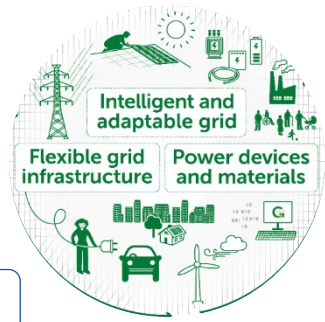
Resilient and Sustainable Electricity Supply

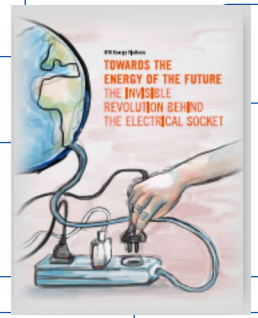


Lina Bertling Tjernberg

Professor in power grid technology

Director of KTH Energyplatform

linab@kth.se linabertling



SEEEP High Level Summer course, 19, August, 2022, KTH, Stockholm

Thanks and Welcome!

- Sharing experience and learnings, contributes in making a better and safer world for everyone.

PMAPS, KTH, Stockholm, Sweden, 2006, (Conference chair Lina Bertling**)**

Introduction – Lina in brief

- **Professor in Power Grid Technology at KTH** Royal Institute of Technology, Director of Energy platform, at the School of Electrical Engineering and Computer Science, Stockholm, Sweden.
- Docent 2008, Ph.D. 2002 Electric Power Systems, at KTH.
- Current: National expert in the ISGAN Academy of Smart Grid, National committee of CIRED, Program committee of the Swedish Electro mobility Center, IEEE ISGT Europe steering committee.
- *Past:* Member of the Swedish Government Coordination Council for smart grid (2012-2014), IEEE Sweden Chapter PE/PEL chair 2009-2019, IEEE PES board Secretary/Treasurer (2012-2016), Editor of the Smart Grid Transaction (2010-2015), the IEEE Reliability Risk and Probability Applications (RRPA) Subcommittee board (chair 2011-2013).
- *Author:* more than 100 papers, several chapters and one book on *Asset Management* *Details here: www.kth.se/profile/linab/page/publications*

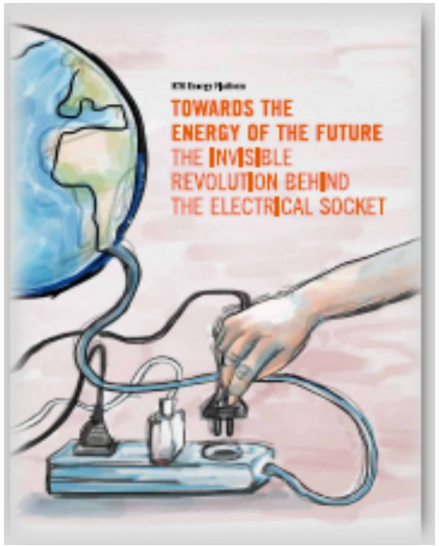
Contact details:
linab@kth.se
www.kth.se/profile/linab
LinkedIn LinaBertling
Twitter @linabertling

KTH Energy platform

- KTH's platform for research in energy was created to support and catalyze interdisciplinary research in the energy field.
- KTH's Energy Platform connects more than 450 researchers in 30 research groups and five competence centres in 17 research areas related to energy issues.
- The role of the platform is to provide new opportunities for KTH's energy research and innovation.
- An important goal is to facilitate interaction between expertise at KTH and external partners within academia, public organisations and companies with an interest in energy research.
- Inclusive platform for everyone interested in energy research at KTH.

➢ More information and articles here: www.kth.se/energy

KTH Energyplatform – book



Researchers at KTH have recently published an anthology focused on providing knowledge about the challenges and opportunities of energy. Researchers provide answers in the energy debate | KTH

The book is available in Swedish and English and can be down leaded for free or can be bought in hard copy.

More information from here: Anthology on energy - Vetenskap & Allmänhet (v-a.se)

Overall targets to reach the SDGs

What does it mean to be resilient?

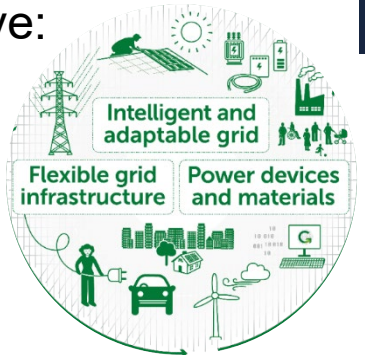
Resilient according to the Dictionary (Bing Search)

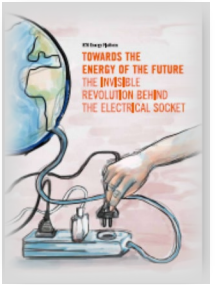
- the capacity to recover quickly from difficulties; toughness:
- the ability of a substance or object to spring back into shape; elasticity:
- *synonyms:*
  flexibility · pliability · suppleness · plasticity · elasticity · springiness ·

❑ This lecture focus on the electric power grid and power grid technologies and how these can support in transformation of the energy system targeting a sustainable society. In this context flexibility is a key feature which will be further explored.

Key Messages

- Global targets for sustainable developments
  - 100% renewable energy system
  - Increased electrification in transport and industry
- Target for energy independence
- Challenges from the electricity grid's perspective:
  - need for flexibility
  - capacity shortage
  - new market solutions with prosumer
  - circular economy
- Examples TYNDP2022 scenarios and *GreenGrids , book KTH Energyplatform*





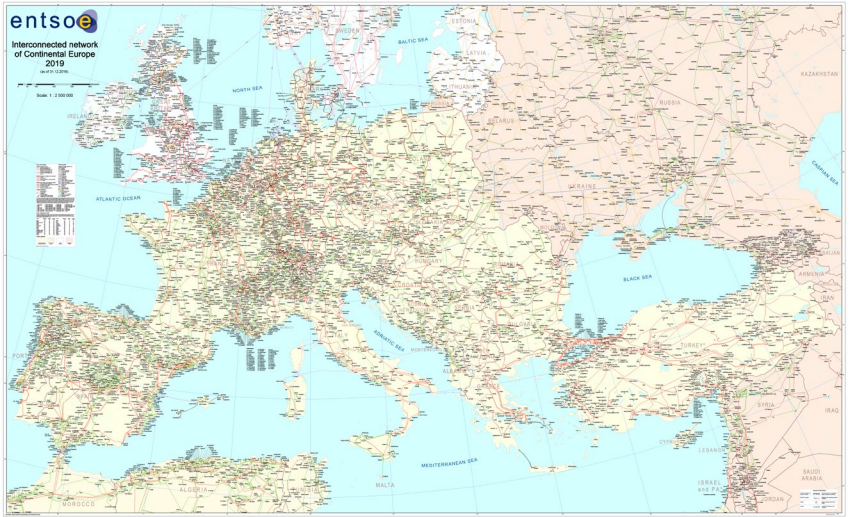
Sustainable power grids

- ✓ Huge increase in electricity generated from wind and solar
- ✓ Reduction of use of fossil fuel
- ✓ Electrification of transportations and industrial processes

Sustainable power grids

Interconnected power grid in Europe

- ENTSO-E is the European association for the cooperation of transmission system operators (TSOs) for electricity
- A much deeper coordination between operators close to real-time is needed to integrate more renewables into the grid and reduce carbon emissions cost-effectively and in all security.



Sustainable power grids
Interconnected power grid in Europe

- Urgent request by Ukrenergo and Moldova for emergency synchronization due to the war
- TSOs of Continental Europe agreed to start on 16 March 2022 the trial synchronisation of the Continental European Power System with the power systems of Ukraine and Moldova.

➢ contribute to a stable and efficient electricity supply in the Ukrainian power grid.

Sustainable power grids - RePowerEurope

REPowerEU: Joint European Action for more affordable, secure and sustainable energy, May 18, 2022.

- objective of breaking away from Russian energy ASAP.
- Member State interventions, whether fiscal or regulatory, will be necessary in order to secure affordable prices for end consumers and to prevent energy poverty
  - care must be taken not to discourage investments by energy companies in low-carbon solutions.
- A versatile energy palette must be used in order to secure energy supply to European households and businesses. It is important to make use of the wide variety of low-carbon energy, that fit economically and ecologically within an energy system.
  - need to remove unnecessary administrative barriers in order to accelerate rollout of renewables.

Sustainable power grids - RePowerEurope

REPowerEU: Joint European Action for more affordable, secure and sustainable energy, May 18, 2022.

- recommend to enhance the energy infrastructure in order to accommodate the switch to the green transition and also to diversified gas sources, while at the same time ensuring the flow of energy among Member States via transmission interconnections.
  - In these times, solidarity is needed more than ever.
- REPowerEU suggests that biomethane production be boosted to 35 bcm by 2030. While this goal is welcome, it is very ambitious
  - calls for concrete measures and incentives to achieve this goal.

Sustainable power grids
European Green Deal

- European Green Deal Call: €1 billion investment to boost the green and digital transition (launched 22 Sept. 2020)
- boost the efficient use of resources by moving to a clean, circular economy restore biodiversity and cut pollution
- The plan outlines investments needed and financing tools available. It explains how to ensure a just and inclusive transition.

Sustainable power grids

European Green Deal

Jul 14, 2021 - 04:32 pm

EU Commission presents ‘Fit for 55’ climate package

2035 | *CO2* | *DIESEL* | *EU* | *EU COMMISSION* | *EUROPE* | *GASOLINE* | *ICE* | *ICE BAN*

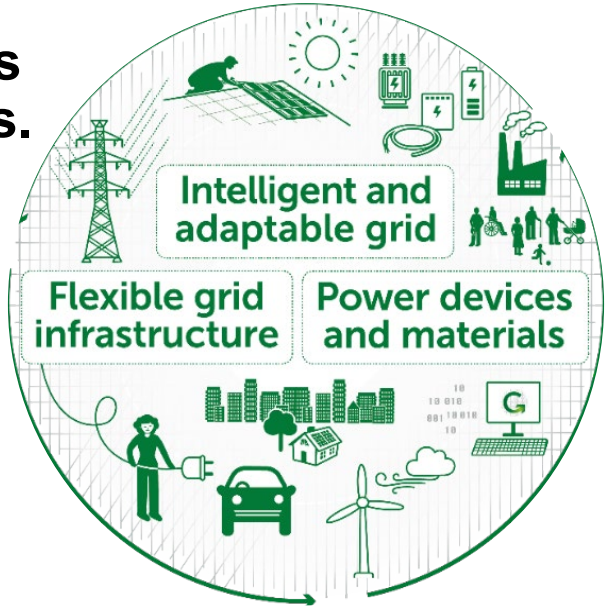
The EU Commission has presented its ‘Fit for 55’ climate package. It contains legislative initiatives with which the Commission wants to achieve the goals of the ‘Green Deal’. An important point for the car industry: CO2 emissions from new cars are to be reduced to zero by 2035, which would mean the end of petrol and diesel.

In concrete terms, the Commission has presented twelve legislative initiatives, eight of which are updates of existing laws. In addition to the targets for cars, the focus is on a tightening of emissions trading. With the ‘Green Deal’ – and the reduction of CO2 emissions by 55 per cent by 2030 compared to 1990 as an intermediate step – Commission President Ursula von der Leyen wants to make Europe the first CO2-neutral continent. “Our economy, which is based on fossil fuels, has reached its limits,” von der Leyen said at the presentation of the climate package. “CO2 must have a price. This price must be so high that people choose the clean and environmentally friendly solution.”

Sustainable power grids

A 360 degree view on electrification ingredients for a sustainable society with 100% renewables.

- **Intelligent and adaptable grid**
  - *to create new values for utilities and customers*
- **Flexible grid infrastructure**
  - *to be ready for power grids evolution and decarbonization trend*
- **Improved power devices and materials**
  - *for enhanced material capability and circular economy!*

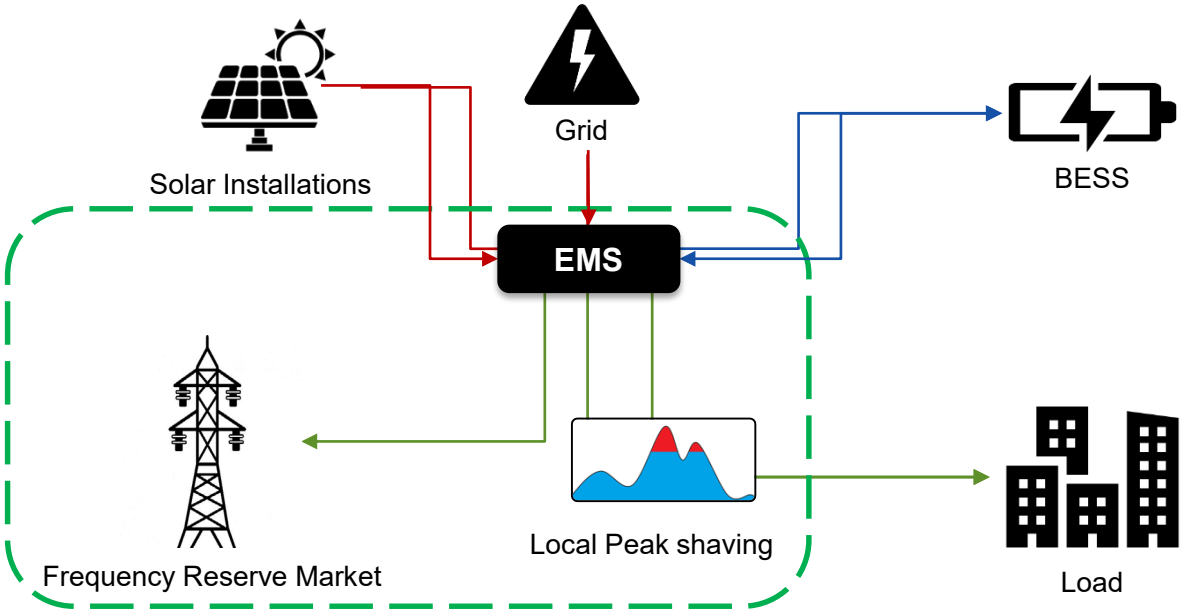


GreenGrids initative

@LinaBertlingTjernberg

Sustainable power grids

Example: local generation and battery storage



*__EMS:__
Energy Management System

*__BESS:__
Battery Energy Storage System

H. Shafique *et al.*, "Behind the Meter Strategies Energy management system with a Swedish case study," *IEEE Electrification Magazine*, vol. 9, no. 3, s. 112-119, 2021.

Ten-Year Network Development Plans

Gas and electricity joint Scenario Report.

- Result from collaboration between ENTSOG and ENTSO-E to develop scenarios for the whole energy system
  - Input from ~ 80 TSOs and > 35 countries
- “ambitious and technically robust scenarios which are fully compliant with the Paris Agreement and with the European ambitions for achieving climate neutrality by 2050”
- Scenario work is the first important step to capture the interactions between the gas and electricity systems!

TYNDP 2022 Scenario Report | Version. April 2022 (entsos-tyndp-scenarios.eu)

TYNDP2022 - statement

- In a rapidly changing energy landscape and impacts due to geopolitical influences, the energy policies of the EU and many Member States are continuously developing.
- The invasion of Ukraine by Russia on 24 February 2022 has led to a major overhaul of energy policy objectives in terms of energy security and diversification of supply that the TYNDP 2022 scenarios do not currently reflect.
- ENTSO-E and ENTSOG would like to explain that due to these recent events affecting the energy supply in Europe, some assumptions used in this report regarding gas supply may be impacted for the short and longer terms.
- ENTSO-E and ENTSOG are committed to developing TYNDP scenarios that will support the European Union plans for energy infrastructure and to achieve the objectives of the EU Green Deal as well as the Paris Agreement, and to ensure a fair, affordable and secure transition towards a clean and decarbonised energy system. A next report is planned to be published in end of 2022.

TYNDP2022 – in brief

- In view of the 1.5 °C target of the Paris Agreement and the EU Climate Law ambition of minimum 55 % GHG emission reductions by 2030 and net zero by 2050, the ENTSOs have developed the Global Ambition and Distributed Energy Scenarios using a top-down approach with a full-energy perspective.
- New features in the scenarios include:
  - sector-coupling methodologies and dedicated modelling tools both to optimise overall system efficiencies and flexibility use as well as to capture better the interactions and new dynamics at the interfaces between various end-use sectors (e.g. vehicle-to-grid and prosumer modelling), at various geographical scales (e.g. district heating) and with other carriers (Power-to-Gas and Power-to-liquid).
  - hydrogen and electrolysis at pan-European scale.

TYNDP2022 – Executive summary

- Net-zero can be achieved by 2050 while ensuring the security of energy supply
- Energy efficiency is key to achieve the EU long-term Climate and Energy objectives
- Ambitious development of renewable energy across Europe
- Sector Integration provides efficient decarbonisation solutions
- Integrated energy systems: hydrogen is a game changer for gas and electricity systems
- Innovation is key to achieve a sustainable energy future

TYNDP2022 – Best estimate and 3 scenarios

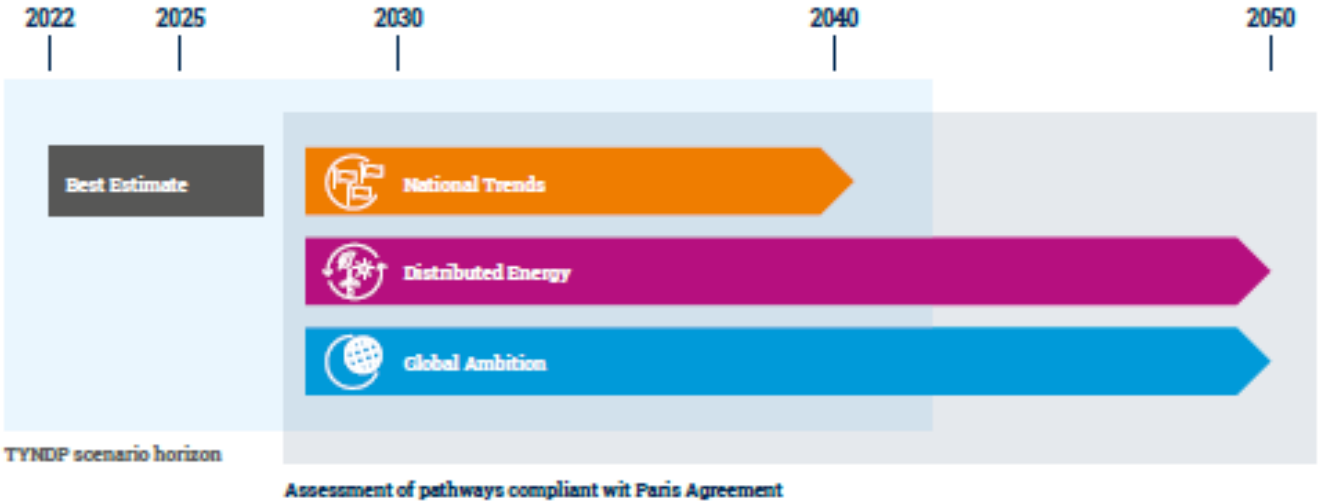


Figure 1: Scenario framework for TYNDP 2022

TYNDP 2022 Scenario Report | Version. April 2022 (entsos-tyndp-scenarios.eu)

TYNDP2022 – Scenarios

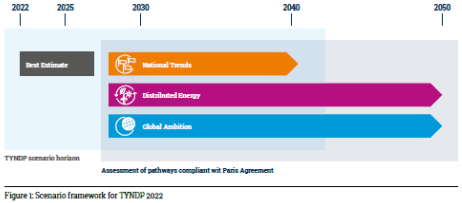


Figure 1: Scenario framework for TYNDP 2022

- For 20224 and 2025 a “Best Estimate” scenario is developed.
  - Data has been collected from the TSOs.
  - These figures reflect current national and European regulations.
- For the assessment of the carbon budget, ENTSOG and ENTSO-E will build upon the work performed together with CAN Europe for the TYNDP 2020 scenarios.
- The present scenarios only cover technologies having reached some degree of maturity in the early 2020s. Other technologies such as Direct Air Capture or innovative ways to produce synthetic fuel are not considered in the scenarios up to 2050. But it is assumed that these technologies can reach commercial maturity after 2050.
- As the 2022 time horizon are not used in ENTSO-E TYNDP, the report figures for this year refer to gas TSO data collection without modelling of the electricity system.

TYNDP2022 – Scenarios

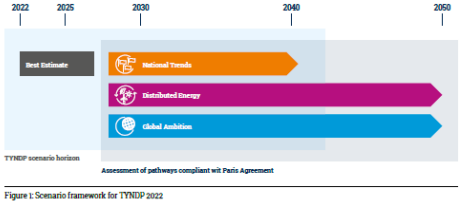


Figure 1: Scenario framework for TYNDP 2022

The long-term goals, starting from 2030, includes three scenarios, reflecting increasing uncertainties towards 2050.

- The National Trends scenario (NT) is in line with national energy and climate policies (NECPs, national longterm strategies, hydrogen strategies, etc.) derived from the European targets.
- The electricity and gas datasets for this scenario are based on figures collected from the TSOs translating the latest policy- and market-driven developments as discussed at national level. The quantification of National Trends focuses on electricity and gas up to 2040.
- ENTSOG and ENTSO-E invite stakeholders to refer to the national documents to have a more energy-wide perspective.

TYNDP2022 – Scenarios

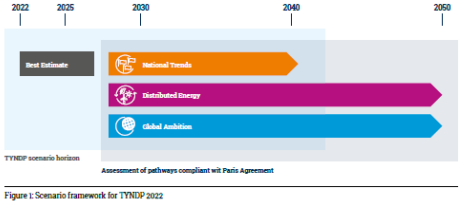


Figure 1: Scenario framework for TYNDP 2022

The long-term goals, starting from 2030, includes three scenarios, reflecting increasing uncertainties towards 2050.

- Two COP21 compliant scenarios have been developed that are:
  - **Distributed Energy (DE)** and **Global Ambition (GA)**
- These are full energy scenarios (all sectors, all energy carriers) in order to quantify compliance with EU policies and climate ambitions.
- Both scenarios aim at reaching the 1.5 °C target of the Paris Agreement following the carbon budget approach.
- They are developed on a country-level until 2040 and on a EU27-level until 2050.

TYNDP2022 – Scenarios

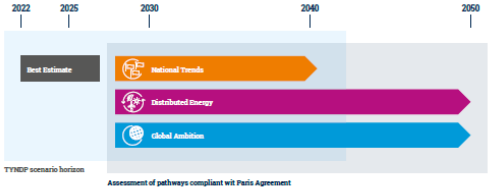


Figure 1: Scenario framework for TYNDP 2022

The COP21 scenario of Distributed Energy (DE)

- A pathway achieving EU27 carbon neutrality by 2050 and at least 55 % emission reduction in 2030.
- The scenario is driven by a willingness of the society to achieve energy autonomy based on widely available national renewable energy sources.
- It translates into both a way-of-life evolution and a strong decentralised drive towards decarbonisation through local initiatives by citizens, communities and businesses, supported by authorities.
- This leads to a maximization of electricity from renewable energy resources in Europe and a strong decrease of energy imports

TYNDP2022 – Scenarios

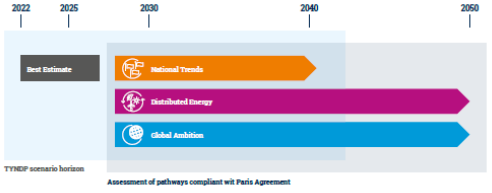


Figure 1: Scenario framework for TYNDP 2022

The COP21 scenario of Global Ambition (GA)

- A pathway to achieving carbon neutrality by 2050 and at least 55 % emission reduction in 2030
- Driven by a global move towards the Paris Agreement targets.
- It translates into the development of a wide range of renewable and low-carbon technologies (many being centralised) and the use of global energy trade as a tool to accelerate decarbonization.
- Economies of scale lead to significant cost reductions in emerging technologies such as offshore wind, but also imports of decarbonised energy from competitive sources are considered as a viable option.

TYNDP2022 – Best estimate and 3 scenarios

	Distributed Energy Higher European autonomy with renewable and decentralised focus	Global Ambition Global economy with centralised low carbon and RES options
Green Transition	At least a 55 % reduction in 2030, climate neutral in 2050	
Driving force of the energy transition	Transition initiated at a local/national level (prosumers)	Transition initiated at a European/international level
	Aims for EU energy autonomy through maximisation of RES and smart sector integration (P2G/L)	High EU RES development supplemented with low carbon energy and imports
Energy intensity	Reduced energy demand through circularity and better energy consumption behaviour	Energy demand also declines, but priority is given to decarbonisation of energy supply
	Digitalisation driven by prosumer and variable RES management	Digitalisation and automation reinforce competitiveness of EU business
Technologies	Focus of decentralised technologies (PV, batteries, etc.) and smart charging	Focus on large scale technologies (offshore wind, large storage)
	Focus on electric heat pumps and district heating	Focus on hybrid heating technology
	Higher share of EV, with e-liquids and biofuels supplementing for heavy transport	Wide range of technologies across mobility sectors (electricity, hydrogen and biofuels)
	Minimal CCS and nuclear	Integration of nuclear and CCS

Figure 2: Storylines for the two COP21 scenarios

Source: TYNDP 2022

CCS – Carbon Capture and storage

TYNDP2022 – Results – final demand

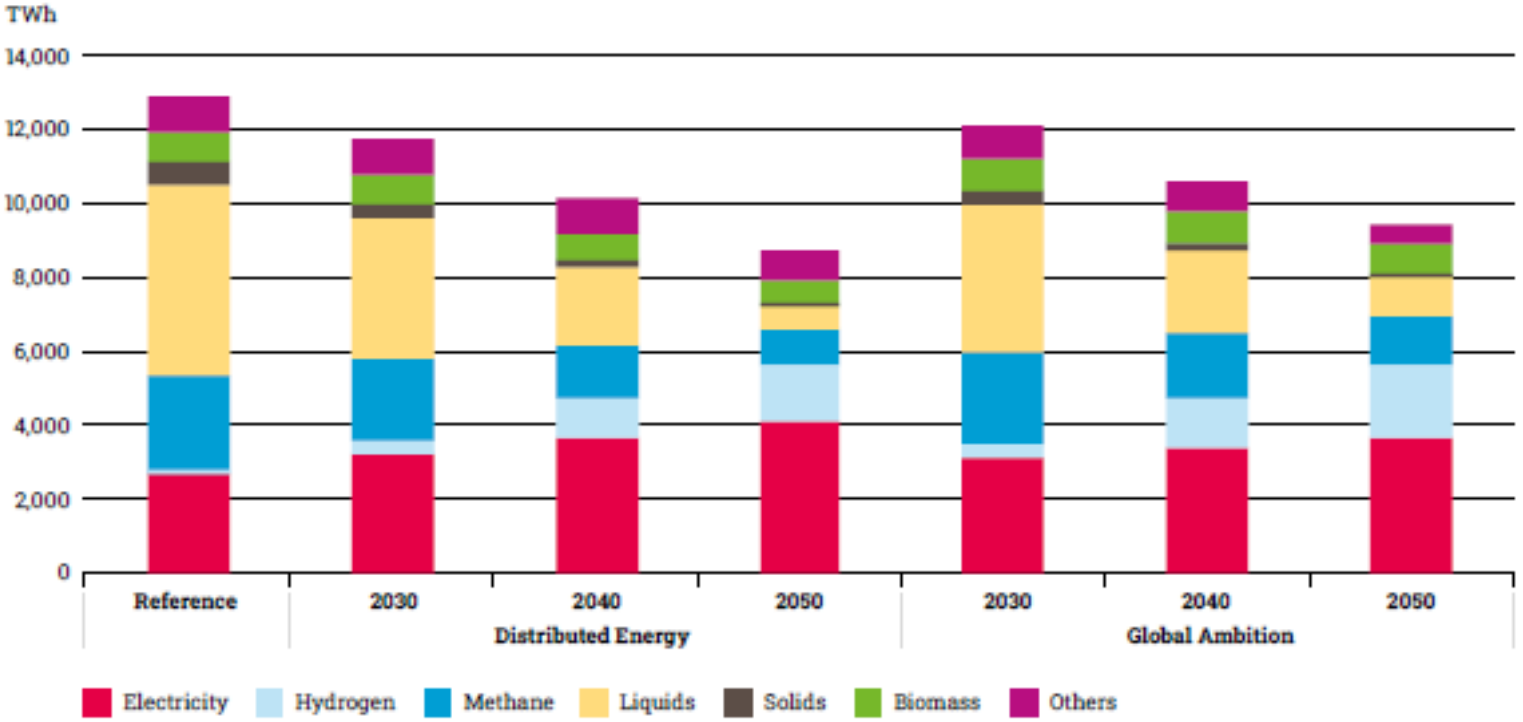


Figure 3: Final energy demand per carrier (energy and non-energy use for feedstock) for EU27

Source: TYNDP 2022

TYNDP2022 – Results – energy demand

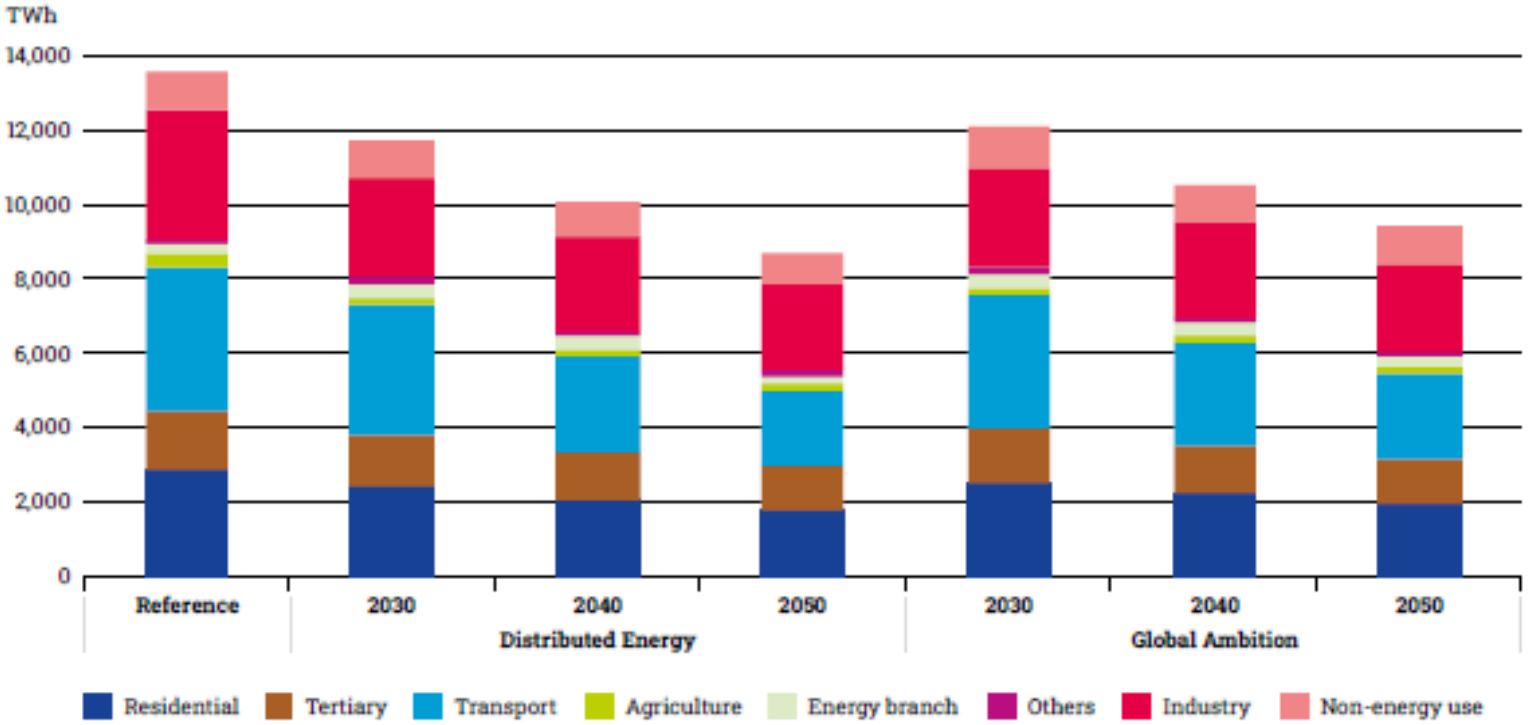


Figure 4: Energy demand per sector (energy and non-energy use for feedstock)[6] for EU27

Source: TYNDP 2022

TYNDP2022 – Results – demand of biomass

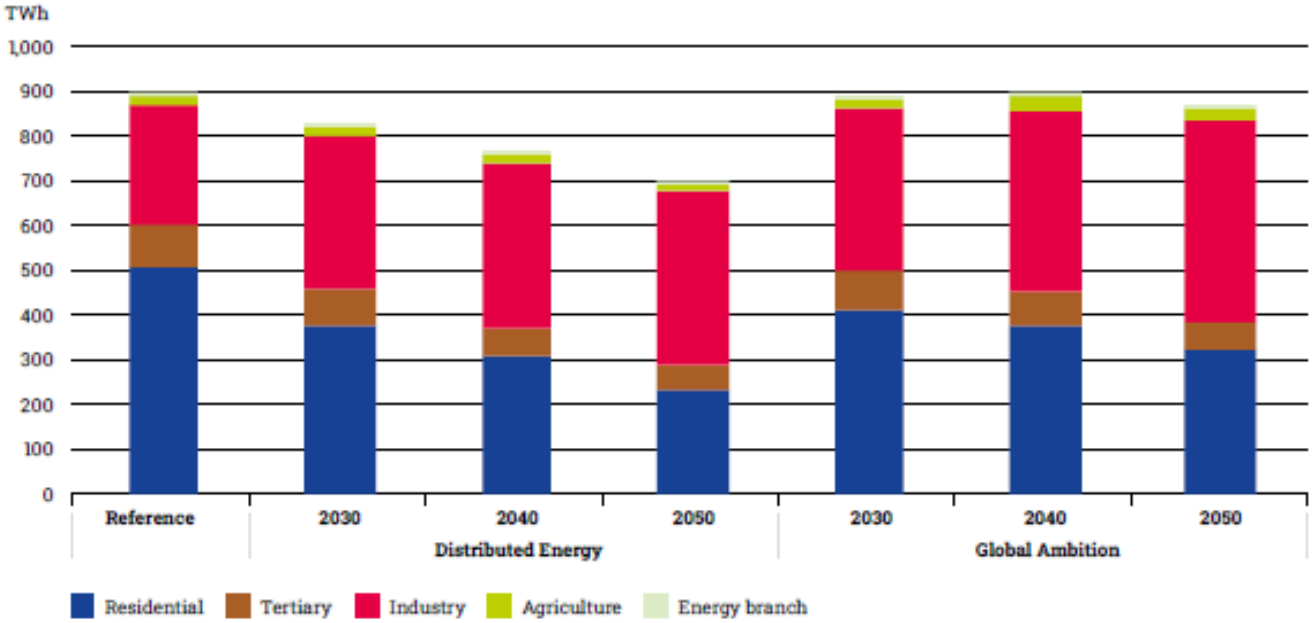


Figure 5: Final demand of biomass

Source: TYNDP 2022

TYNDP2022 – Results – share district heating

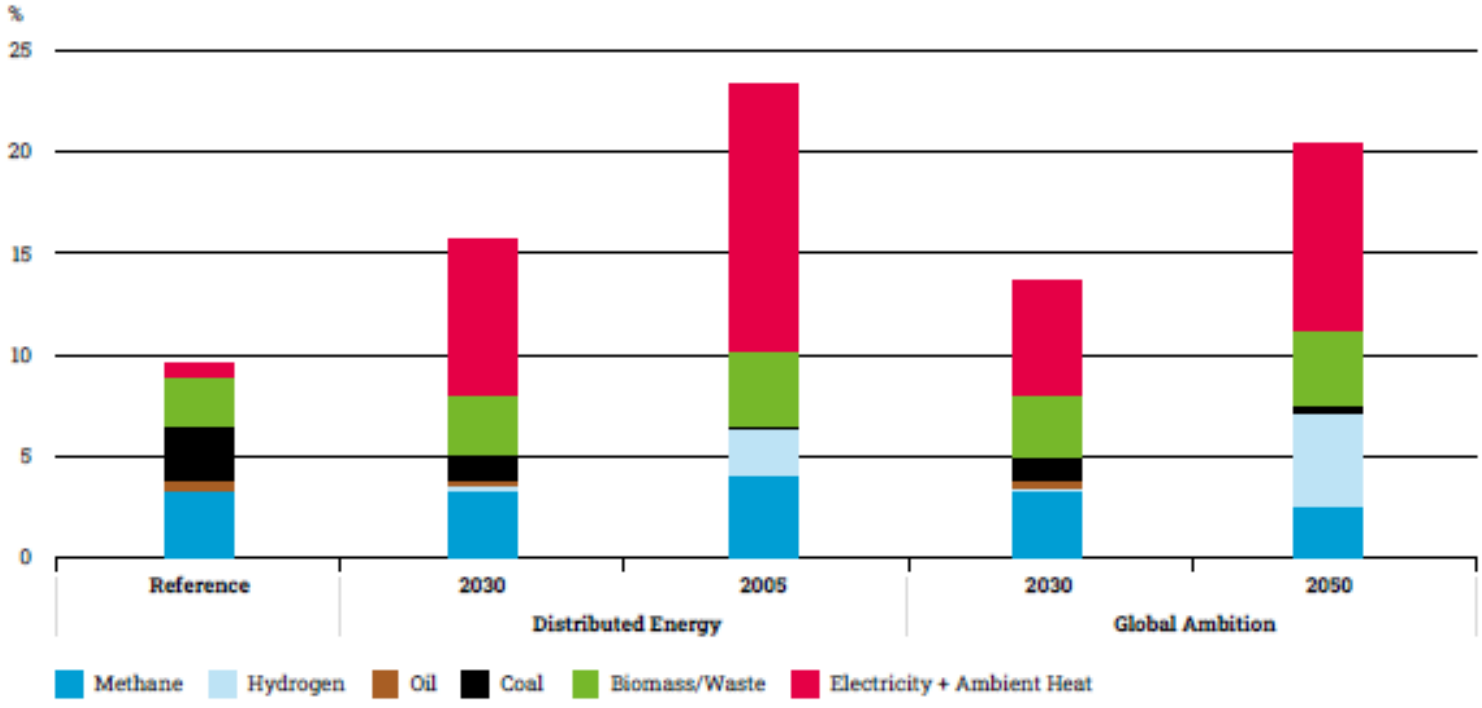


Figure 6: EU-27 share of district heating

Source: TYNDP 2022

TYNDP2022 – Results – share heat pumps

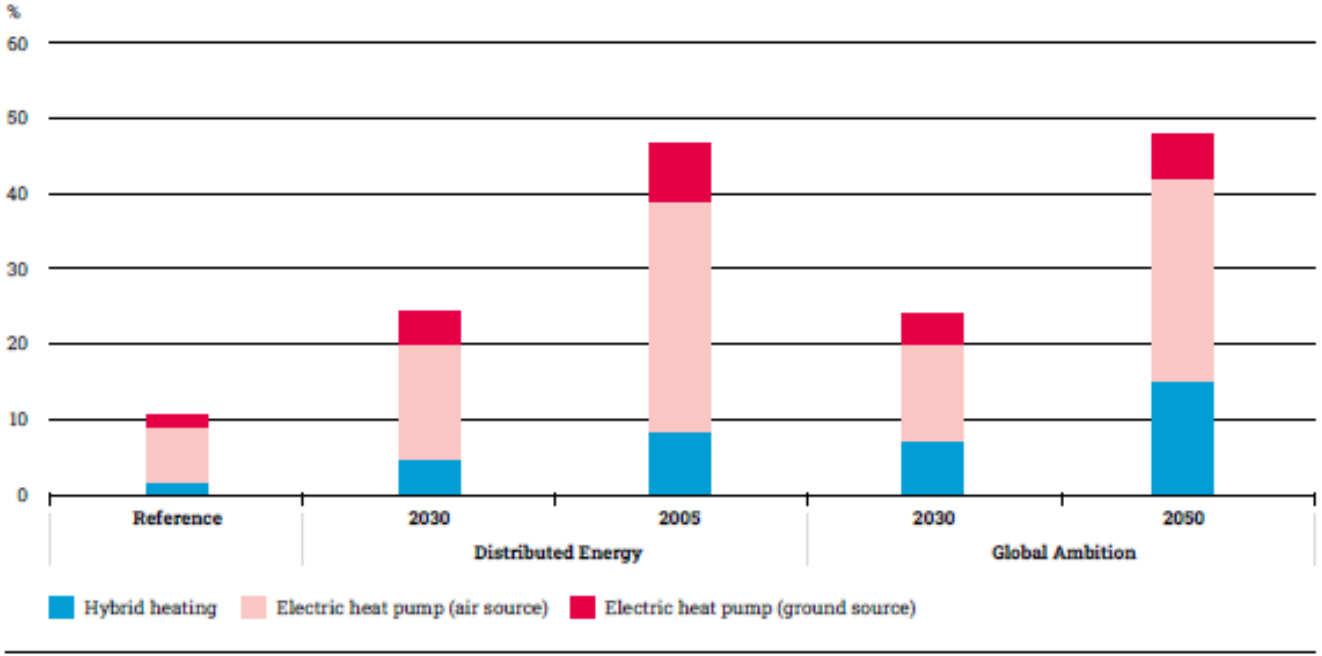


Figure 7: EU-27 share of individual heat pumps

Source: TYNDP 2022

TYNDP2022 – Results – final electricity consumption

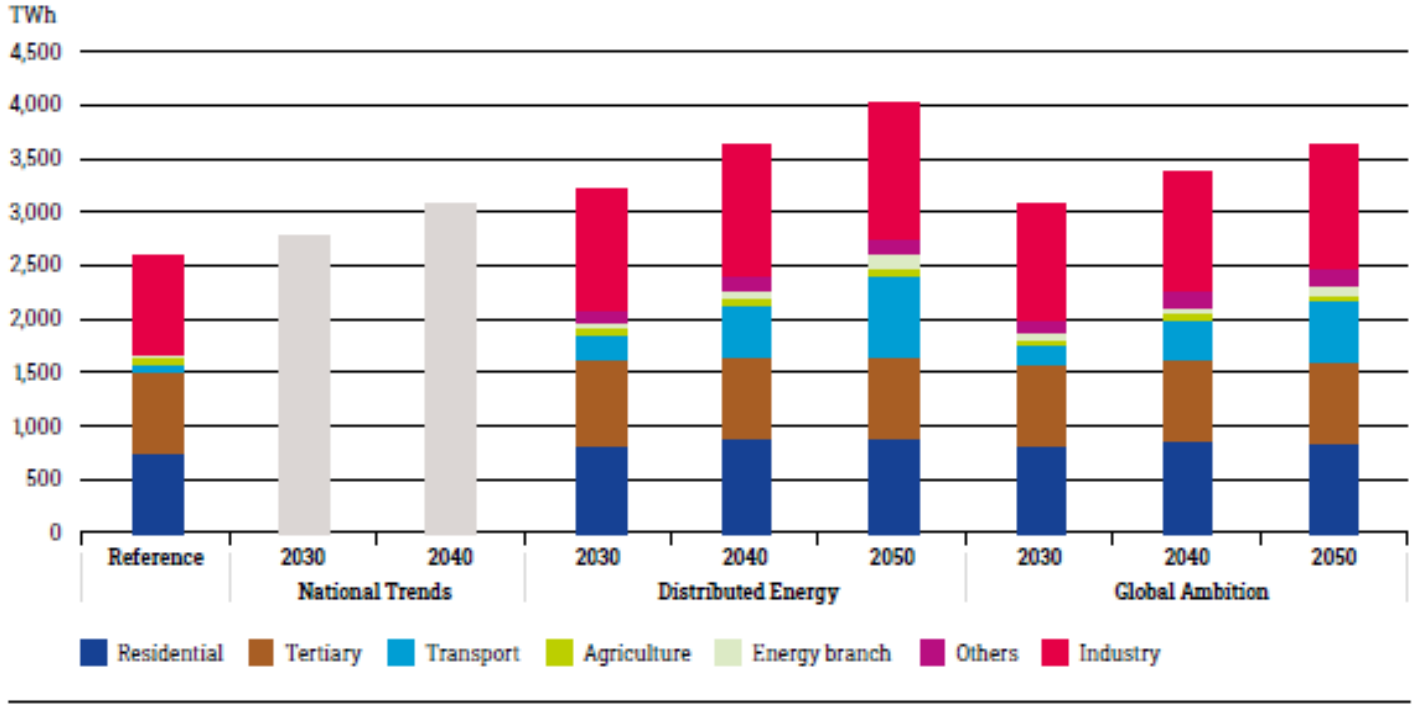


Figure 8: Final electricity consumption (excluding transmission and distribution losses) for EU27

Source: TYNDP 2022

TYNDP2022 – Results – transport technologies

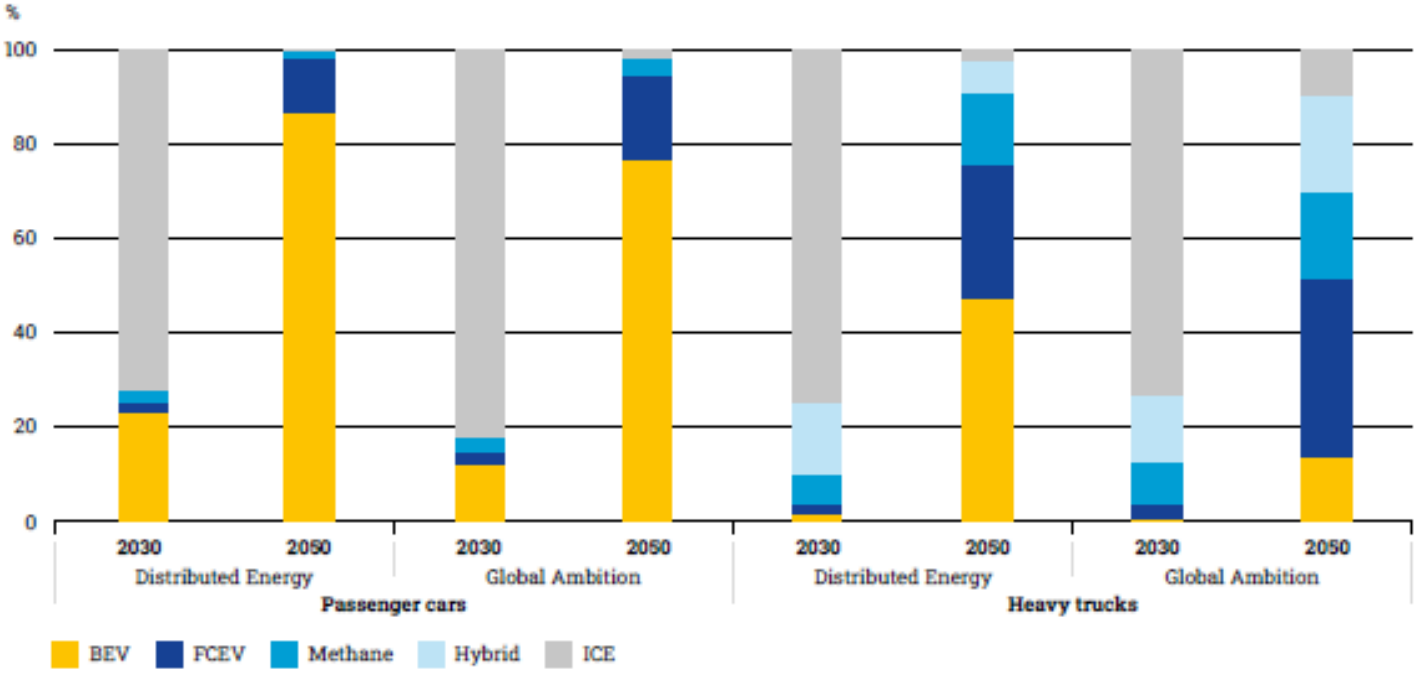


Figure 9: Share of transport technologies for EU27

Source: TYNDP 2022

TYNDP2022 – Results – electricity demand

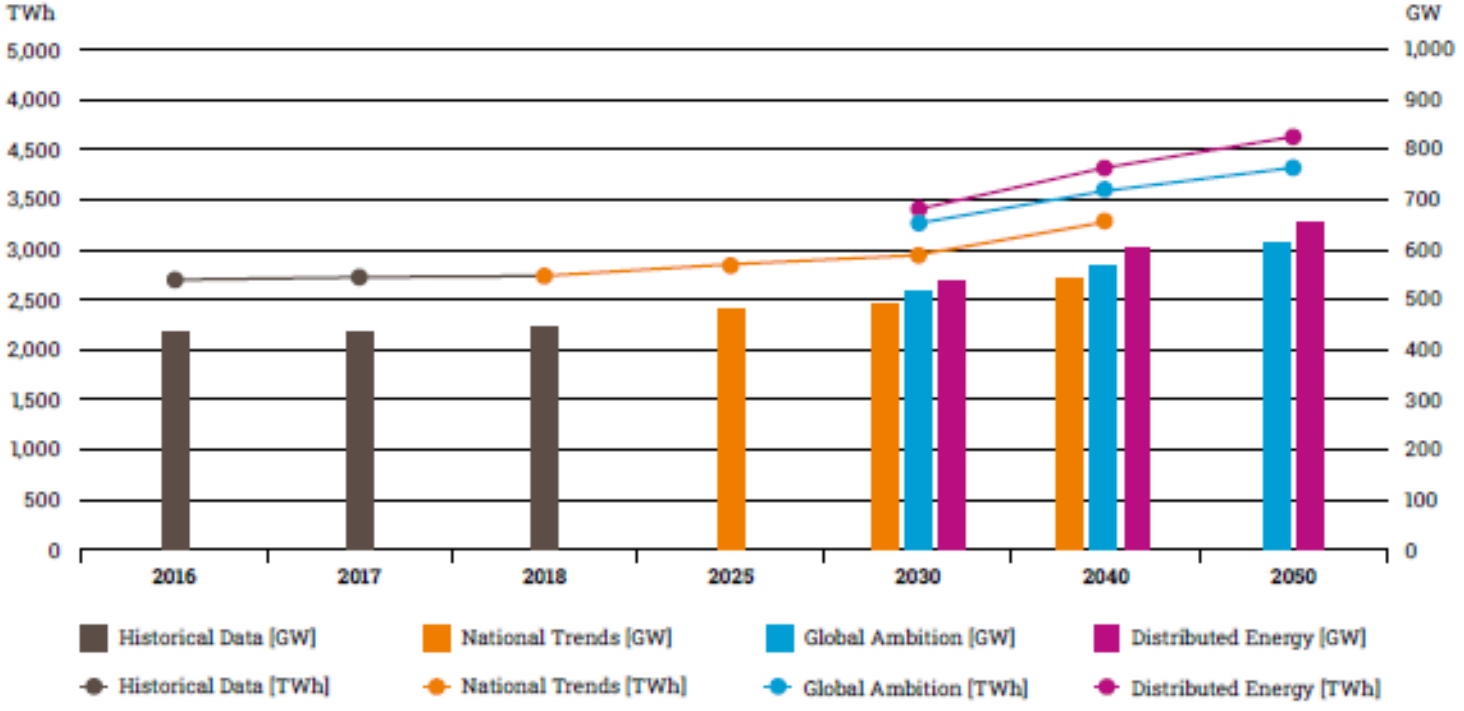


Figure 10: Evolution of average electricity demand and peak (including transmission and distribution losses)[10] for EU27

Source: TYNDP 2022

TYNDP2022 – Results – transport demand

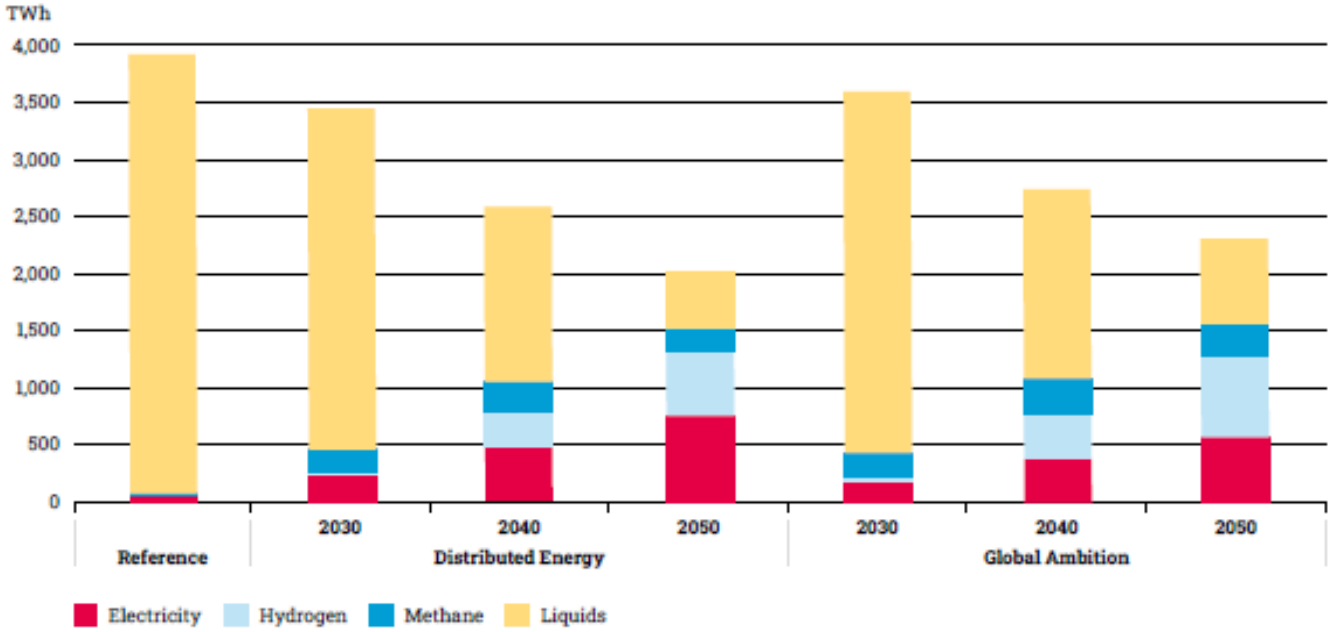


Figure 17: Transport demand per energy carrier for EU27

Source: TYNDP 2022

TYNDP2022 – Results – primary energy supply

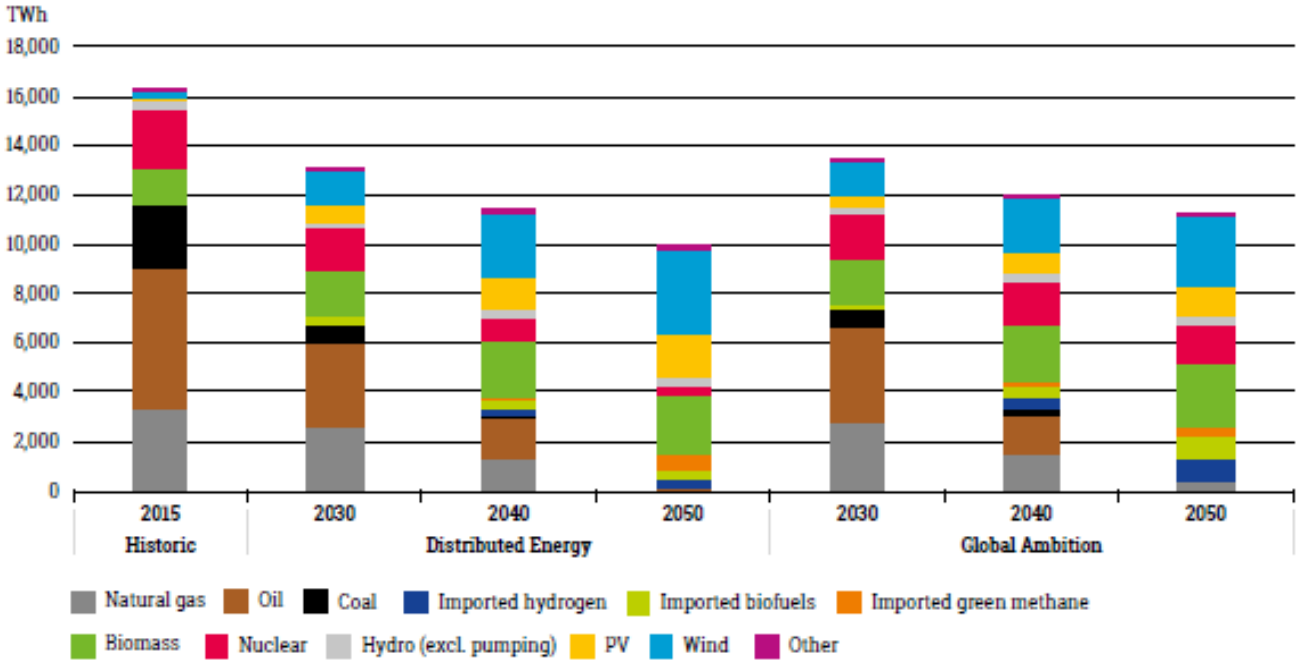


Figure 18: Primary energy supply in the two COP 21 scenarios (for energy and non-energy use) for EU27

Source: TYNDP 2022

TYNDP2022 – Results – mix of energy supply

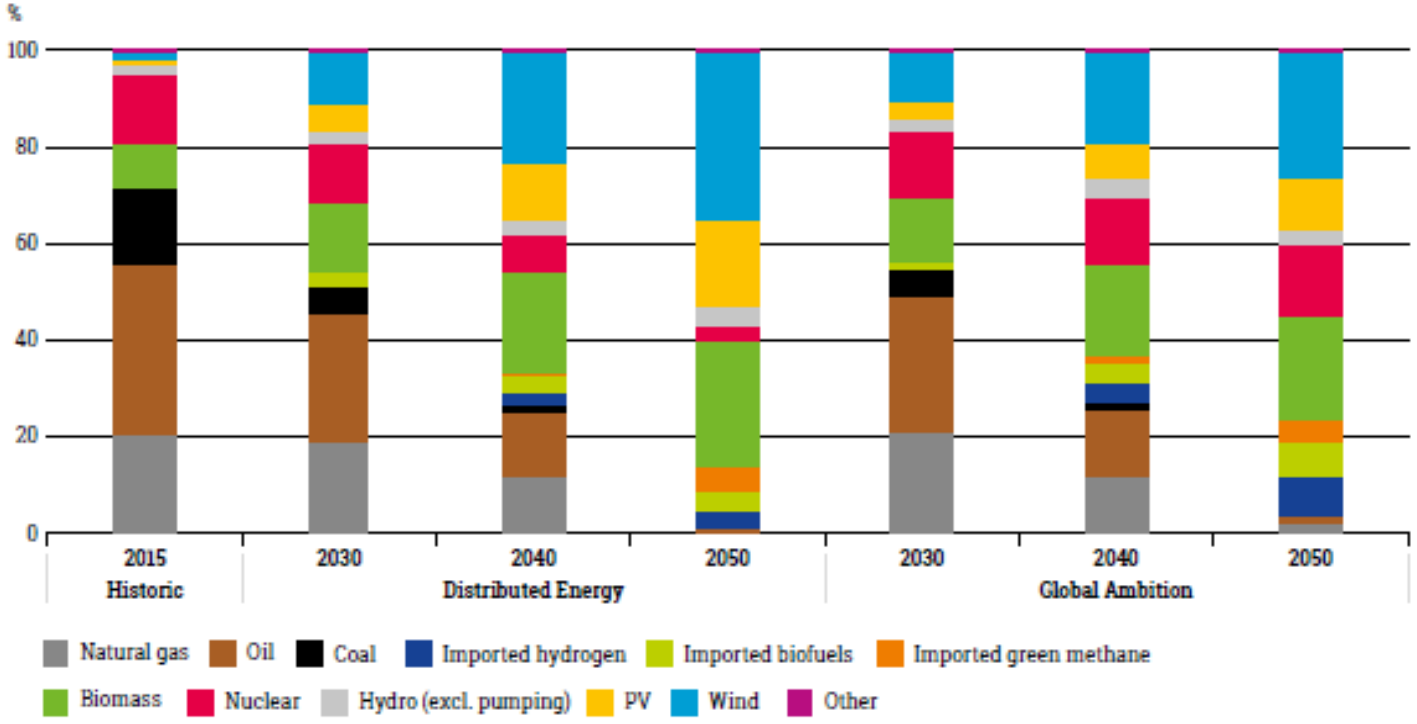


Figure 19: Primary energy supply mix in the COP 21 scenarios (for energy and non-energy us) for EU27

Source: TYNDP 2022

TYNDP2022 – Results – share of fuels

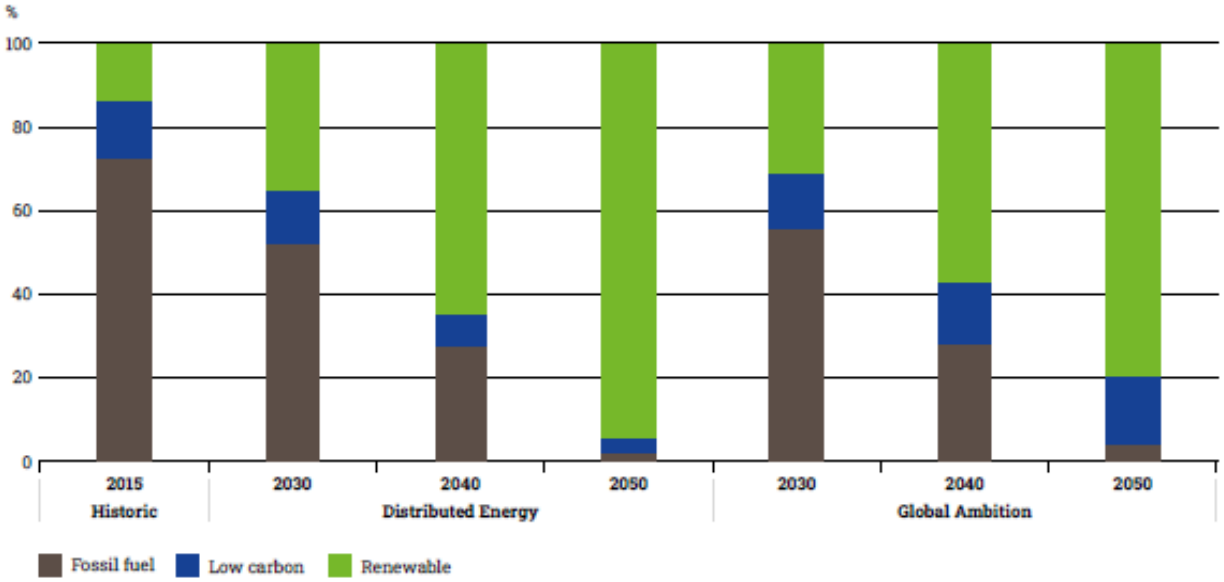


Figure 20: Share of fossil, low carbon and renewable energy in the primary energy supply mix (including non-energy)

Source: TYNDP 2022

TYNDP2022 – Results – biomass

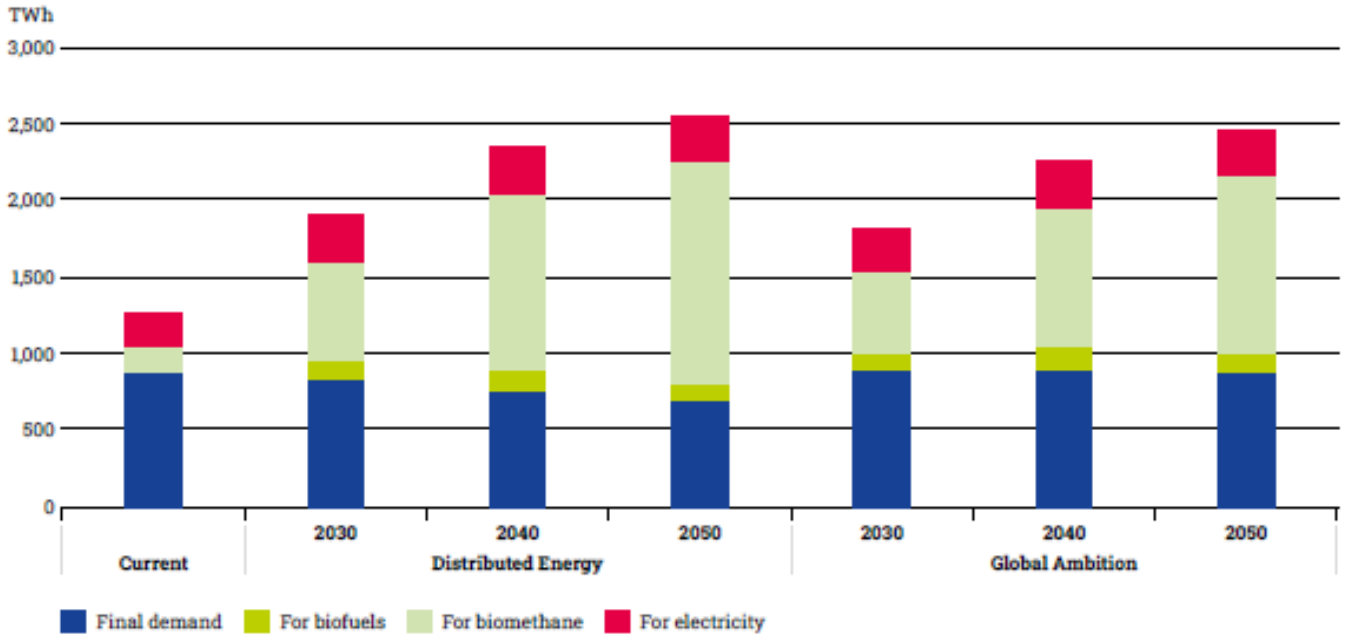


Figure 21: Biomass utilisation

Source: TYNDP 2022

TYNDP2022 – Results electricity demand

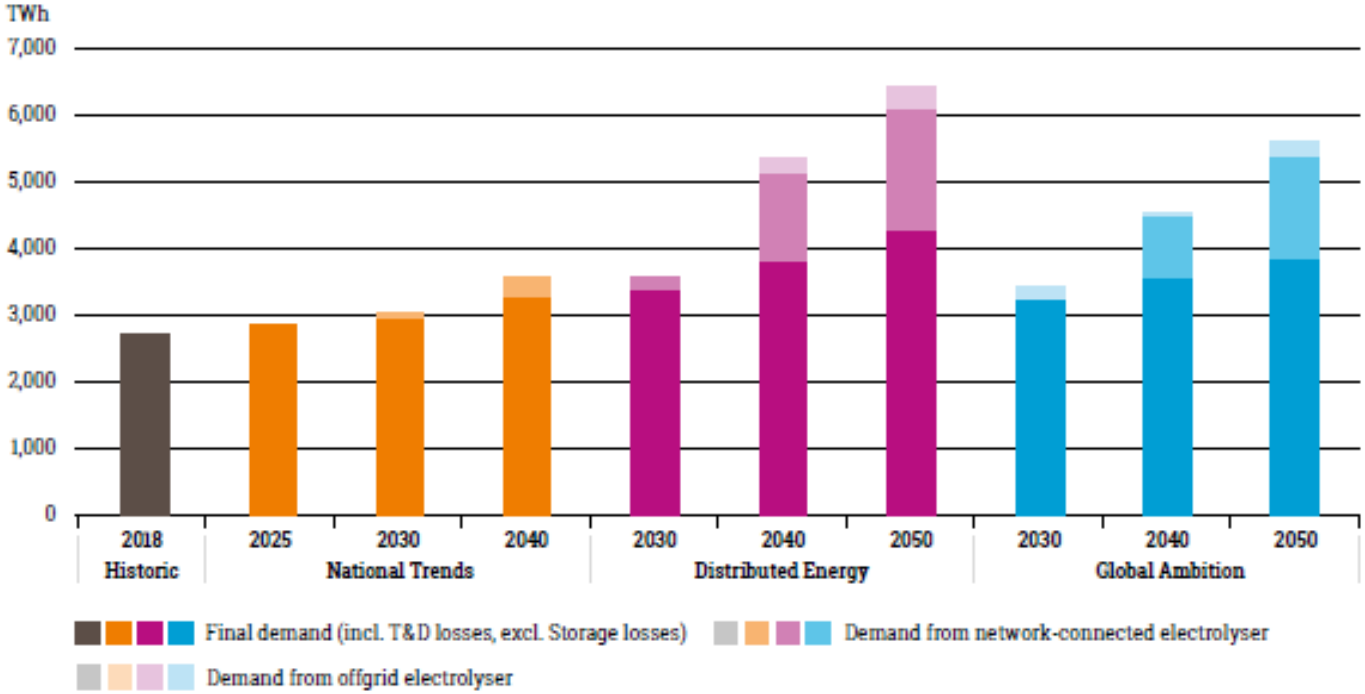


Figure 22: Electricity demand for final use and electrolysis for EU27

Source: TYNDP 2022

TYNDP2022 – Results – electricity demand

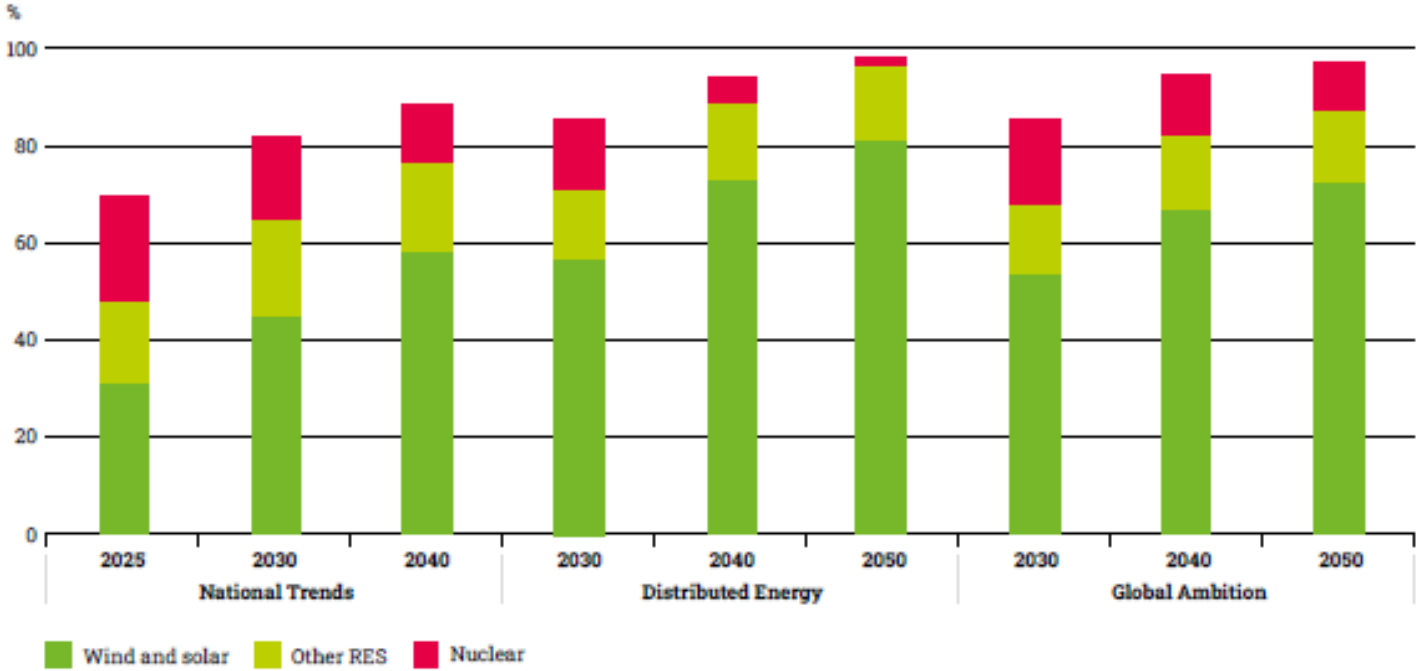


Figure 23: Share of electricity demand covered by low carbon generation in EU27

Source: TYNDP 2022

TYNDP2022 – Results – capacity mix

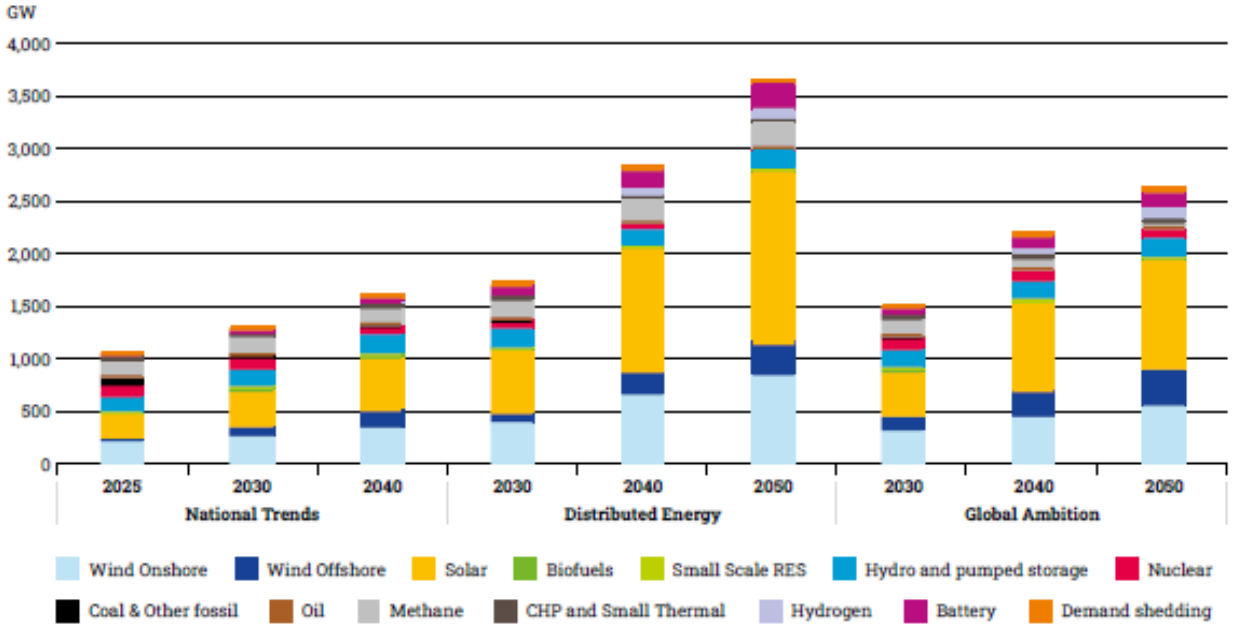


Figure 24: Capacity mix for EU27 (including prosumer PV, hybrid and dedicated RES for electrolysis)

Source: TYNDP 2022

TYNDP2022 – Results – power generation mix

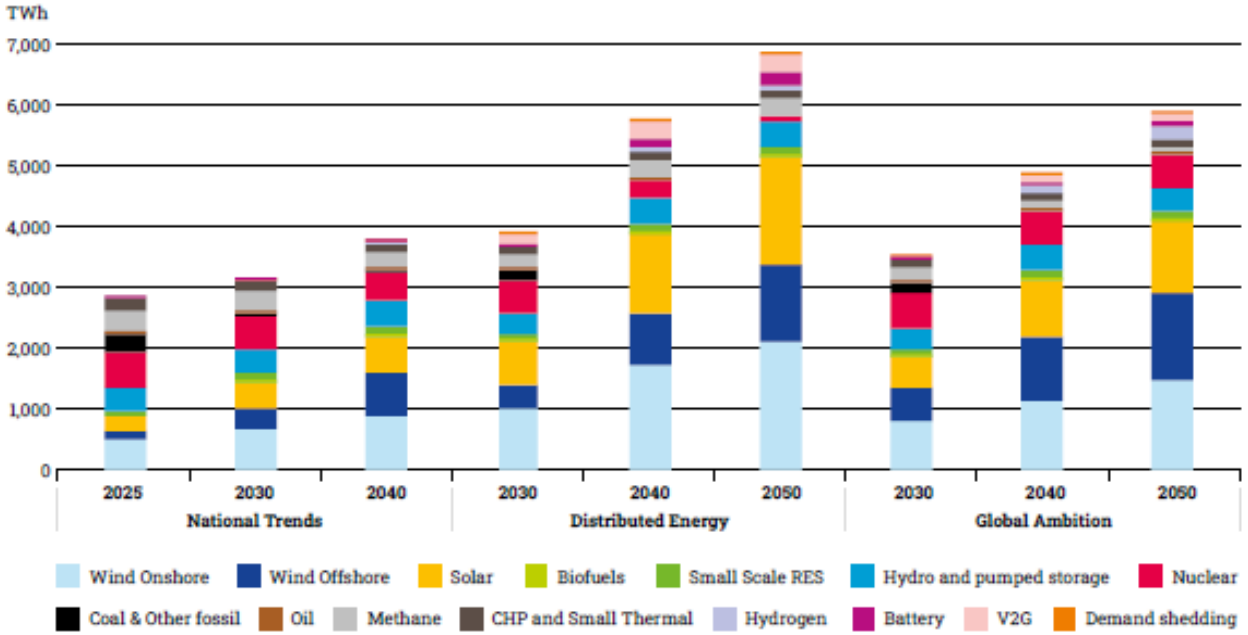


Figure 25: Power generation mix for EU27 (including prosumer PV, hybrid and dedicated RES for electrolysis)

Source: TYNDP 2022

TYNDP2022 – Results – flexibility sources

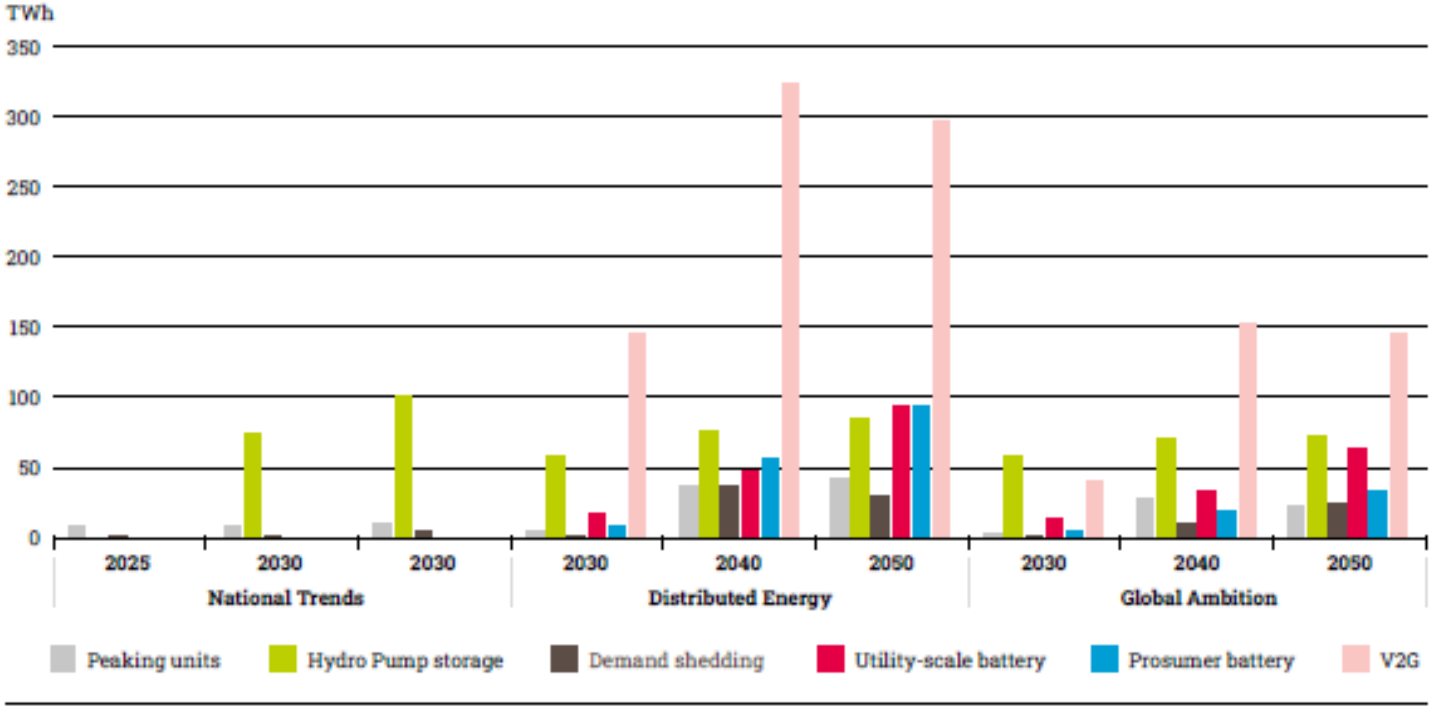


Figure 28: Main flexibility sources for adequacy for EU27 (Peaking units are to be understood as methane-fired open cycle units and peakers as resulting from the new adequacy step. Battery cover utility-scale and prosumer installation)

Source: TYNDP 2022

TYNDP2022 – Results

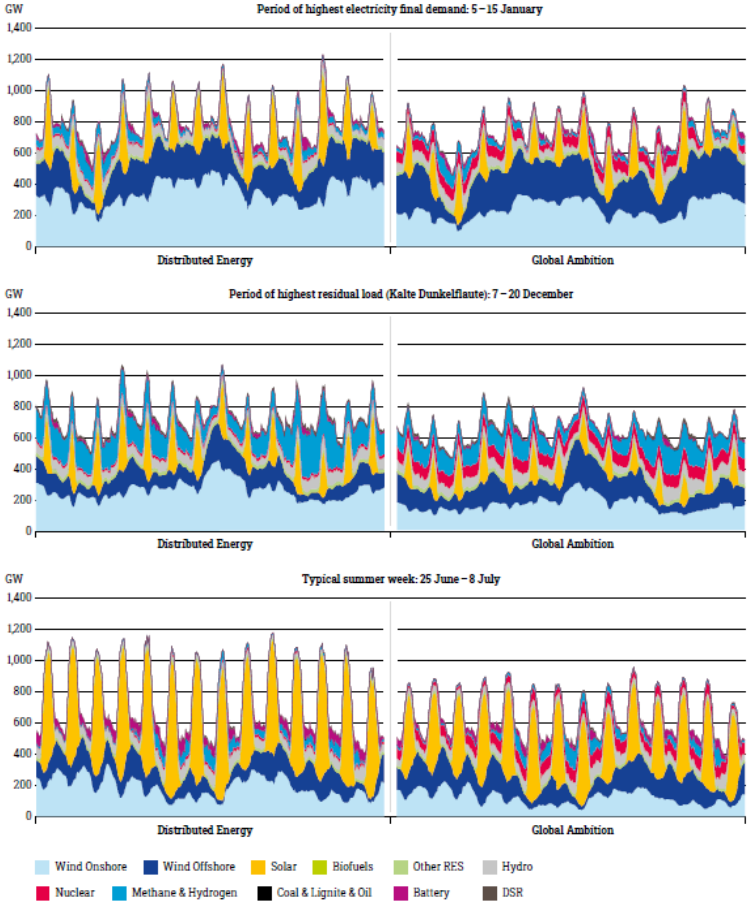


Figure 29: Hourly generation profile of power generation
(Distributed Energy, left – Global Ambition, right; excluding RES dedicated to Power-to-Methane from the P2G Configuration 5)

Source: TYNDP 2022

TYNDP2022 – Benchmark RES technologies

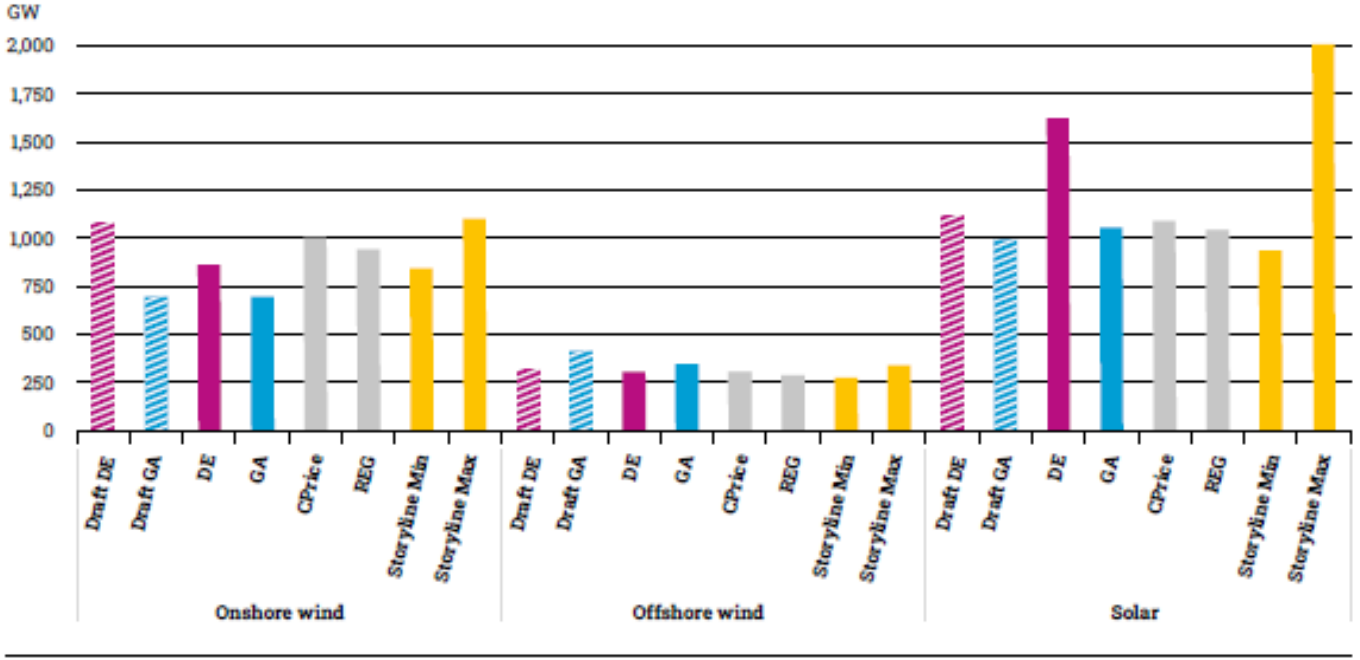
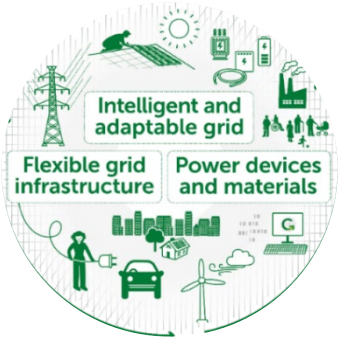


Figure 53: Benchmark of RES technologies in 2050 for EU27

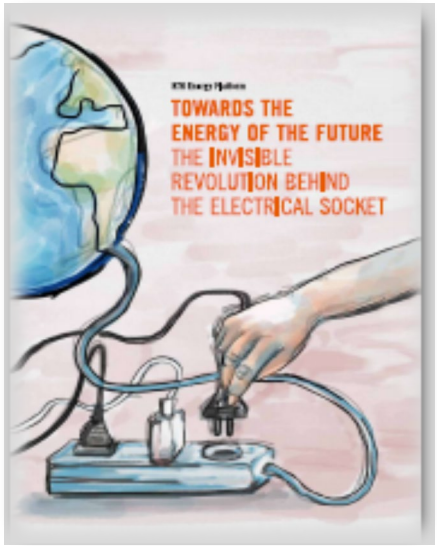
Source: TYNDP 2022

Summary



- Overall targets for the sustainable developments - SDGs
- Geopolitics with an urgent need for energy supply independence – speed up the energy transition and smart grid developments
- Solutions with European Green Package and Green Grids
- Key trends and technology areas:
  I. Intelligent (software) – access to data e.g. condition monitoring, cyber security, internet of things
  II. Flexible (hardware) –integration of storage, EVs, PV,..
  III. Circular economics with recycling of material and second life time usage

KTH Energyplatform – book



Researchers at KTH have recently published an anthology focused on providing knowledge about the challenges and opportunities of energy. Researchers provide answers in the energy debate | KTH

The book is available in Swedish and English and can be down leaded for free or can be bought in hard copy.

More information from here: Anthology on energy - Vetenskap & Allmänhet (v-a.se)