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WG1 Webinar

Sector Coupling

concepts, potentials and barriers

ETIP SNET

online, 24th June 2020

ETIP SNET PLAN. INNOVATE. ENGAGE.

Agenda and Speakers

A comprehensive overview on concepts & definitions
setting an overarching frame for assessing sector coupling initiatives

An unbiased description of state-of-the-art & development potentials
of Power-to-X technologies and processes

1. ETIP SNET and the role of WG1	JAN OKKO ZIEGLER	Enel, Italy
2. White Papers on Sector Coupling	ANTONIO ILICETO	Entso-E, Italy
3. Framing and conceptual components	ANTONIO ILICETO	Entso-E, Italy
4. Power to Gas&Fuels	MARIE MUNSTER	DTU, Denmark
5. Power to Heat & Cooling	DANIEL MOLLER	DTU, Denmark
6. Power to Mobility	GORAN STRBAC	Imperial College, UK
7. Conclusions and take-aways	ILICETO & MUNSTER	
8. Q&A Session	Audience & Speakers	

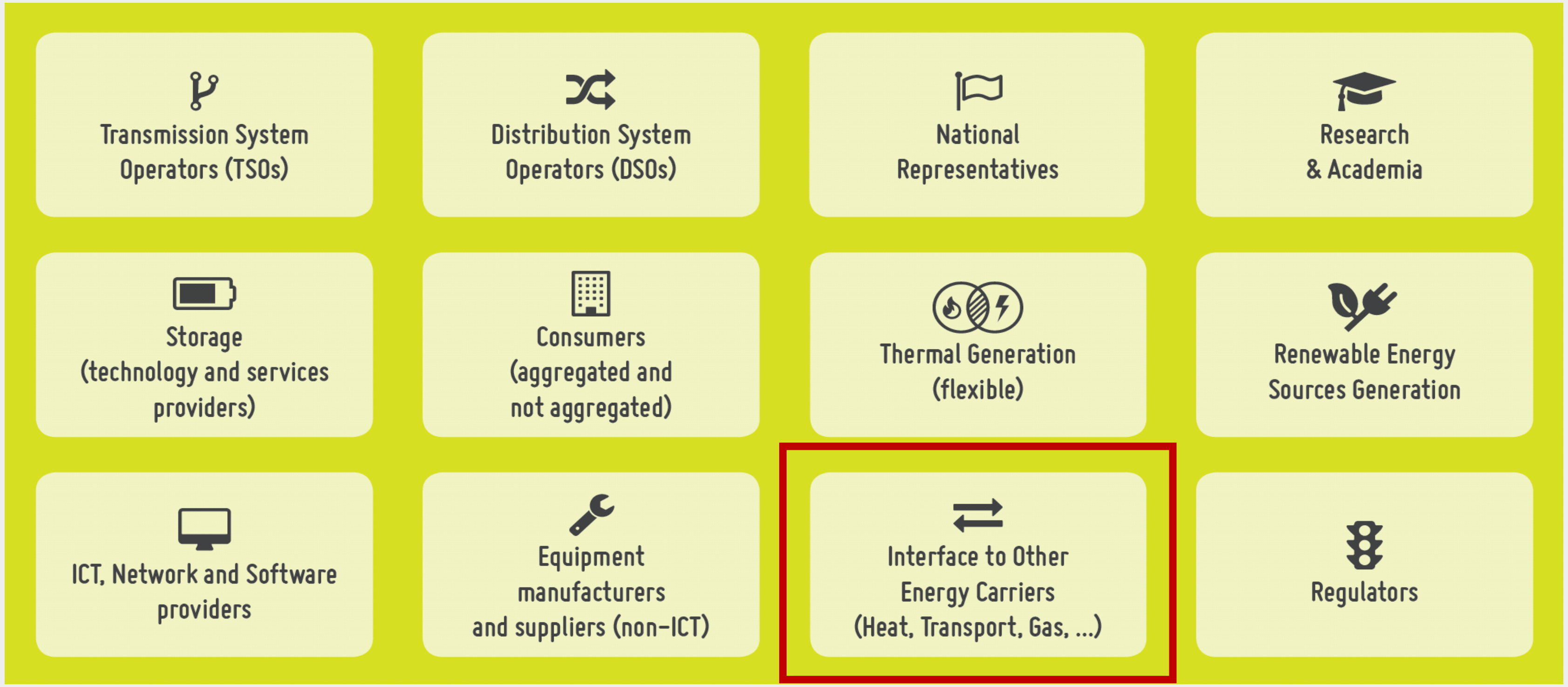
ETIP SNET and the role of WG1

Jan Okko Ziegler

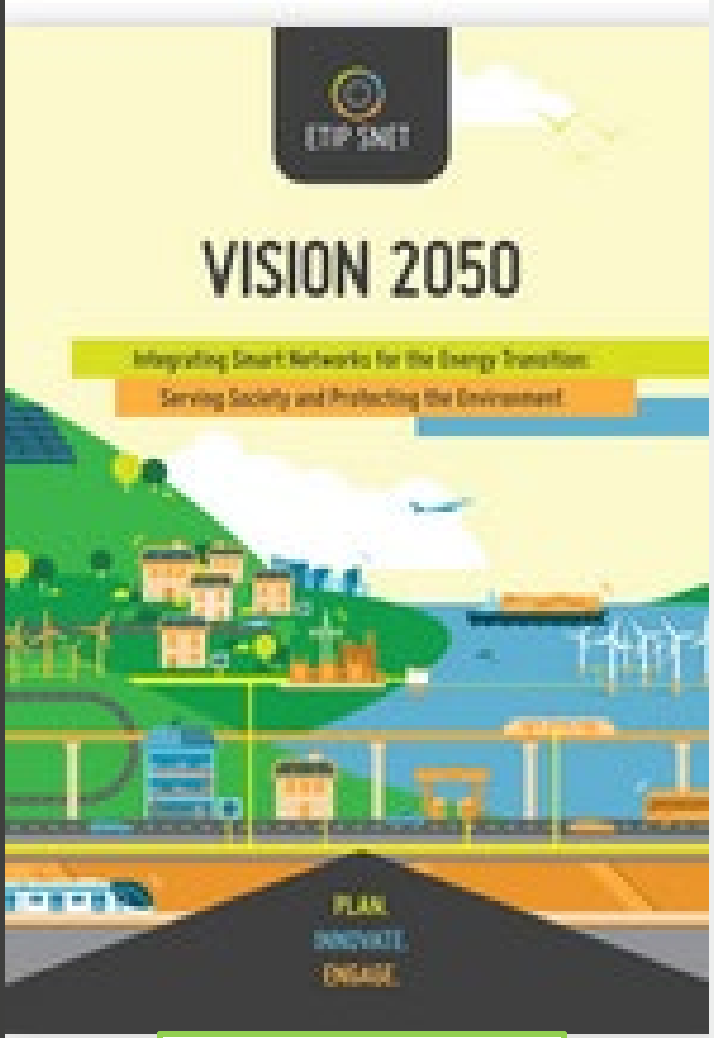
WG1 chair

ETIP SNET Mission and Stakeholders

- **Integrated approach** among all stakeholders of the energy value chain
- Exploit **synergies** and enhance **knowledge-sharing** on European RD&I
- Prepare **consolidated stakeholder views** as authoritative input to European Energy Policy initiatives



ETIP SNET Main documents for R&I priorities



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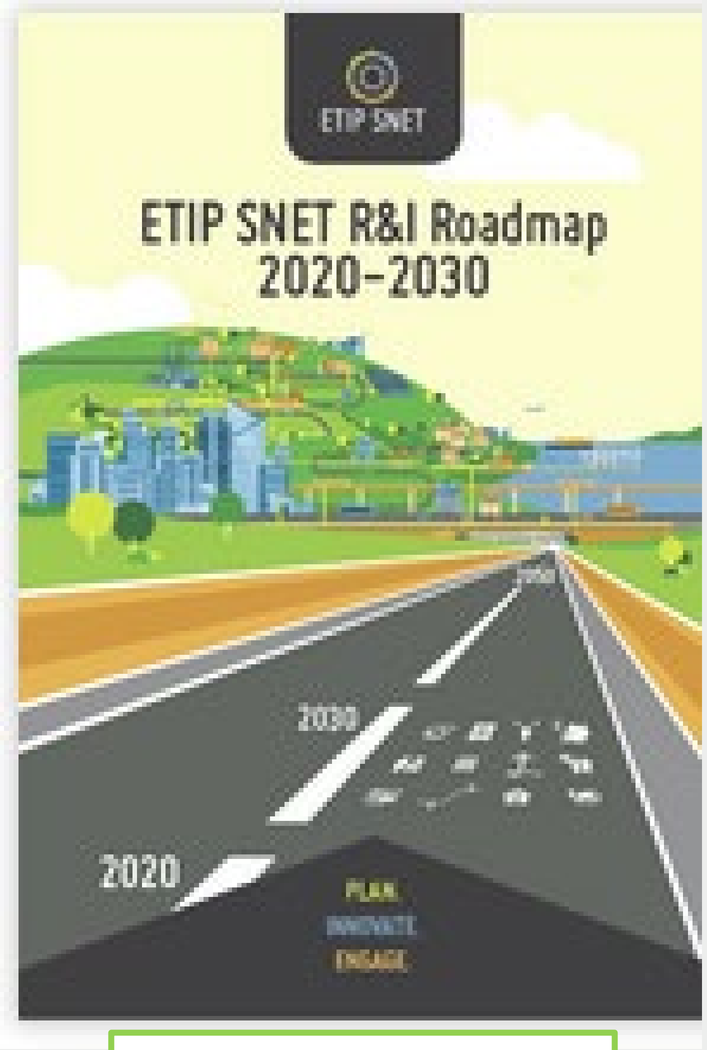


Published Feb 2020

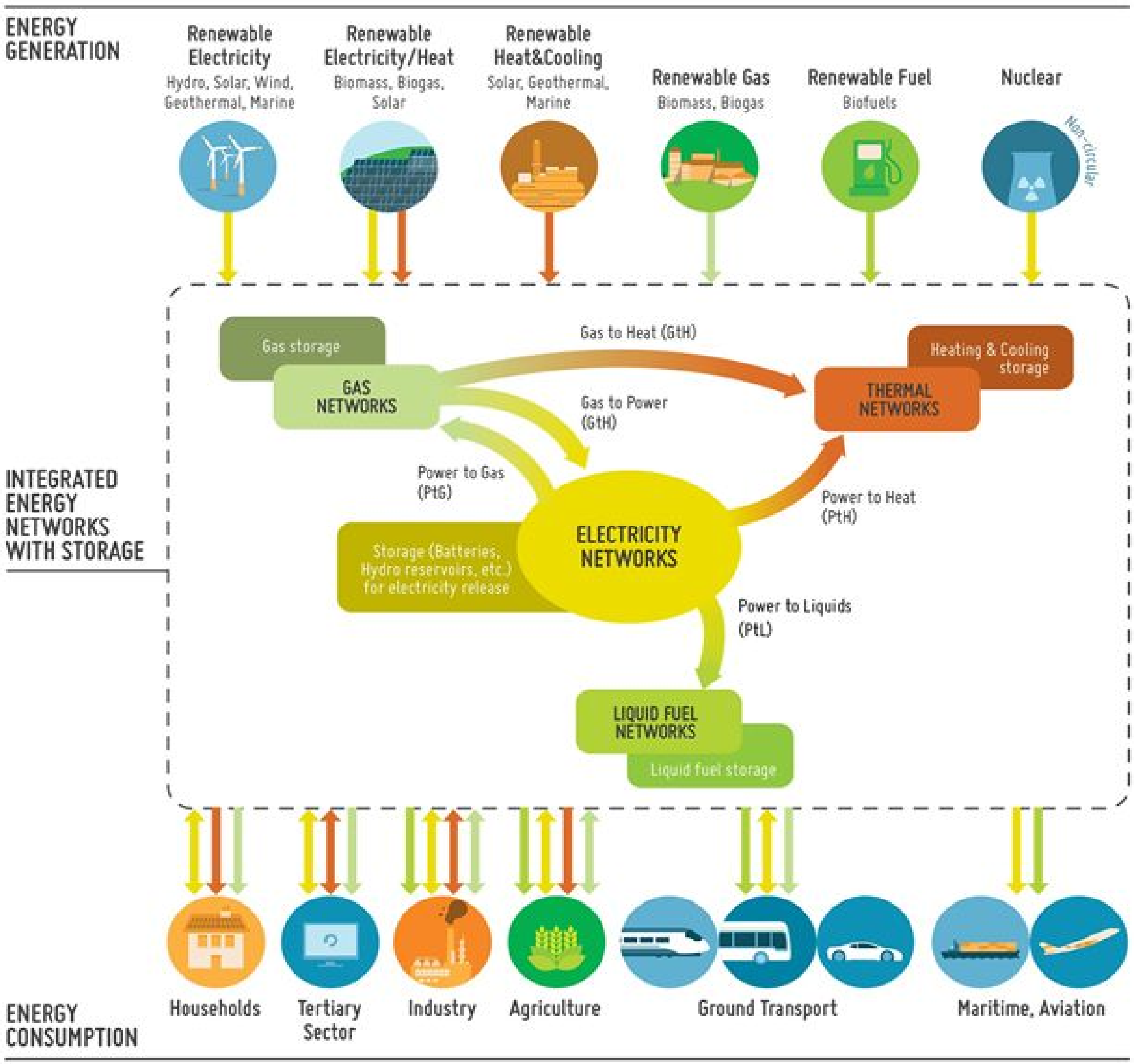
https://www.etip-snet.eu/wp-content/uploads/2020/02/ETIP-SNET-RI-Roadmap-2020-2030_WEB.pdf

Published 14th May 2020

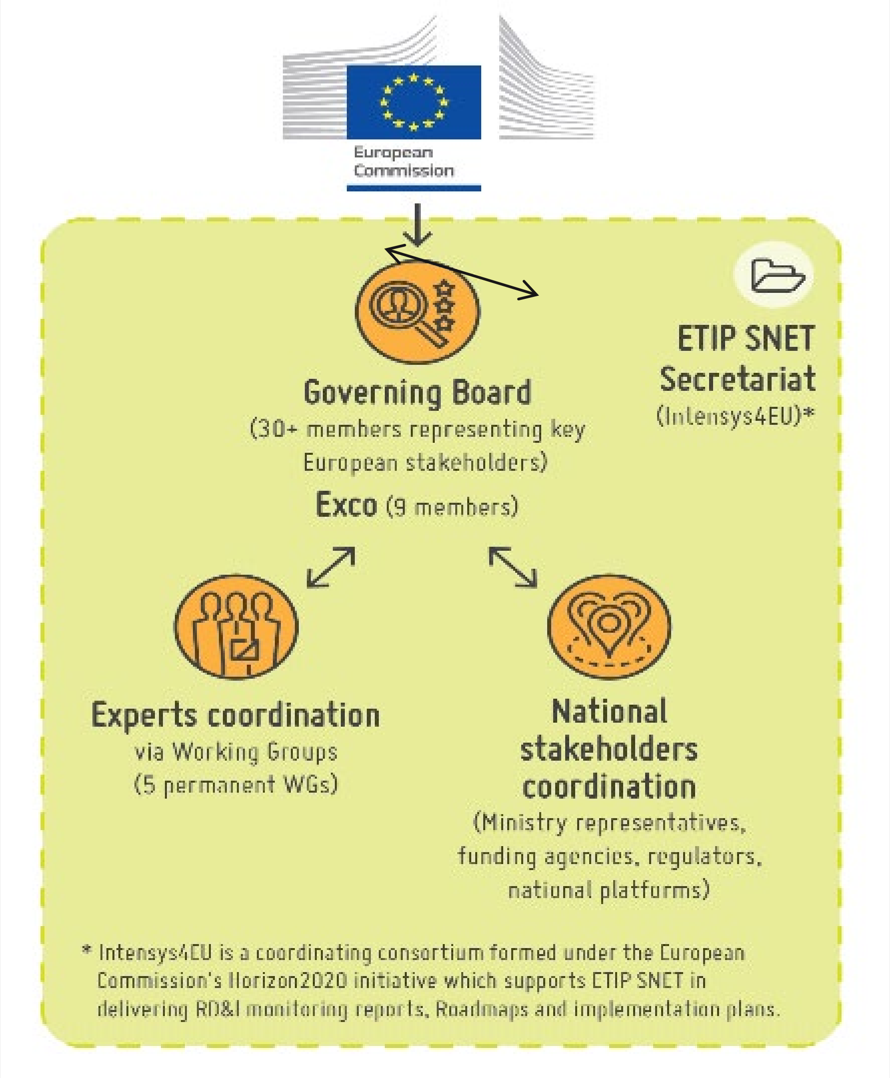
https://www.etip-snet.eu/publications/etip-publications/

Power system and grids as backbone of the energy transition

- A very extensive electrification of (nearly) all sectors of the energy system
- Europe to target global leadership in Renewables deployment
- Deep energy efficiency improvements in all sectors
- Extensive use of carbon neutral fuels
- Adoption of a widely circular approach
- Sustainable buildings
- Progressive societal changes
- Widespread digitalisation



ETIP SNET Organisation



WG1
Reliable, economic and efficient smart grid system

WG2
Storage technologies and sector interfaces

WG3
Flexible Generation

WG4
Digitisation of the electricity system and customer participation

WG5
Innovation implementation in the business environment

NSCG
National Stakeholders Coordination Group

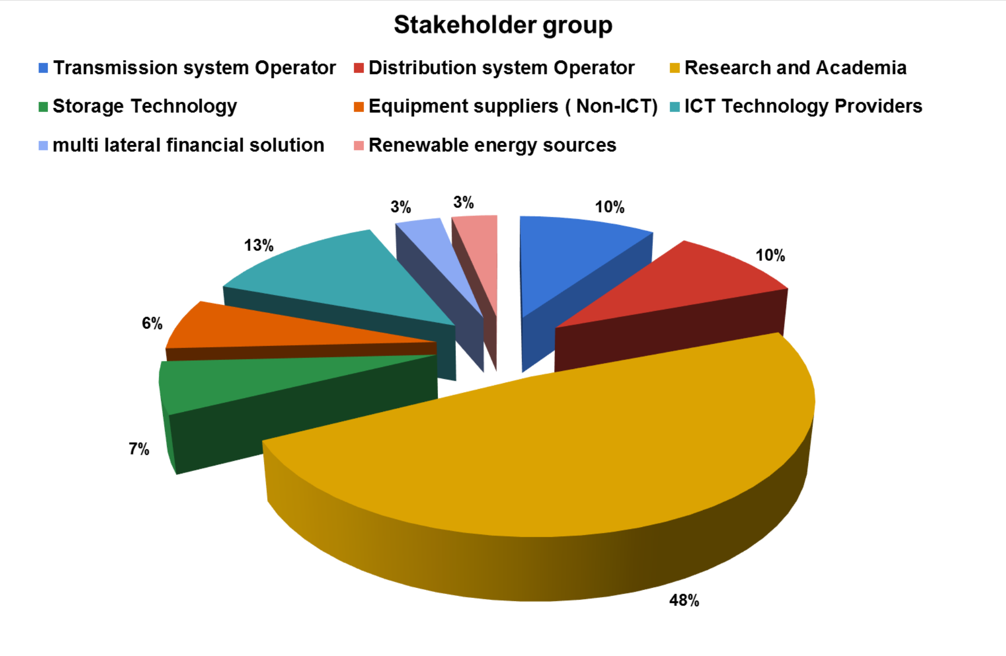
Working Group1: Reliable, economic and efficient smart grid system

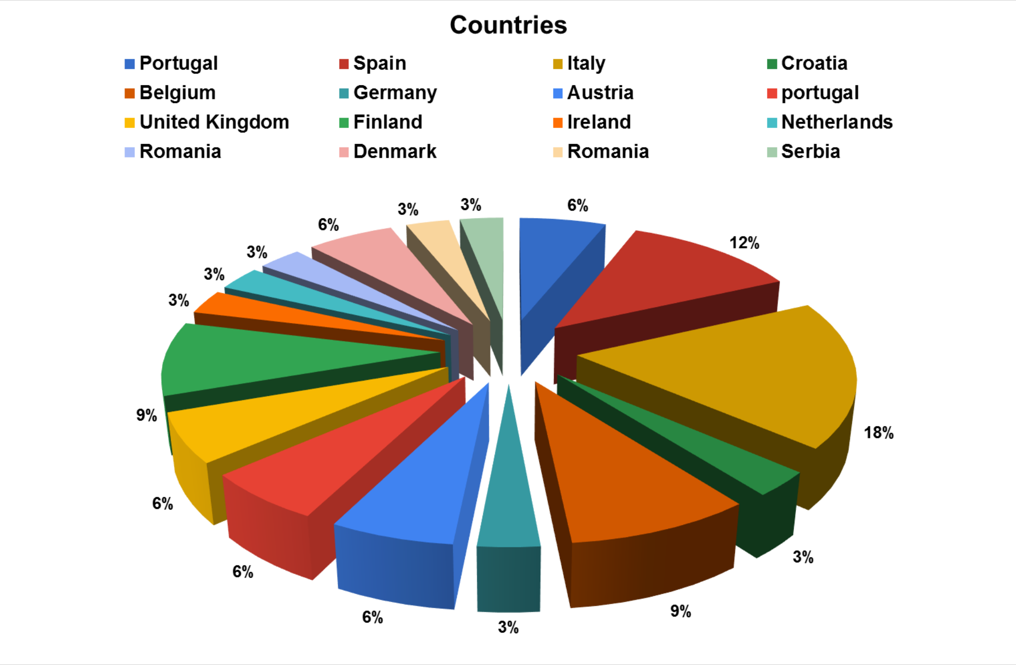
- WG1 focuses on the business and technology trends contributing to the overall energy system optimization at affordable costs

- It deals with system aspects, addressing the main functionalities, quality and efficiency of the electricity system as such and consider the benefits of its integration with the other energy vectors

WG1 Members

	Surname	Name	Company	Stakeholder group	Country
1	Amann	Guillermo	T&D EUROPE	Equipment suppliers (Non-ICT)	Spain
2	Berger	Mathias	University Of Liege	Research and Academia	Belgium
3	Bermudez Llamusi,	Victor	REE	transmission system operator	Spain
4	Carrilero Borbujo	Isabel	Sodena	Storage Technology	Spain
5	Constantinescu	Norela	ENTSO-E	TSO	Belgium
6	Del Grosso	Filippo	Università di Trento	Research and Academia	Italy
7	Ernst	Jan-Hendrik	reactive technologies	ICT Technology Providers	Germany
8	Frydas	Nick	IFC	Multi-lateral Financial Institution	Serbia
9	Giannelos	Spyros	Imperial College London	Research and Academia	United Kingdom (UK)
10	Hasanpor Divshali	Poria	VTT	Research and Academia	Finland
11	Howitt	Mark	Storelectric.	Storage	United Kingdom (UK)
12	Iliceto	Antonio	Terna	TSO	Italy
13	Ilo	Albana	TU Wien	Research and Academia	Austria
14	Jimenez Chillaron	Lorena	ITE	Research and Academia	Spain
15	Kulmala	Anna	VTT	Research and Academia	Finland
16	Losa	Ilaria	RSE	Research and Academia	Italy
17	Marecek	Jakub	IBM Research	Equipment suppliers (Non-ICT)	Ireland
18	Mitcan	Daniel	Ampacimon	ICT Technology Providers	Netherlands
19	Munster	Marie	DTU	Research and Academia	Denmark
20	Otero	Santiago Jose	ENEL	DSO	Italy
21	Pastorelli	Michele	Politecnico di Torino	Research and Academia	Italy
22	Pöllänen	Tuuli	regeneralevante	Renewable	Finland
23	Radu	David	univeristy of Liege	Research and Academia	Belgium
24	Reisner	Manfred	actaron	Research and Academia	Austria
25	Samovich	Nathalie	Enercoutim	ICT Technology Providers	Portugal
26	Sanduleac	Mihai	Polytechnic University of Bucharest	Research and Academia;	Romania
27	Silva	Nuno	EFACEC	ICT Technology Providers	Portugal
28	Souza e Silva	Nuno.	nester	nester	Portugal
29	Tomsic	Zeliko	University of Zagreb	Research and Academia	Croatia
30	Wolf	Markus Wolf	EPRI International	Research and Academia	Switzerland
31	Zengin	Emre	gosb	DSO	Turkey
32	Ziegler	Jan Okko	ENEL	DSO	Italy

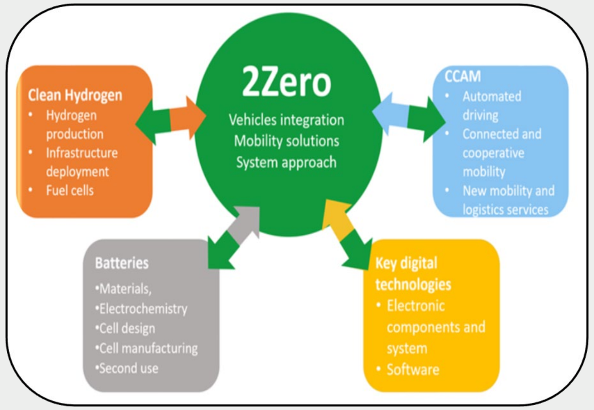




International cooperation

ENLIT Event

WG1 involved in organization committee of ENLIT conference



2Zero Partnership

WG1 is strongly involved in the core team of workstream “integration of EV into the grids”

CIGRE

Cooperation MoU established

ISGAN

A MoU was signed to prepare cooperation of topics of common interest (e.g. grid flexibility)

White Papers on Sector Coupling

ANTONIO ILICETO

WG1 co-chair

WG1 published a White Paper on Sector Coupling

- There are great **expectations** about the role of sector coupling, but it is unclear to which extent current technologies can provide on this agenda
- Sector coupling brings new opportunities as well as new challenges
- It requires a **mindset change and new metrics** in how to plan, operate and assess multi-energy projects
- This White Paper aims to elaborate on those questions, clarifying concepts, envisaging perspectives and **impacts on the grids**

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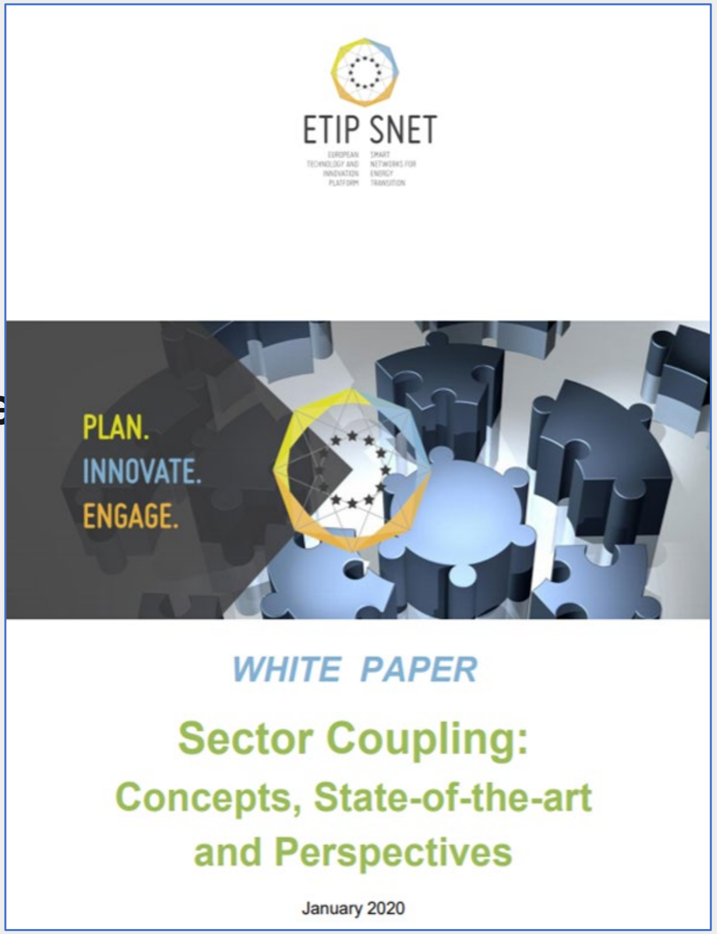

https://www.etip-snet.eu/wp-content/uploads/2020/02/ETIP-SNEP-Sector-Coupling-Concepts-state-of-the-art-and-perspectives-WG1.pdf

Scope and contents

Unbiased contribution to wide present debate:

- **Establish definitions, concepts and scoping/framing of sec coupling**
- **Focus on integration potentials, from an electric system perspective**
- **Technologies/processes covered:**
- **Role of storage, power to heating & cooling, to mobility, to gas/fuels**

For each technology:

- **State-of-the-Art of conversion technologies**
- **System integration potential**
- **Barriers to implementation and possible solutions**
- **Deployment prospects and impact of the most promising solutions**

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3.3 PTH IN INDUSTRY
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6 CONCLUSIONS AND RECOMMENDATIONS
6.1 CONCLUSIONS
6.2 RECOMMENDATIONS
7 APPENDICES

White Paper Sector Coupling 2

Paper Objectives :

- ✓ R&I Needs – timing budgets other considerations
- ✓ What are criteria for projects assessment. Overall system benefits with the single actor and an overall impact
- ✓ Tools and facilitators needs
- ✓ Subchapters conclusions/ main messages
- ✓ Excellence I Impact I Implementation
- ✓ Energy transition context focus
- ✓ Regulatory and market barriers

ETIP SNET

EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM SMART NETWORKS FOR ENERGY TRANSITION

WHITE PAPER

Sector Coupling beyond energy conversion

Building blocks, interoperability, evolving architectures, electricity hybridisation and economic assesment of use cases

(Tentative) fourth quarter 2020

Framing and conceptual components

ANTONIO ILICETO

WG1 co-chair

Beyond present concept of ‘residual load profile’

- **Evolution of electric system operating philosophy:**

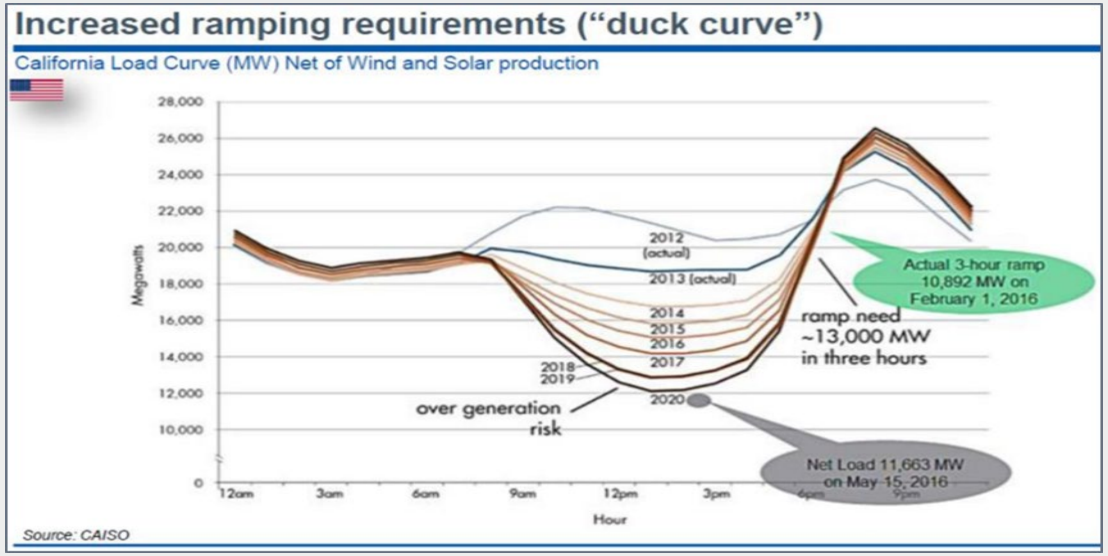
Generation follows Load

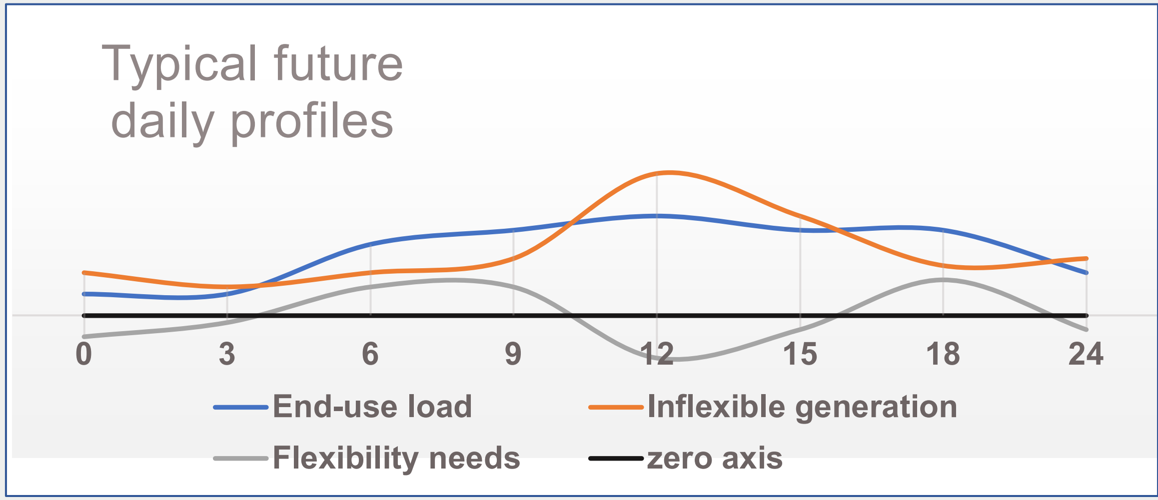
THE PAST → Load profile given as independent variable (inflexible load), generation has to follow the load

THE PRESENT → Residual load profile (total load minus variable RES generation) covered by traditional flexible generation + pioneering flexibility means

THE FUTURE → Generation profile given as independent variable (inflexible generation), so grid and load have to become flexible through a wide portfolio of flexibility means

Load follows Generation





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Many flexibility means are available, inside or outside the electricity system

- Main goal of power system management shall become:
  - Operation: how to best use and combine the many flexibility means available to maximise integration of RES generation having quasi-zero variable cost
  - Planning: optimise development of power grid in coordinated manner with development of many other indipendent actors and sectors: not only generation and load, but also new services and new interfaces → infrastructure optimisation, avoid stranded assets

Flexible Grid

- Extended use of grid components
- Interconnections
- Exchanges with neighbouring areas

Flexible generation

- Traditional plants' modulation
- Enhanced ancillary services
- Improved performances (ramps, response speed, capability range, start-stop sequences, duty cycles)

Flexible loads

- Demand response
- Interruptible customers
- Balancing services
- Aggregators
- Market & trading mechanisms
- **Smart EV charging**

Storage within electric system

- Grid batteries
- Fly wheels
- CAES/LAES
- Supercapacitors
- Pump Hydro
- **Vehicle-to-Grid**

Storage in other energy systems

- Thermal
- Thermochemical
- Molecules:
- Gases
- Liquid fuels
- Chemicals

Perimeter of Sector Coupling

Storage within electric system	Storage in other energy systems	Conversion interfaces with other industrial processes	Planning and/or operational coordination with other systems
- Batteries	- Electric vehicles →	- External control of charging/discharging →	- TRANSPORT & MOBILITY
- Fly wheels	- Thermal →	- Alternative energy source for heat/steam/freeze production for industrial uses and for buildings →	- DISTRICT & INDUSTRIAL HEATING/ COOLING
- CAES/LAES			
- Supercapacitors/ Supermagnetes	- Thermochemical →	- Alternative energy source for desalination and energy industry →	- DESALINATION & ENERGY INDUSTRY
- Pump Hydro → **Water basins management**	- Chemicals →	- Endo/Eso-thermic chemical reactions and no-losses energy storage →	- CHEMICAL INDUSTRY
	- Gases/Liquids →	- Electrolysis →	- HYDROGEN AS: ▪ INDUSTRIAL PRODUCT ▪ STORAGE MEAN ▪ ENERGY CARRIER
		- Electro-synthesys of Ammonia, Methanol →	- CHEMICAL INDUSTRY
		- Synthetic fuels with no-fossil production →	- FUELS INDUSTRY - METHANE/LNG GRID

SECTOR COUPLING: optimisation among multi-energy options for supplying final uses

ADVANCED SECTOR COUPLING: additionally, a CO2-free alternative option for energy transport, via certified green molecules

Storage, Flexibility, Sector Coupling, Power-to-X: not synonyms

System component -> Characteristics:	Pure load (traditional)	Flexible Load	Storage in electric sytem	Storage in other energy systems	Molecules (chemicals & gases)
Energy Conversion / Electric End Use	End Use	End Use	Conversion	Conversion	Conversion
Energy Flow reversible	NO	NO	YES	YES	YES
Controlled by electricity operators	YES	YES	YES	NO	NO
Providing storage capabilities	NO	NO	YES	YES	YES
Providing flexibility capabilities	NO	YES	YES	YES	YES
Energy carrier capabilities	NO	NO	NO	NO	YES

Storage, Flexibility, Sector Coupling, Power-to-X: not synonyms

System component -> Characteristics:	Pure load (traditional)	Flexible Load	Storage in electric sytem	Storage in other energy systems	Molecules (chemicals & gases)
Energy Conversion / Electric End Use	End Use	End Use	Conversion	Conversion	Conversion
Energy Flow reversible	NO	NO	YES	YES	YES
Controlled by electricity operators	YES	YES	YES	NO	NO
Providing storage capabilities	NO	NO	YES	YES	YES
Providing flexibility capabilities	NO	YES	YES	YES	YES
Energy carrier capabilities	NO	NO	NO	NO	YES

SECTOR COUPLING

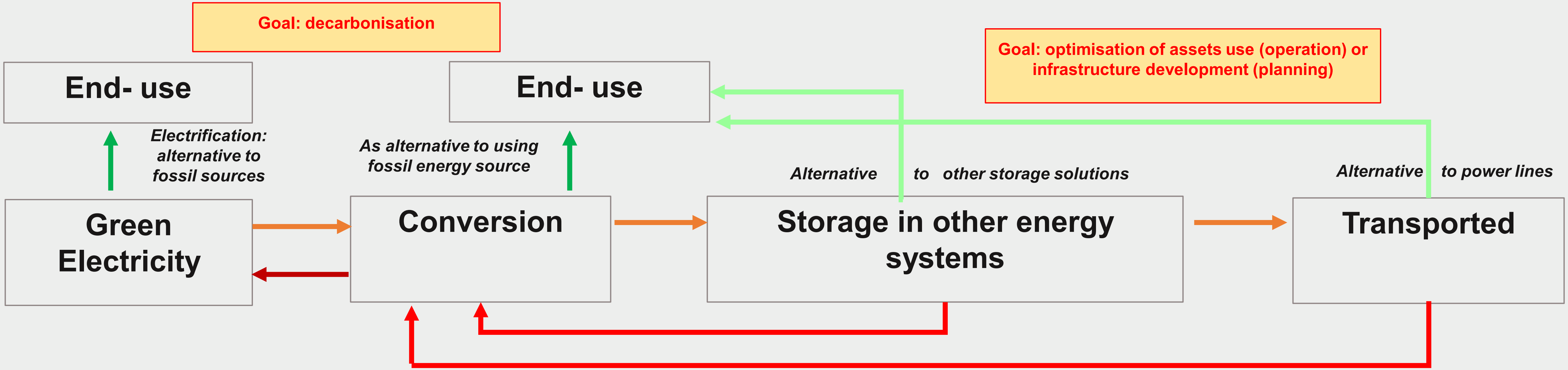
POWER – TO - X

Storage

Flexibility

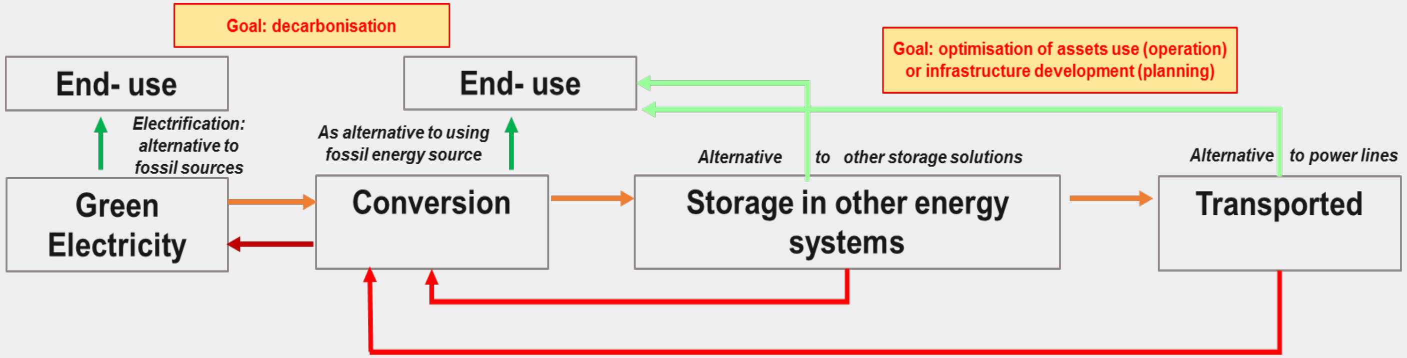
Energy carrier

Conceptual components & rationale of Sector Coupling



- ➢ Energy **conversion** process towards an adjacent energy sector, where energy can follow different paths:
  - **stored** more easily than within the electric system, for successive re-conversion to electricity: shift in time and in some cases also in space
  - **consumed**, if it is cheaper/cleaner than other energy sources typical of that sector, either temporarily (operational optimisation) or permanently (**electrification**, which increases the amount of coupling potentials)
  - **transported,** in some cases where transport performances can be higher than transmitting electricity
  - **re-converted** for final use, but with multiple losses (conversion+reconversion+transport+storage losses)
- ➢ Electrification of end-uses in itself **is not coupling** separate energy sectors, but it can bring more flexibility and decarbonisation

General principle to assess sector coupling projects



* Techno-economic, at LCA level

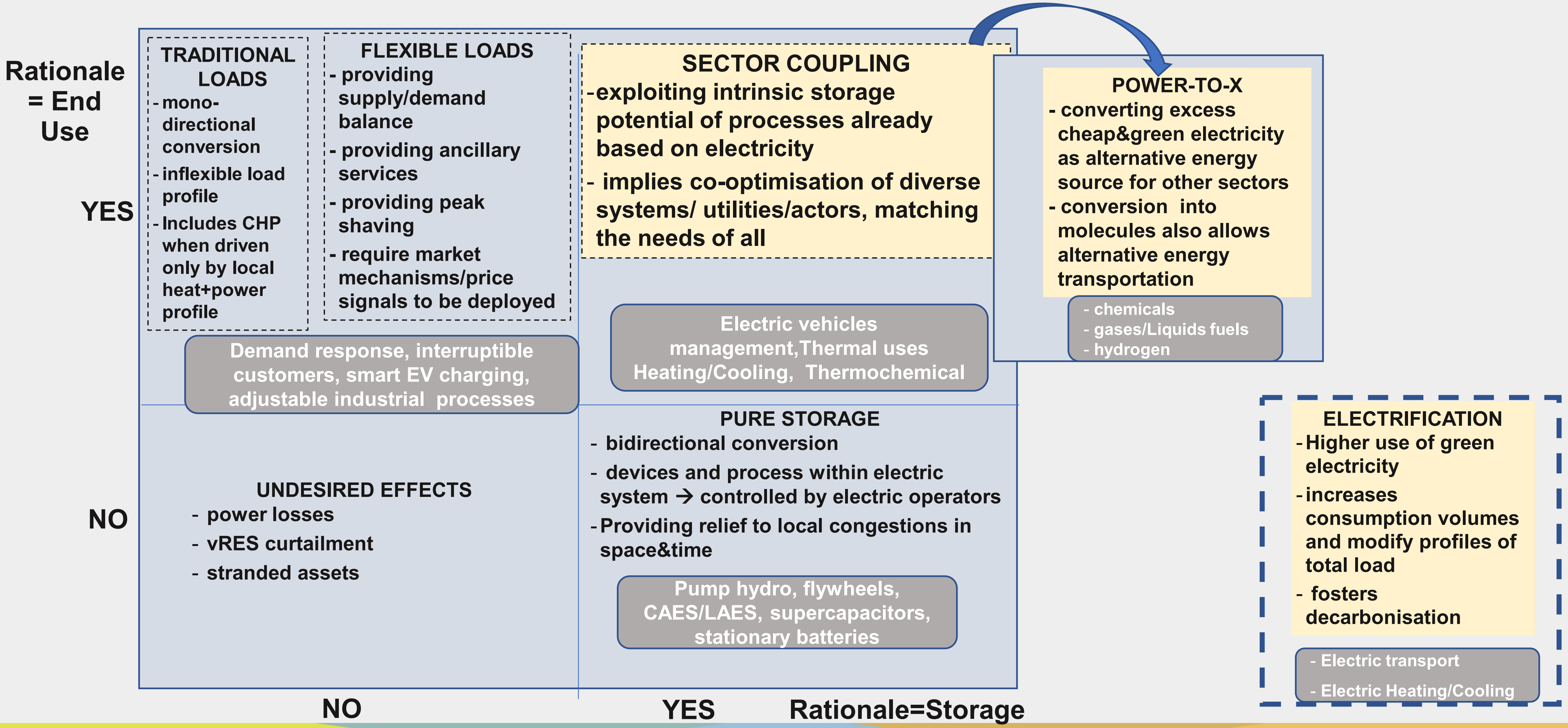
- Many combinations of the above options are possible → sector coupling is a complex multi-variables optimisation problem, with the objective of minimal cost, with given goal (decarbonisation and/or assets optimization) and boundary conditions

- Any proposed project/initiative must be assessed for costs & performances vs the best alternative to achieve the same goal → definition of the use case, then evaluation of the business case

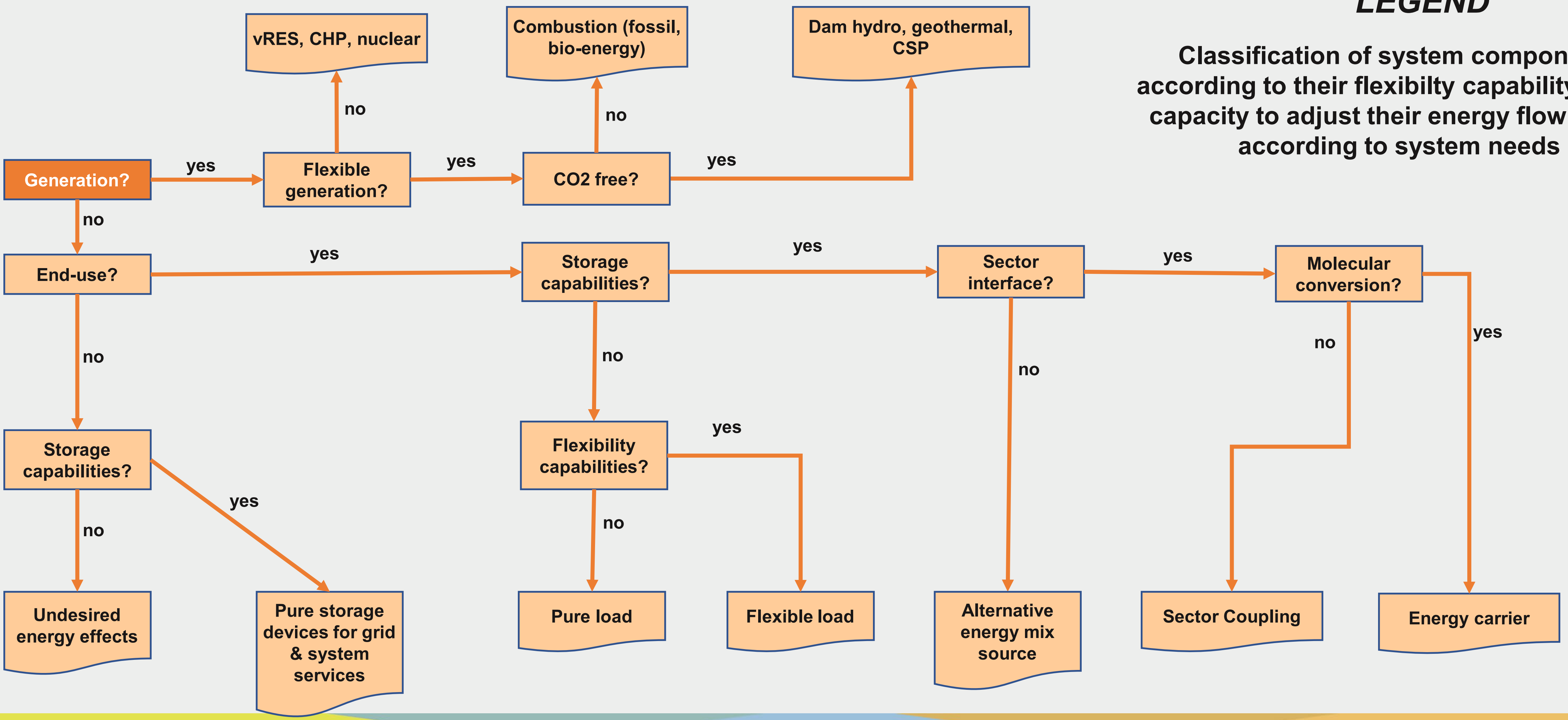
- Assessment must include externalities (positive and negative, not only CO2) and possibly on life-time horizon, from raw materials supply to dismissal/disposal (Life Cycle Assessment)

- Assessment must consider conversion (double conversion if back to electricity and multiple if logistic is included) costs and losses in realistic duty cycles as well as proper valorisation of the perfomances

Matrix Taxonomy of electricity end-uses



Taxonomy based on flexibility features



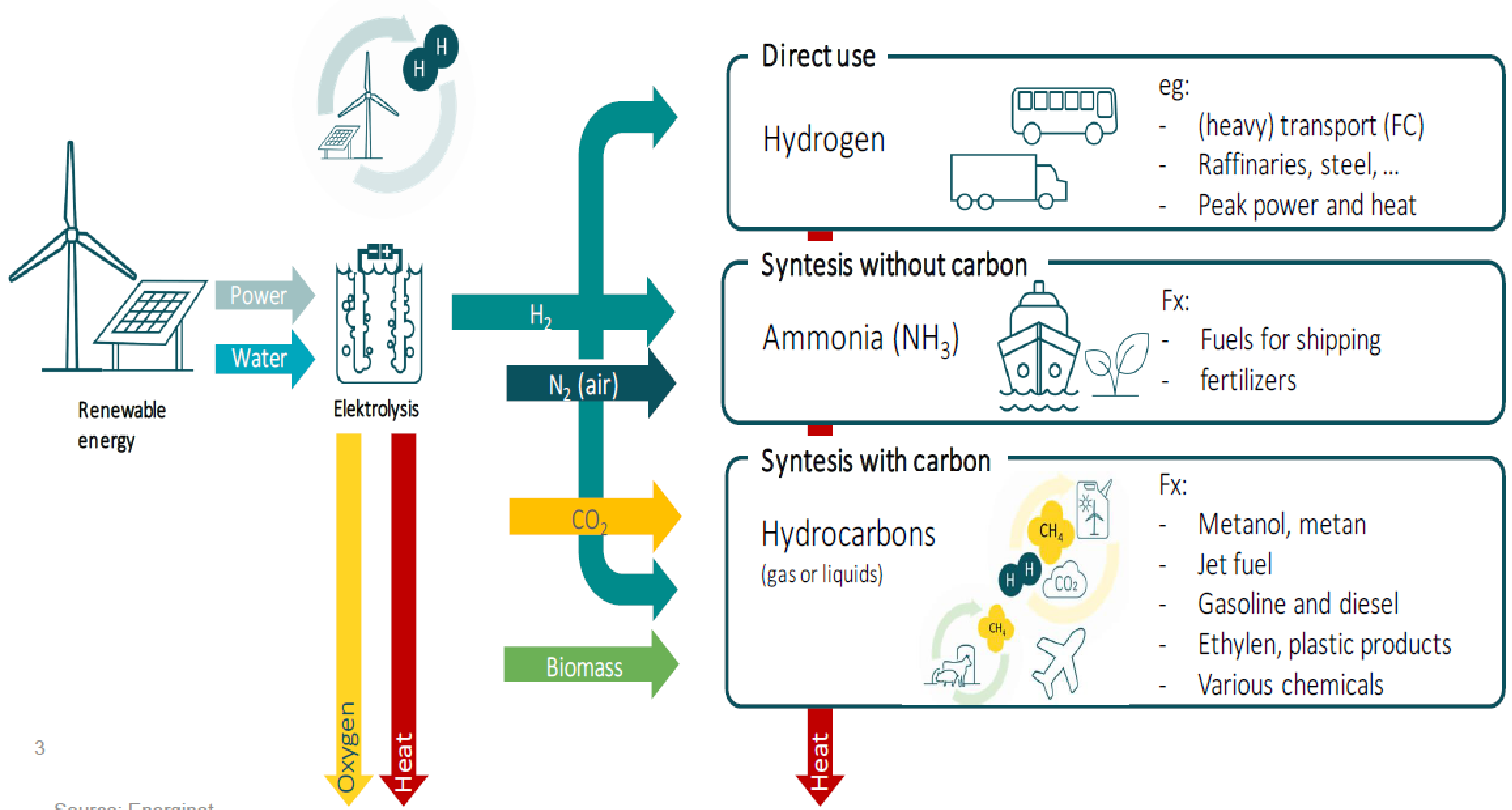
LEGEND

Classification of system components according to their flexibilty capability, i.e the capacity to adjust their energy flow profile according to system needs

Power to Gas&Fuels

MARIE MUNSTER

Leading Author of White Paper



Source: Energinet

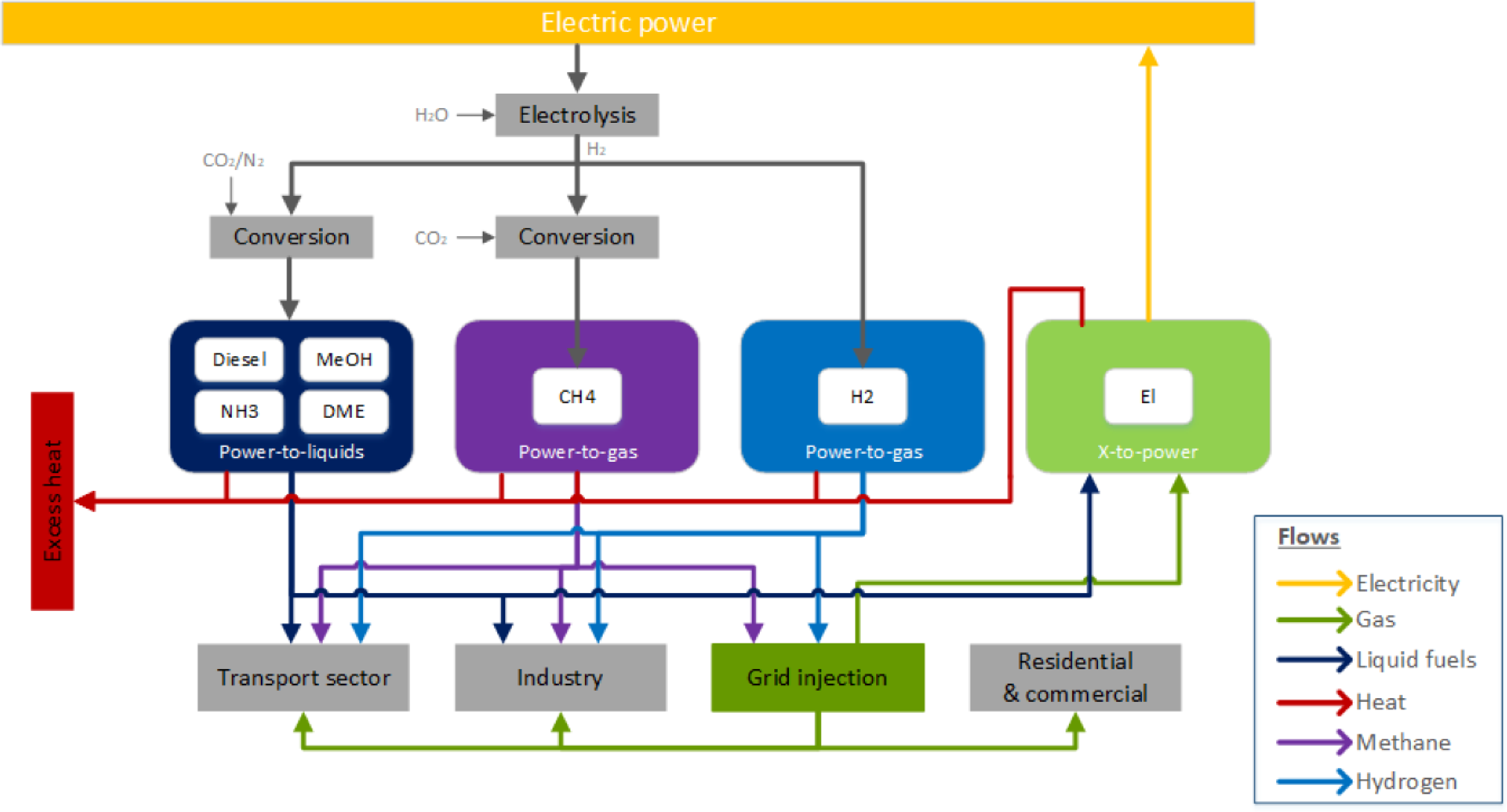


Figure 5.1: Power-to-X concept. Based on (European Commission 2018)

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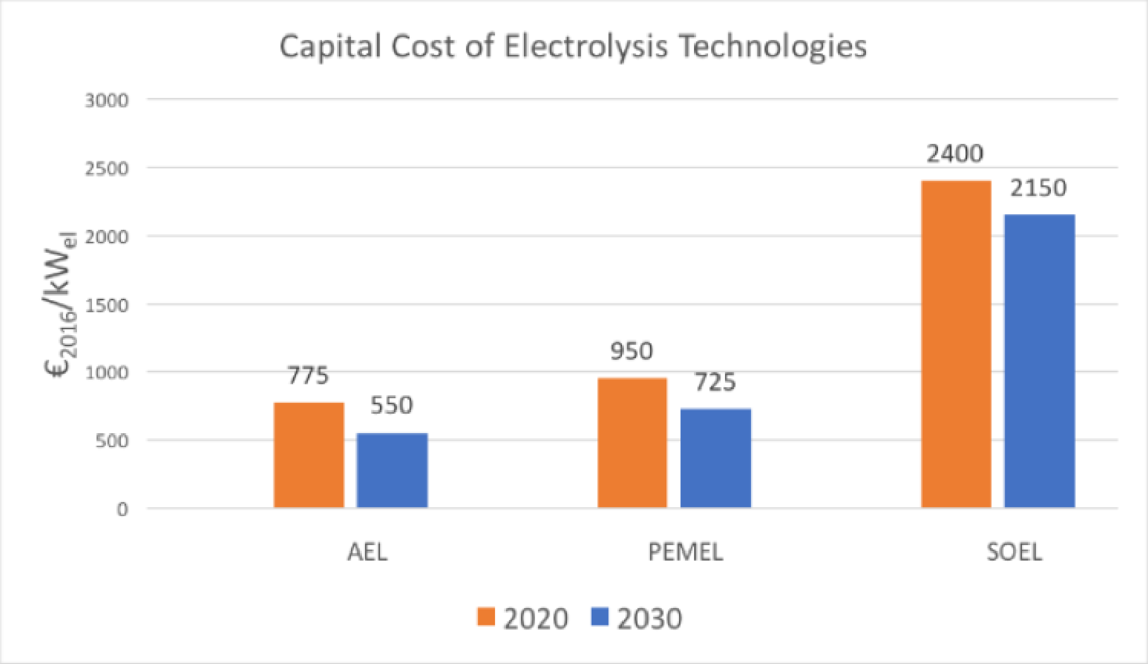
COST



EFFICIENCY

	AEL	PEMEL	SOEL
Stack	63-71 %	60-68 %	98%
System	46-60 %	50-60%	< 84.6%

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MATURITY

AEL	Mature (TRL 9)
PEMEL	Commercial with development potential (TRL 8)
SOEL	Demonstration (TRL 6)

DEPLOYMENT SCALE

AEL	MW
PEMEL	MW
SOEL	kW

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CH_4 from biogas/CO_2 and H_2

Catalytic

- exothermic thermochemical process operated at high temperatures (200 to 700°C) and pressures (1 to 100 bar)
- deployed at MW-scale (TRL 8), with hydrogen-to-methane conversion efficiencies around 77% (in energy terms) and overall power-to-methane efficiencies reaching 54%

Biological

- microorganisms act as catalysts under anaerobic and aqueous conditions, at moderate temperatures (lower than 100°C) and low pressures (below 10 bar)
- emerging technology (TRL 6), currently deployed at kW-scale and expected to reach hydrogen-to-methane conversion efficiencies of 80%

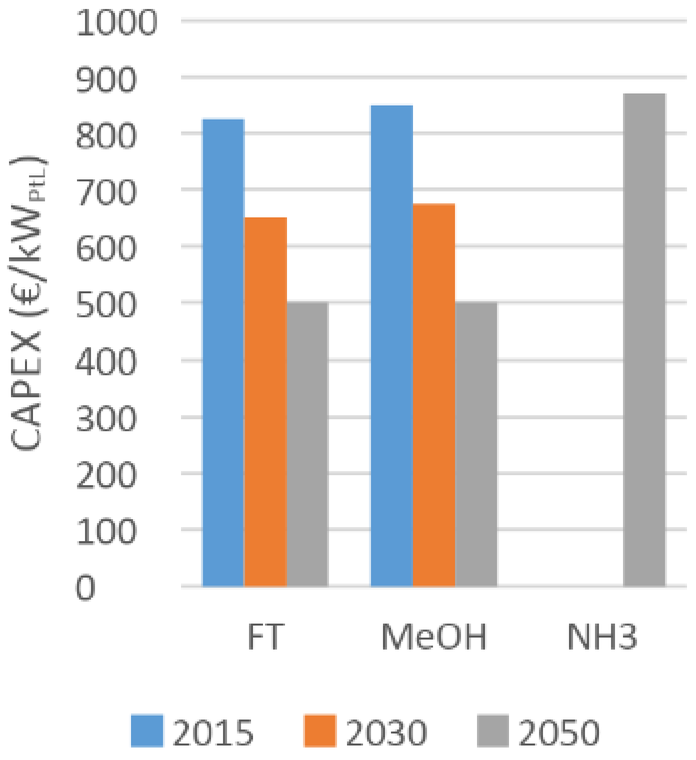
Projected costs of methanation beyond 2030 lie between 75 and 1000 €/kW SNG

As of 2018, more than 30 catalytic or biological power-to-methane pilot-projects for mobile and stationary applications were operational or planned in at least nine European countries, with installed capacities ranging from kW to MW scales

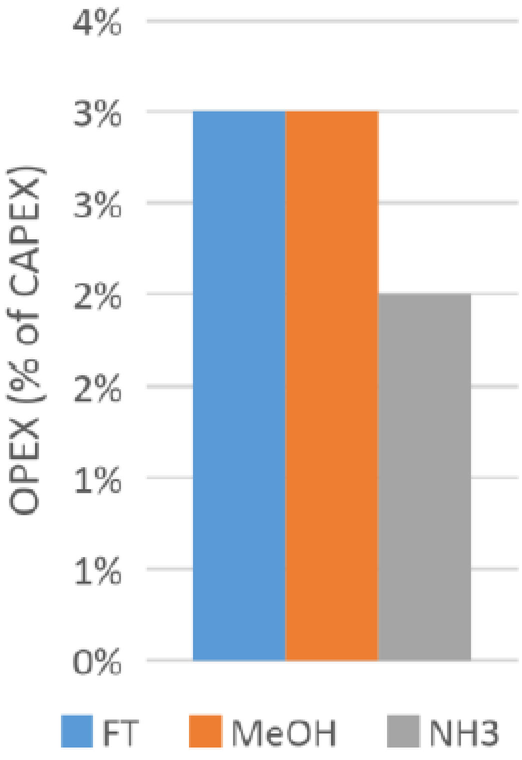
Electrofuels

Costs

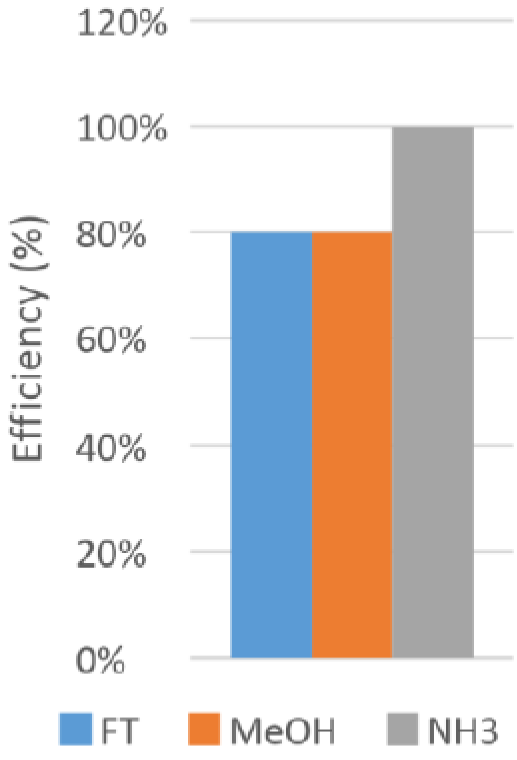
CAPEX



OPEX



Efficiency



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Electrofuels

MATURITY

FT	Relatively established technology, however, not yet mature for power-to-liquids processes
MeOH	Relatively established technology, however, not yet mature for power-to-liquids processes
NH3	Relatively established technology, however, not yet mature for power-to-liquids processes

Examples of DEPLOYMENT

FT	Sunfire demonstration plant in Dresden [168]. Nordic Blue Crude in Norway [169].
MeOH	Carbon Recycling International in Iceland [170].
NH3	Proton Ventures – small-scale ammonia plant [171] World's first Green Ammonia power demonstrator developed by Siemens, Cardiff and Oxford University [172,173]

Note: liquid fuels production via; FT: Fisher Tropsch synthesis; MeOH: Methanol synthesis; NH3: Ammonia synthesis [159,160,161,115]

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EU: PtX providing flexibility to RES-dominated power systems => for 63% EU-wide vRES supply in the electricity sector, 58 GW of electrolysis and additional 9 GW of methanation deployed (with the latter relevant solely in countries with low el prices and high vRES shares) (Bossavy, et al., 2018) (study commissioned by the EC)

EU: 95% reduction GHG levels compared to 1990 in the electricity, transport and heating sectors =>
- methanation as a cost-optimal solution to the decarbonisation of the heating sector
- PtX competes with cross-border interconn.; potential of at least 260 TWh of synthetic methane is identified (Brown, et al., 2018)

NE Asia: 100% renewable energy supply in NE Asia => up to 720 TWh synthetic methane potential region-wide by 2030 (Breyer, et al., 2015)

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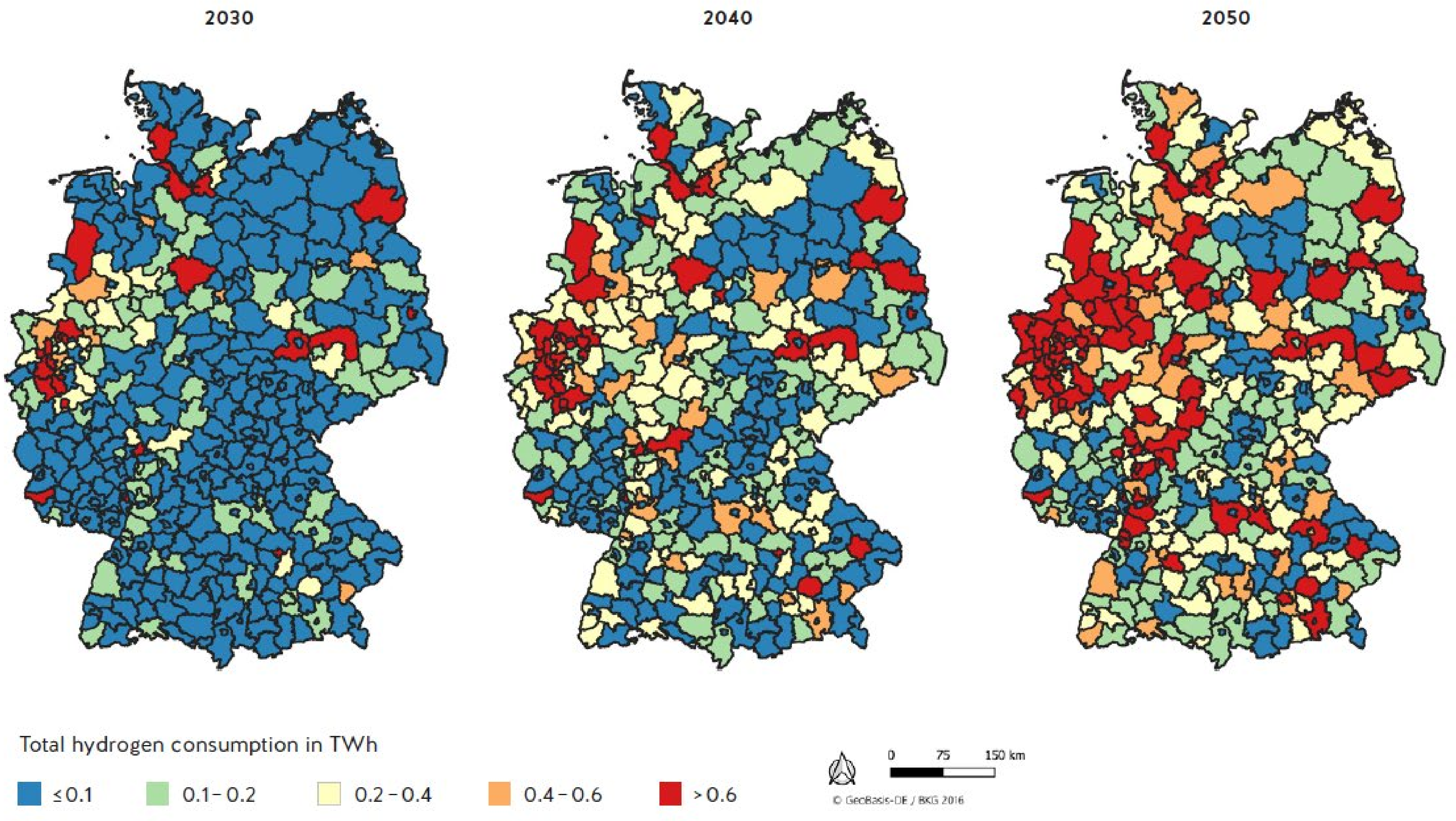
Figure 2: Combined hydrogen demand in the industrial and traffic sectors on a regional basis



Source: FfE 2019

From fnb-gas.de


?
Nordsøen
?
Storbritannien
Irland
Belgien
Prag
Paris
Østrig
Frankrig
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Italien
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Barcelona
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Portugal
Spanien
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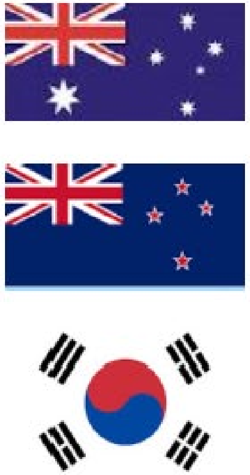
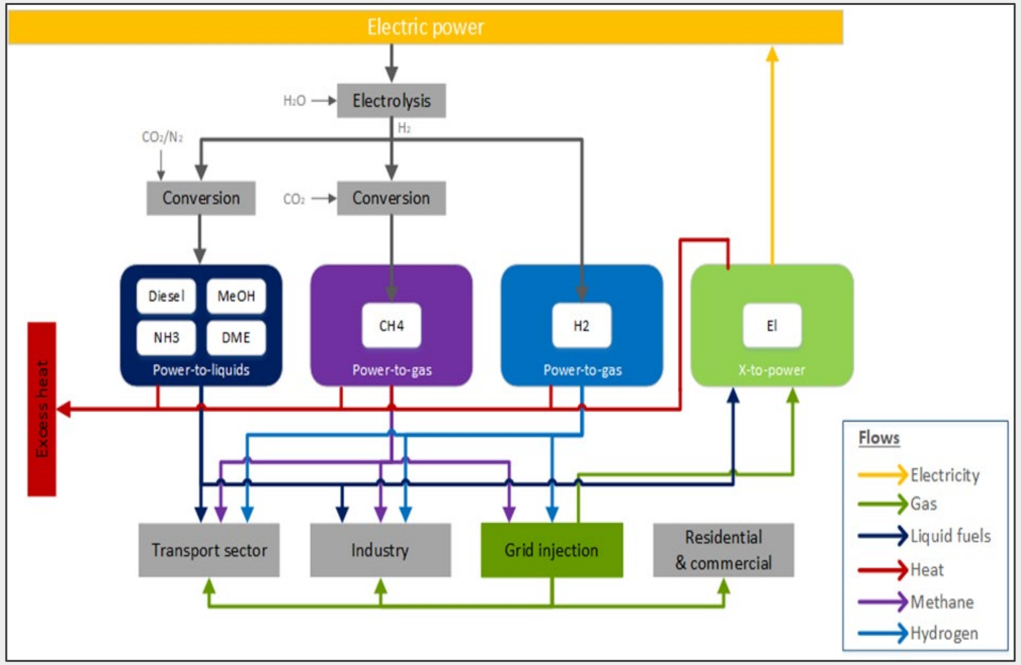


Power-to-Gas in brief

- Power-to-X shows a promising future:
  - ✓ it can be an enabler for sector coupling as it couples power, gas/liquid fuel, and heating sectors
  - ✓ provides flexibility to the power system through demand side management
  - ✓ it can contribute to the production of the gas and liquid fuels which are needed in the future
  - ✓ boosts the production of gas/liquid fuels from limited sustainable carbon/biomass resources



Power-to-X concept

- Barriers and solutions are classified into three broad categories:
  - ✓ Technical
  - ✓ Economic
  - ✓ Institutional and regulatory considerations

Power to Heat & Cooling

DANIEL MOLLER

co-Author of White Paper

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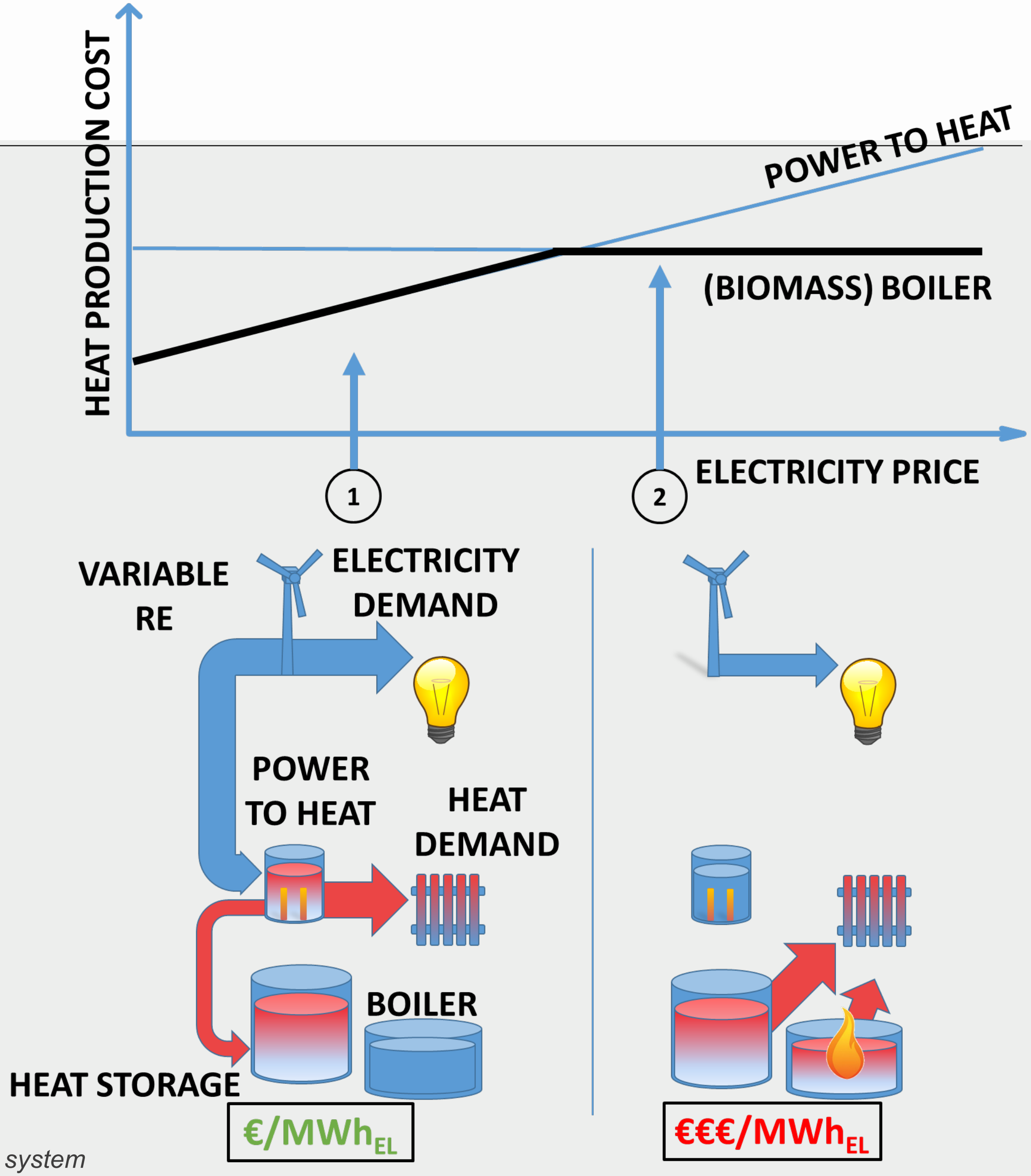
Uses

- PTH IN INDIVIDUAL RESIDENTIAL BUILDINGS
- PTH IN INDUSTRY
- PTH FOR DISTRICT HEATING
- PTC

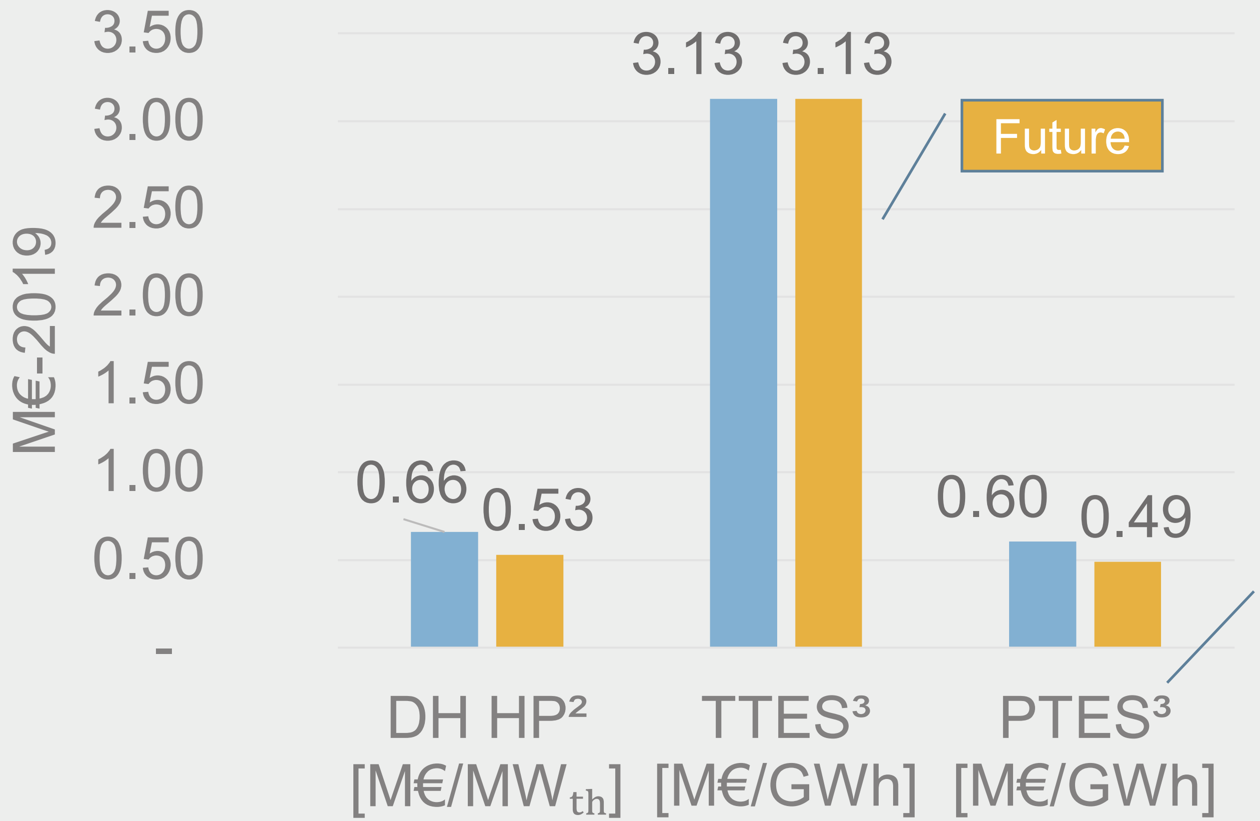
EXAMPLE: Power to heat in district heating

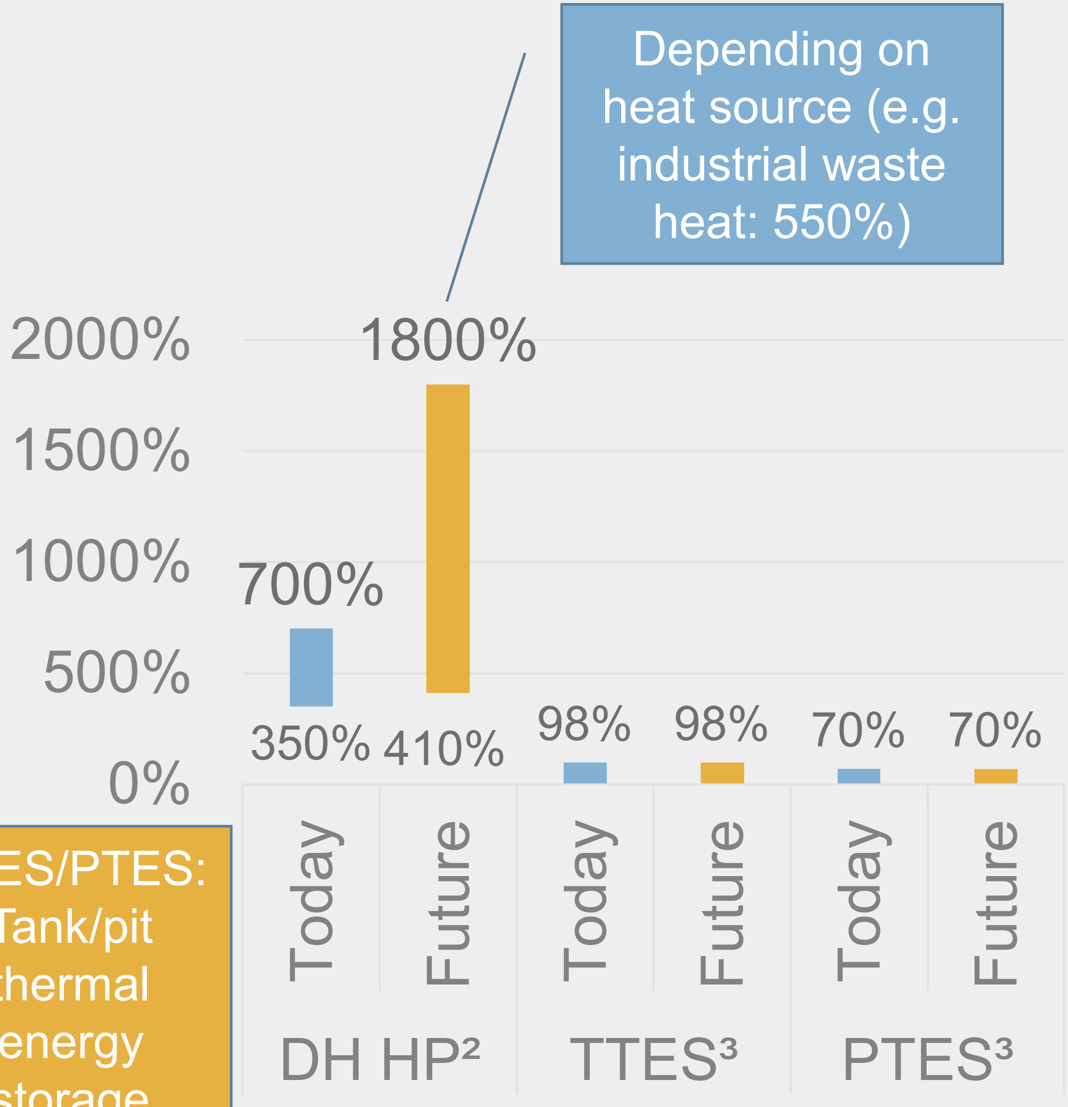
1. Low prices; high renewables
2. High prices; low renewables



Based on *Sneum 2020 – Flexibility in the interface between district energy and the electricity system*

COSTS & EFFICIENCIES



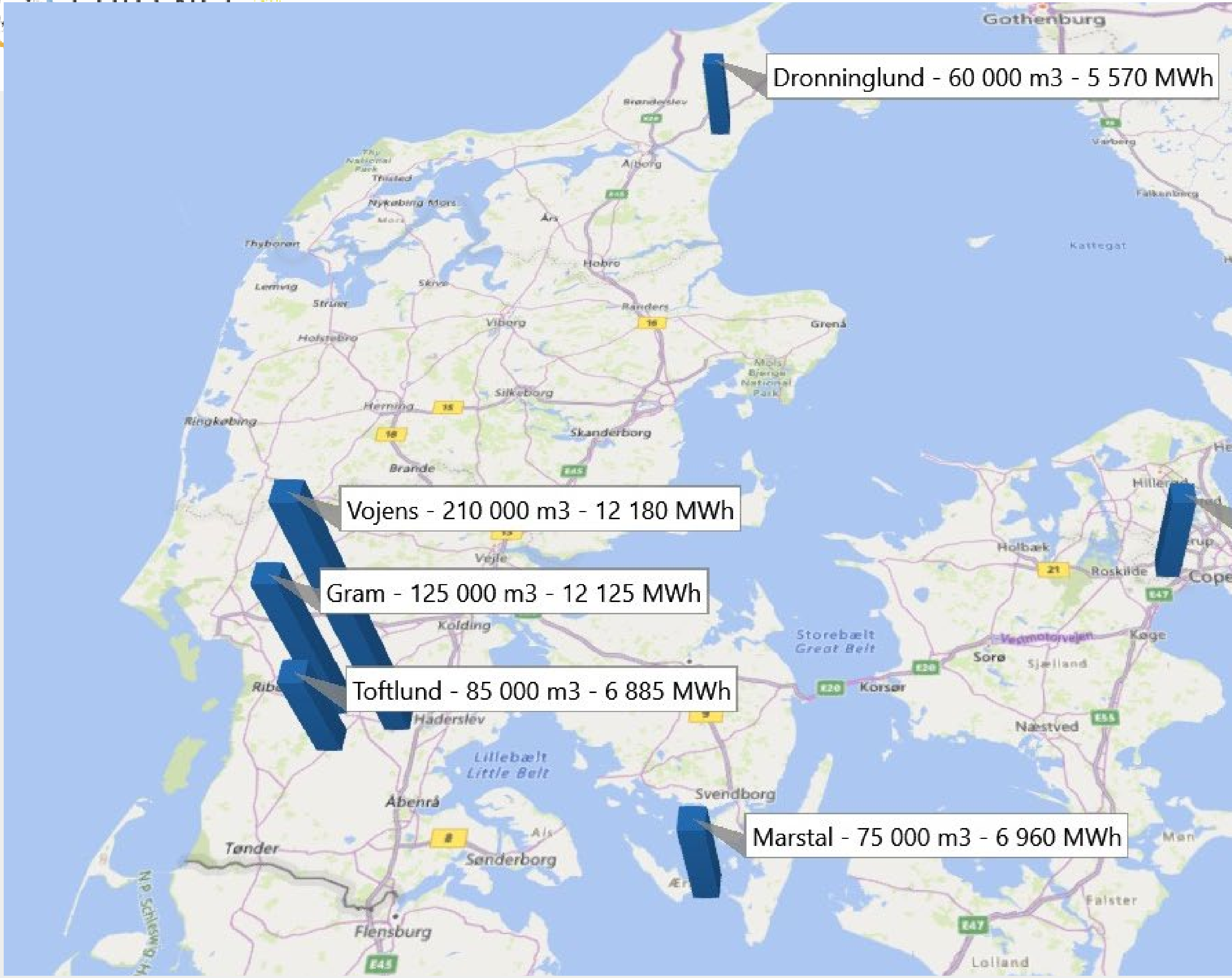


TTES/PTES: Tank/pit thermal energy storage

TRL + DEPLOYMENT

HP	8-9 Commercial with development potential[2]
TTES	9 Commercial[3]
PTES	8-9 Commercial with development potential[3]

HP	1 580 MW_{heat}	Europe[4]
TTES	91 GWh	Denmark, Iceland, Finland, Norway and Sweden[1]
PTES	46 GWh	Denmark[3]



Danish Energy Agency. Technology Data for Energy Plants for Electricity and District heating generation - Feb. 2019. Copenhagen: 2019.
Pedersen MBB. Nyt damvarmelager skal op- og aflades 25 gange om året - Energy Supply DK. Energy Supply 2019. https://www.energy-supply.dk/article/view/659490/nyt_damvarmelager_skal_op_og_aflades_25_gange_om_aret

FUTURE POTENTIALS

Large uncertainty; large potentials:

Thermal storage

- 750 GWh thermal storage by 2050 [8]
- 1360 GWh Baltics + Nordics alone by 2050 [9]

Power to heat

- 23.75 GW_{ELEC} by 2050 [10,11]

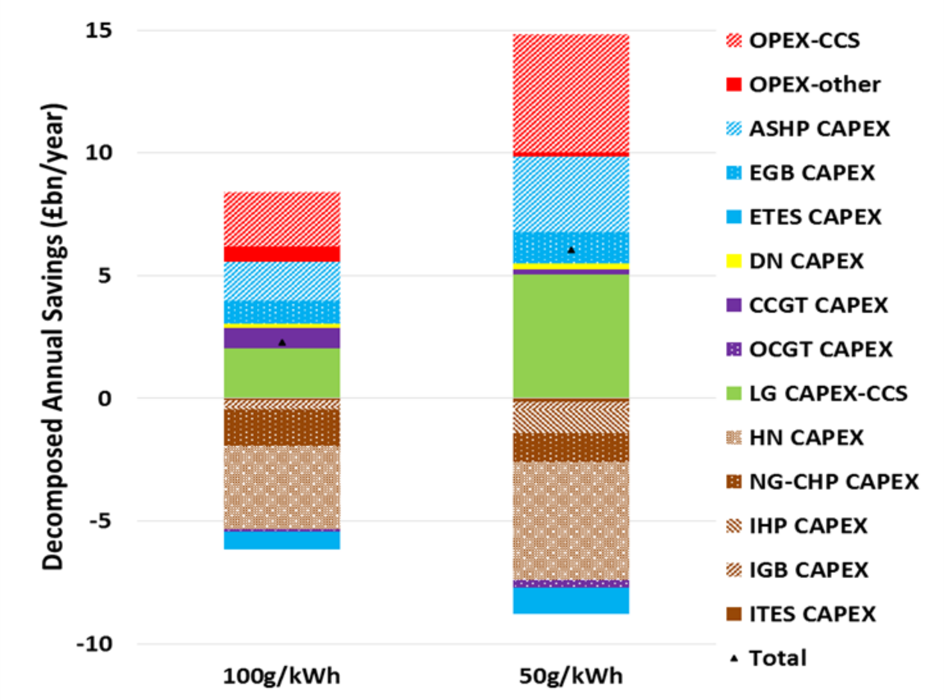
Coupling with Heating/Cooling

- Heating makes up around 50% of primary energy demand but less than 20% share of RES, being a difficult sector to decarbonize. Electrification provides a potential for providing cheap solutions scaling from household level to industry, as well as potentials for contributing to conversion and storage of fluctuating power in cheap large-scale thermal storage systems

- Feasibility and practicability depend strongly on the industrial sector and process

- Heat pumps in District Heating systems provide coupling through electrification, and flexibility by not operating during peaks. Pit and tank thermal energy storage decouple heat generation from heat demand, unlocking further flexibility. This is useful for frequent cycling and short-term storage.

- Cooling shows significant potentials either using the plant as is or by including dedicated cold storage in a plant facilitating flexible consumption of electricity; cooling demands will increase due to climate changes and adaptation, for servers in data centres and liquefaction of natural gas



Annual savings regarding the investment and operational cost of the UK system in different system segments enabled by the integration of electricity and heat systems in two carbon scenarios considered

Power to Mobility

Goran Strbac, Alexandre Oudalov
co-Authors of White Paper

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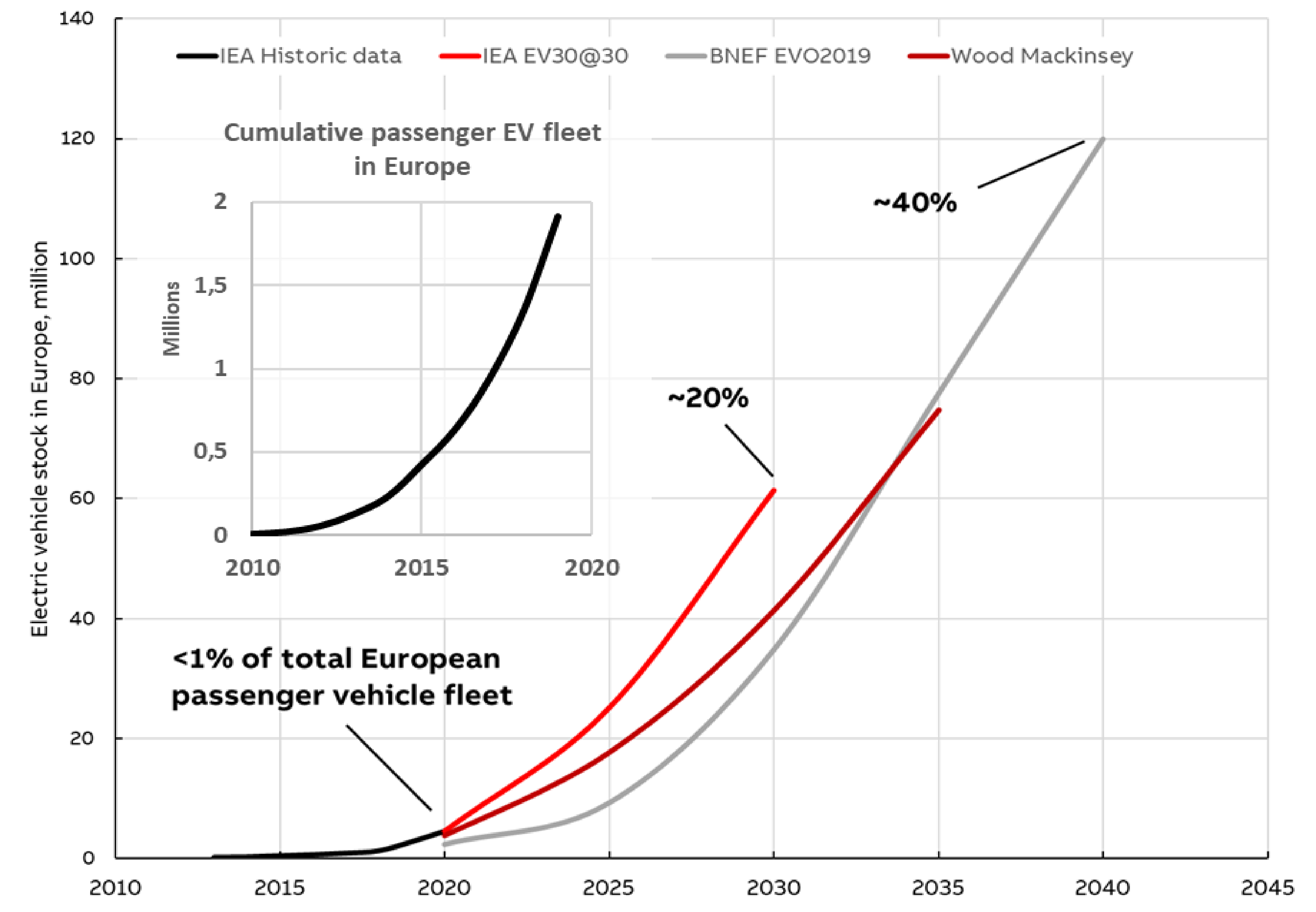
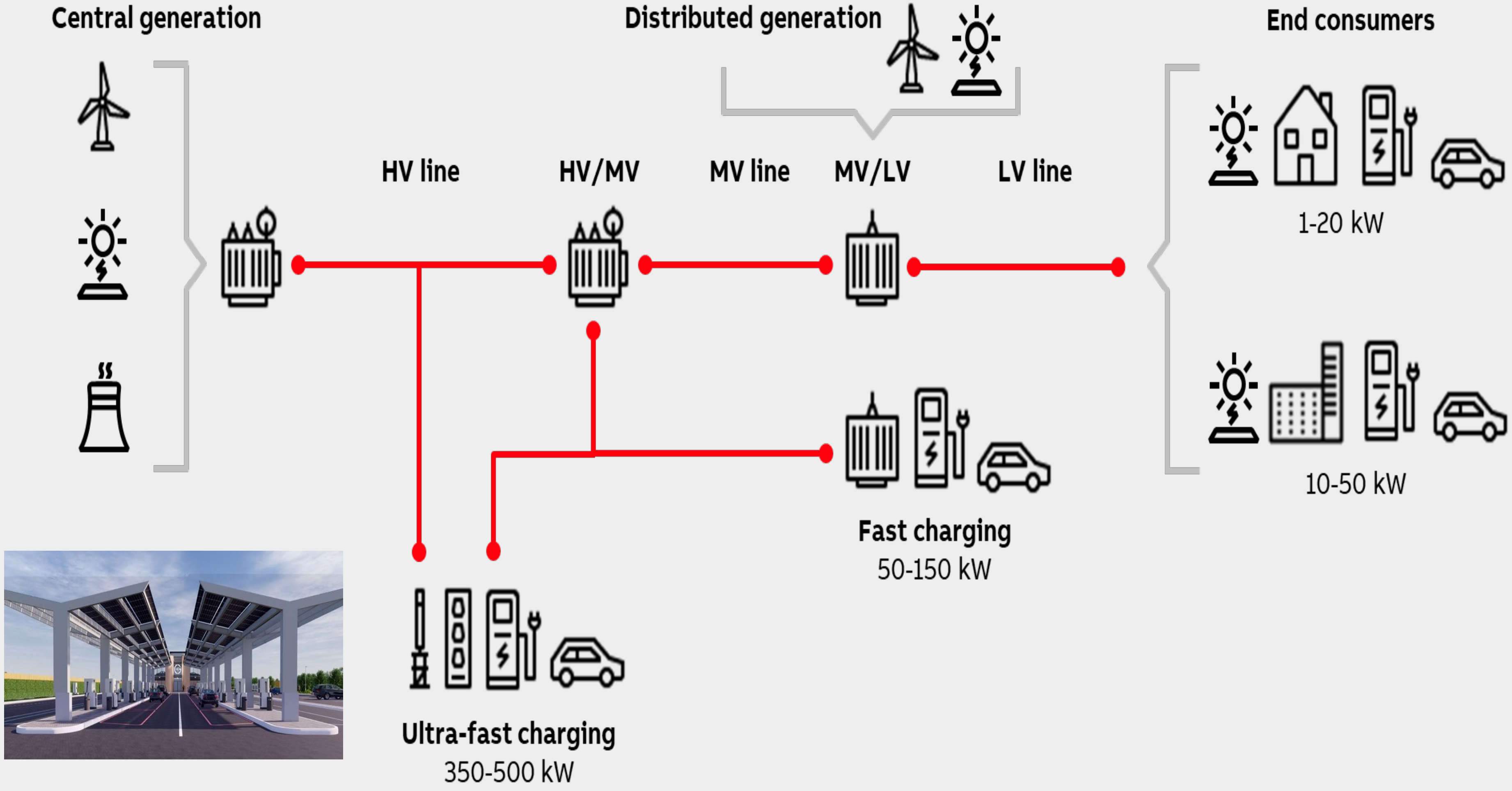
Penetration level of EVs in EU



System integration potential



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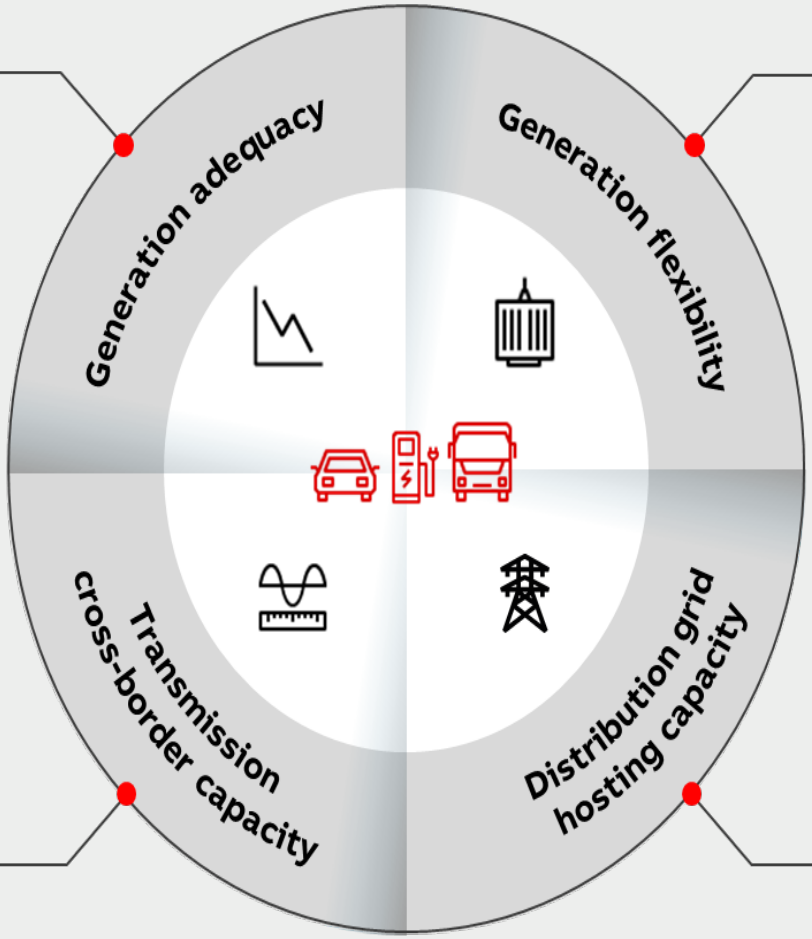
System integration potential

Can we produce enough energy to satisfy charging needs on different time horizon (annual energy and peak demand)?

Do we have enough energy sources which may quickly start, ramp up and down, and stop when e-mobility charging demand raises sharply?



Do we have enough transmission grid capacity (especially cross-border) to accommodate a regional vehicle charging demand?

Do we have enough distribution grid hosting capacity to accommodate a local vehicle charging demand?

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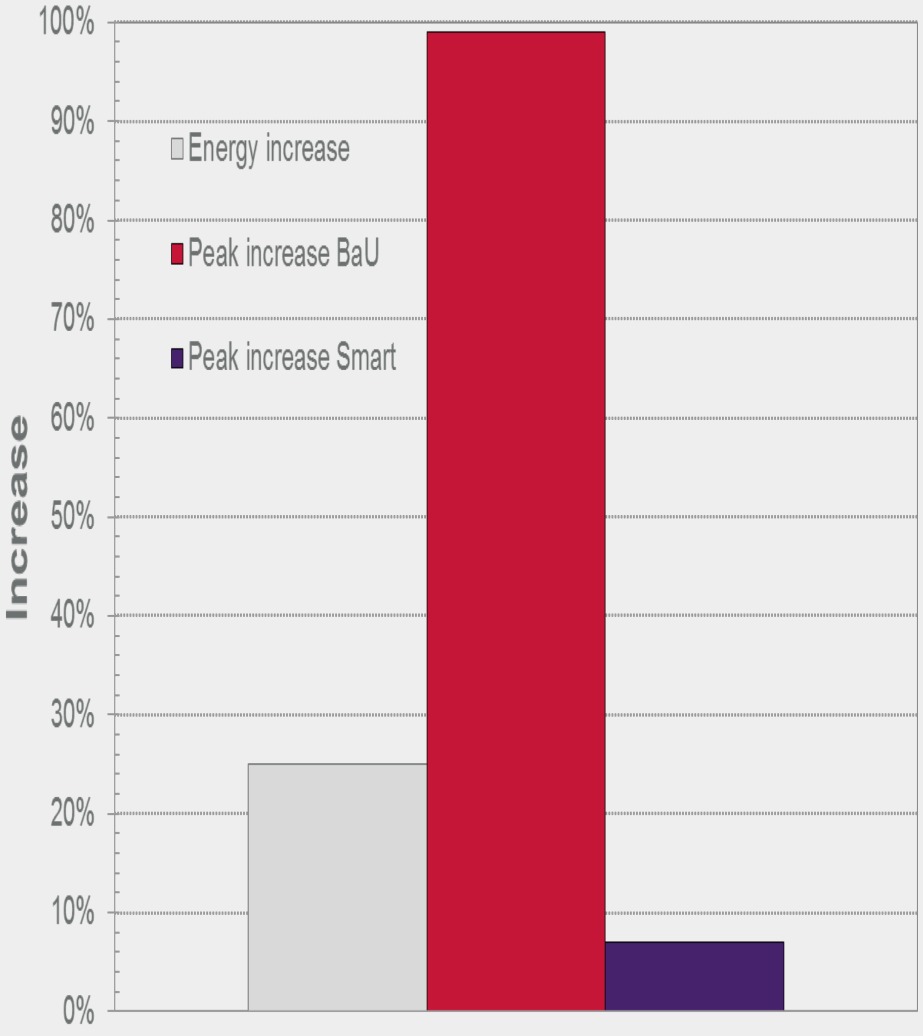
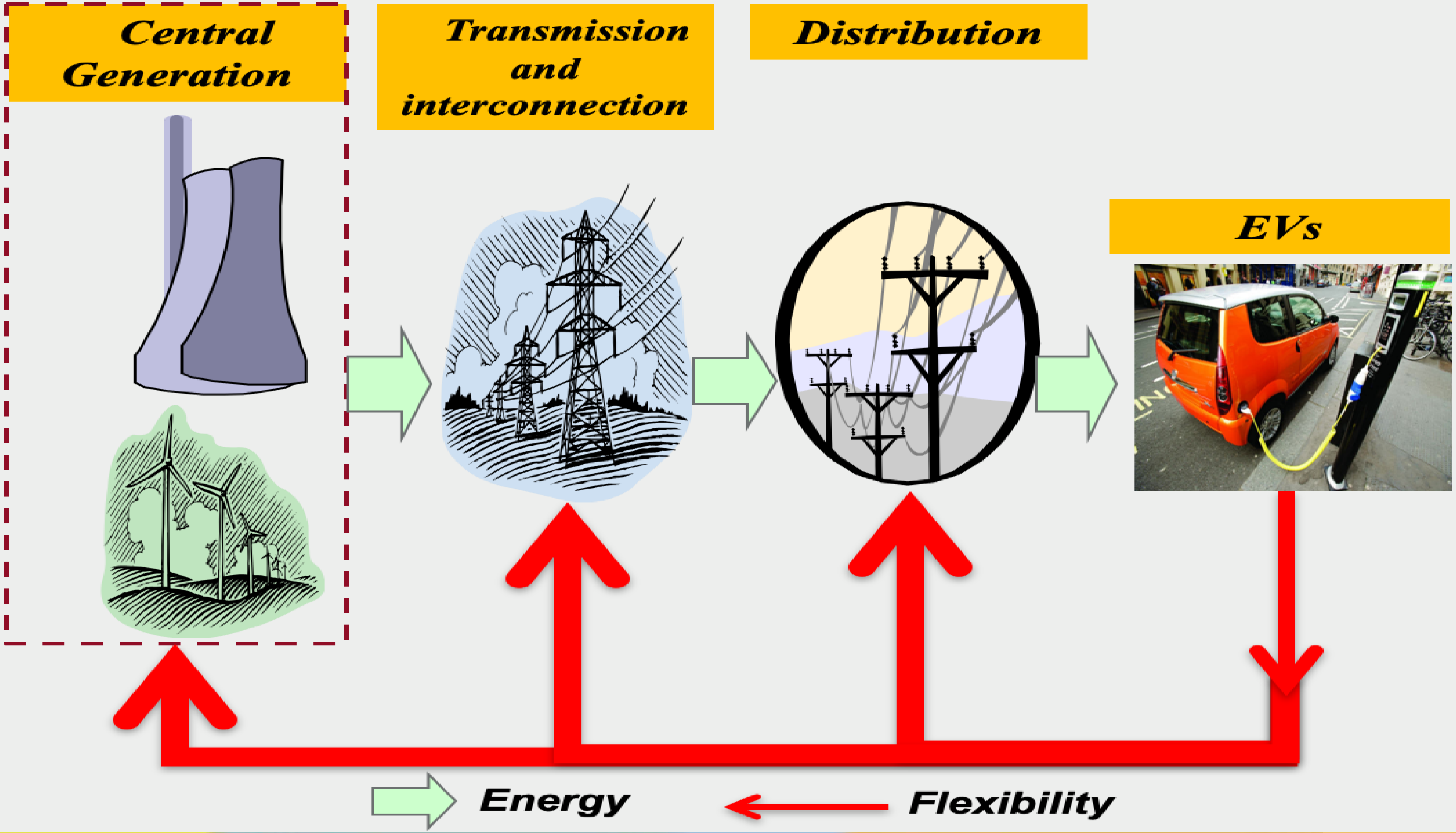
Increases in energy & peak load

- Increase in unmanaged peak demand due to EV uptake disproportionately higher than increase in energy demand
- Flexibility of EV is potentially very significant (stationary ~90% of the time)
- Significant opportunities for smart charging and V2G



Energy: From the System to EVs

Flexibility: from EVs to the system – V2G



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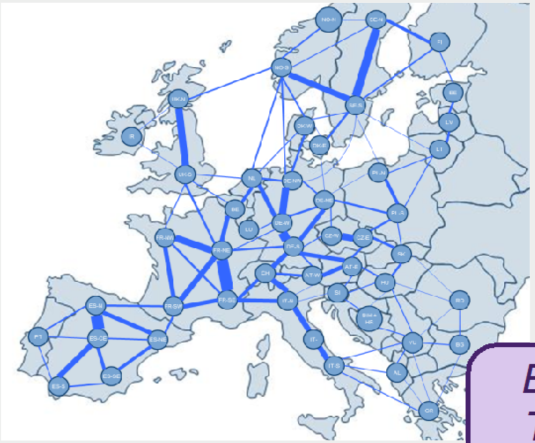
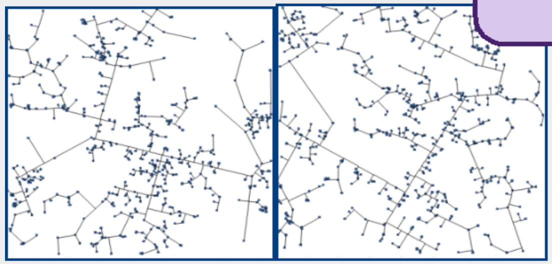
Whole-system impact assessment of the impact of EV deployment





Future development scenarios:
- *EV penetration & characteristics*
- *Electricity system evolution (RES)*
- *Market integration of European systems*

EU Grid Model: Transmission + Distribution

EU Generation, Transmission and Distribution Investment and Operation Model

Key results

- *Adequate system capacity (generation and transmission)*
- *RES curtailment & Carbon emissions*
- *Overall investment and operation cost*
- *Benefits of smart EV charging → Value of different charging strategies*

EU-wide impact of mass rollout of EVs

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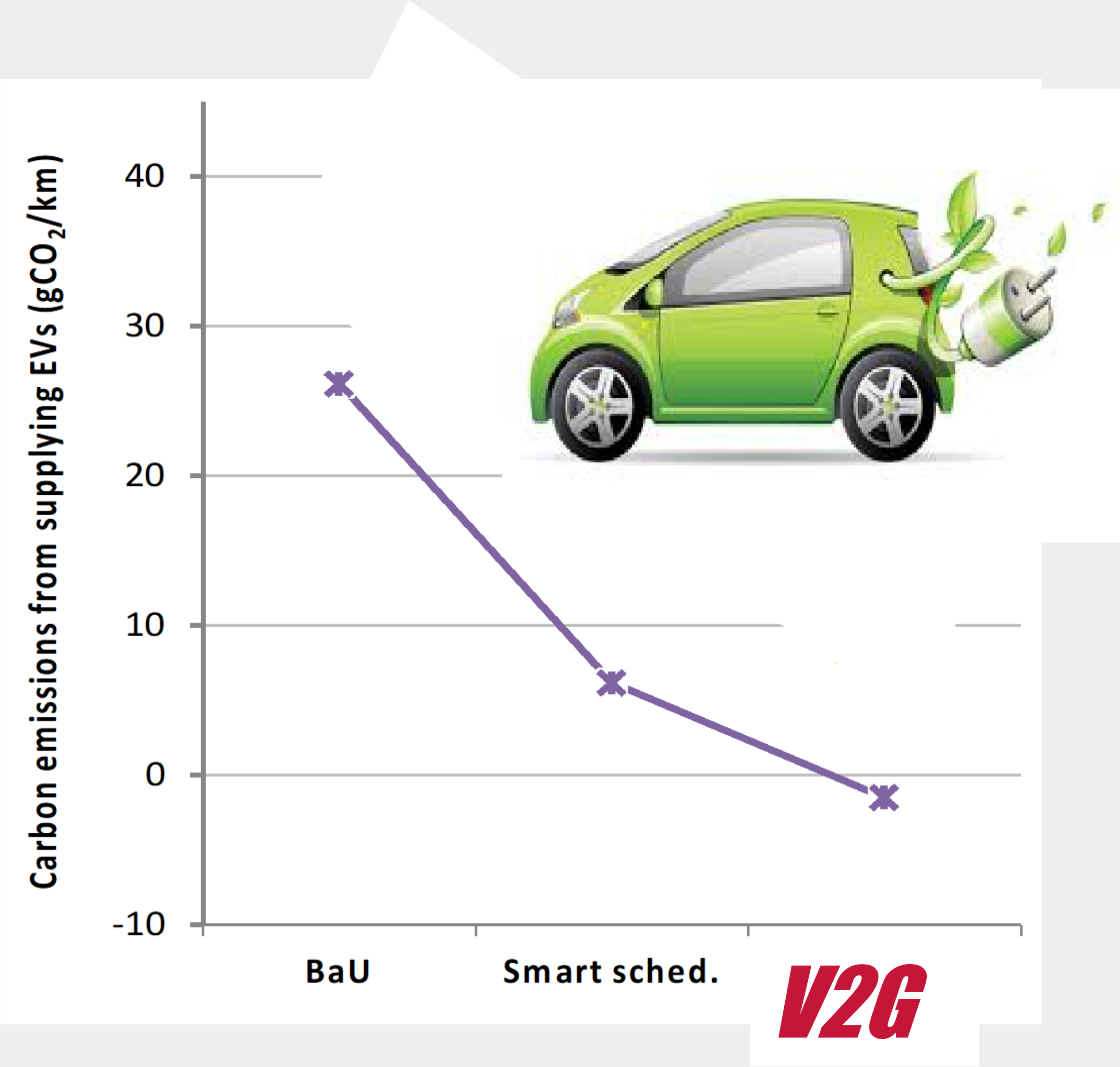
Carbon emissions – V2G

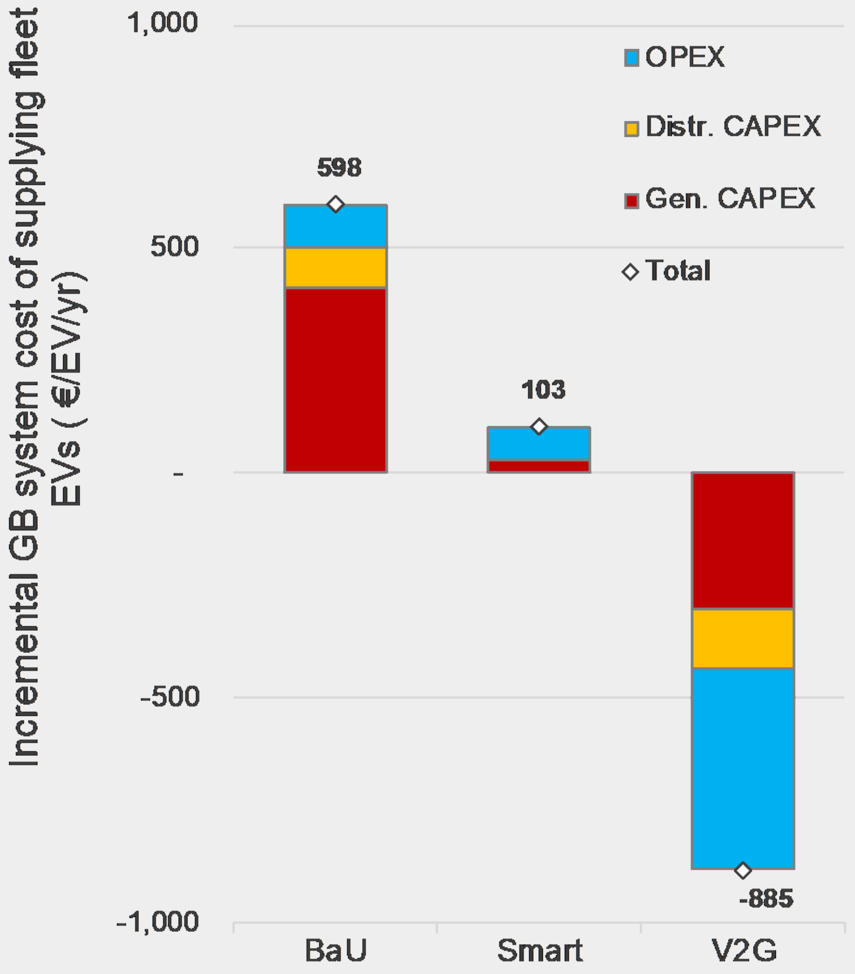


Emissions from new cars in EU (2015): 120 g/km

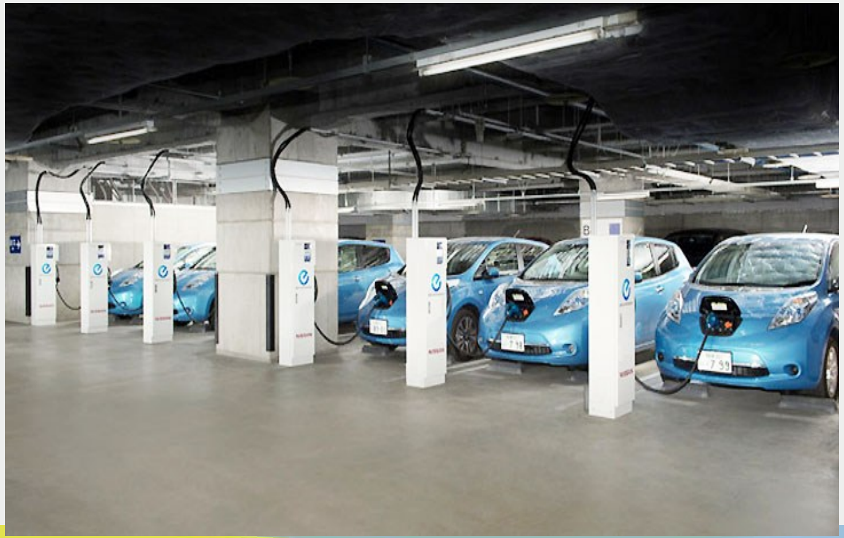
V2G makes electrification of EV carbon negative!

Cost and carbon benefits of V2G-enabled EV fleets

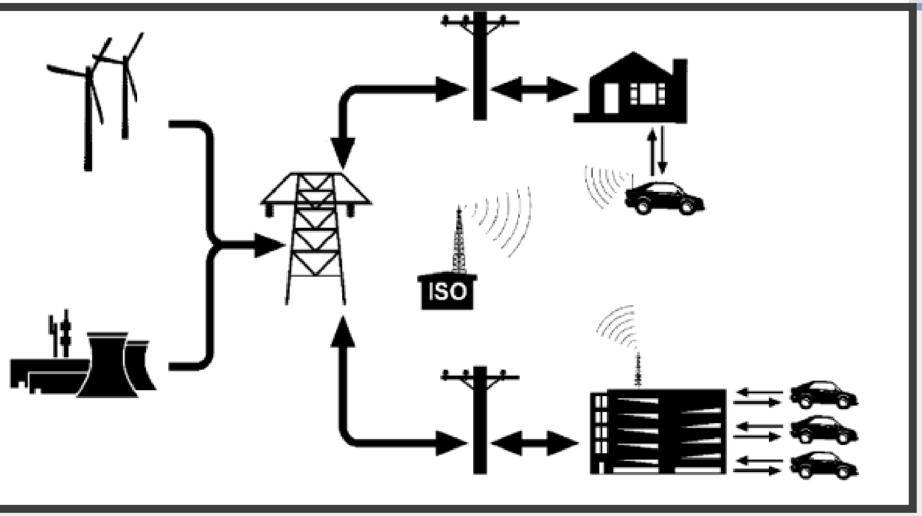
- Electrification of road transport with V2G-enabled fleets can be carbon-negative i.e. V2G fleets can actually reduce power system emissions despite adding to the electricity demand
- V2G-enabled EV fleets can also bring significant net system value through reduced reinforcement cost of electricity infrastructure and improved system operation
- V2G can greatly help with integration of renewables as its flexibility will:
    - Ensure EVs are charged with low-carbon electricity
    - Reduce renewable output curtailment

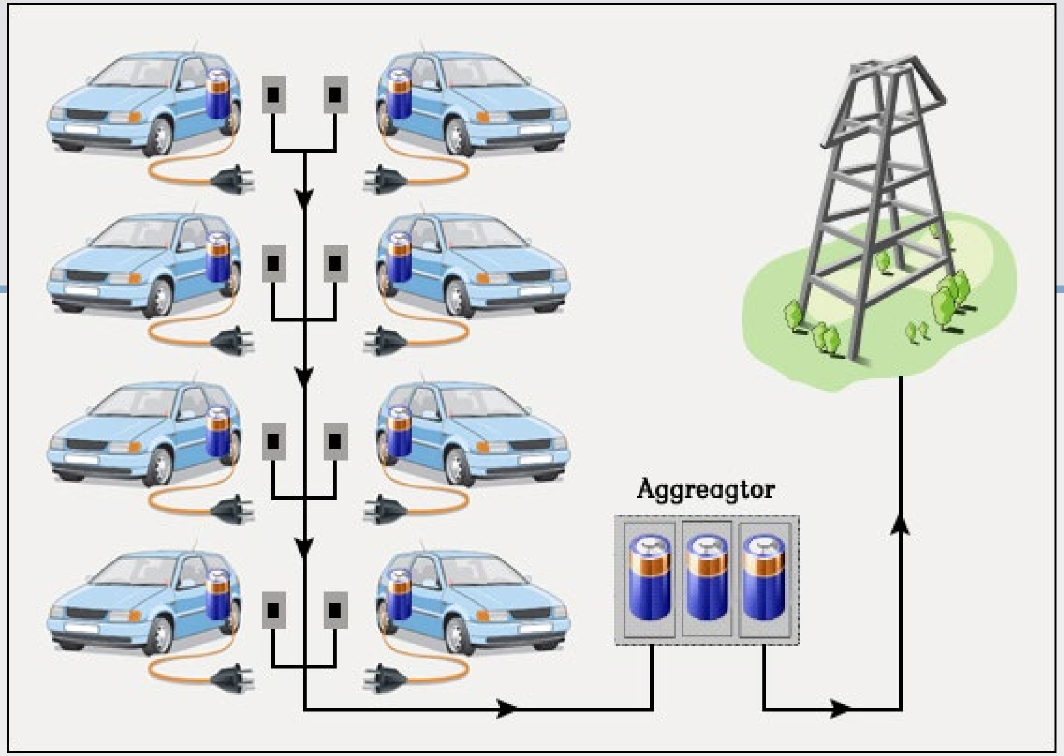


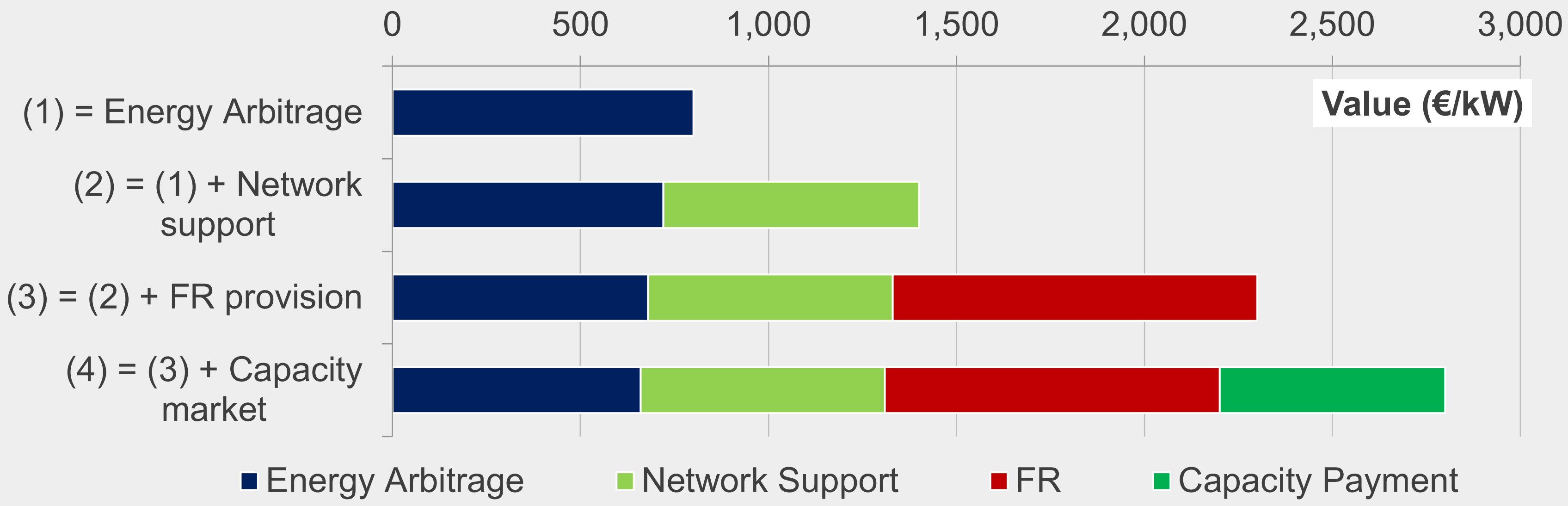
EV HUB



Business case for smart EV charging

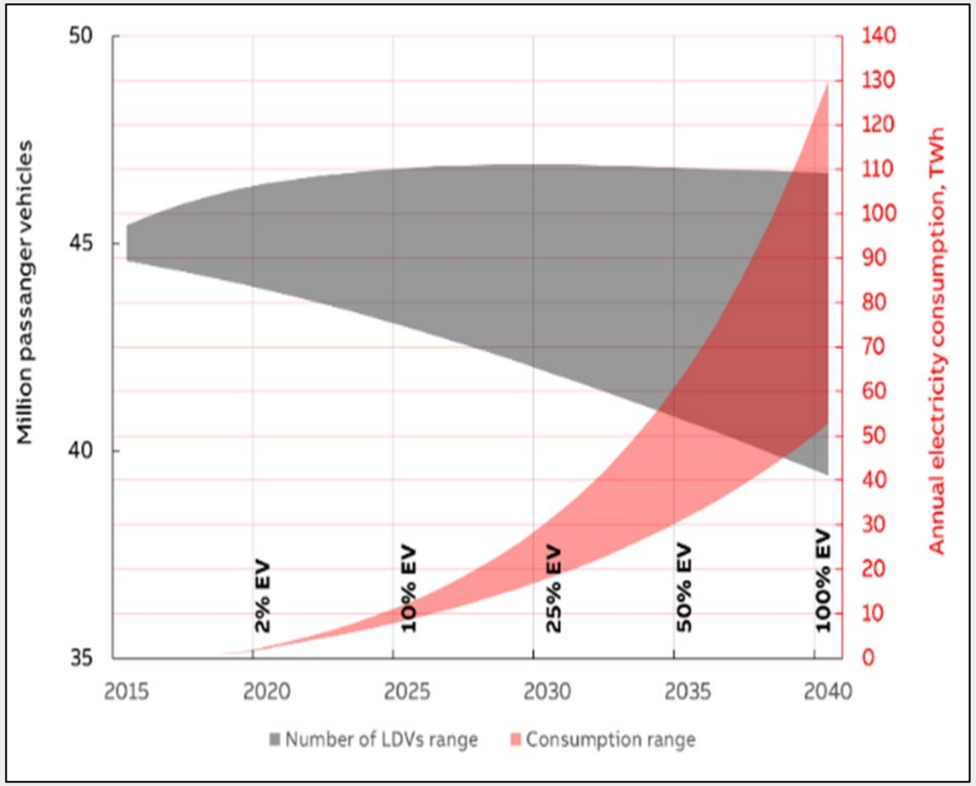






Coupling with Mobility

- The integration of EVs into the power system poses challenges from the perspective of power generation and transmission due to charging the battery in uncontrolled way, i.e. charging starts immediately after plugging EV to the mains at rated charger power
- Continued retirements of generation and 100% EVs cause adequacy issues during two instances in the day
- On the distribution level, batteries can be used to shave the EV peaks by charging during low-demand hours
- EV battery capacity can be used to provide ancillary services (e.g. frequency regulation) or load balancing for loss of generation or VRES variability



Expected annual electricity consumption in the German grid for different levels of electrification for Light Vehicles

Conclusions and take-aways

Conclusions – concepts & definitions

- Sector Coupling is an integrated system approach aimed at one or more of these goals:
  - ✓ cheaper/faster/broader decarbonization
  - ✓ provision of extra flexibility to at least one of the coupled sectors
  - ✓ improved use of infrastructures either existing (operation stage) or to be built (planning stage)
- Both in Operation and Planning the number of independent/interlinked variables to be optimised grows exponentially → need of advanced tools, metrics and modelling
- This is achieved exploiting synergies and complementarities across linked energy sectors:
  - ✓ transport (only with smart charging)
  - ✓ heating/cooling (only with associated storage)
  - ✓ some industrial processes (chemicals, high temperature & energy intensive processes)
- Power-to-Gas (hydrogen and its derivatives) allows "smart integration" of multiple heavy industrial processes, particularly for hard-to-electrify ones
- Electricity converted to molecules can be stored with near-zero losses for long periods and transported as alternative to power lines
- Electrification of final use, aiming at decarbonization, per se is not coupling sectors, but often implies similar positive effects (new/larger flexible loads, new storage options, dual fuel options)

Conclusions – technologies

- In a European context, the potential for electrification of heat, transport and industry could double the electricity consumption; with a fully decarbonized power generation, this would reduce substantially overall CO2 emissions

- If electrification paths are managed smartly, it may contribute to balance and stabilise power grids; if not, it will stress the grids and call for higher investments in grid expansion and flexibility means

- Technologies are available for making the first steps of sector coupling in all sectors, where particularly the PtH/C technologies are near commercial, but also EV's are well on the way, while some development is still needed to scale up PtoX technologies and decrease their costs

Recommendations

- Any proposed project/initiative must be assessed in **agnostic way** its the best alternative to achieve the same goal (clear definition of targtes and of the use-case), including externalities and realistic duty cycles, possibly at Life Cycle Assessment level

- Continue and improve joint planning efforts like ENTSO-E TYNDP evolving to a **Multi-sector planning tool**

- Demos and pilots, on specific cases, should receive European support and deserve important attention in the forthcoming **HorizonEurope** program. They should also be incentivised by local system/authorities whenever there is a transversal portfolio of benefits

- Demo projects should include analyses of **regulation and markets** and involve **stakeholders** across sectors to cater for different needs