available energy for oil (6367TWh), but rather close to final energy consumption for energy use in EUROSTAT (4000TWh). We then assumed that feedstocks and international transports were not included in primary oil consumption in AGORA's report. We then recalculated primary energy, assuming:

- 1923TWh of primary energy reported on page 64 of AGORA's report
- 700TWh of oil feedstocks, recalculated for 2030 as the difference between values in pages 44 and 64
- 791TWh for international bunkers assuming:
  - Consumption of bunkers similar to EC-S3: 1057TWh
  - 145TWh of EU synfuels production (p.28) and 121TWh of imported H2-derivatives (recalculated from p.64) assumed to be dedicated to bunkers

[22] (European Commission, 2024, Part 5/5, p.10)

LULUCF - Carbon removal from the land sink

ESABCC values used to assess feasibility

(ESABCC, 2023) defined, for carbon removals from the land sink, a net sink of 400 $MtCO_{2e}$ per year by 2050 as the maximum to avoid environmental risks.

CCUS – Carbon capture, use and storage

ESABCC values used to assess feasibility

(ESABCC, 2023) defined, for CCUS (from fossil fuels, bioenergy, industry or direct air capture), a maximum of 425 $MtCO_{2e}$ per year by 2050 to avoid environmental risks. The scenario benchmark (ESABCC, 2024) ranges from 169 to 233 $MtCO_{2e}$ in 2040 and from 308 to 348 $MtCO_{2e}$ in 2050.

Comments on scenario data

PAC2.0: We estimated a need of 60 $MtCO_{2e}$ to fuel the domestic e-fuels production (270TWh).

SP90: 127 $MtCO_{2e}$ mentioned in the report (p.7), but the scope is unclear and might include CCS but not CCU.

AGORA: 77 $MtCO_{2e}$ of CCS in 2040 (p.64). No data for CCU.

TYNDP-DE: Values for CCUS has been modified between the draft version and the final version (January 2025). Indeed, in the annex of the final version CCS over 2030-2050 is doubled in comparison to the draft version. Then the amount of CCS in 2040 in the draft version (120 $MtCO_2$) is added to the amount of CCUS in the draft version (250 $MtCO_2$) to obtain the value of CCUS of the final version (370 $MtCO_2$).

Wind, solar and hydro

ESABCC values used to assess feasibility

Electric renewables (Wind, photovoltaics and hydro) in the scenario benchmark (ESABCC, 2024) ranges from 4655 to 5384TWh in 2040.

These values are well above most evaluations at the EU level. If we exclude TYNDPs, the higher value we found in latest EU studies is in the scenario "System Change" by EMBER which reaches 4682TWh in 2040. This corresponds to the lower value of ESABCC benchmark.

Primary biomass

Definition, scope and ESABCC values used to assess the feasibility

(ESABCC, 2023) defined a maximum of 2500TWh (or 9 EJ) of primary biomass use per year by 2050, to avoid environmental risks. This upper boundary is based on (Material Economics, 2021).

Primary biomass is referred in this note as the primary consumption of biomass for energy use, which can be assimilated to the gross available energy from bioenergy for comparison to EUROSTAT and scenarios from the European Commission. This scope includes gross available energy from primary biomass, biogases, liquid biofuels and the renewable share of wastes.

Comments on scenario data

Values for EC scenarios are only provided for 2050.

Values for EC-S2, EC-S3 and TYNDPs respectively include 123, 127 and 61TWh of bioenergy imports.

AGORA's report (p.64) mentions a primary consumption of biomass of 935TWh in 2040. AGORA modellers informed négaWatt that the actual value corresponding to the scope of this study is 1418TWh, which more coherent with data by sector in the rest of the report.

H2/e-fuels imports

Definition, scope and ESABCC values used to assess the feasibility

"E-fuels" refer to hydrogen derivatives used for energy consumption (e.g. synthetic kerosen for aviation), including non-energy uses (also called feedstocks) like inputs for production of fertilisers or plastics.

Hydrogen imports (and by extension imports of hydrogen derivatives) are "generally not available in ESABCC scenarios, with zero or miniscule imports in available scenarios" (ESABCC, 2024)

Comments on scenario data

SP90

- The Pathways explorer indicates 37TWh, but the report mentions 160TWh on page 9. We considered the mean of these 2 values.

AGORA

- the value was recalculated using the following indicators on page 64 (AGORA, 2023): demand for hydrogen, demand for synthetic fuels, associated shares of imports and "Import of other renewable H2 derivatives".

TYNDPS

- "H2/e-fuels imports" were retrieved from figure 33 and include ammonia imports (135-154TWh) but probably not other synthetic fuels (65-83TWh)

Nuclear

ESABCC values used to assess the feasibility

The ESABCC do not assess the feasibility of nuclear neither in (ESABCC, 2023), nor in (ESABCC, 2024). To inform feasibility, we followed the logic used for assessing TYNDPs: we extracted projected nuclear electricity production in 2040 for a selection of ESABCC scenarios respecting feasibility thresholds and reducing GHG by at least 87% in 2040 (see section "ESABCC resources used in this note"). For these 32 selected, nuclear production ranges from 306 to 417 TWh.

Final energy consumption (FEC): reduction and share of electricity

Definition and scope

Final energy consumption (FEC) Is defined considering the scope of the Energy Efficiency Directive (EED), then including international aviation and excluding ambient heat, feedstocks and international maritime.

The FEC reduction is calculated by comparison to the value in 2019 (11389TWh). This approach is different from the one retained for EDD objectives for 2030

Electrification is the share of electricity in FEC.

ESABCC values used to assess the feasibility

In the ESABCC scenarios, final energy demand (FED) has a broader scope than FEC (as defined in the EED). It includes international maritime, ambient heat, the energy sector and feedstocks. ESABCC scenarios do not provide data for FEC, then we do not have directly indicators from ESABCC to assess reduction of FEC and its electrification.

Therefore, we used absolute values of FED and electrification rate of FED in 2040 as reported in (ESABCC, 2024), which are respectively 7766-8025TWh and 50-54%. Then, for scenarios where FED was available (CLEVER and TYNDPs), we compared FED values with ESABCC scenario benchmark and deduced feasibility for FEC (reduction in comparison to 2019 and electrification rate). Then, we deduced feasibility for other scenarios by comparison with CLEVER and TYNDPs.

Comments on scenario data

PAC2.0

- Total FEC in 2040 was estimated at 4988TWh by summing FEC for buildings, domestic transports, industry (without feedstocks), agriculture and international aviation from Pathways Explorer.
- Electric FEC in 2040 was estimated at 3512TWh by summing electric FEC for buildings, domestic transports, industry, agriculture and international aviation from Pathways Explorer.
- The electrification rate was estimated in 2040 at 70% dividing electric FEC by total FEC
- This result for FEC in 2040 is different from the value in the technical report on page 50 (5354TWh). This 366TWh gap is assumed to be related to:
    - the inclusion of exports (191TWh) in the figure from the report
    - different values for FEC in buildings in the Pathways explorer: 2018TWh in "Total > d. Energy demand" and 1841TWh ("Buildings > b. Energy demand")

SP90

- Total FEC in 2040 was estimated at 6177TWh by summing FEC for buildings, domestic transports, industry (without feedstocks), agriculture and international aviation from Pathways Explorer.
- Electric FEC in 2040 was estimated at 3548TWh by summing electric FEC for buildings, domestic transports, industry, agriculture and international aviation from Pathways Explorer.
- The electrification rate was estimated in 2040 at 49% dividing electric FEC by total FEC

ANNEX 2 – Main sources for scenarios and ESABCC comparison

Main sources used to compile data from scenarios

PAC 2.0

- **Technical report**: CAN Europe (2024) “Paris Agreement compatible energy transition scnearios – Technical report”. https://www.pac-scenarios.eu/news/detail/news/summary-report-for-the-pac-scenario-updated-results-launched-in-brussels.html
- Some data provided or confirmed by CAN Europe

CLEVER

- **Main report**: négaWatt association (2023) “Climate neutrality, energy security and Sustainability : A pathway to bridge the gap through Sufficiency, Efficiency and Renewables” https://clever-energy-scenario.eu/wp-content/uploads/2023/10/CLEVER_final-report.pdf
- **Scientific article**: Wiese F., Taillard N.et al The key role of sufficiency for low demand-based carbon neutrality and energy security across Europe. *Nat Commun* 15, 9043 (2024). https://doi.org/10.1038/s41467-024-53393-0
- **Online interactive results**: https://data.clever-energy-scenario.eu/Results_EU.html
- Main assumptions and intermediate results by country: https://data.clever-energy-scenario.eu/Data_CLEVER.xlsx

SP90

- **Report:** Strategic perspectives (2023) “Choices for a more strategic Europe” https://strategicperspectives.eu/strategic-transition-choices-ahead-for-europe/
- Some data provided or confirmed Strategic perspectives

AGORA

- **Report:** Agora Energiewende (2023): Breaking free from fossil gas. A new path to a climate-neutral Europe. https://www.agora-energiewende.org/publications/breaking-free-from-fossil-gas
- Some data provided or confirmed by AGORA Energiewende

EC-S2 and EC-S3

- **Report:** European Commission. (2024). Impact assessment report accompanying Europe’s 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52024SC0063
- Supplementary information containing the data of the graphs of the ANNEX 8 of the main report. Available here: https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2040-climate-target_en

TYNDP-DE and TYNDP-GA

- Report: ENTSOE and ENTSO-G (2025) “TYNDP 2024 – scenarios report” https://2024.entsos-tyndp-scenarios.eu/
- Report data figures available at the same address
- Data already processed by ESABCC for its advice on draft TYNDPs (ESABCC, 2024).

ESABCC resources used in this note

- **Recommendations for climate targets and feasibility thresholds:** ESABCC. (2023). *Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050.* https://data.europa.eu/doi/10.2800/609405
- **Scenario benchmark** used to assess ambition and feasibility of draft TYNDPs: ESABCC. (2024). Towards climate-neutral and resilient energy networks across Europe : Advice on draft scenarios under the EU regulation on trans European energy networks. Publications Office. https://data.europa.eu/doi/10.2800/083
- **A selection of 32 scenarios from the ESABCC scenario database** respecting ESABCC feasibility thresholds and a GHG reduction of at least 87% by 2040. It was elaborated with the "Emissions scenario database of the European Scientific Advisory Board" hosted by IIASA: https://data.ece.iiasa.ac.at/eu-climate-advisory-board/#/workspaces/122

List of Abbreviations

CCUS	Carbon capture, use and storage
ESABCC	European Scientific Advisory Board on Climate Change
EC scenarios	Scenarios from (European Commission, 2024)
EED	Energy efficiency directive
EU27	European Union as defined in 2023
EU28	EU27 + UK
FEC	Final Energy Consumption
GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
SDG	Sustainable development goals
TYNDPs	"Ten-year network development plans", scenarios from EU TSOs (ENTSO-E and ENTSO-G)

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