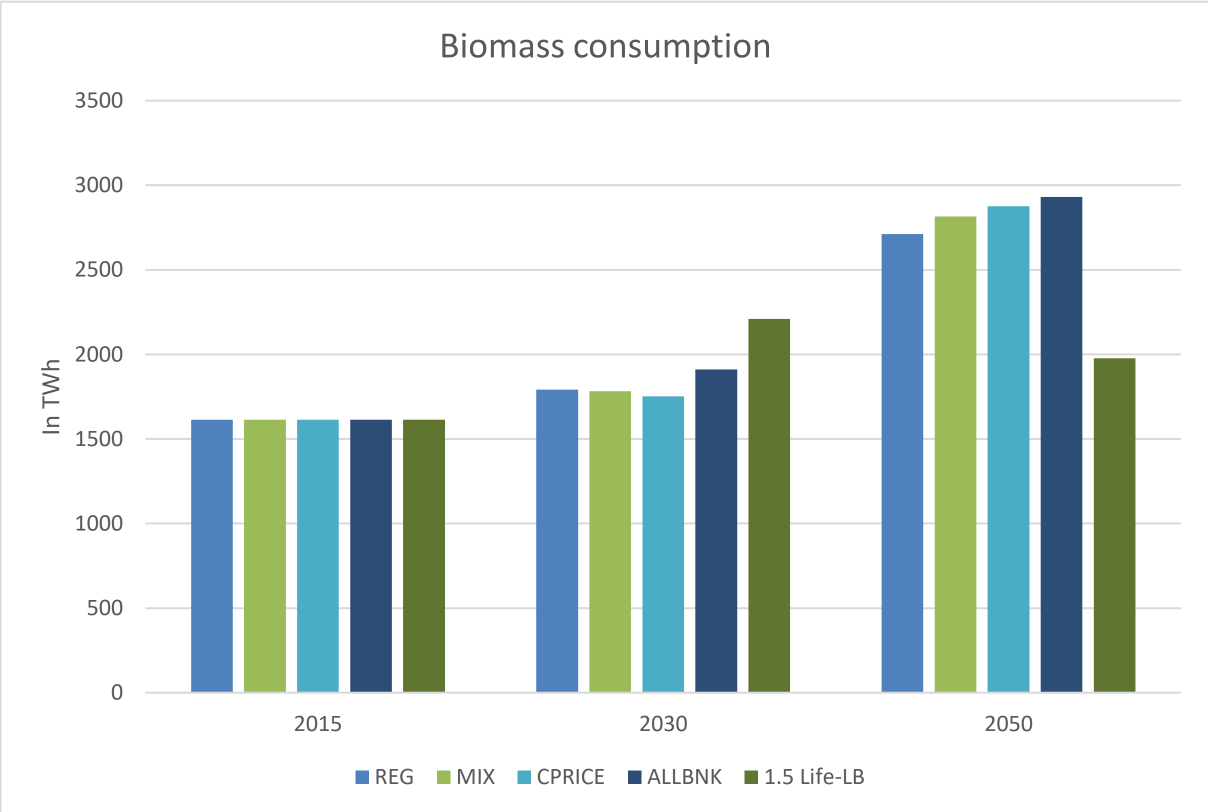
Main stakeholder comments on draft storyline report

**Biomass**

1. **Feedback**: Ranges observed in 1.5LIFE and 1.5TECH are too high and not realistic: technologies, costs, environmental problems.
   **Response**: ENTSOG and ENTSO-E value the alignment between TYNDP and EC Long Term Strategy and Impact assessments. This to ensure that the TYNDP scenarios are fit for purpose to the PCI selection process. We acknowledge however that 1.5LIFE and 1.5TECH scenarios do not necessary explore the lower end of the range for biomass. For the 2022 scenario we plan to use the new EC Impact Assessment as an upper limit. Furthermore, we can use the 1.5LIFE-LB (low biomass) from the LTS as the lower limit. In the end for the level of biomass our scenarios we will aim to remain within this bandwidth.




2. **Feedback**: More transparency on carbon footprint of the different bioenergy carriers is required to understand climate benefits. Bioenergy use in energy category, details of biomethane production, use of bioenergy by all sectors should be included in the study.
   **Response**: Scenario storylines are essentially qualitative descriptive) in nature. Although we proved some quantitative ranges at storyline level, we are not yet able to provide full energy scenarios at this stage. ENTSOG and ENTSO-E fully acknowledge the need to assess biomass sources and carbon footprint. More information on these topics will be included draft

scenario report to be published later this year.

3. **Feedback**: Its application should be limited with those sectors where reduction of carbon emission is hard to achieve through electrification only.
**Response**: We use third party studies to obtain appropriate assumptions of the biomass quantities in our scenarios. Based on studies available we indeed acknowledge that biomass supply potential is essentially limited. Given the limited nature of supply, application of biomass is directed towards hard to decarbonized sectors. Furthermore, the quantitative ranges provided show that our scenarios (especially Distributed Energy) aims to achieve high levels of electrification, especially in domestic heating and mobility. This leaves little room for biomass in these particular sectors.

4. **Feedback**: According to CAN Europe & EEB: Maximum low risk biomass quantities: 789 TWh solid biomass and 956 TWh fermentable biomass in 2030, 533 TWh biomass in 2050. DNV GL 2020 sees 1000 TWh of biomethane production as feasible in 2050. McKinsey study sees 2200 TWh as a bioenergy potential
**Response**: The impact assessment of the EC shows a scenario-dependent production of renewable bioenergy in a range between 2.900 and 3.000 TWh. Solid biomass accounts for almost half of the production, liquids and gas each for around 25%. The scenarios of the ENTSOs will carefully assess their bioenergy potential against these benchmarks.

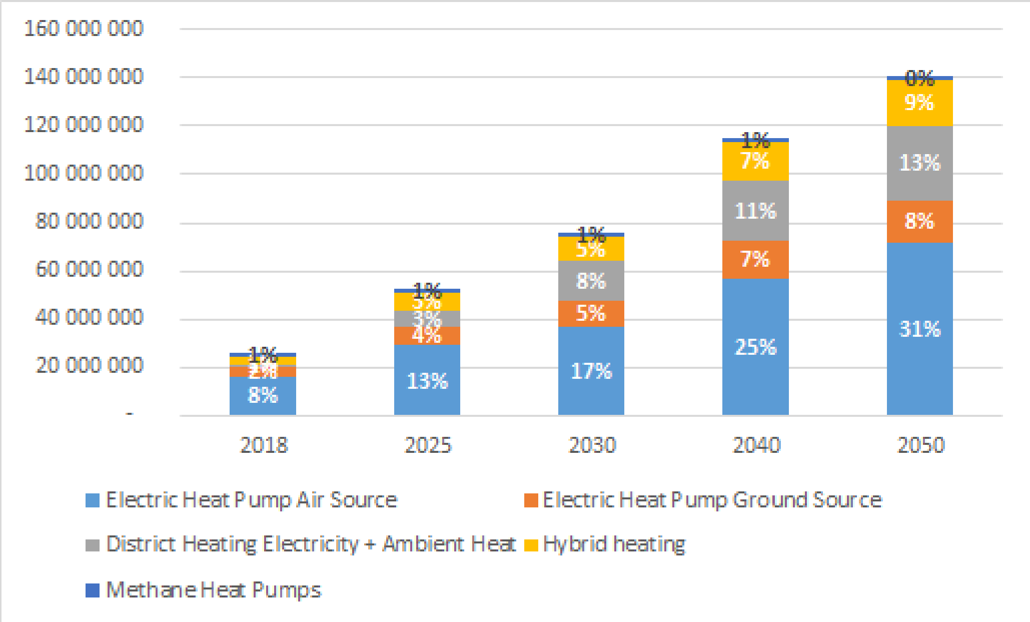
**Electric heat pumps**

5. **Feedback**: HP penetration on a national level is not clear, which makes it difficult to challenge the ranges. Heat supplied by heat pumps is not clear. NGO view: should be >60%, PAC shows up to 90% in 2050.
**Response**: Scenario storylines are essentially qualitative in nature. However, for TNYDP 2022 storylines we included some quantitative ranges for key parameters to better illustrate differences between the storylines. We acknowledge that the quantitative information is still rather limited. This is due to the fact that full energy quantification is not yet available at storyline level. As we proceed further in the scenario building exercise, we will be able to also provide more detailed information. As such will country specific information full energy quantification will be included in the draft scenario report to be published later this year.

6. **Feedback**: More information on HP types, numbers, temperature where resistive heating comes in, peak management
**Response**: The final storyline report provides some additional information regarding these topics.

7. **Feedback**: Higher market shares for heat pumps (up to 90%?), Fuel cells and gas heat pumps should be considered more.
**Response**: The quantitative range for heat pumps only included individual installations in households and buildings. Additionally, heat pumps will also play a role in the heat supply for district heating. If you add up the different individual and collective heat pump types, the

market share in Distributed Energy in 2050 is above 60%. In the final storyline report we also added additional information on fuel cells.




**8.** **Feedback**: Heat pumps in other sectors, like industry (up to 9% of heat demand) and agriculture.
**Response**: Heat pumps could indeed also be attractive decarbonization options for industry and agriculture sectors. To illustrate how these developments are covered in the TYNDP 2022 storylines, we included some additional quantitative ranges for these sectors in the final storyline report.

**9.** **Feedback**: Scenarios should consider improvement of HP efficiency (30-50% by 2030, 40-60% by 2050)
**Response**: The scenarios consider an evolution of the efficiency of all technologies. The efficiency gain is particularly marked for the "new" technologies, such as heat pumps. The assumptions are the result of ENTSO-E and ENTSOG elaborations on PRIMES data. In particular, intermediate values (for 2018, 2025, 2030 and 2040) are obtained interpolating between 2015 and 2050.

**Hybrid heat pumps**

***10.*** **Feedback**: Hybrid HP may be attractive for certain countries, but overall EU market share should stay below 15%. Share of hybrid/electric heat pumps should differ between cold and warm climates. And with higher penetration in 'mature' markets.
**Response**: ENTSOG and ENTSO-E acknowledge that the optionality of hybrid heat pumps is country and climate specific. Generally, hybrid heat pumps will be more attractive in in countries with a cold/humid climate and a well-developed gas infrastructure in the built environment. In the quantification of the country specific scenarios this will be considered.

More information will be released as part of the draft scenario report later this year.

11. **Feedback**: Hybrid HP are considered valuable scenario design element because its implications on peak demand and SoS.
    **Response**: Indeed, hybrid heat pumps could provide some form of flexibility to the electricity grid. As such these technologies will further enhance sector coupling. This is also one of the reasons why hybrid technologies are an import aspect in the TYNDP scenarios.

12. **Feedback**: Choice of E/G switching temperature (below zero) greatly affects energy demand. Even below zero HP/boiler can work in parallel.
    **Response**: Hybrid heat pumps are managed through a temperature dependent load profile with full electricity mode above 7°C, full gas mode below 3°C and mixed mode in between.

13. **Feedback**: Lower shares for hybrid heat pumps, or consider it only as a bridge option.
    **Response**: Compared to the proposed ranges in the draft report (10% - 25% in 2050), the market shares of hybrid heat pumps were lowered in the Final Storyline Report. More information can be found in the quantitative ranges chapter.

14. **Feedback**: Hybrid HP should use renewable gas or otherwise lead to lock-in of fossil infrastructure. Associated emissions should be tracked.
    **Response**: Hybrid heat pumps use both gas and electricity in their operations. Both energy carriers should indeed be renewable to capture the decarbonization potential of this technology. Both storylines aim for carbon neutrality no later than 2050. This means that in the long run all energy (including gas and electricity) will be carbon free.
    In the draft scenario report we publish later this year we will include an assessment of emissions in our scenarios.

15. **Feedback**: Hydrogen (hybrid heat pumps) should also be considered for heating
    **Response**: This is a good point. Indeed, the gas boiler of a hybrid heat pump can both operate with methane or with hydrogen. Which gas type will be used will differ from country to country? The optionality of hydrogen will largely depend on the possibility to convert or develop gas infrastructure for hydrogen in the built environment. In our country specific quantification, we will consider this.

16. **Feedback**: The role of thermal storage and other flexibility options is unclear
    **Response**: Thermal storage could indeed provide valuable flexibility to the electricity grid. For example, through sector coupling with district heating networks. We are working together with Euroheat to consider this type of flexibility in our modelling.
    Following this stakeholder feedback, we provide some addition information on the methodologies we plan to use in the final storyline report.

**District heating**

17. **Feedback**: Mixed support of our proposal considered either as:Too low (NGOs, wind and medium energy suppliers), should rather be 33-70% as easing RES integration. Too high (large electricity suppliers), should rather be around 15% favoring individual HP
**Response**: In TYNDP 2020, both Distributed Energy and Global Ambition had a 19% market share for district heating in 2050. Our proposal for a 15-32% range represents both a better differentiation and a higher ambition for district heating. It also pictures the different feedback received while still enabling a strong development of individual heat pumps. The exact market share is still to be defined as part of the scenario quantification process.

**Electric vehicles**

*18.* **Feedback**: Upper range of 95% share in 2050 is appropriate. The Lower end of the range in 2050 is too low as there is no alternative to electric engine efficiency for mainstream use.
**Response**: The ranges shown in the draft storyline report for EVs (passenger cars) are referred to external studies. The highest range is from Eurelectric scenarios and the lower end of the range is stems from the EC Policy scenario. As shown in the final storyline reports the values for Distributed Energy and Global Ambition scenarios are 73% and 89% for 2050 according to the scenario. Global Ambition scenario, the one with the lowest EVs share accounts for a higher FCEVs share.

19. **Feedback**: Mixed reaction to our 2030 range lowering
**Response**: Compared to TYNDP 2020 we indeed slightly lowered the EV fleet trajectory in 2030. In the TYNDP 2020 quantification we used a linear progression to estimate the EV level in 2030. However, considering supply chain effects and replacement rates (EV sales per year) we now conclude this this 2030 is too high. That is why for the TYNDP 2022 we defined a lower range for 2030, consistent with existing projection compared the most optimistic sales figures up to 2030 (Eurelectric 95% Scenario for 2050).

20. **Feedback**: Request of additional information on the modeling assumptions regarding charging infrastructure or constraints on mobility.
**Response**: It is intended to use in market modelling both predefined charging profiles and Vehicle-to-Grid. The profiles will reflect transport activity, load factor, technology shares and efficiency. As a result, charging profiles will depend on EV types. Some specific constraints will be used to reflect events such as summer holidays weekends.

**Fuel cell electric vehicles**

21. **Feedback**: FCEV induces a significant energy loss compared to BEV. FCEV should be limited to specific mobility segments.
**Response**: As explained in the final storyline report, the market share of FCEV in passenger cars remains limited compared to EVs. Battery EVs and Plug-in hybrid technologies cover between 73% and 89% of the passenger cars market in 2050 according to the scenario. In other transport sectors however, FC technology could prove a better alternative. For example, in heavy goods transport FC shares reach between 23% and 32% in 2050 according

to the scenario.

**Electrolysis**

22. **Feedback**: No sufficient data shown in storyline report. Lack of information on hydrogen demand evolution. More transparency about location, operation mode and full load hours.
**Response**: As already stated in the draft storyline report, we cannot yet provide specific information on electrolysis at storyline level. The development of electrolysis (or flexibility options in general) depends on wide range of other parameters still to be quantified. In the end the role of electrolysis (installed capacity, annual full load hours) is an output of the electricity market models used to help quantify each of the scenarios. More information on this topic can and will be provided after the modelling has been completed. Results will be released as part of the draft scenario report to be published later this year.

23. **Feedback**: Hydrogen is expensive and therefore its use should be limited to hard-to-decarbonise sectors (feedstock etc.). Scenarios should rather focus on electrification than hydrogen demand.
**Response**: The EC hydrogen strategy considers hydrogen as a key priority to achieve the European Green Deal and Europe's clean energy transition. Renewable electricity is expected to decarbonise a large share of the EU energy consumption by 2050, but not all of it. Hydrogen has a strong potential to bridge some of this gap. For example, is an end use demand in hard to decarbonise sectors. But also as vector for renewable energy storage, alongside batteries, and transport, ensuring back up for seasonal variations and connecting production locations.

24. **Feedback**: National hydrogen strategies do not add up to EU hydrogen strategy (40 GW). Electrolyser capacity in a 100% renewable Europe by 2050 could reach 1,8 TW. Numbers are way too low and large-scale hydrogen production from offshore wind play will play an important role.
**Response**: As stated in the EC hydrogen strategy, almost all Member States have included plans for clean hydrogen in their National Energy and Climate Plans, 26 have signed up to the "Hydrogen Initiative", and 14 Member States have included hydrogen in the context of their alternative fuels infrastructure national policy frameworks. Some have already adopted national strategies or are in the process of adopting one. The draft storyline report listed the electrolysis ambitions from 5 members states. It is clear however that more is needed. In our Distributed Energy scenario we aim to explore a reasonably upper range for electrolysis, which may exceed the current ambitions. Our assumptions on electrolysis development will be based on third party studies.

25. **Feedback**: Electrolyser capacity should by modelled based on the scenario-specific hydrogen demand.
**Response**: As expressed in the draft storyline report, both scenario storylines differ in terms of technologies. This includes both electrolysis as well as hydrogen consuming (heating, mobility, etc). technology. Both scenarios will differ in terms of (country specific) hydrogen demand levels. The hydrogen demand levels are subsequently used in the modelling of

electrolysis. The outcomes of this modelling exercise will be released in the draft scenario report later this year.

26. **Feedback**: No significant capacity before 2030 to be expected.
**Response**: Based on the studies we observe an accelerated growth expectancy for electrolysis. The EC hydrogen strategy for example foresees 6 GW in 2025 and 40 GW in 2030. TYNDP scenarios will also consider accelerated growth patterns for electrolysis. As a result, will the levels for 2025 in both storylines still rather limited.

27. **Feedback**: Electrolysers should be fully integrated to the electricity market.
**Response**: In the 2020 TYNDP edition, P2G was modelled with mostly dedicated RES outside the electricity market. Therefore, the requirement in terms of market modelling was minimum. In the 2022 edition, P2G will modelled as part of the electricity network with greater modelling requirement.

28. **Feedback**: Electrolysers will have limited flexibility offer due their own contractual commitments.
**Response**: the scenarios are based on a system perspective for electrolysers as for power generation plants, as such contractual commitments are not considered. It is assumed that the market design will evolve to extract maximum value from infrastructure.
From a technical perspective, electrolyser flexibility will depend on the flexibility source available for alternative hydrogen supply (H2 tank, steam methane reformer or H2-grid).

29. **Feedback**: Hydrogen and hydrogen-based fuels can also be imported and should be taken into account for infrastructure assessment.
**Response**: DE and GA storylines assume different combination of European renewable energy potential with energy imports. Their shares vary from one scenario to the other in order to illustrate the impact they have on energy infrastructure. Distributed Energy aims for energy self-sufficiency whereas Global Ambition foresees higher import dependency in the long run. Import of hydrogen and hydrogen-based fuels will be considered in the scenario quantification

30. **Feedback**: Configurations and market models are uncertain.
**Response**: As a difference with the 2020 edition, a wide range of electrolysis configurations will be modelled in order to better capture the interaction between hydrogen, electricity and methane systems. The anticipated configurations are:
- Electrolyser running on electricity market and dedicated RES, with H2-tank as back-up
- Electrolyser running on electricity market and dedicated RES, with a steam methane reformer as back-up
- Electrolyser running on electricity market and dedicated RES and injecting into a H2-grid
- Dedicated electrolysers for methanation with injection in methane network

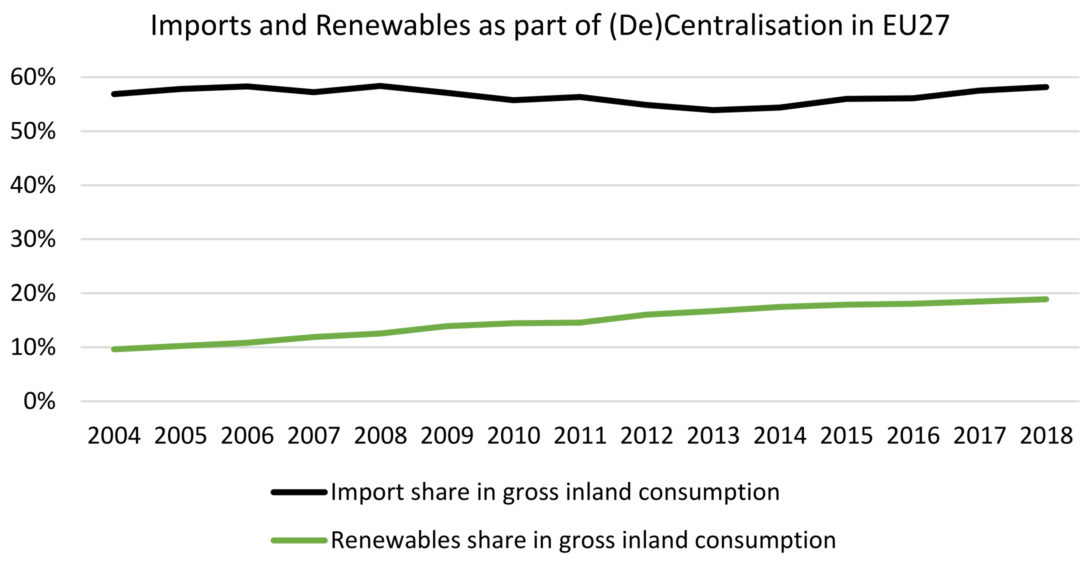
In parallel to electrolyser configurations, their operation will be influenced by the level of development of potential dedicated hydrogen infrastructures. Both electrolyser configuration and H2 infrastructure development will depend on scenarios and time horizons.

**Energy imports**

31. **Feedback**: Lack of quantitative data to make proper comment
**Response**: It is hard to tell at storyline level how much import is exactly needed in the scenarios. That is because import largely depend on the level of demand and the level of supply in Europe. In turn, the development of both demand and EU supply depends on wide range of other parameters still to be quantified. More information on this topic can and will be provided after the modelling has been completed. Results will be released as part of the draft scenario report to be published later this year. The import figures included in the draft storyline report only give an indication of the upper limits we expect to explore and will benchmark against.

32. **Feedback**: GA and DE storylines are identical to the GA and DE scenarios in for TYNDP 2020.
**Response**: Import dependence is an important factor to consider in TYNDP scenarios because it is a key driver for infrastructure requirement. In other words, infrastructure requirements are different when energy production and consumption close together, compared to when they are far apart. This driver was already explored in TYNDP 2020 and remains important for TYNDP 2022. That is why the new TYNDP 2022 storylines are similar to the previous editions with regard to import dependency.

33. **Feedback**: Some respondents feel energy imports should be avoided altogether. Stakeholders argue that import won't be cost-competitive with domestic production and would create security of supply issues. Uncertain impact of energy imports on decarbonisation and it's unclear if upstream emissions are considered. Possible political implications of "outsourcing" decarbonisation.
**Response**: As of today the European import dependence across all energy carries is roughly 60%. Currently these import sources are competitive with EU production. Measures are put in put in place to ensure security of supply. The uptake of renewables in Europe during the last 15 years have not yet resulted in lower import dependence. Whether European import dependence will decline in the future is uncertain. This uncertainty is captured in the two storylines developed for TYNDP 2022. Distributed Energy seeks to minimize imports by accelerating energy production in Europe. Whereas Global Ambition explores a pathway where import dependence will lower be compared to today but remains substantial in the long run




34. **Feedback**: Import of methane (and to a lesser extent hydrogen) in GA is seen critically. Lack of clarity on the source of the methane imports and the use in Europe. Lack of clarity on the source of hydrogen or its CO2-footprint
**Response**: Assessment of import sources and associated emissions cannot be provided yet at storyline level. Instead, this is detailed in the scenario quantification phase. More information will on this topic will be released as part of the draft scenario report to be published later this year.

35. **Feedback**: Importing energy at odds with the narrative of the DE storyline – no imports should be included
**Response**: The scenarios show possible pathways towards the energy future of the EU. Our aim is to differentiate the scenarios even further in terms of energy imports vs. autarky. One risk always to be considered is that creating extreme scenarios would not pass a "reality check". Therefore, distributed energy entails imports but on a lower level than in the TYNDP 2020 in terms of import shares as well as in quantitative numbers to stronger reflect the narrative of self-sufficiency in the DE storyline.

**Wind capacity**

36. **Feedback:** Wind capacity potential should be split into onshore and offshore ranges as technologies and development challenges differ

    **Response:** we acknowledge the value of providing such split at storyline level and updated and split ranges are provided in the Final Storyline report

37. **Feedback:** Ranges are too wide to enable meaningful feedback. It is partly linked to the use of EC Baseline scenario as a lower range. Only scenarios reaching carbon neutrality in 2050 should be used to define the ranges. The Offshore Renewable Energy Strategy from the European Commission should be used as a benchmark.

**Response:** Ranges need to be reasonably wide in order to provide flexibility to the investment loop building the generation fleet of the scenarios. Difference between scenarios is key to a robust infrastructure assessment at TYNDP and CBA stages. In any case Distributed Energy and Global Ambition have the constraint to reach carbon neutrality in 2050.
We acknowledge that the Baseline scenario may be a too low range to ensure the reach of carbon neutrality in most of the situation. As a result, the lower range of the Final Storyline Report will be based on current trend for 2030 and scenarios reaching carbon neutrality in 2050.
The upper range will also be adapted when differentiating offshore and onshore wind technologies.

38. **Feedback:** Global Ambition is said to focus on offshore wind while requiring less electrolysis due to higher energy imports. There is merit to include a scenario combining offshore wind, electrolysis and hydrogen infrastructures.

    **Response:** The relative share of offshore wind among other RES may be higher in Global Ambition than in Distributed Energy. Nevertheless, the higher RES penetration in Distributed Energy in order to minimize imports and low-carbon technologies is likely to result in a higher offshore wind capacity. As a result Distributed Energy will be a scenario combining offshore wind, electrolysis and hydrogen infrastructures.

39. **Feedback:** the scenarios should provide information on the land use associated with wind development
    **Response:** It could be included in the Draft and Final Scenario report level but it would require well-establish public sources and it should apply to all onshore generation technologies (wind, PV, thermal…). We invite stakeholders to provide feedback on the possible data sources.

**<u>Solar capacity</u>**

40. **Feedback:** The upper limit of the solar trajectory is too low compared to some studies (between 600 and 1000 GW in 2030 and close to 2000 GW in 2050) may prevent an adequate grid assessment considering RES growth potential. It does not take into account the ever decreasing cost of self-consumption.

    **Response:** the solar upper limit taken into account in the Draft Storyline level is 24% higher than EC CPRICE scenario. At the same time, a strong acceleration of solar could be the least challenging to achieve if integrated to a building renovation wave. As a result the upper bound of the Final Storyline report is increased up to 2 000 GW covering some of the most ambitious scenarios combining high energy efficiency and solar capacity development.

41. **Feedback:** the lower limit of the solar trajectory is too low in 2030 and 2050 as it is based on the European Commission Baseline which is not compatible with carbon neutrality in 2050.

    **Response:** Ranges need to be wide enough to capture sufficiently diversified scenarios with one looking at RES maximisation (Distributed Energy) and the other looking at a RES combination with low-carbon technologies and imports (Global Ambition). For the Final Storyline report, le lower limit will be increase to 300 GW in 2030 (close to current trend) and to 900 GW in 2050 (around 10% lower than EC REG scenario in order to give flexibility to the investment loop defining the electricity mix).

42. **Feedback:** RES ranges should be wide enough to enable efficient grid planning. Ranges are too wide to comment on solar development.

    **Response:** As an enhancement compared to the TYNDP 2020 Scenario building process, the Draft Storyline report provides quantitative ranges for some key parameters. These ranges intend to strike the right balance between visibility of possible deployment scale and flexibility to be provided to the investment loop in order to build sufficiently contrasted scenarios.

43. **Feedback:** the scenarios should provide information on the land use associated with solar development

    **Response:** It could be included in the Draft and Final Scenario report level but it would require well-establish public sources and it should apply to all onshore generation technologies (wind, PV, thermal…). We invite stakeholders to provide feedback on the possible data sources.

**<u>Nuclear</u>**

44. **Feedback:** A common trajectory should be used for both scenarios in order to not largely impact the other technologies.

    **Response:** We acknowledge the significant impact of nuclear capacity development on other technologies hence on the electricity grid. Taking into account that scenarios are primarily used to assess infrastructure projects, it is key to analyze such different levels in order to ensure the robustness of infrastructure analysis.

45. **Feedback:** The 45/55 years lifetime may be appropriate for an average lifetime at European level but some countries foresee longer ones.

    **Response:** At scenario level, the trajectory will be breakdown at national level offering the ability to take some country specifics into account. In any case even for countries considering lifetime expansion beyond 55 years, it may not apply to the whole national reactor fleet.

46. **Feedback:** Due to technology and cost challenges, the role of nuclear in Global Ambition may not be as high as the upper limit.

**Response:** the scenarios may not reach the upper or lower limit of each technology. The decrease of nuclear capacity in the new EC policy scenarios to a 80-90 GW range in 2050 compared to the previous EC 1.5 Tech and Life scenarios is part of the elements to be analyzed when defining the nuclear capacity level.

47. **Feedback:** At least one scenario should picture a nuclear phase-out based on the low acceptability and high cost of the technology.

**Response:** The low trajectory is based on the absence of development of new projects. As such it would translate into a nuclear phase-out even if beyond the 2050 time horizon of the scenarios. TYNDP scenarios are not policy scenarios but aim at a robust infrastructure assessment. With a lower bound at 25 GW in 2050 compared to the 80-90 GW range of the new EC policy scenarios, the proposed range already offer the opportunity to defined a scenario with very low nuclear power generation capacity.

Flexibility

**Feedback:** Inclusion of upward flexibility, i.e. additional electricity use during low electricity prices e.g. through electric boilers for heat production or through production of synthetic methane, reducing the need to curtail RES generation.

Importance of existing reservoir hydopower and pumped-storage power in providing power market flexiblity in  all timeframes.

Distributed (i.e. residential) demand response should be mentioned together with the other flexibility options (tertiary and industrial demand side response).

Large/medium batteries are expected to provide specific services for electricity system/network management.

When considering investments in assets, one should keep in mind that these investments on flexibility will only take place if/when/where investors are able to justify sound business cases over the corresponding investment horizon. In practice, the market design and the investment frameworks in place will be essential for the scenarios to materialize."

**Response:** Hydropower and pumped storage is a fundamental part of the capacity mix and will be included in the scenario based on TSO feedback, it is not as easy as creating new hydro storage but must be meticulously planned due to location, protected areas, costs, terrain etc, therefore we rely on more concrete knowledge.

In this scenario cycle, in terms of flexibility, we focus on innovations in flexibility of transport and battery storage in the market and prosumer network. DSR in Tertiary and Industry are based on TSO feedback. We have already started a dialogue with the heat associations including demand shifting from heating in the residential sector, but we are not yet ready to implement this flexibility in the scenarios.

**Feedback**: Flexibility can also be provided from renewable power plants and renewable hybrid power plants (wind/solar and potentially storage). In the case of wind turbines new technologies and new capabilities are expected to be brought to the market soon (e.g. grid forming capabilities, storage directly integrated at wind turbine level). Wind farms can provide local downward flexibility (flexible connections e.g. Belgium, France, Netherlands) balancing or frequency regulation (e.g. UK, Ireland, Germany, Ireland, Belgium), voltage control and later other commodities related to inertia and black start (e.g. stability pathfinder in the UK). This flexibility can be modelled based on available market data in the respective countries. Inertia and black start services are much more difficult to model as they are in their very early stages in the case of wind. However, there are already some pilot projects that can be considered (Scottish Power/SGRE grid forming project in the UK)."

**Response:** The balancing markets are not considered in the scenario, only the day ahead markets. We note the mention of integrating storage directly into wind turbines, but we wont be able to consider this in this cycle as it will require a lot more analysis on the parameters of these new technologies.

**Feedback:** Ideally, the TYNDP 2022 would illustrate the contribution of the different flexibility options to greenhouse gas emission reductions. It is important to fully mobilise the potential of co-benefits from renewable energy installations and different demand response schemes. Keeping fossil gas fired power plants as the default backup option in the electricity system would neither reflect technological progress in the area of ancillary services nor be compatible with the climate target.

The analysis should not exclusively rely on studies from TSOs and DSOs but also try to integrate aggregators' expertise and capacity to provide flexibility. It is not clear to what extent heat sector flexibility options and thermal storage are included in the modelling. Given that so-called hybrid heat pumps play a very important role in the TYNDP 2022 storylines, interaction of electric heat pumps with distribution grids in different European regions under different weather constraints should be modelled with sufficient granularity."

**Feedback:** More transparency is needed on the contribution of the different flexibility options to greenhouse gas emission reductions. It is important to fully mobilise the potential of ancillary services from renewable energy installations and different demand response schemes. The role of fossil gas must be redefined to the integration of alternative and climate compatible backup options in the electricity system.

Response: we welcome openly the expertise of aggregators in all areas of scenario development. Thermal plants are not back up plants for renewable, they form the fundaments of the current system and as the system changes due to decarbonisation needs, they will be phased out and replaced with cleaner sources of energy, therefore thermal units are not classed under flexibility. The scenario will be created in order to meet the climate targets.

**Response**: We are trying to take into account more and more flexibility options from the tertiary, industrial and Transport sectors and will continue to in the future editions. We don't suggest that thermal units will continue to be the solution to the provision of ancillary services, we don't model the ancillary services markets in the scenarios. It is clear that there are many different future solutions for ancillary services which don't have to come from thermal units, but in the scenarios we are modelling the day ahead market.

**Feedback:** Hydrogen transmission, electrolysis, and wind power combined in large scale seem to be a promising path to ~~european~~European carbon neutrality which also offers quite good large scale flexibility. We do suggest either to construct an additional scenario with this option, or that it is attempted to somehow introduce this into the GA scenario.

Response: this will be included in both top down scenarios. It will not be limited to wind power but all renewables.

**Feedback:** ENTSO scenarios on flexibility don't provide quantitative assumptions to support feedback evaluation. ENTSOs scenarios should in general consider a greater penetration of storage and demand response services through aggregators, and the new role of DSOs in supporting the energy transition connecting distributed resources to the distribution system and enabling their active participation to energy market through the provision of flexibility services by means of large investments in communication and automation technologies suitable to sharply enhance the grid "smartness". Both large and small-scale battery storage will become contributors to balance the system. Furthermore, electric heat pumps can effectively contribute to implicit demand response, something that is not recognized in the scenario storylines.

**Response:** all mentioned above with be assessed in the 2022 scenarios on an economic basis.

**Feedback**: "With independence of the relation of the balance between distributed and utility size generation, 2050 generation mix is expected to be fully decarbonised and largely based on renewable sources. In principle, not a single source of flexibility should be disregarded. The increasing presence of variable renewable will extend the requirements of facilities to provide flexibility in the range provided by the scenario EU 1.5 TECH. Pumping hydro (not contemplated in the Storyline report) could provide close to 50 TWh through the most efficient installations adapted to integrate the variability of massive renewable. Batteries can progressively take the lead of storage with 130 TWh and DSR (including the capacity of VE batteries) could became very supportive in areas with dominant presence of distributed resources.

The presence of significant capacity of electrolysers (511 GW according the scenario EU 1.5 TECH) and the availability of imported clean hydrogen may provide the means for additional balancing capacity, as far as the demand for hydrogen as industrial feedstock and for niches hard to decarbonise is primarily met."

**Response:** we see hydro potential to be significantly higher than 50TWh, indeed we see it to be up to 10x this when considering, Run of River, Reservoir, Open Loop Pump storage and Closed loop pump storage, this will naturally be included in the scenario as it is a fundamental part of the capacity mix. Hydro wasn't included in the storyline ranges as it is not an expansion option. We also agree that battery storage will take a progressive role, in the 2020 scenarios we saw up to 83TWh of generation from batteries in 2040 and this doesn't include prosumer batteries, so for us it is also clear batteries will have their role. We will aim to model vehicle to grid in the 2020 scenarios, but this depends on the EV fleet and development of the infrastructure.

**Feedback:** We believe that the Hybrid Heat Pump modelling should be further explained. Hybrid heat pump is a flexibility option. We understand that the switch between electricity and gas will occur between 3 and 5 degrees. However, we would like to know when exactly the gas boiler part and electric heat pump will work simultaneously.

**Response**: there is not a direct switch but a transition period from 100% electricity to 100% gas between the temperatures of 5 and 3.

**Feedback:** We agree with the identification of the flexibility options, however the lack of quantitative figures for both scenarios poses a challenge to giving feedback. Along with this, it makes it difficult to steer investment projects for the future without useful data.

**Response**: In the storyline report we wanted to include some quantitative parameters to illustrate the storyline. We acknowledge however that the availability of quantitative information at storyline level is rather limited. This is because we still have to perform our modelling. This is especially true for flexibility options which are an output of the modelling rather than an input. In the scenario report to be published in summer we plan to release more figures and more information.

**Feedback:** Maintaining a fleet of fossil based generation operating at assumed unrealistic capacity factors is not appropriate and should be reconsidered. Thermal generation with CCS should not be included in future installed capacities.

**Response:** the model will determine when thermal units should be decommissioned based on economic principles.

**Feedback:** "On the whole, Ember welcomes the consideration of multiple sources of flexibility beyond traditional dispatchable capacity. We would encourage that the full range of grid services available from the flexibility options and renewable generation are taken into account, as well as estimates of their market value where possible. These include ancillary services provided by battery storage, and synthetic inertia from wind and solar farms. We would also caution against the assumption that fossil based units provide the default option for back-up generation.

The storylines refer to hybrid heat pumps as a source of flexibility, but many other synergies exist between the electricity and heating systems that can provide flexibility. Widespread use of district heating is a key enabler for many of these. Large heat pumps can absorb excess electricity generation, with heat networks and associated thermal storage providing medium-term storage in the form of heat. This provides flexibility to the electricity system while simultaneously helping to decarbonise the heating sector. Combined heat and power units can also complement variable renewable production, while utilising their heat output for district heating maximises the efficiency of these remaining combustion units. We would urge that the modelling approach taken is capable of capturing the benefits of sector integration, such as those described here."

**Response:** the scenarios do not include ancillary services therefore these will not be assessed in the scenarios but we agree that these services should be assessed, we see this more as a role for the individual TSOs as each system has their own individual needs in terms of services. For example  Ireland will have very different requirements compared to Poland.