International Renewable Energy Agency

Innovation landscape for smart electrification of end-use sectors

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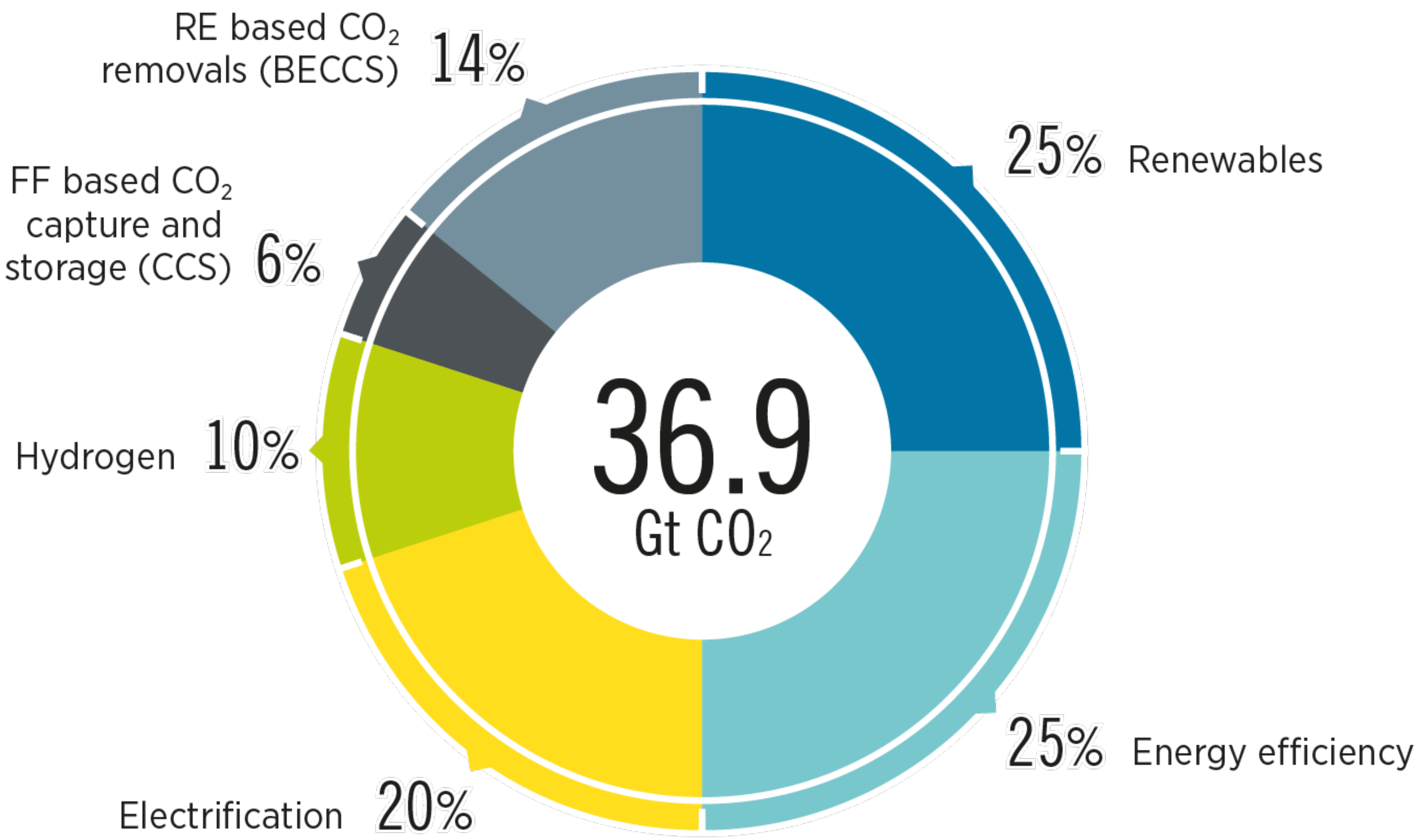
Asia Clean Energy Forum 2022

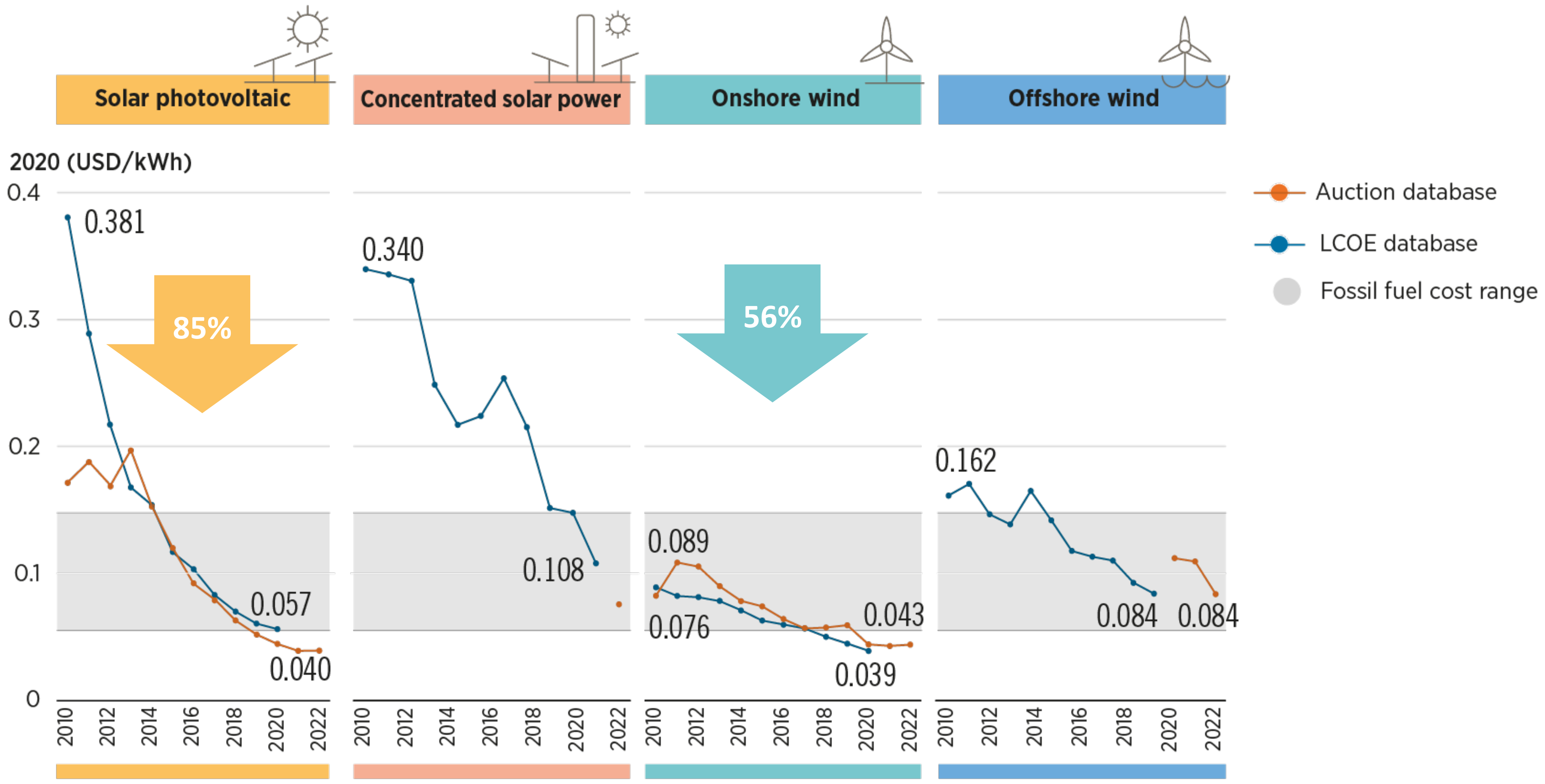
Renewables, efficiency and electrification dominate energy transition

Reducing emissions by 2050 through six technological avenues



90% of all decarbonisation in 2050 will involve renewable energy and energy efficiency

Renewables-based electricity is already the cheapest power option in most regions



In the last 10 years, the global weighted average levelised cost of electricity from utility-scale solar photovoltaic (PV) projects fell by 85%, concentrating solar power (CSP) by 68%; on-shore wind by 56%, and off-shore wind by 48%.

Variable Renewable Energy to become main source of power generation globally by 2050

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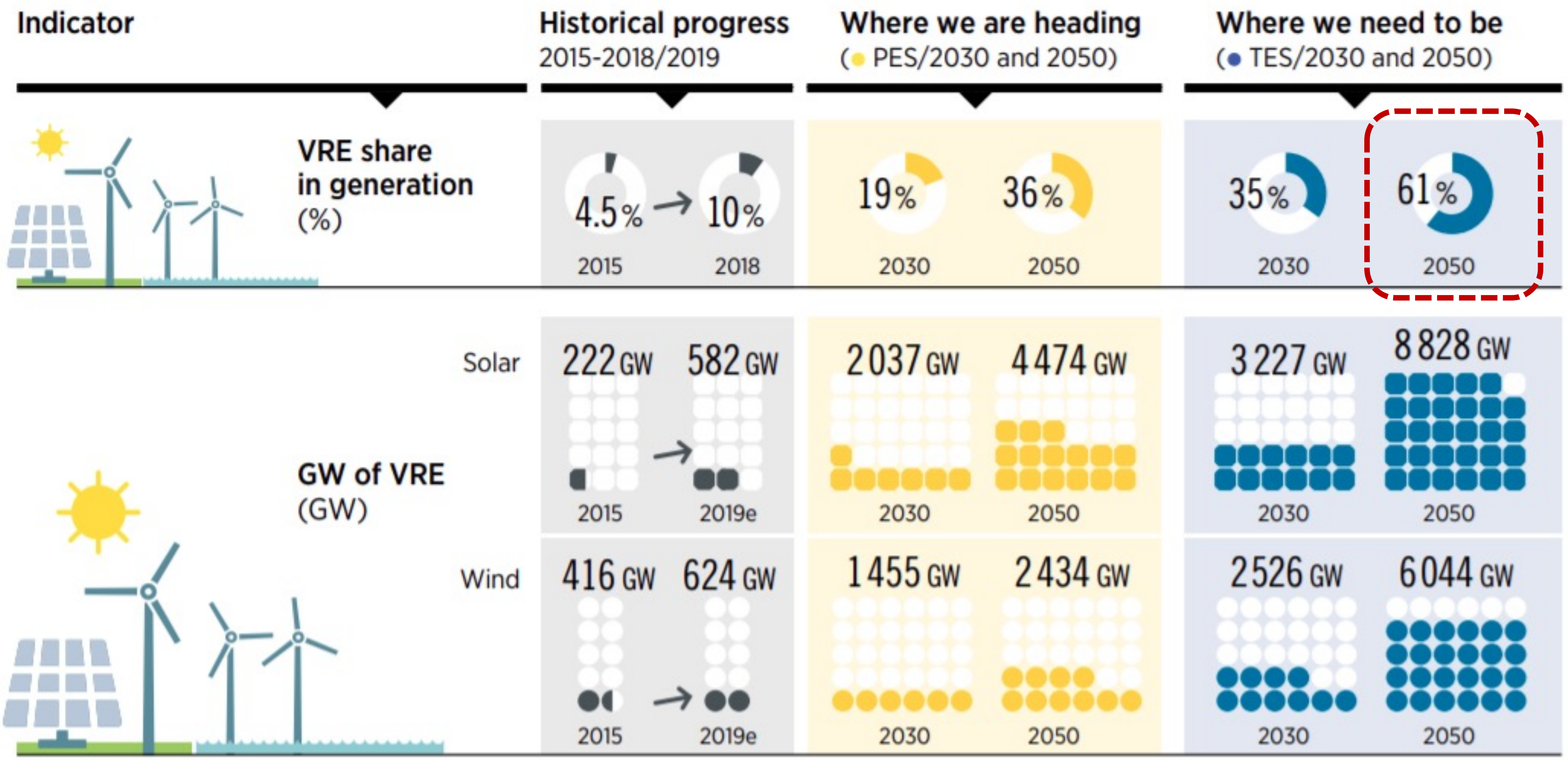

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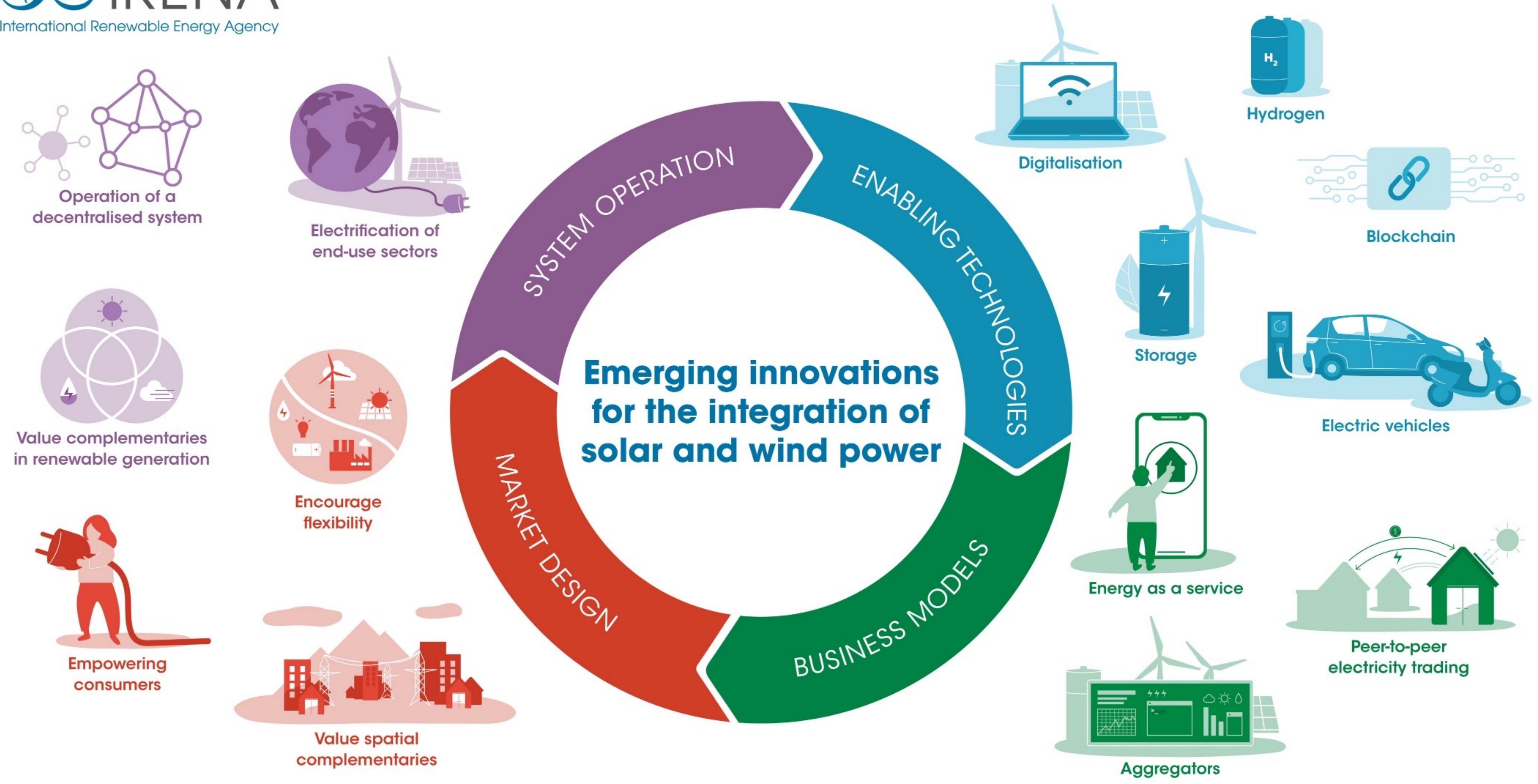


30 key innovations for wind and solar PV integration

ENABLING TECHNOLOGIES

1 Utility-scale batteries
2 Behind-the-meter batteries

3 Electric-vehicle smart charging
4 Renewable power-to-heat
5 Renewable power-to-hydrogen

6 Internet of things
7 Artificial intelligence and big data
8 Blockchain

9 Renewable mini-grids
10 Supergrids

11 Flexibility in conventional power plants

BUSINESS MODELS

12 Aggregators
13 Peer-to-peer electricity trading
14 Energy-as-a-service

15 Community-ownership models
16 Pay-as-you-go models

MARKET DESIGN

17 Increasing time granularity in electricity markets
18 Increasing space granularity in electricity markets
19 Innovative ancillary services
20 Re-designing capacity markets
21 Regional markets

22 Time-of-use tariffs
23 Market integration of distributed energy resources
24 Net billing schemes

SYSTEM OPERATION

25 Future role of distribution system operators
26 Co-operation between transmission and distribution system operators

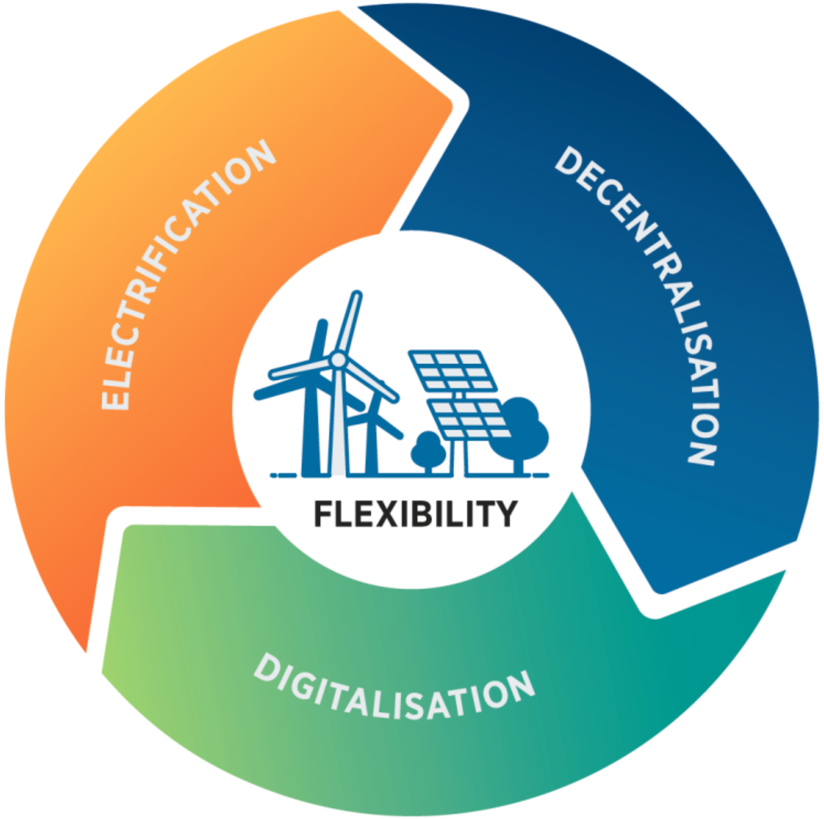
27 Advanced forecasting of variable renewable power generation
28 Innovative operation of pumped hydropower storage

29 Virtual power lines
30 Dynamic line rating

Source: IRENA (2019),

Three innovation trends

- Electrification of end-use sectors is an emerging solution to **maintain value and avoid curtailment of VRE**, and help decarbonize other sectors



- The increasing deployment of Distributed Energy Resources (DERs) turns the consumer into an active participant, **fostering demand-side management**.

- Digital technologies enable **faster response, better management of assets** by **connecting devices, collecting data, monitor and control**

Electrification: Electricity becomes the main energy carrier in future energy systems

	Recent years	2050 [22]
Share of direct electricity in final energy consumption	21 % [13]	50 %

The share of electrification in end-use sectors from today to 2030

- **Industry from 26% to 28%**
- **Buildings from 32% to 56%**
- **Transport from 1% to 9%**

ELECTRIFICATION IN END USE SECTORS (DIRECT)

Key Indicators	Historical 2019	Where we need to be (1.5°C Scenario) 2030	2050
Heat pumps - **Industry**	<1 million	35 million	80 million
Electric car stock*	18 million	381 million	1780 million
Heat pumps - **Buildings**	53 million	142 million	290 million

Smart electrification of end-use sectors

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Why smart?

Uncontrolled and simultaneous charging of EVs/heat pumps lead to…

…Increase in peak demand and frequent congestion in distribution grids…

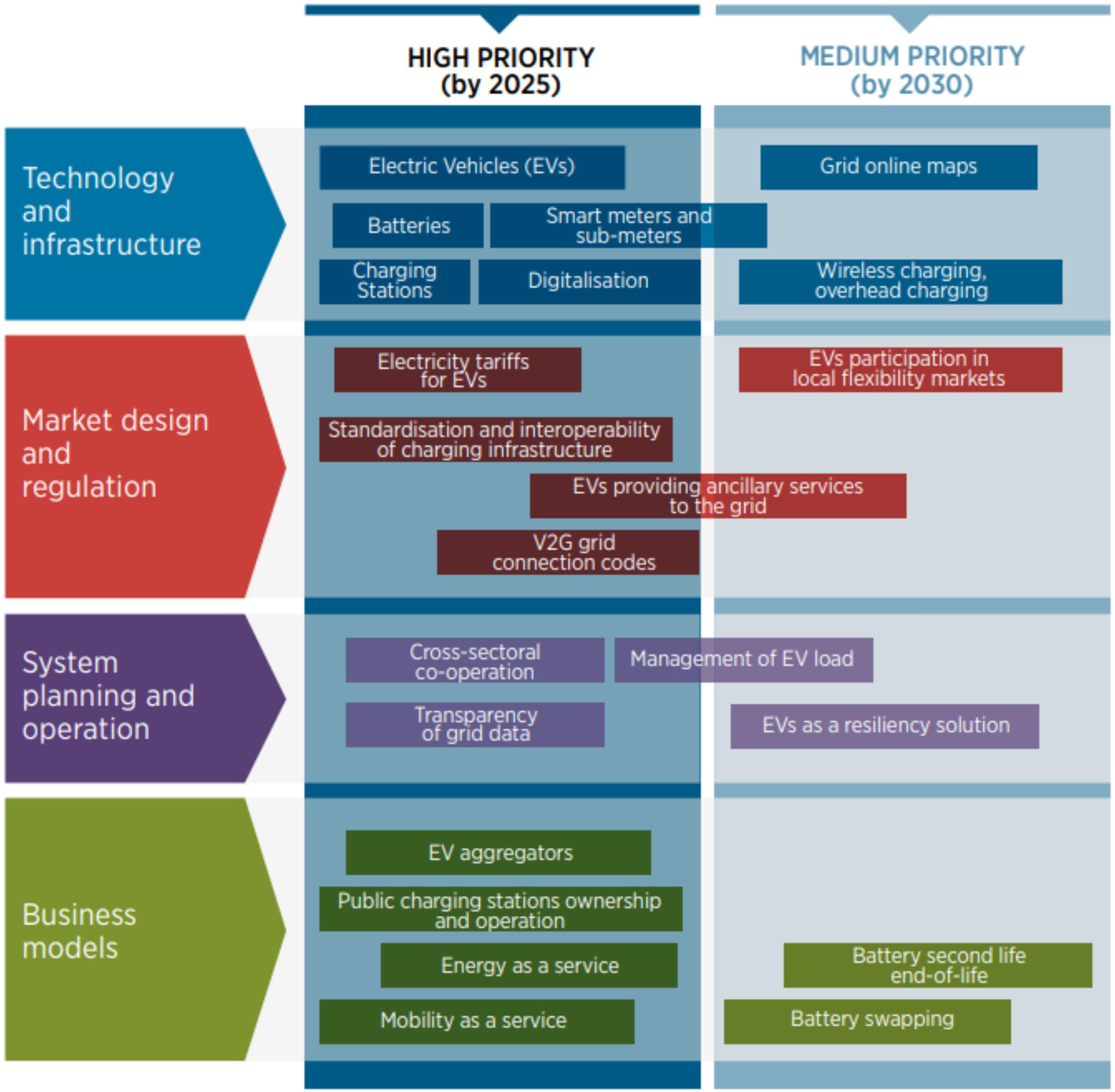
…Requiring additional investments in grid infrastructure and limiting the integration of solar PV and wind

What is smart electrification?

Smart electrification means adapting the electricity use to the needs of the end-use sector/ users as well as to the conditions of the power system

Source: IRENA (2019) Innovation Outlook: Smart charging for Electric Vehicles

Smart electrification of mobility sector



Battery capacity

Utility scale	BtM Decentralised	
10.8 TWh	5.5 TWh	> 50 TWh (passenger cars only)

Huge flexibility potential from smart charging of Evs

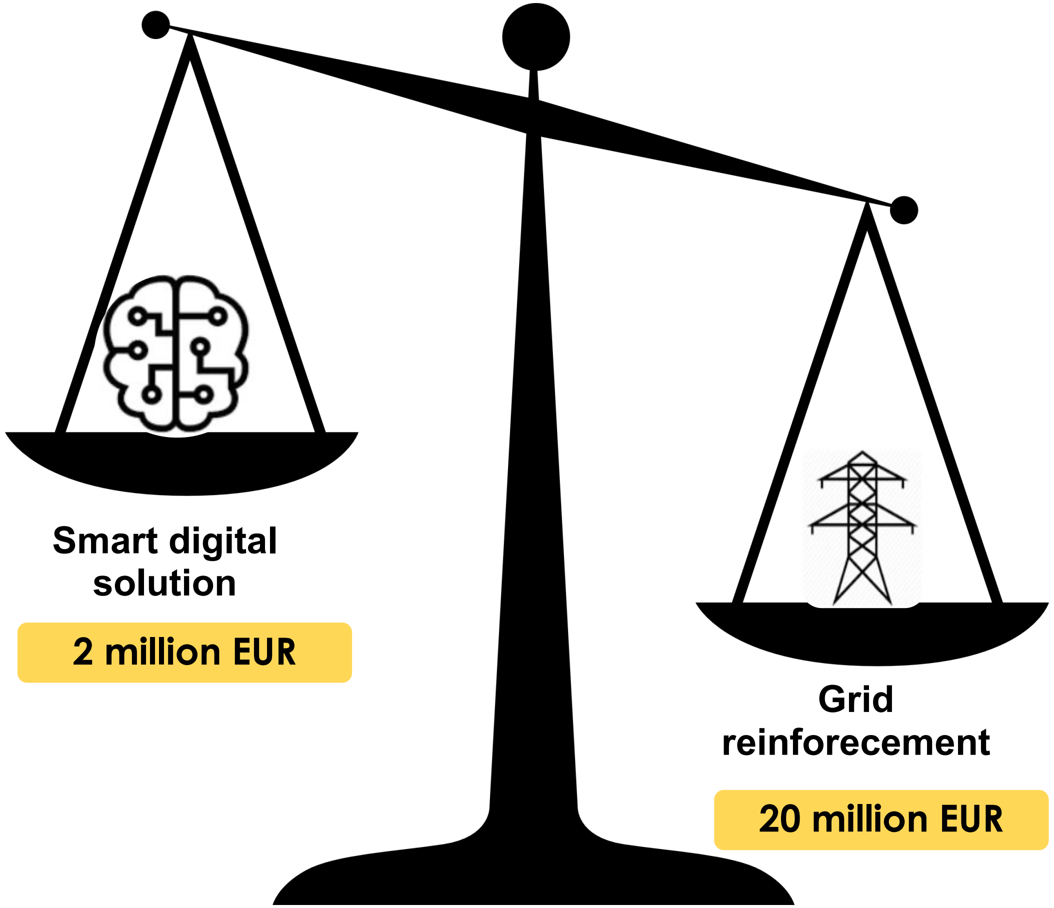
- Power system cost for smart vs dumb charging of around 1:10
- **Smart is the only way to go**

EVs impact in Hamburg

Power system cost for smart vs dumb charging of around 1:10

Stromnetz Hamburg assessment: 9% EV share (60.000 EVs) would cause bottlenecks in 15% of the feeders in city's distribution network

- Decrease the simultaneity. All charging points need to be visible by the DSO
- A real-time communication system enables DSO to reduce charging points loads.



Source: IRENA (2019) Innovation Outlook: Smart charging for Electric Vehicles

California's Electrification Strategy

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Technology & infrastructure

EVs
- 420.000 full EVs on road

Diversity and ubiquity of charging infrastructure
- 57,000 Level 2 + 4,900 DC fast (public chargers)
- 240,000 Level 2 + 10,000 DC fast (2025)

Batteries and battery recycle
- lithium-ion batteries
- ReCell Center: first advanced battery recycling R&D center

Digitalization
- Interoperability and connectivity : BMW piloting the Chargeforward System Architecture

Market design & regulations

V2G regulatory framework
- Grid codes enables V2G charging: The new Rule 21 revisions clarify that V2G-DC or V2G-AC systems can be interconnected
- Recommendation to Allow V1G and V2G to qualify for SGIP, but V1G would get less incentive compared to V2G based on permanent load shift logic

Smart charging enablement by wholesale market constructs
- V2G company Nuvve participating in California's wholesale energy markets to help balance the grid

Time of Use Tariffs for EVs (US$/kWh)
- Daily Peak at 0.5 (4 - 9 p.m.), Partial Peak at 0.3 (3 - 4 p.m. and 9 p.m. - 12 a.m.) and Off-Peak at 0.15 (all other hours)

California

System operation & planning

Cooperation of regulatory agencies for VGI
- The Vehicle Grid Integration Working Group that brings together CARB, CAISO, CEC and CPUC

Management of EV load to integrate renewables
- BMW Chargeforward takes into account renewables: shifting charging during the late morning hours can help with oversupply of solar generation.

Management of EV load to defer grid updates
- PG&E is purchasing distribution capacity for either generation or load (Evs can participate)

EV as a resiliency solution
- EV battery and solar as backup systems for wildfires and blackouts

Business models

EV load peak shaving
- ChargeForward vehicles can create an average of $325 in estimated grid savings annually per vehicle in California

Battery second life
- California Awards $10.8M to Reuse EV Batteries in Solar & Microgrid Projects (4 projects)

Charging stations ownership and operations
- Four community choice aggregators (CCAs) are funding $65 million in infrastructure to support the rising number of electric vehicles (EVs) in the state.

Impact of smart charging in California

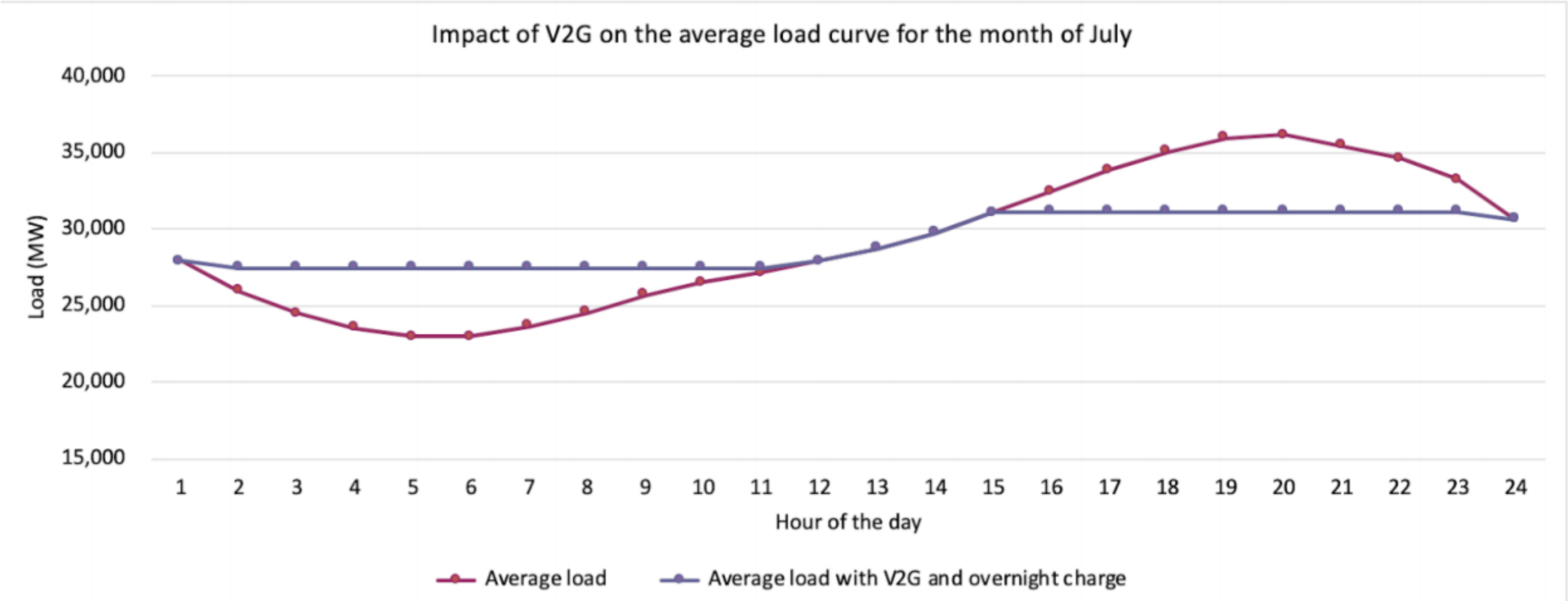
BMW's ChargeForward program finished the second phase of testing

The report highlighted :

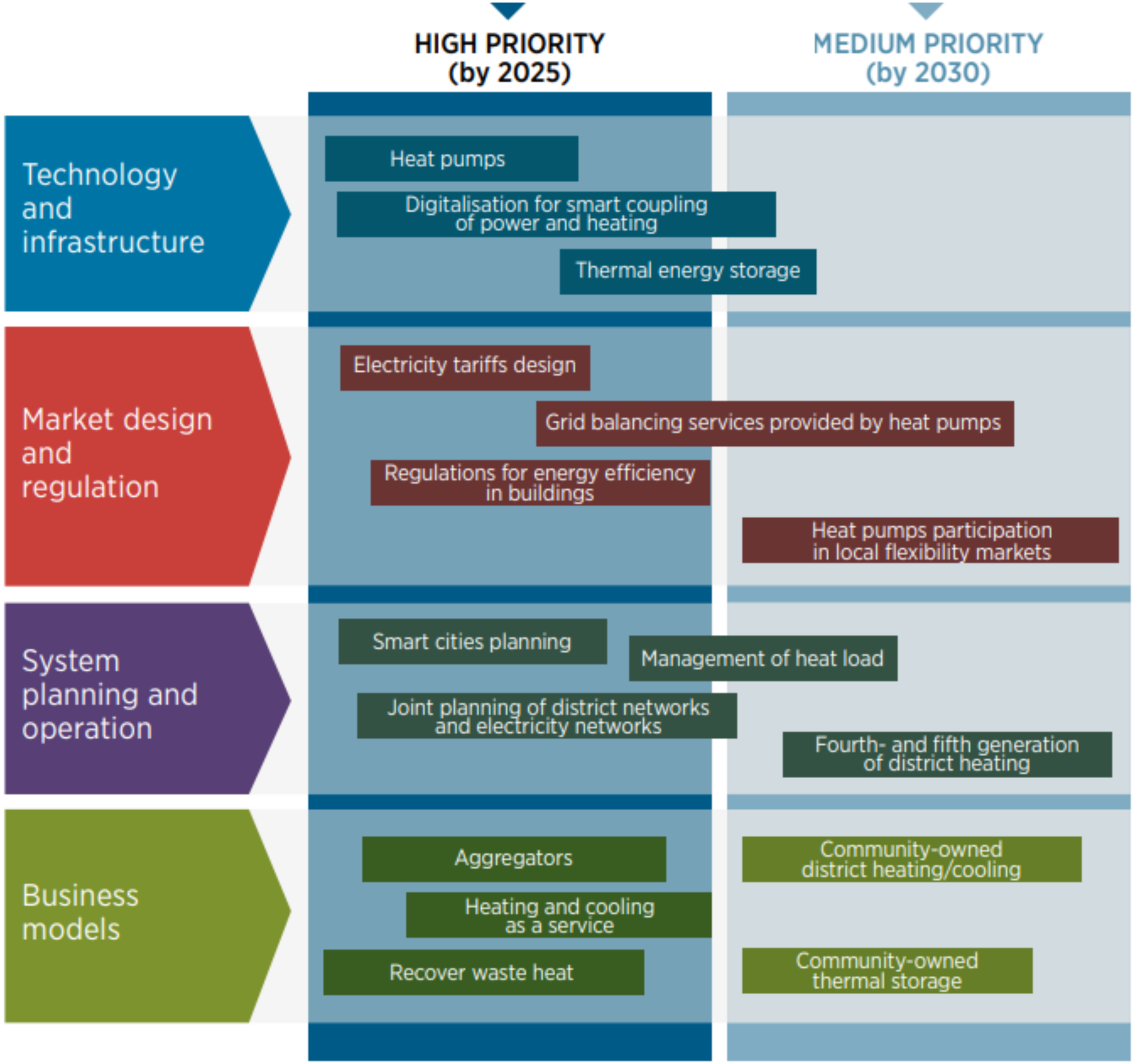
- Smart charging can enable EVs to accept an additional 1,200 kWh of renewable energy per vehicle per year. This is the equivalent of 3,500 to 5,000 miles of additional zero carbon travel.
- Smart-charging EVs have the ability to reduce greenhouse gas emissions by an additional 32% on average in Northern California
- An average of $325 in estimated grid savings annually per vehicle in California with smart charging

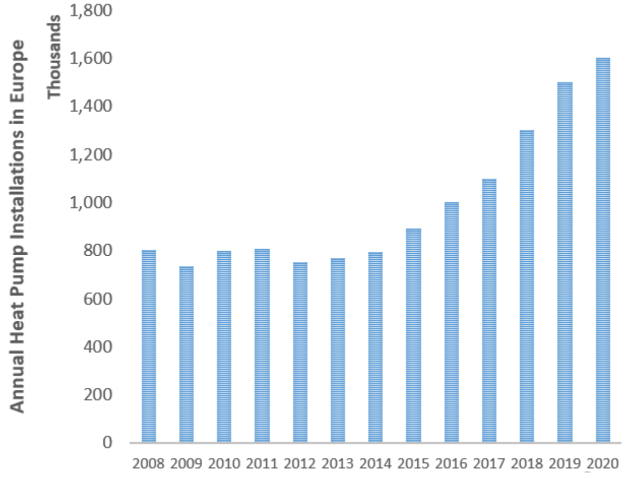
Vehicle-Grid Integration Study in California

40% EV penetration in 2025



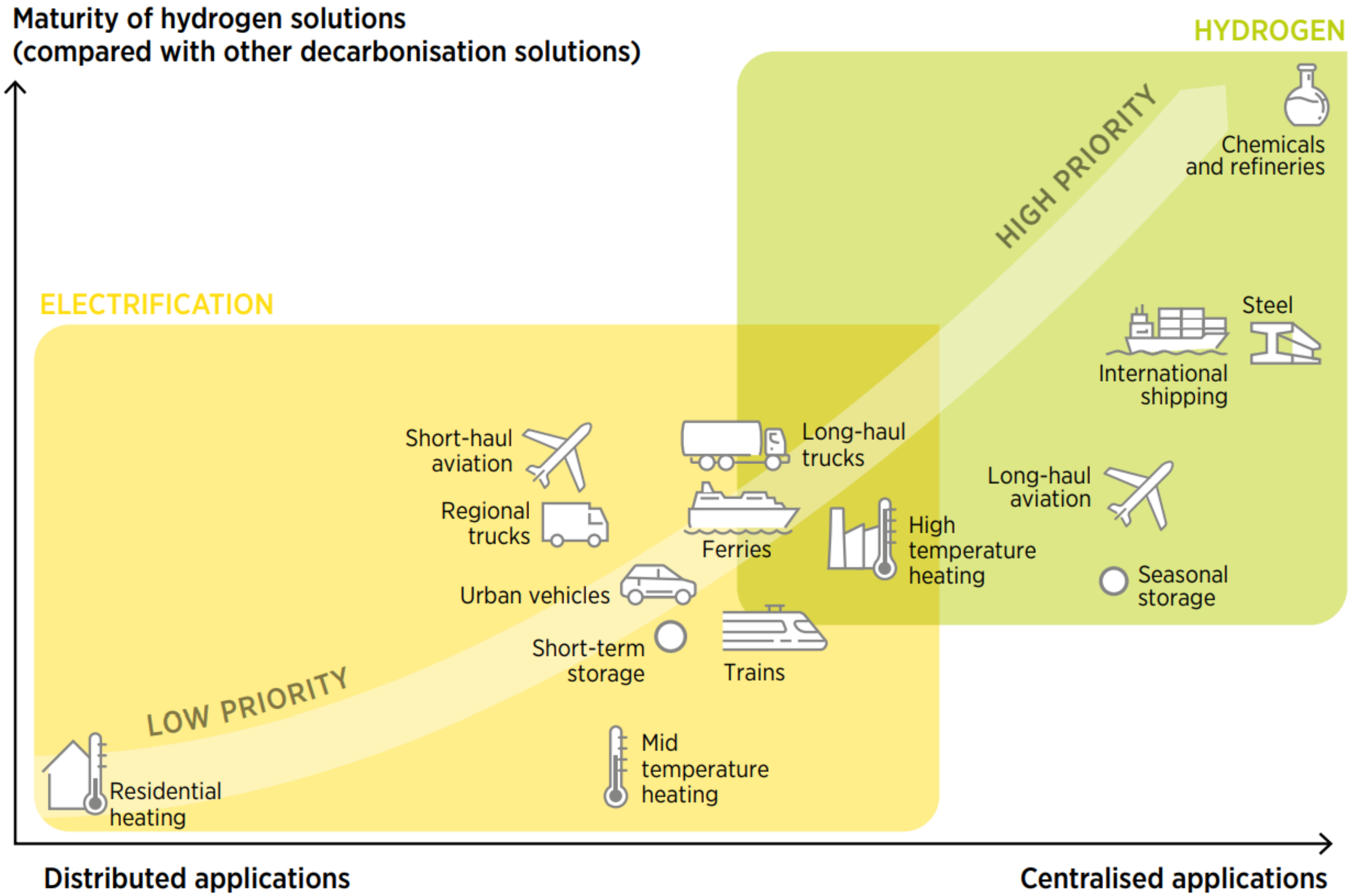
Smart electrification of heating and cooling sectors



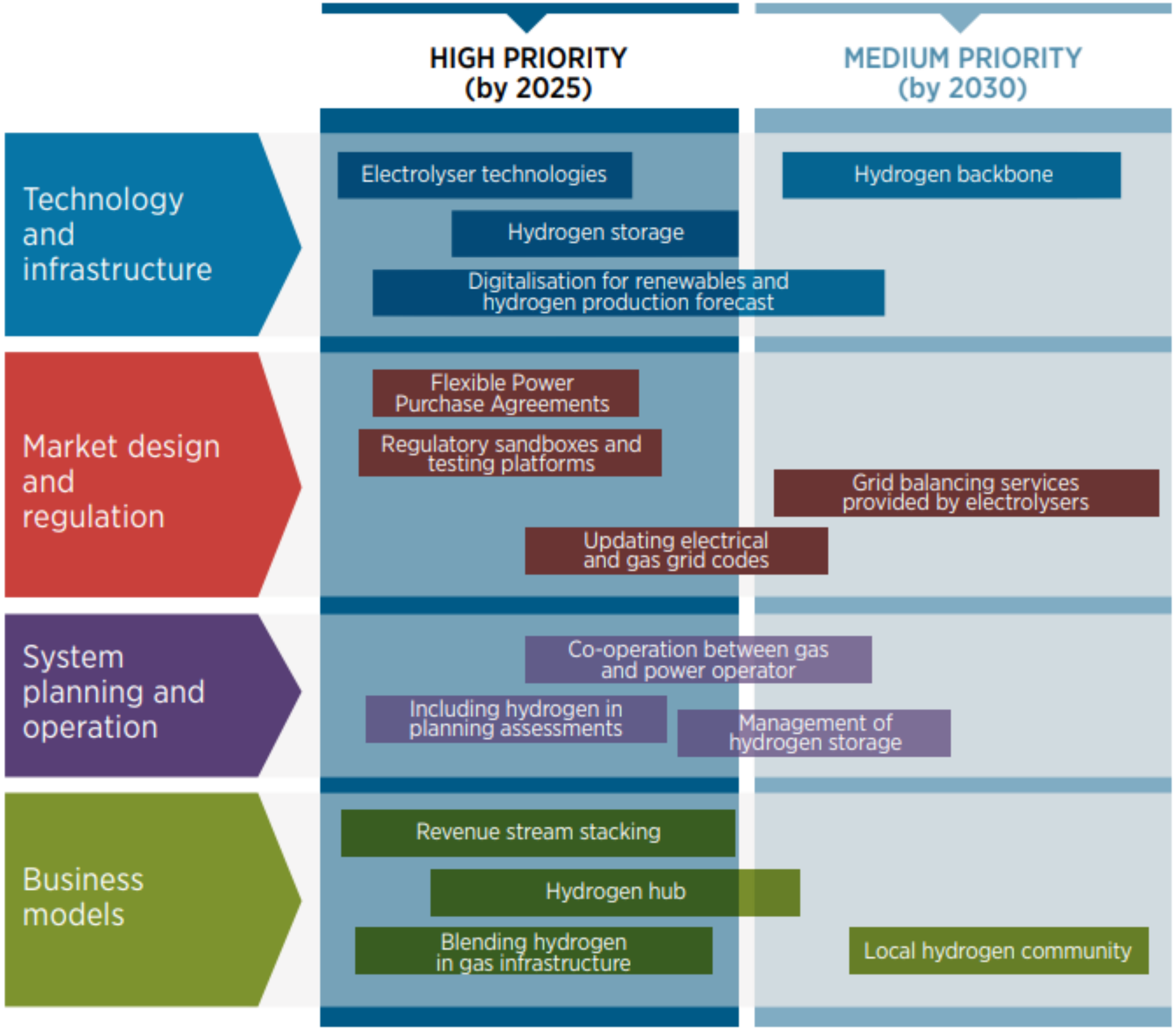


- ❑ Almost 15 million heat pumps installed in 21 European countries.
- ❑ 1.6 million heat pump installed in 2020 alone. The top three markets were France (394k), Italy (233k) and Germany (140k).

Green Hydrogen is key for the energy transition

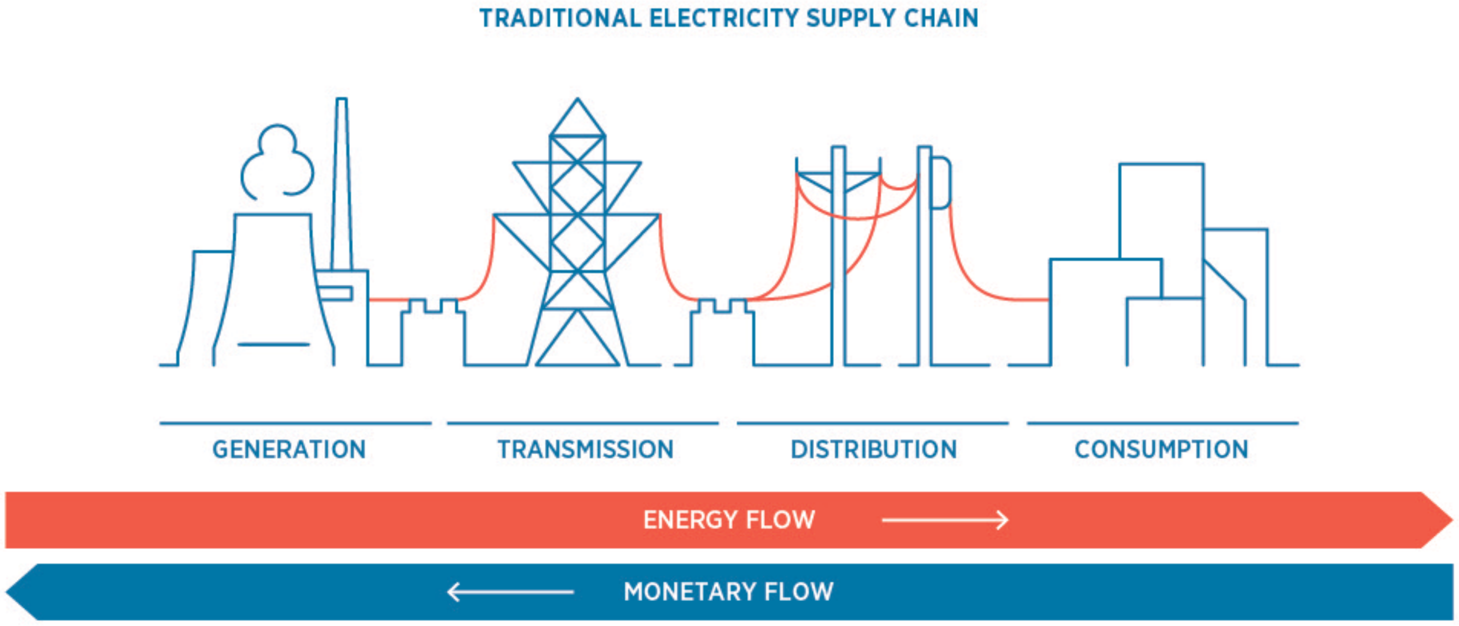


Smart hydrogen production



- Cost-effective production of green hydrogen requires **high capacity factors** (no dreams of using RE surplus)
- Compared to DER, electrolysers are **centralised and large loads** (modularity not so attractive)
- No clear **business case** for H2 producers to **provide flexibility** services

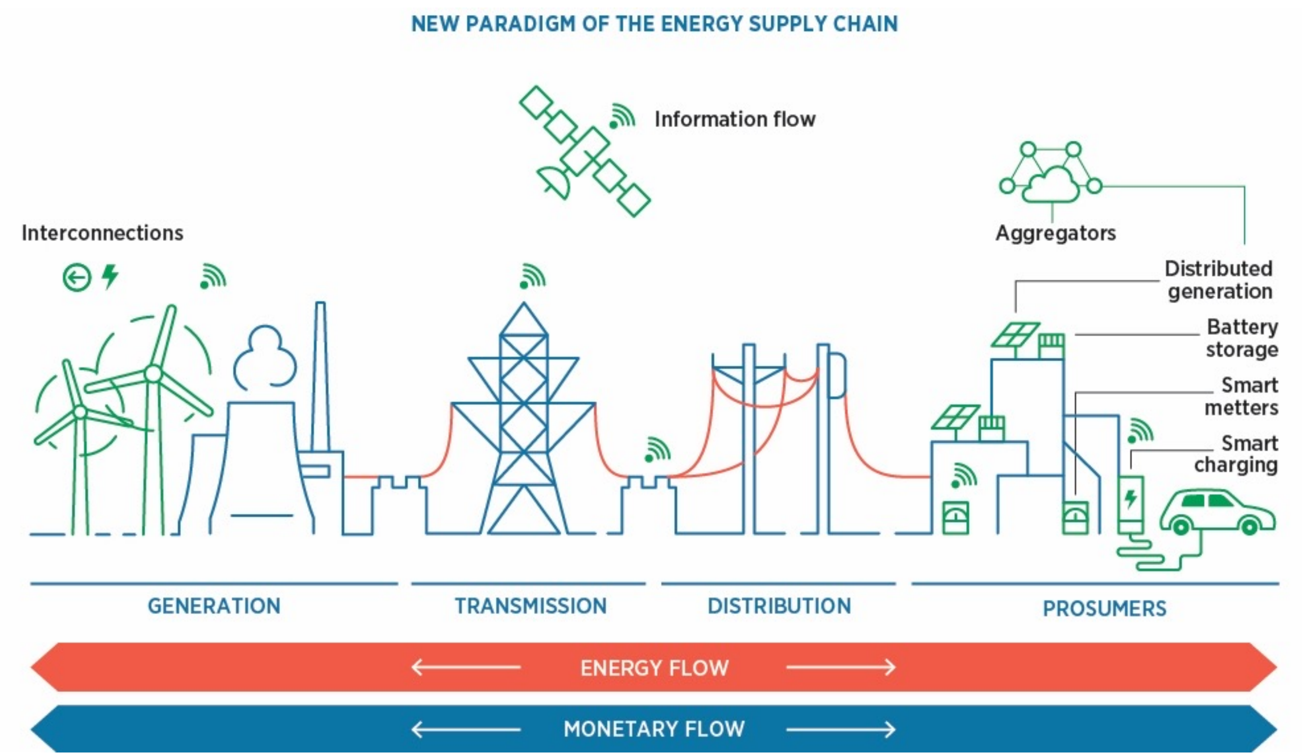
Ongoing Energy Transformation: Flexibility



Flexibility providers in the current system:

Flexible generation

Ongoing Energy Transformation: Flexibility



Flexibility providers in tomorrow's system:

Flexible generation,
Regional markets,
Demand response,
Storage, Power-to-X.

Key messages

- **Power system is the backbone of the energy system**. A renewable-based power system would ensure the decarbonisation of the end-use sectors as well.

  Flexibility is key to integrate high share of renewables!

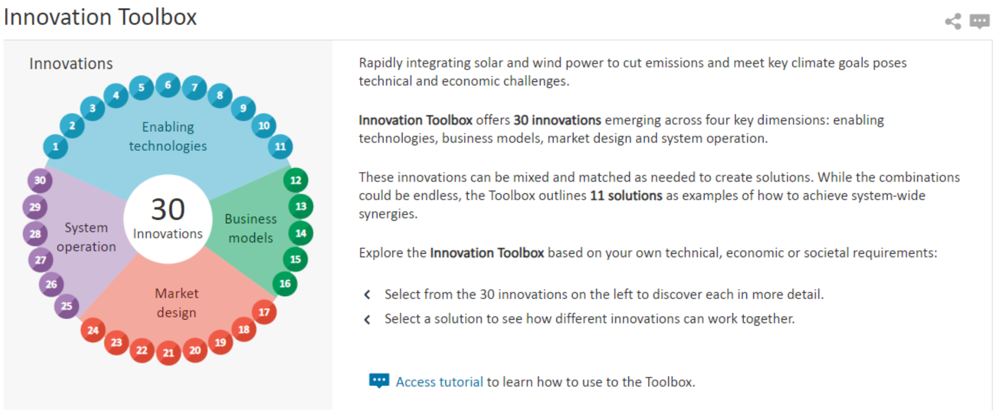
- Three trends: **decentralisation, digitalisation and electrification of end-uses**!
- **Smart electrification of end-use sectors is key for minimizing investments** needs in power networks.
- We have to **think holistically: systemic innovation**
- Electrify hydrogen production is very different than electrifying road vehicles or heating appliances.

  Smart strategies needs to be adapted for each demand segment, for each power system.

IRENA Innovation Landscape

https://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future

https://www.irena.org/innovation/Toolbox



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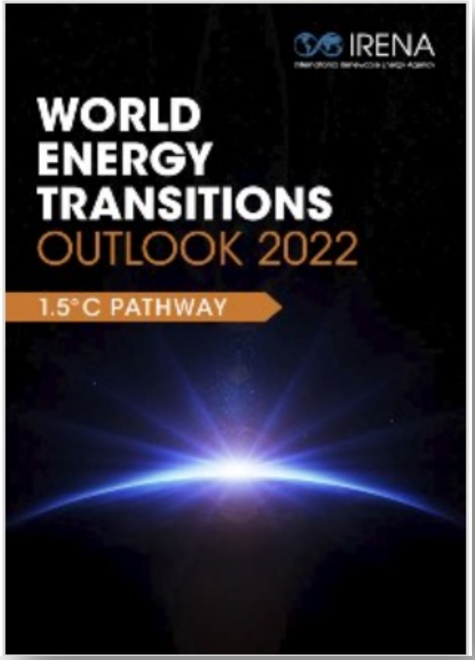

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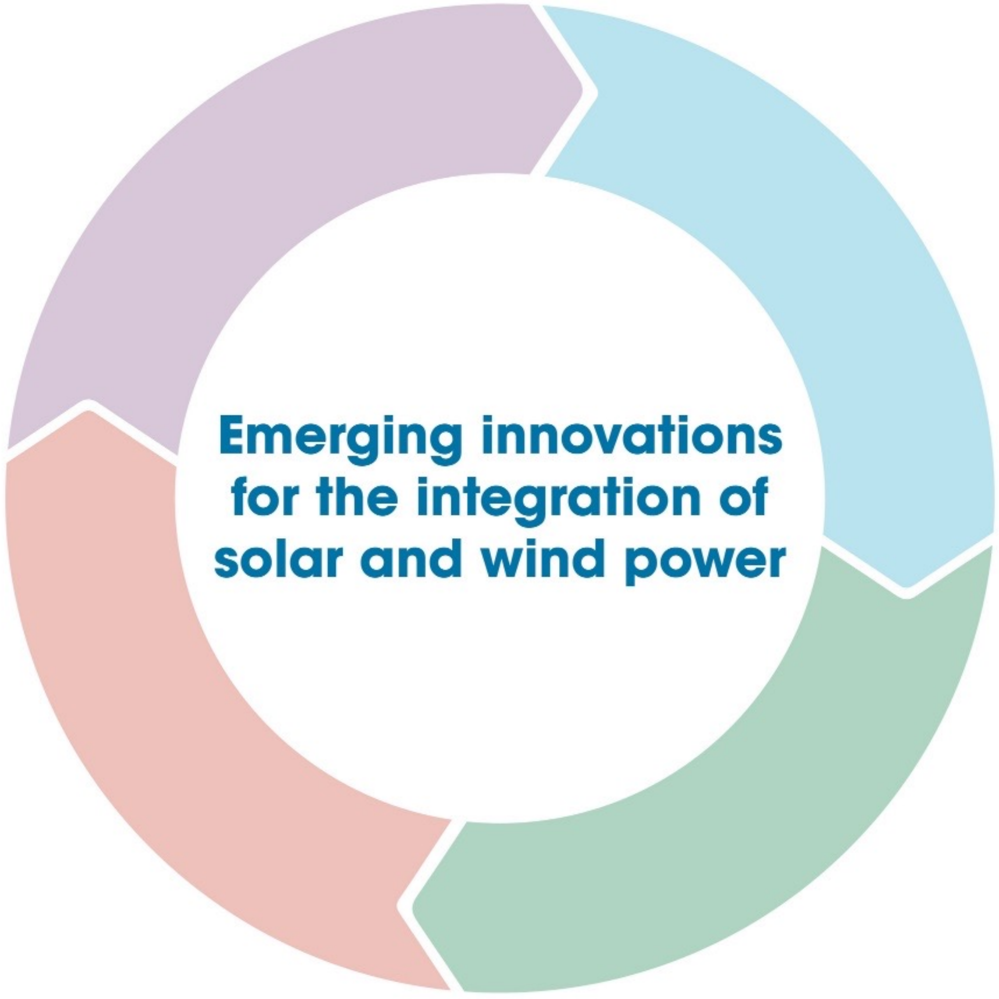

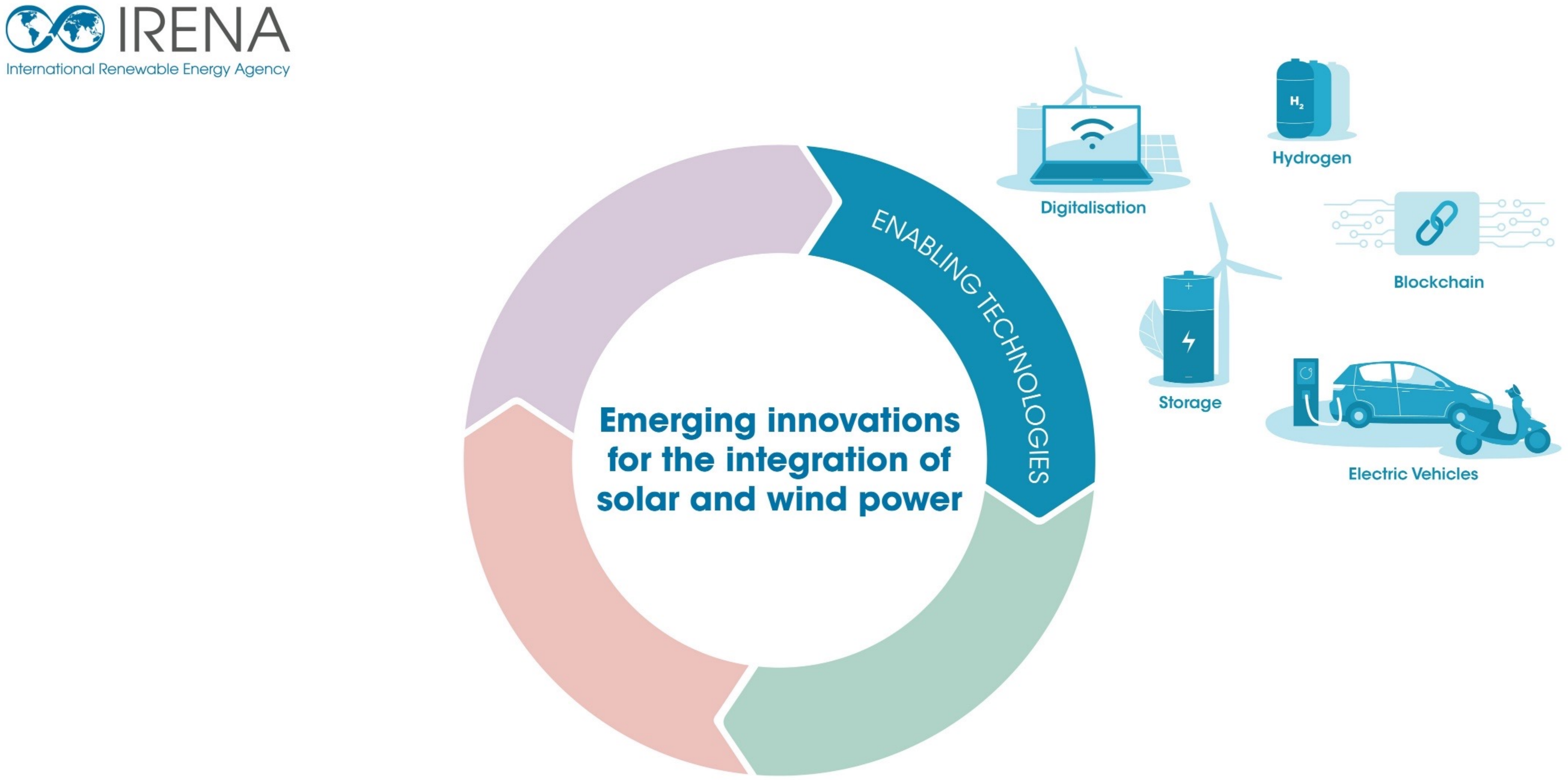
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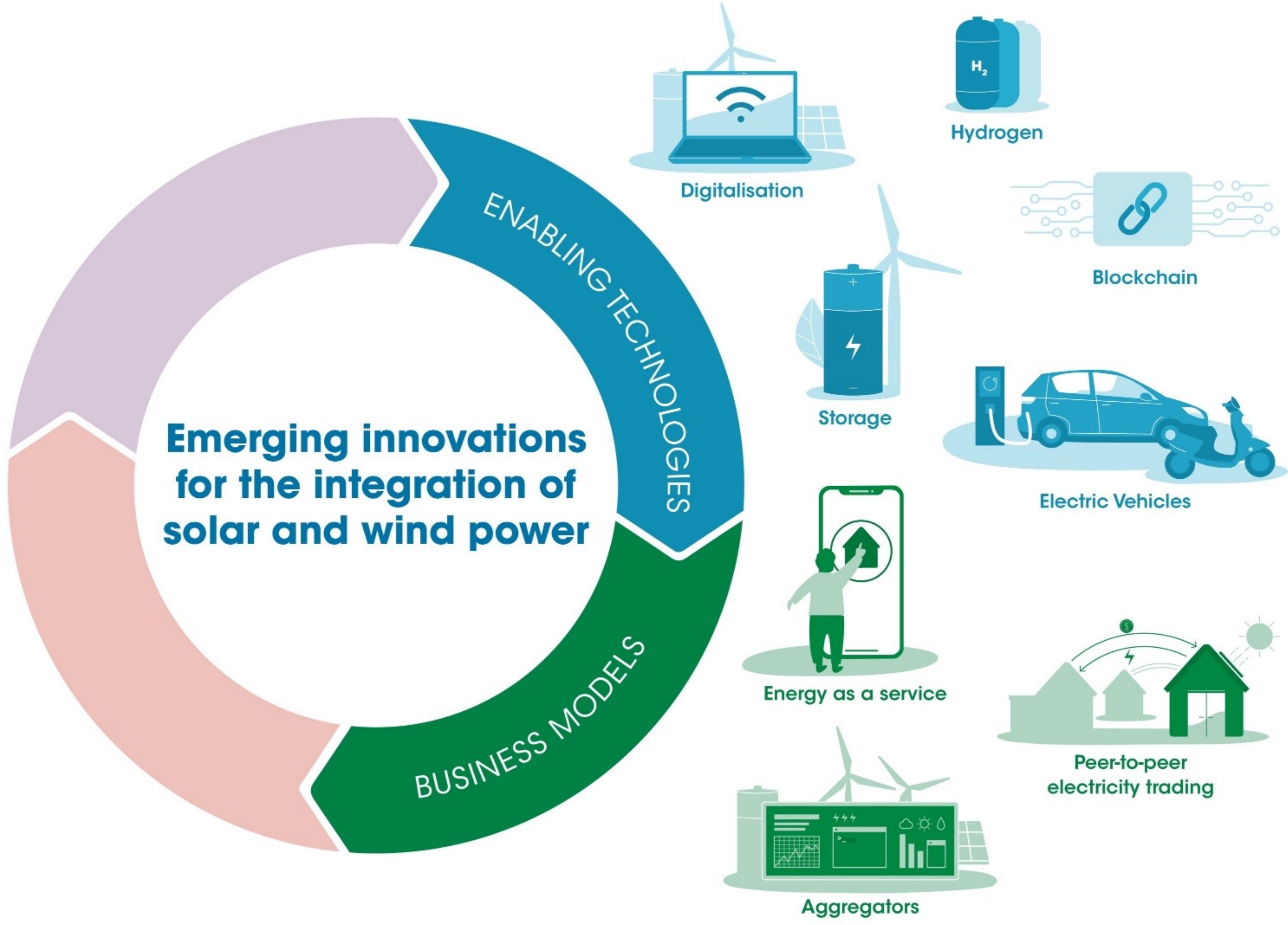
ENABLING TECHNOLOGIES
Emerging innovations for the integration of solar and wind power
Digitalisation
Hydrogen
H_2
Blockchain
Storage
Electric Vehicles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