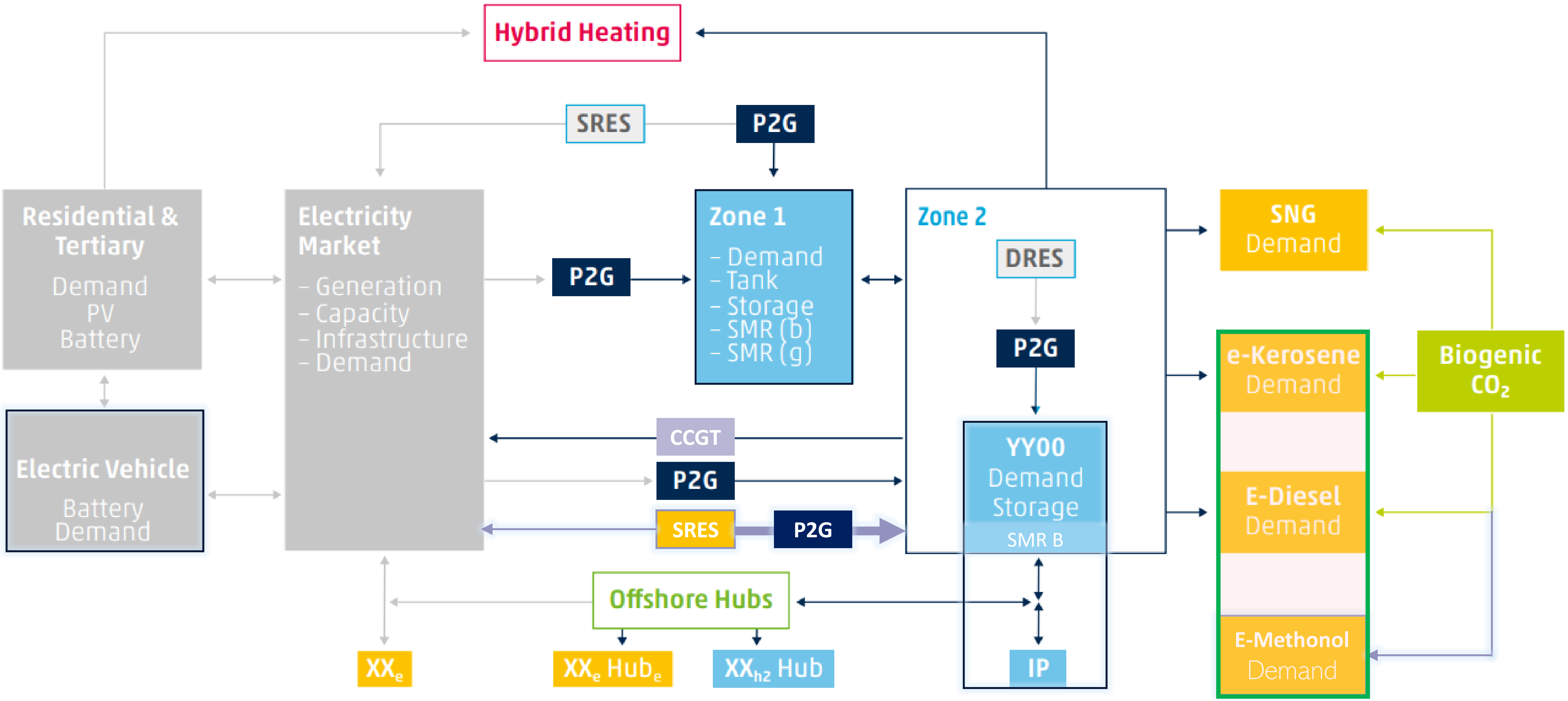
TYNDP 2026 Scenarios

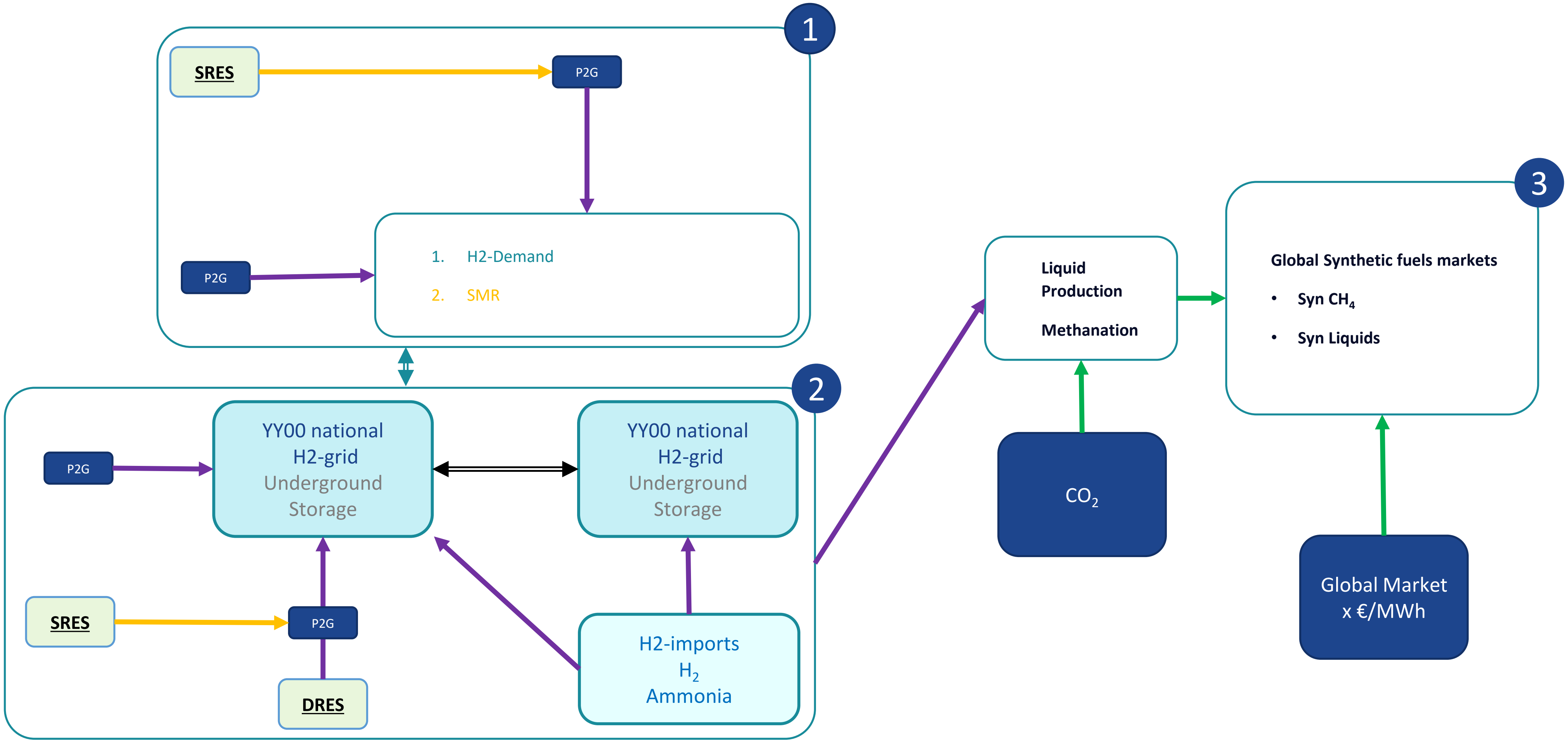
Draft Market Modelling Methodologies for Consultation

Model Structure 2026



Hydrogen Methodologies

Scenario 2026 Hydrogen Topology



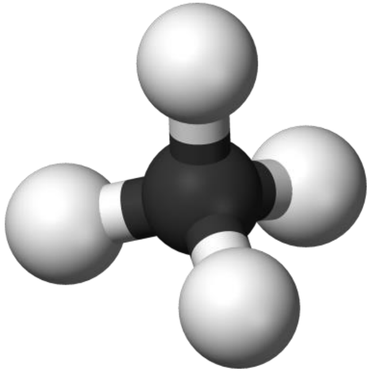
Synthetic Fuels

Synthetic Fuels will be split into Synthetic Methane and Synthetic Liquids.

Due to difficulties in forecasting demand for Synthetic Liquids, they will be merged into 1 process. An average stoichiometric breakdown will be determined to understand how much CO_2 and Hydrogen are required per unit output of liquids.

The fuels considered in the Synthetic Liquids are:

- Synthetic Methanol
- Synthetic Kerosene
- Synthetic Diesel



To simplify the modelling, all countries will be able to feed into the synthetic fuels demands. This is a simplification to avoid having to build out 2 additional transport networks for methane and liquid fuels.

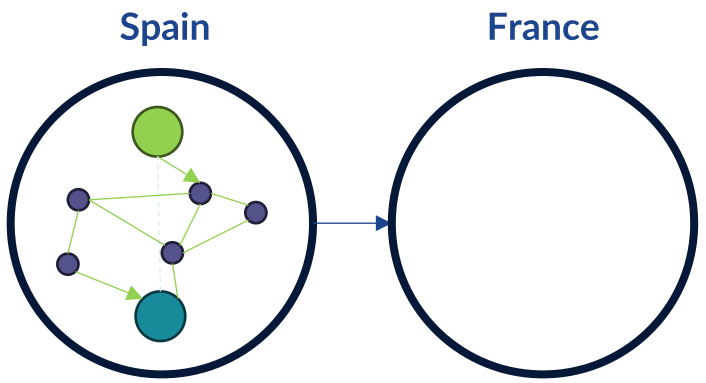
PPA and Dedicated RES

SRES – Virtual PPAs:

- These represent renewables that are contractually obligated to supply energy to electrolysers without a direct physical connection. Electrolysers must prioritize the absorption of renewable energy when available. Any surplus energy can then be sold to the electricity market.
- Shared RES will be treated as dedicated RES in the model, to ensure the connection to the electricity market and it prices is severed. Production profiles for hydrogen production and additional electricity for the electricity market should be provided as model inputs.

DRES – Physical PPAs:

- These include renewables that are physically co-located with electrolysers. The co-location can involve a contractual agreement between the electrolyser owner and the renewable farm owner or a scenario where both are owned by the same entity. In the latter case, while it would not technically be a PPA, it would still fall under the Dedicated RES category.



Example of shared RES following RED III delegation act

Shared RES Profiles

Create shared renewable profiles which prioritises hydrogen. Key Drivers of the Allocation:

- Determined by the installed capacities of shared Solar, Onshore, and Offshore wind.
- Shape the hourly generation patterns (based on climate data).
- The maximum hourly rate of hydrogen production is dictated by the available electrolyser capacity.

Primary Outcomes & Insights for Market Modelling:

- Hourly Hydrogen Production Potential: Quantifies the volume of green hydrogen that can be produced from the prioritized renewable sources.
- Impact on Electricity Market: Reveals the amount of renewable energy diverted to hydrogen, and consequently, the remaining renewable energy available to the grid.

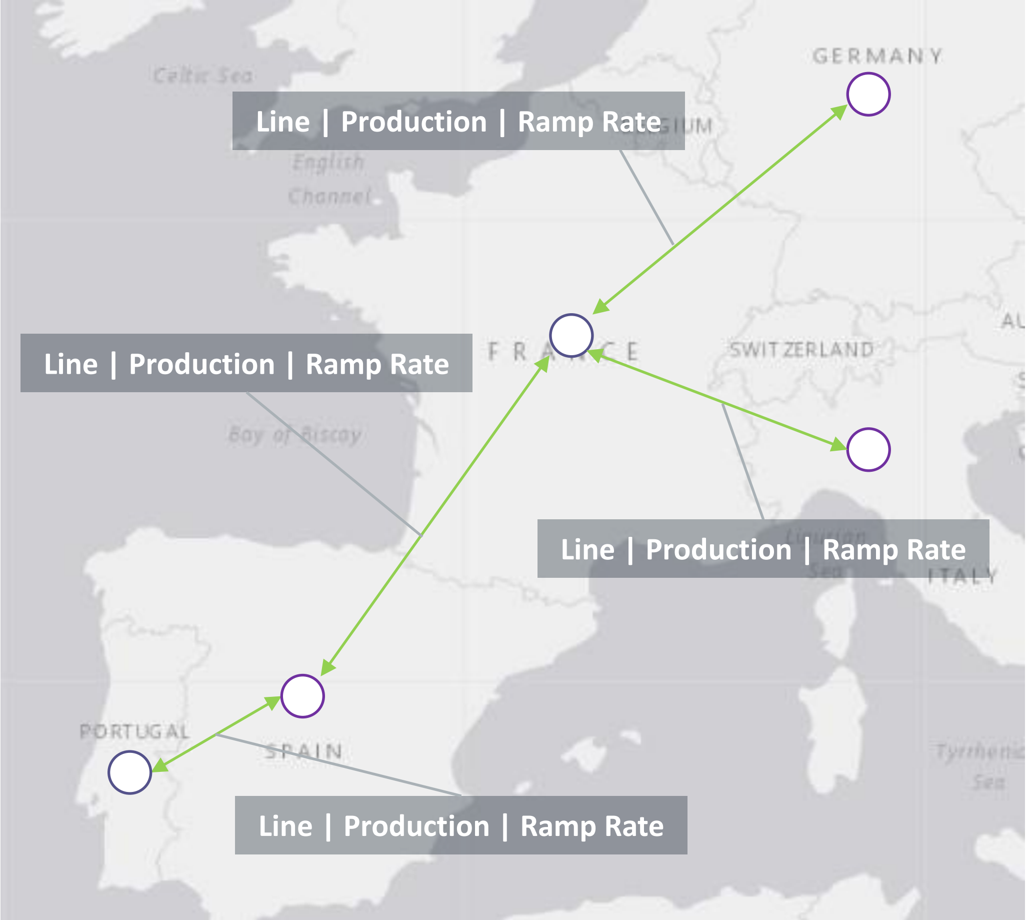
Hydrogen Pipeline Flow Constraint

Addressing Unrealistic Flow:

- Challenge the assumption that hydrogen can be transported instantaneously through pipelines over long distances.
- Considers practical limitations using ramp-up rates.

Increased Dependence on Local Storage:

- Adding this constraint will provide a more accurate representation of how storages will operate. This will help in managing daily fluctuations in supply and demand
- TSOs use assets such as storages in order to balance day ahead nomination. The methodology tries to better reflect this.



Methodology for Hydrogen Storage

Different storage geologies and behaviors, have different parametrizations and flexibility levels. such as:

- Salt Caverns
- Aquifers
- Depleted Gas Fields

The geological structures carry distinct behaviours, however the aggregation of multiple caverns of the same type may illicit a different behaviours. Therefore, Storages should be grouped by flexibility levels.

Aiming to capture flexibility levels such as

- Weekly
- Monthly
- Daily

Collecting key technical parameters from TSOs that describe storage behavior, including:

- Working gas volume
- Injection capacity
- Withdrawal capacity

Hydrogen Price Formation

The hydrogen price formation will determine how the hydrogen price is formed in the model. A merit order approach is taken in the economic models. The costing must consider the supply sources

- E-Market Connected Electrolyser
- Shared RES Connected Electrolyser
- Dedicated RES Connected Electrolyser
- Pipeline Imports
- Shipping Import (NH_3)
- Steam Methane Reforming
- Methane Pyrolysis

Shared RES

- The renewable profiles will be predetermined and should be split into hydrogen production and remaining renewables which will be fed into the electricity market

Technical Supply Parameters - Electrolysers

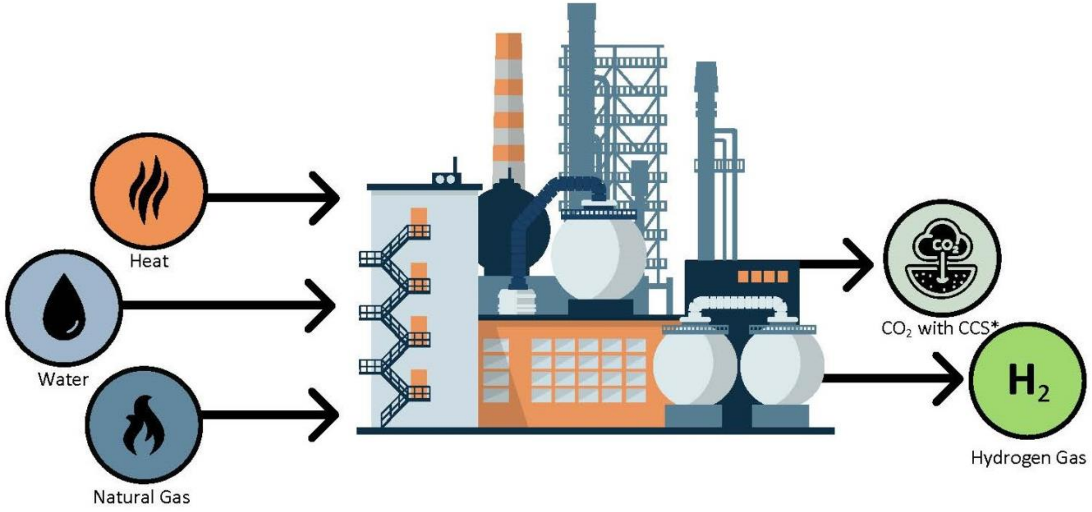
- VO&M
  - The water price is considered as feedstock for the electrolysis process
  - Water price is country based

- Electricity Cost
  - For Electricity market connected electrolysers, cost is based on the market price.
  - For Dedicated or Shared RES the marginal cost of electricity is 0

- Electrolyser efficiency
  - Efficiency for 2030 is 69%, 71% in 2040 and 74% in 2050
  - The electrolyser efficiencies are based on a technology mix

Technical Supply Parameters - Steam Methane Reformers

- VO&M:
  - 3.4 €/MWh (source)
  - An additional cost of 1.1 €/MWh if hydrogen is considered blue
- Fuel Cost:
  - Methane Price
  - Based on methane blend
- CO_2 Price:
  - Based on Methane emissions factor
  - 10% of methane emissions if hydrogen is considered blue
- SMR efficiency
  - Efficiency for blue SMR is 69% and 76% for grey SMR (source)

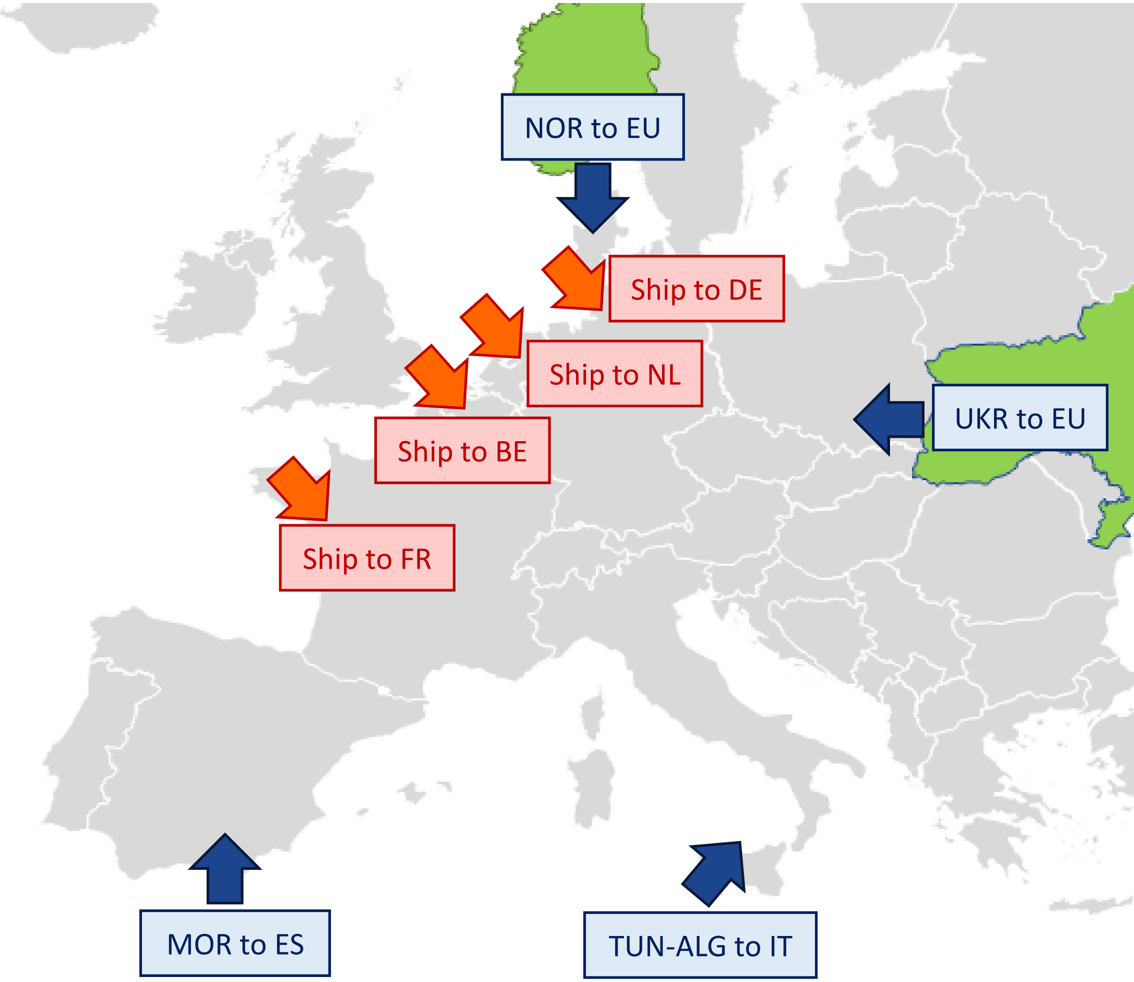


H2 Import Modelling

H2 import – TYNDP 2024 Scenario Approach

For each route, model:

- takes **inputs** from WGSB supply team:
  - Two import bands, whose characteristics are:
    - **Available capacity** (total supply potential, converted to capacity)
    - **Import price**
- gives **outputs**:
  - Import volume
  - Import hourly profile



Areas for improvements:

- Prices not comparable (to EU domestic production and among import routes)
- **Import used as flexibility (instead of storage or other flexibility resources)**
- Penny switching effect
- No differentiation between shipping and pipe import profiles

H2 import – Proposal

Import routes will have different behaviour depending on their nature. They are going to be split in three categories with different proposed characteristics based on their expected role in the EU given marginal hydrogen pricing formation:

1. **Green H2 pipeline import**
2. **Blue H2 pipeline import**
3. **Shipped H2 import**

Each category will be characterized by an overall import profile and potential volume/capacity, which will be split in 2 bands (one reflecting LTC; one reflecting market participation).

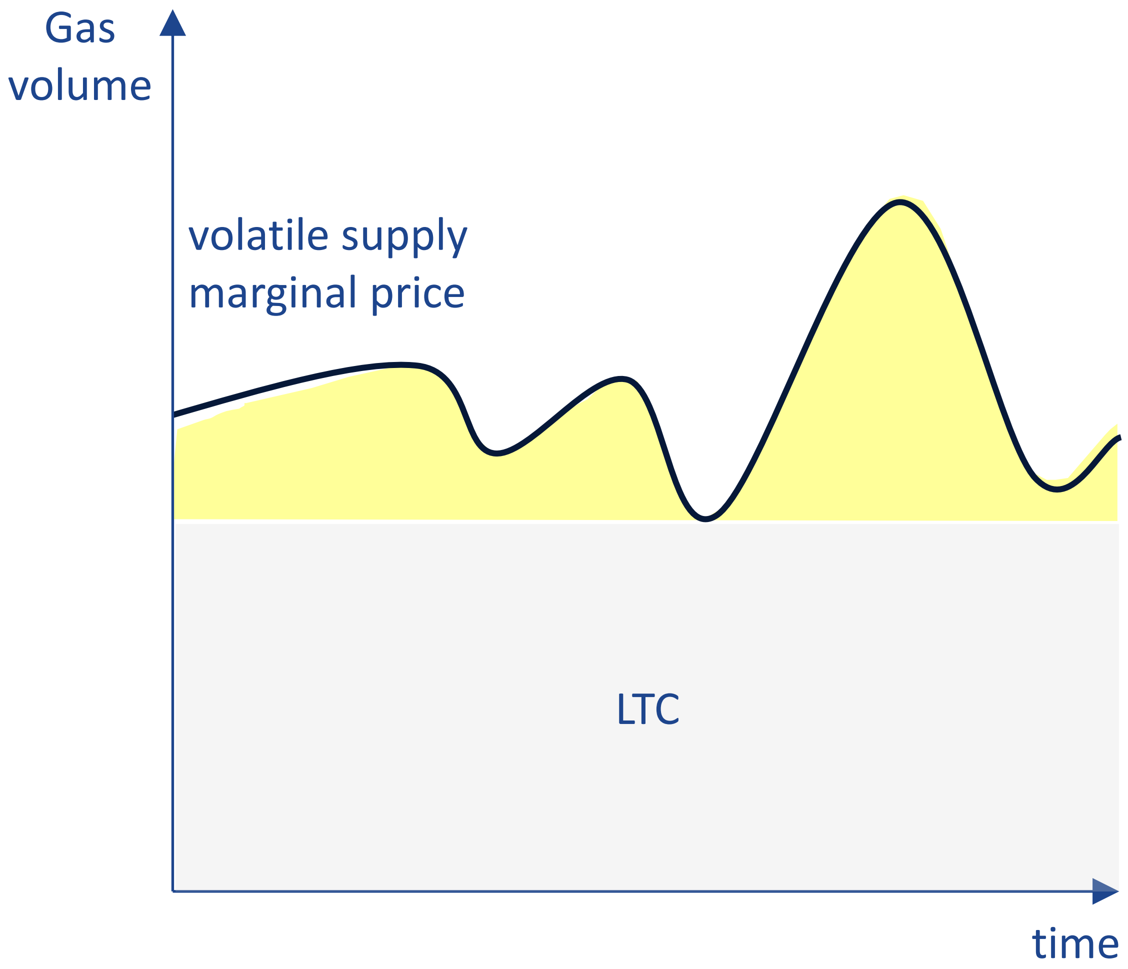
Each band will have:

- Volume/Capacity
- Profile
- Price
- Flexibility

Green H2 pipeline import

	LTC band	Upper band(s)
Volume	50 - 90 % of total approved volumes	Remaining
Profile	Flat	Follows electrolyser production, based on RES
Price	reflecting long term contracts	Marginal or LCOH pricing approach*
Flex	No	Yes

* Two options are presented as testing is ongoing and the methodology is still being finalized.



Not intended to be zero price, but to reflect competiteveness on marginal price formation

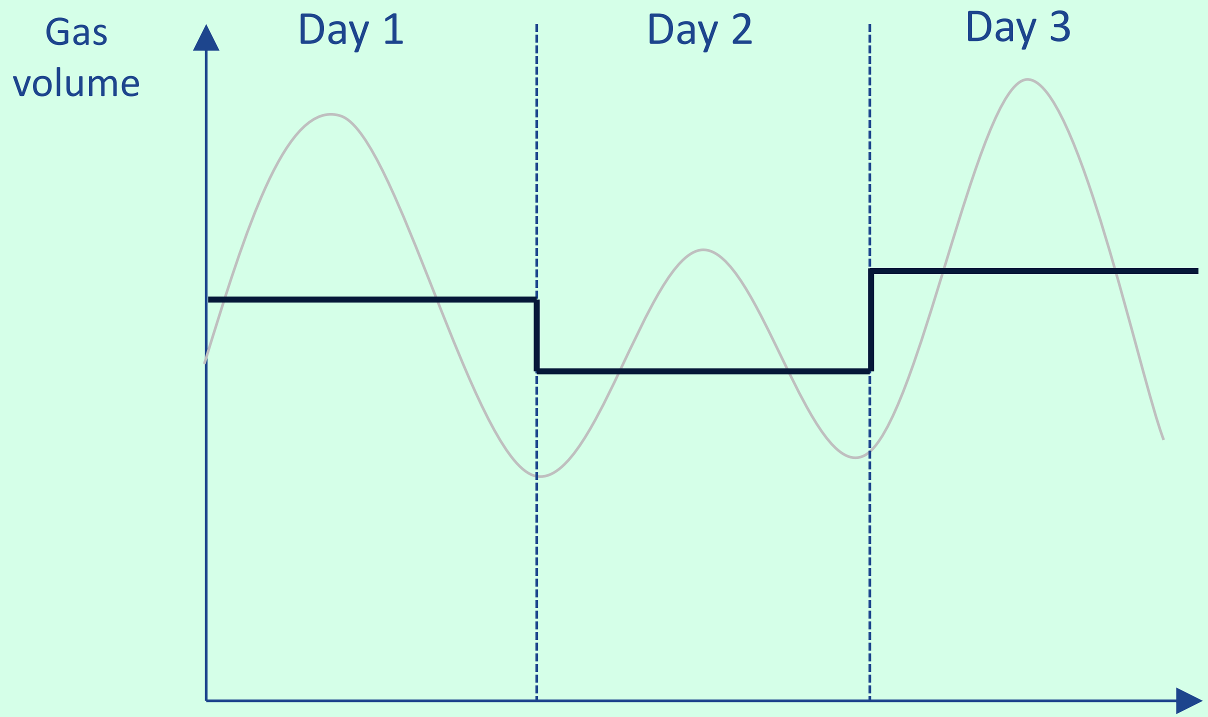
Deep dive

Green H2 pipeline import – Daily profile

Production profile in the exporting country might have strong variability, especially when dealing with green hydrogen, due to non programmable RES.

This might cause underutilization of importing infrastructure, which surely would be avoided by TSO and a flatter profile would be obtained.

We are not going to investigate how it's done – since this is not in the scope – but we will consider what follow



Import profiles are calculated as daily average profiles. The daily average would serve as an approximation of long-distance pipeline transport and storage in exporting countries.

PRO: more reasonable, given the dynamics of pipeline profiles for long-distance transport.

CON: "stepwise effect" on EU supply and marginal pricing. May serve for daily flexibility.

Deep dive

Green H2 pipeline import – Sizing

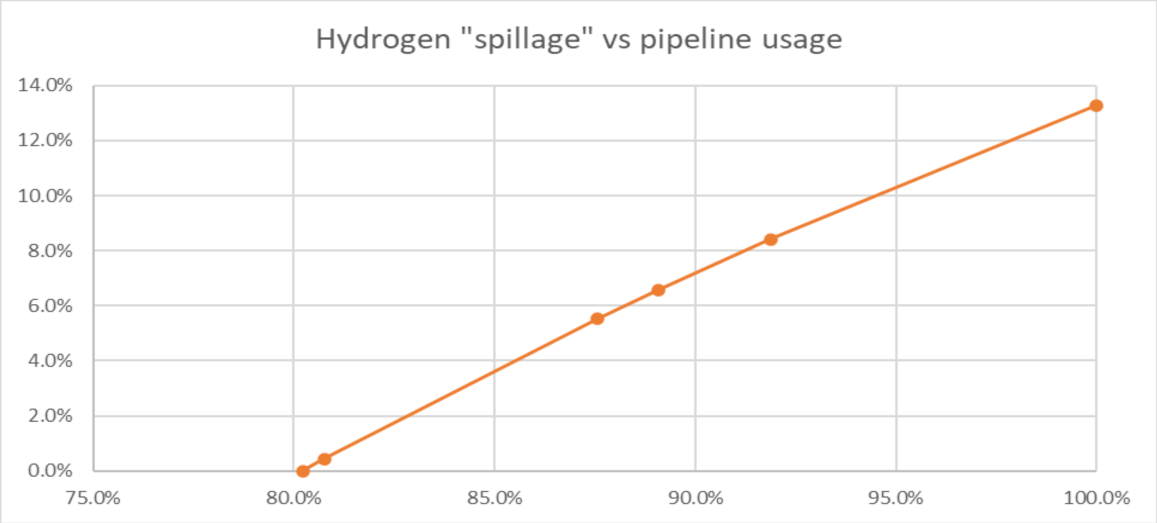
Case Study: Sizing electrolyser capacity based on average H2 production profiles
(example: Morocco, Fraunhofer PtX database).

Question: What is the relationship between installed electrolyser capacity and expected pipeline utilization?

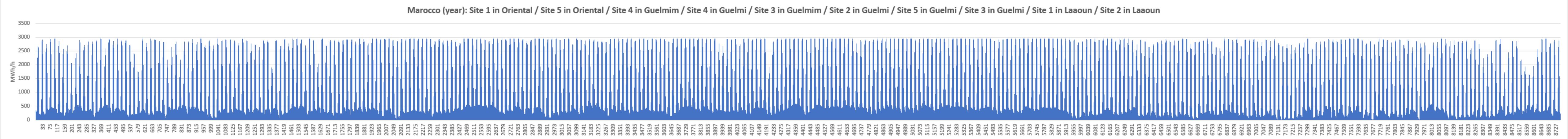
Starting assumption: Normalized electrolyser capacity (1.00 GW) and pipeline capacity (1.0 GW). RES sizing based on currently projected RES capacity for H2 production in Morocco.

Results: Oversizing electrolysers so that maximum average production is enough to use the full pipeline capacity for at least a day, week, month, half a year or the year increases “spillage” at a higher rate than pipeline usage.

Proposal: Only increase pipeline usage to 100% for long-term scenarios (2050) when alternative and domestic demand can be assumed.



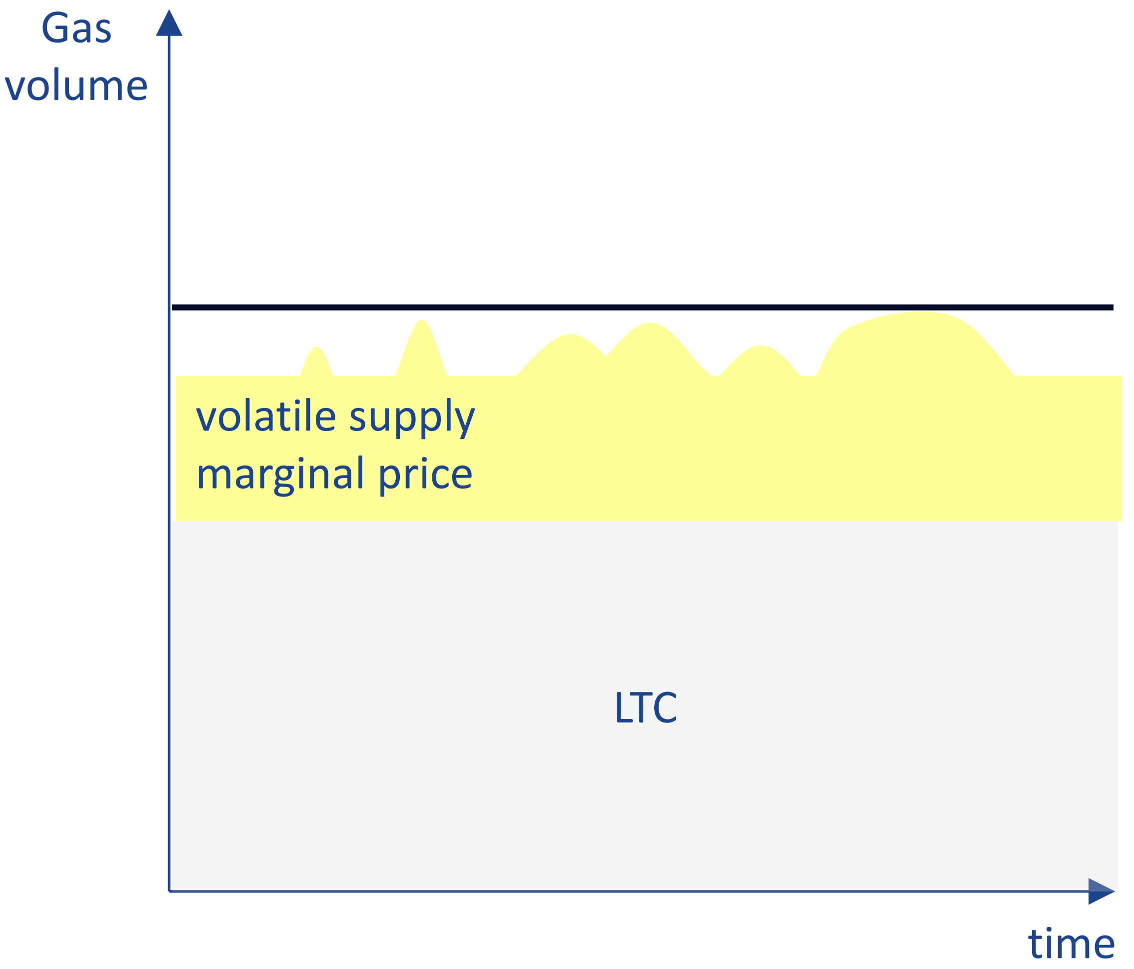
Considering daily average profiles			
max hourly flow	**pipeline usage**	**electrolyser capacity**	**spillage (of production)**
max daily flow	80.2%	1.00	0.0%
max weekly flow	80.8%	1.01	0.4%
max monthly flow	87.5%	1.16	5.5%
max quarter	89.1%	1.19	6.6%
max half year	91.9%	1.25	8.4%
flat yearly	100.0%	1.44	13.3%



Blue H2 pipeline import

	LTC band	Upper band
Volume	70 - 90 % of total approved volumes	Remaining
Profile	Flat	Flat
Price	reflecting long term contracts	Marginal or LCOH pricing approach*
Flex	No	Yes

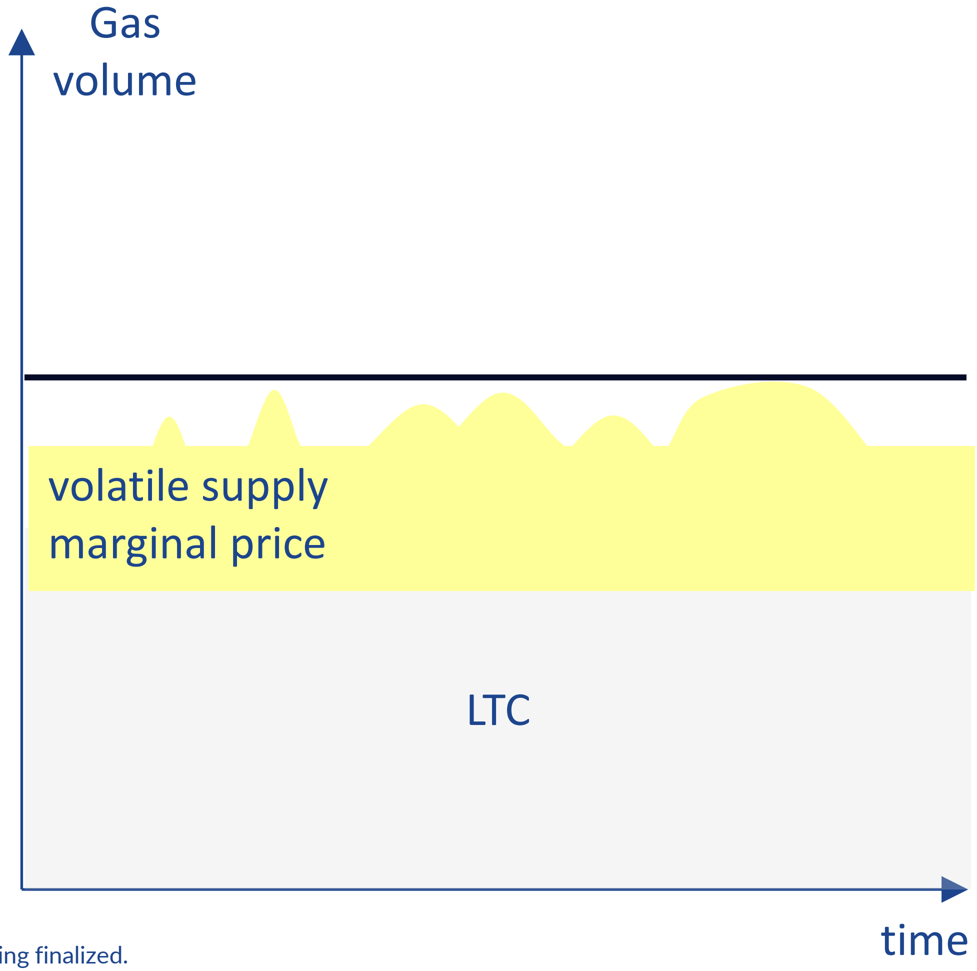
* Two options are presented as testing is ongoing and the methodology is still being finalized.



Not intended to be zero price, but to reflect competiteveness on marginal price formation

Shipped H2 import

	LTC band	Upper band
Volume	70 - 90 % of total approved volumes [projects]	Remaining projects + potential
Profile	Flat	Flat
Price	reflecting long term contracts	Marginal or LCOH pricing approach*
Flex	No	Yes, given the following constraints: - Seasonal: 5% in 2030; 15% in 2040; 30% in 2050 - Weekly: +/- 30%



* Two options are presented as testing is ongoing and the methodology is still being finalized.

It includes NH3, LH2 (and LOHC) carriers

Not intended to be zero price, but to reflect competiteveness on marginal price formation

EV Modelling Innovations

2026 Scenarios

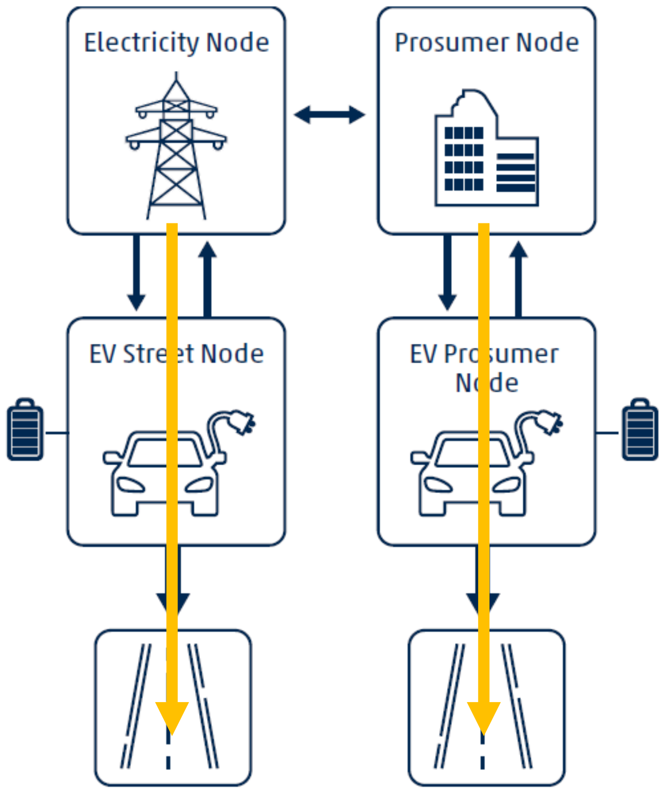
TYNDP24 DE/GA - EV modeling – Issues

TYNDP24 DE/GA dispatch model:

- **Battery Bypass Issue**: a significant portion (30-40%) of EV driving demand is met directly from the grid, bypassing the battery charging/discharging.
- **EV Charging Profiles**: Charging profiles show abnormal, very peaky patterns

→ **Very large flexibility of charging**

→ **New implementation has to decrease the charging flexibility of the EV fleets in the 2026 cycle**



TYNDP 26 Scenarios – EV modeling overview

Electric Vehicles

- **EV passenger cars →** modelled in the market modelling tool (PLEXOS) to capture the relation between market and flexibility. A share of them is considered unflexible and its charging (coming from DFT profiles) is modelled as Fixed Load in Plexos.
- **Trucks, Buses, Vans →** accounted in the electricity demand profiles (input for PLEXOS). They are modelled using one standard charging profile for all EU countries in the Demand Forecasting Tool.

New implementation

Plexos-native Implementation:

- Corrects battery bypassing (accurate energy balance).

Fleet Pooling Effects:

- Provides model with high flexibility on charging EVs
- Overestimates charging flexibility by virtually transferring charging between cars.

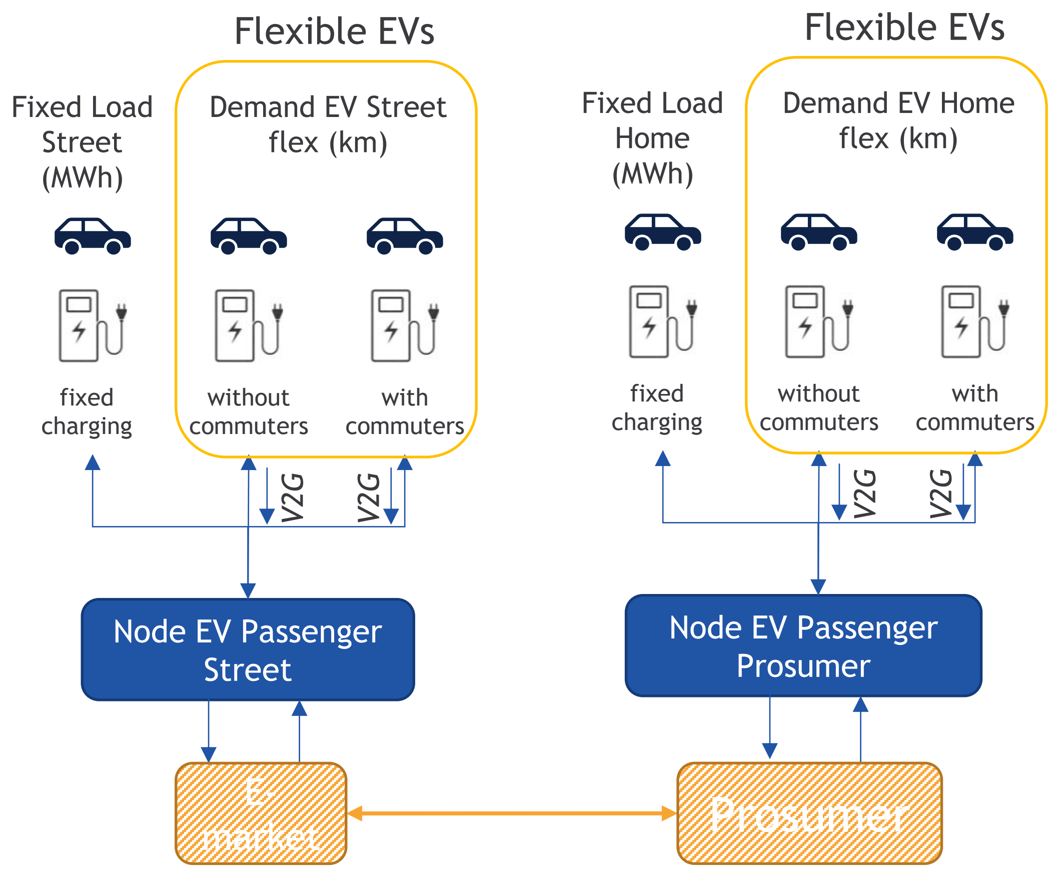
Fleet Segmentation:

- Introduce more fleets to reduce overestimation, e.g. "commuter" and "non-commuter" fleets.
- Commuter fleets avoid charging during office hours, reducing noon peak.

New implementation - modeling

- EV passenger cars modelled with 2 fleets:
  - **User-oriented fleet**: %EVs as Fixed Load from DFT
  - **Market-driven fleet**: %EVs optimized by Plexos
    - 50% With commuters – no charge at noon
    - 50% Without commuters

- Use of Plexos Trasport module:
  - EV
  - Charging Station
  - Demand (km)
  - Fixed Load (MWh)



New implementation - parameters

ELECTRIC VEHICLES PROPERTIES	2030	2035	2040	2050
Fleet type (% EVs)	Survey	Survey	Survey	Survey
Battery Capacity (kWh/EV)	79	81	83	100
Efficiency (Wh/km)	ETM	ETM	ETM	ETM
Transport Demand (km/EV)	ETM	ETM	ETM	ETM
Number of EVs (#)	ETM	ETM	ETM	ETM
Max Charge/Discharge Rate (kW/EV)	7.4			
Initial SoC (%)	50			
Min SoC (%)	TYNDP24			
Availability Profiles (%)	TYNDP24			
Driving Profiles (%)	Updated*			
Street/Home split (%)	30/70			

CHARGING STATIONS PROPERTIES	Home	Street
Max Charge/Discharge Rate (kW/station)	7.4	16
Use of Station Charge (EUR/MWh)	30	35
Charge/Discharge Efficiency (%)	94	94
Number of Stations per EV (#)	1 station – 1 EV	1 station – 2 EVs
Vehicle-To-Grid ratio (%)	Survey	Survey

TSOs Survey

Fleet type	Fixed Charging (%) (DFT)	Optimized Charging (%) (PLEXOS)
Market Driven	30	70
Balanced	50	50
Users Oriented	70	30
Business As Usual	85	15

	V2G (%)	2030	2035	2040	2050
Home	Low flexibility	0	5	10	20
	Medium flexibility	15	20	25	35
	High flexibility	30	35	40	50
Street	Low flexibility	0	1.5	3	5
	Medium flexibility	0	3.5	7	15
	High flexibility	0	5	10	20

*REM 2030 Driving Profiles Database

Introduction to EV Fleet Flexibility

Sources of Flexibility:

- Smart Charging: When to charge
  - **Key Component: Major source of flexibility in our approach.**
  - Charging EVs during off-peak hours or when renewable energy is abundant helps integrate RES generation and reduce peak demand.
  - Cost Savings: EV owners can take advantage of lower electricity rates during off-peak times, reducing overall charging costs.
- Vehicle-to-Grid (V2G): Discharging electricity back to the grid
  - **Smaller Component: so far unclear participation rate and technical feasibility**
  - V2G can provide additional power during peak demand periods
  - EVs can act as mobile energy storage units and EV users can benefit of price deltas during the day

EV Fleet Flexibility Approach

Flexibility Share: Defines the proportion of EVs with flexible charging profiles, that will be used in the market model tool (Plexos) optimization

Four Values per target year possible:

- Market Driven: 70%
- Balanced: 50%
- Users Oriented: 30%
- Business As Usual: 15%

Impact: Higher flexibility shares increase the ability to optimize charging times.

EV Fleet Flexibility Approach

Vehicle-To-Grid participation rate: Defines the proportion of EVs, with flexible charging profiles, that can discharge electricity back to the grid

Three types available:

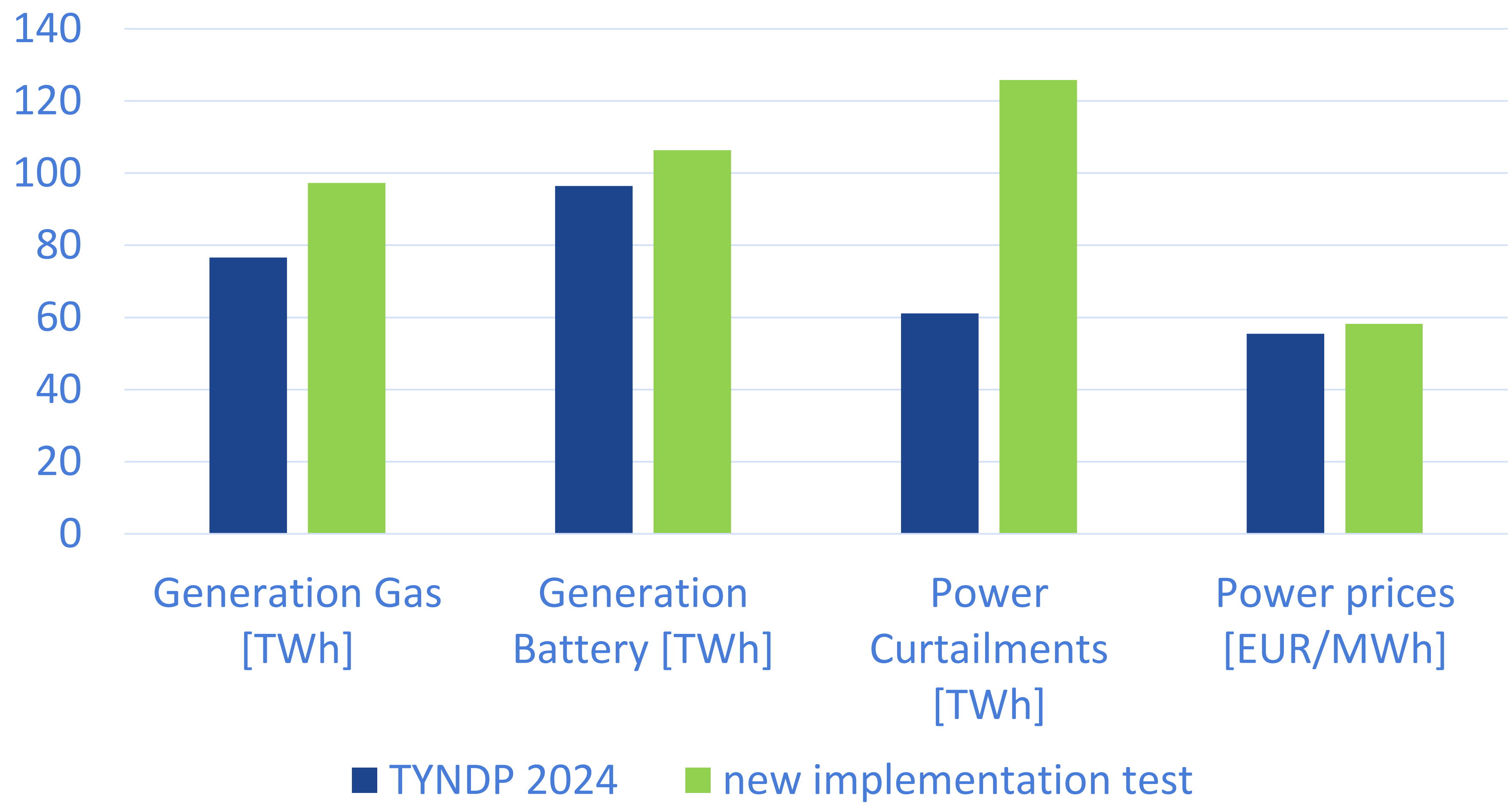
- Low flexibility
- Medium flexibility
- High flexibility

	V2G partecipation rate (%)	2030	2035	2040	2050
	Low flexibility	0	5	10	20
Home	Medium flexibility	15	20	25	35
	High flexibility	30	35	40	50
	Low flexibility	0	1.5	3	5
Street	Medium flexibility	0	3.5	7	15
	High flexibility	0	5	10	20

Impact: Higher V2G ratio increases the flexibility of the electricity system.

Note: The V2G ratio applies only to flexible electric vehicles (EVs). For example, in a balanced fleet where 50% of EVs are flexible, and the TSO opts for medium flexibility, the EVs available for V2G at home in 2030 would be calculated as:
Total number of EVs at home × 50% (flexible EVs) × 15% (V2G ratio in 2030 at home)

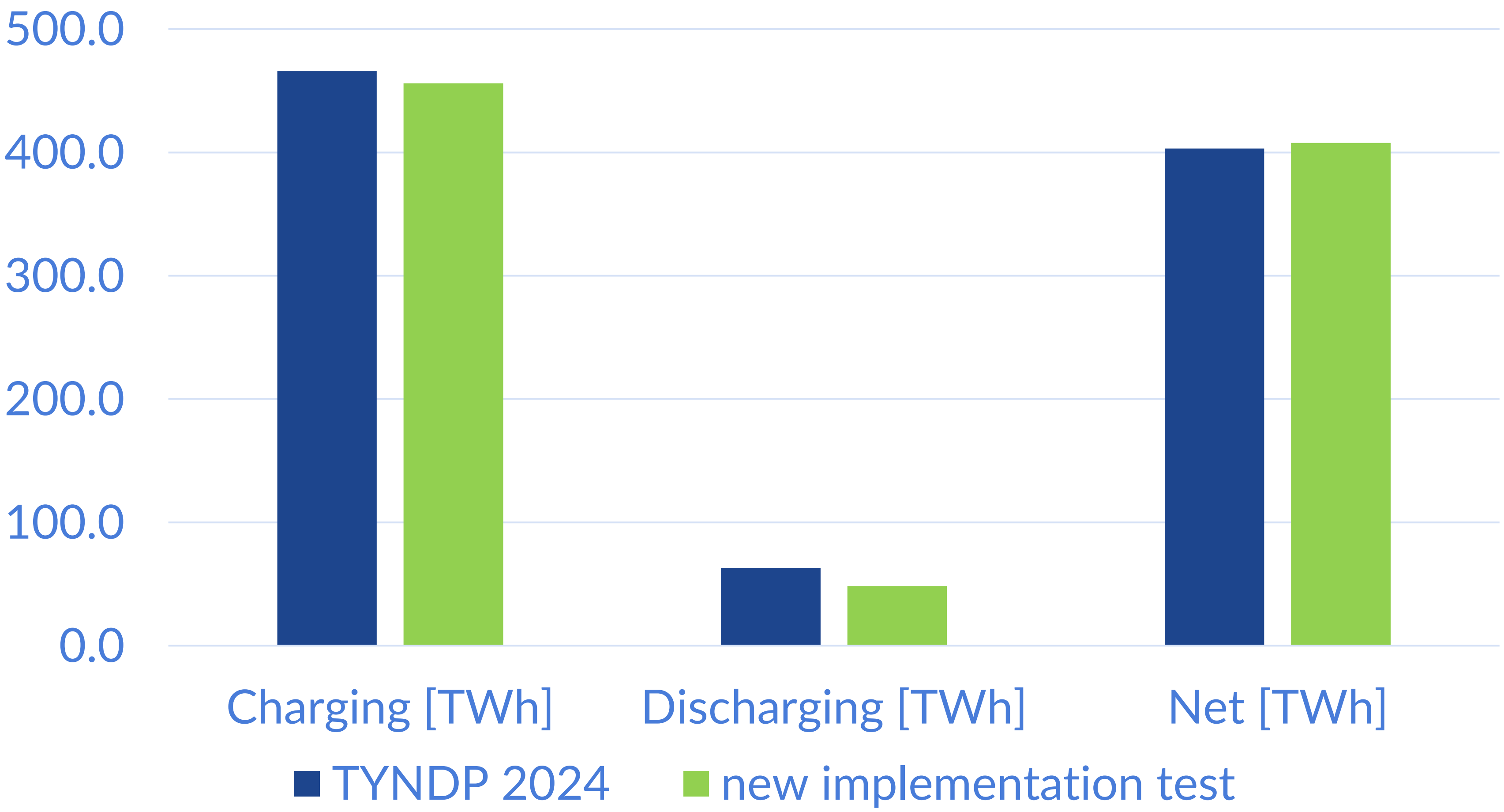
Flexibility criteria – sum of all countries



Measures indicate that model has less room to integrate RES and has less flexibility in new model versions

Scenario Distributed Energy, Target Year 2040, WY 2009

Vehicle to grid – sum of all countries



Vehicle-to-grid is a relatively small percentage and shrinking compared to previous cycle

Scenario Distributed Energy, Target Year 2040, WY 2009

Offshore modelling

Offshore Topology

TYNDP 2024

- It the previous cycle offshore wind was included as an expansion modelling requiring a complex topology and a multitude of data such as
  - Offshore Technology Split
  - Wider cost of infrastructure (e.g. substation)
  - Deeper technical analysis (e.g. bathymetry)
  - Investment information and trajectories

TYNDP 2026

- The investment models will no longer make decision on the capacities for offshore wind
- The topology, capacity and locations will be determined by a data collection
- The topology considered will mirror that of the electricity TYNDP 2024 models

Hybrid Heat Modelling

Heat Modelling

What are we modelling?

- Only flexible heating will be modelled.
- All other heat demand will be integrated into final demand profiles (power, gas)

- There will be connections to:
    - Electricity through electricity nodes
    - Hydrogen through hydrogen nodes
    - Methane through methane fuels object

COP Curve Design

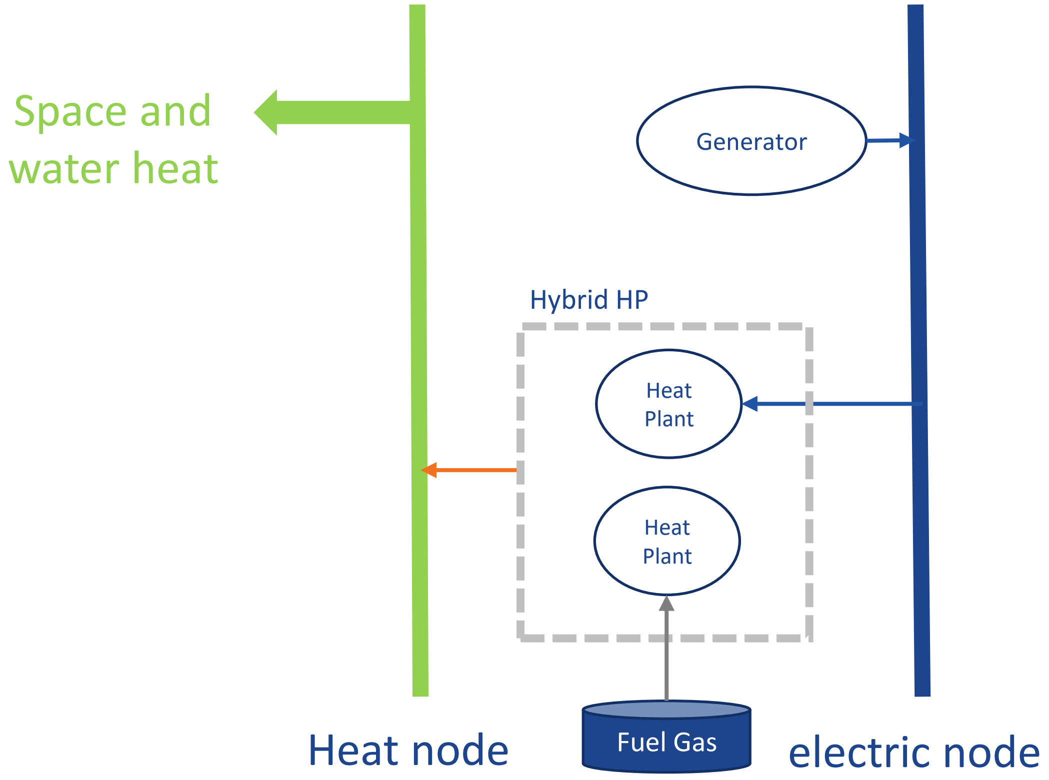
An individual hybrid COP curve will be created for heat pump in each country

Methodology:

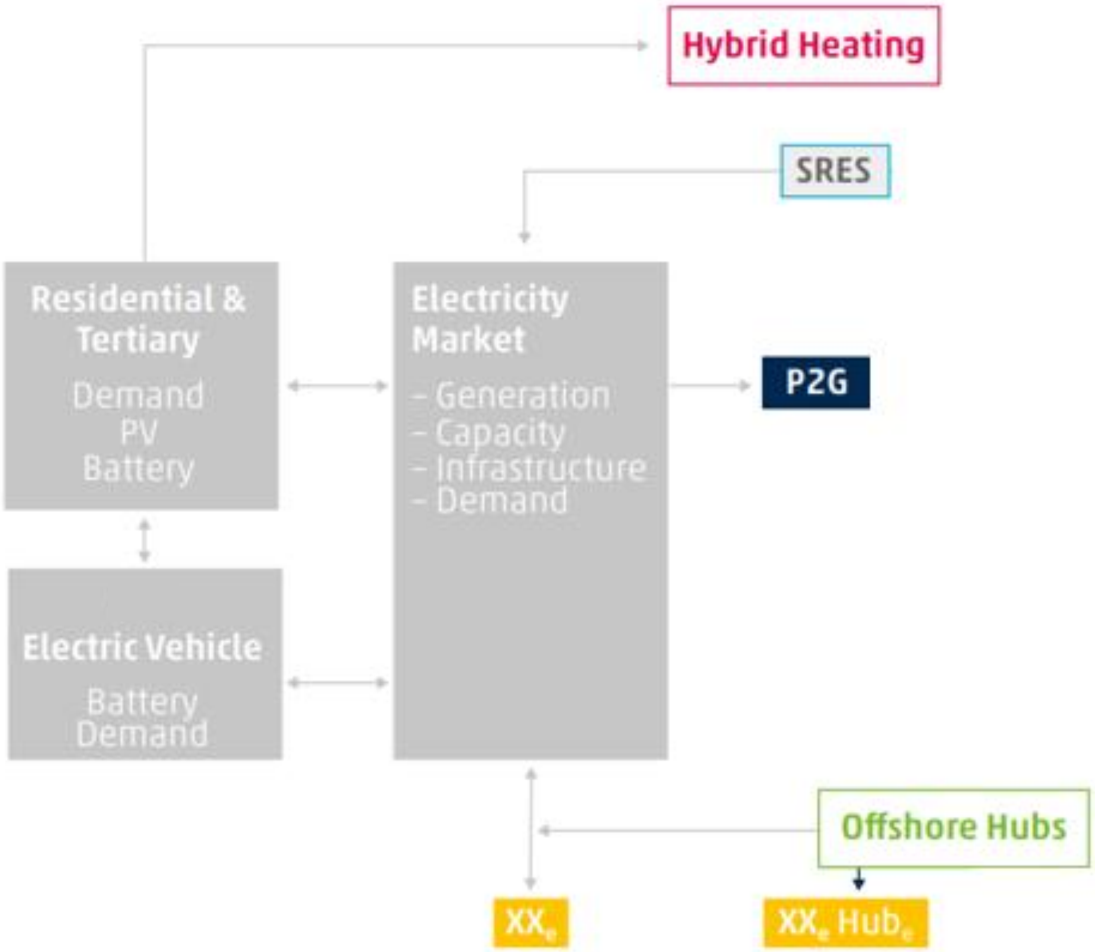
- Weighted capacity (%) of ASHP and GSHP in each country
- Create a hybrid COP curve for each country using the weighted capacities
- The equation of the curve can be extracted and used in a python script with temperature being the variable
- Extract country temperature profiles from DFT
- Create climate, country dependant COP curves for use in PLEXOS heat pumps

Hybrid Heat Modelling

- Each country will have 2 heat sources. Heat Pump & Gas Boiler
  - Heat pump and boiler capacities are sized to be able to cover peak demand
- The hourly demand timeseries for hybrid heat pumps will be extracted from the ETM inputs and decomposed
- A country based hourly COP curve will be used for heat pumps. Boiler efficiency is constant.



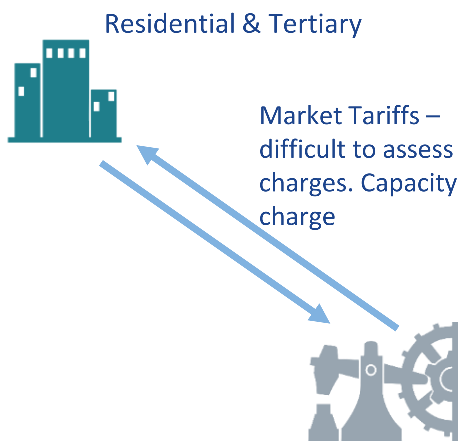
TYNDP 2026 Electricity Topology



Distributed Network – Rooftop PV

Represent each country as several nodes:

- Residential & Tertiary Homes
  - Rooftop solar & Batteries
  - Home charged EVs



There will be a price to provide electricity to prosumer dwellings.

These prices have been updated with the latest information from the datasets in Eurostat (2024).

Methodology for prosumer grid costs

- **Data Source**: The values will be taken from Eurostat, which provides cost information for Europe, including energy costs, network costs, taxes, levies, and VAT.

- **Calculation**: The annual values from 2024 will be used, categorized into energy, network costs, taxes, fees, and VAT. Network and excess costs were summed up to determine the prosumer wheeling charge.

- **Comparison**: The updated values for 2024 have been compared with the previous cycle (2022 values) to identify changes in energy prices, network costs, and taxes.