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Smart Charging for Electric Vehicles

Francisco Boshell
International Renewable Energy Agency

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Session 6: Electric Transportation and Distribution Infrastructure
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Key insights from IRENA's engagement with countries on e-mobility

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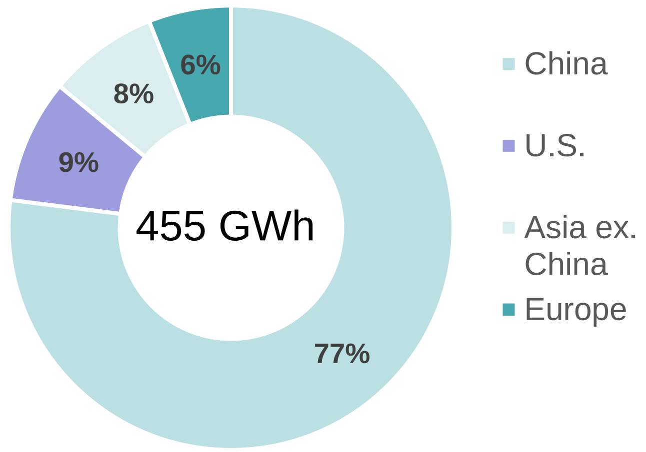
Electric passenger cars

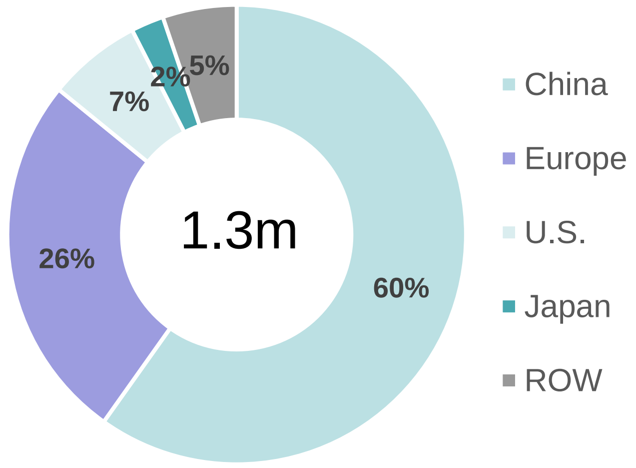
- Europe has become the largest EV market in the world
- There is a lot of attention for EV sales support and public charging points
- Proper long-term planning involving CPO, utility and energy authorities is crucial
- China leading in public charging stations (>800k end 2020)
- There is not sufficient attention for smart charging and power systems integration
- V2G bi-directional smart charging is needed but not getting much attention

Li-ion battery manufacturing capacity (2020)



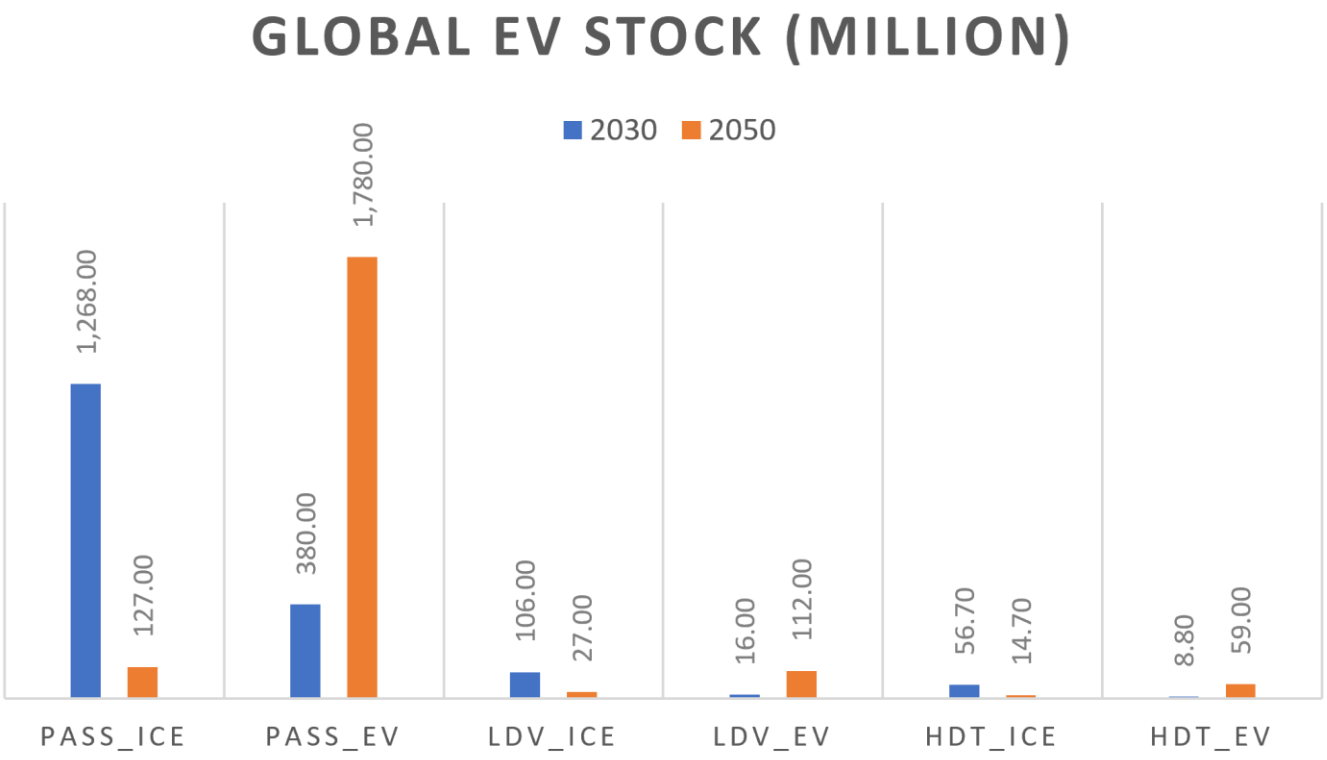
Source: IRENA, based on S&P Global

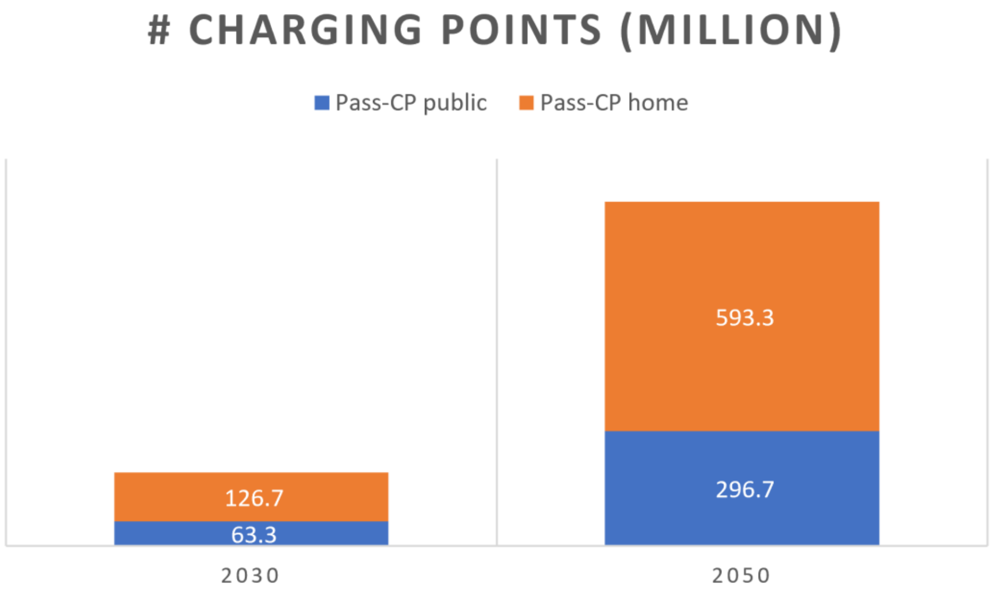
Total public charging points (2020)



Source: IRENA, based on BloombergNEF

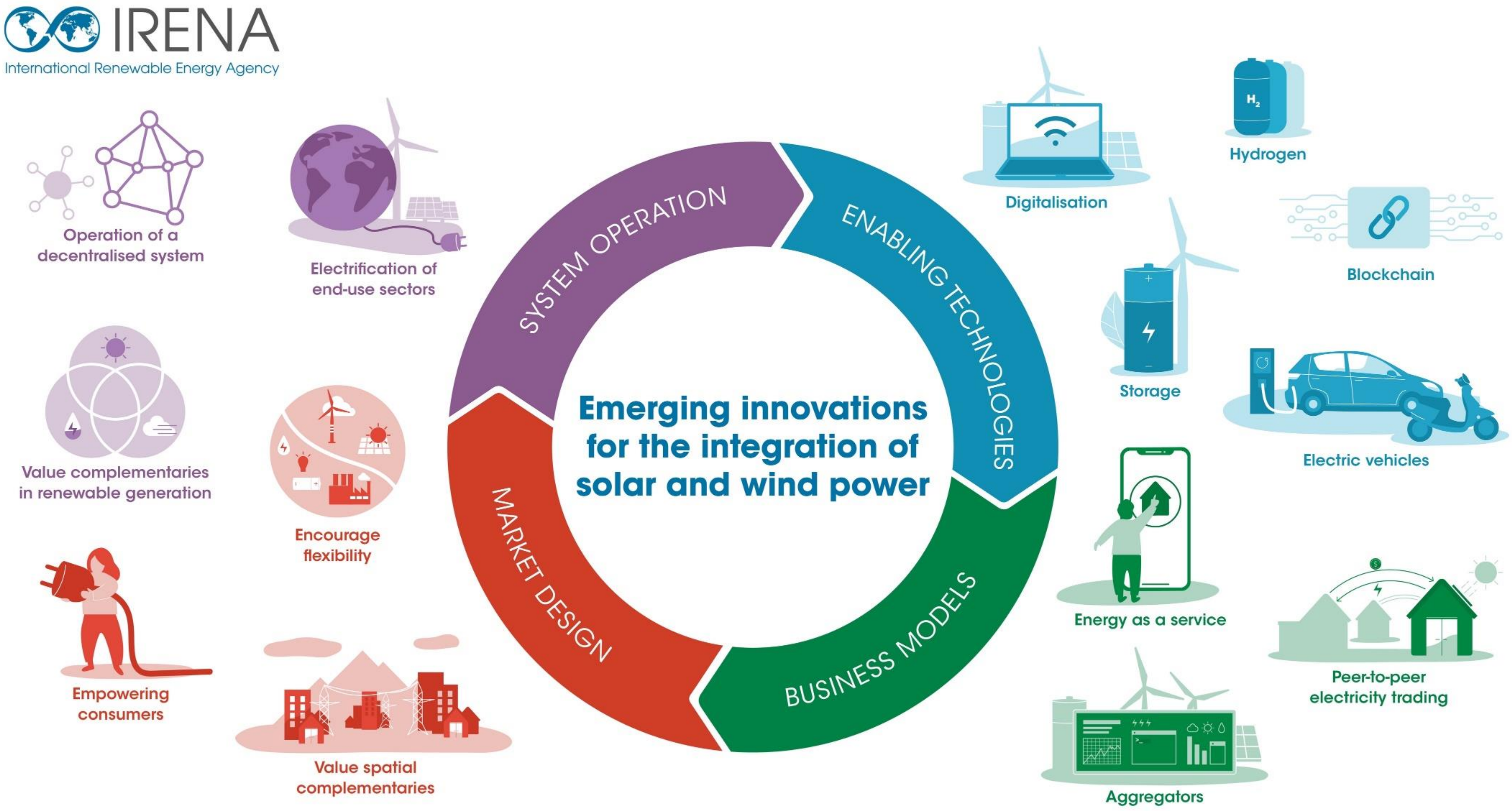
EV deployment in a 1.5oC scenario to 2030 and 2050





- Needed CPs per year for the next 30 years: 30 million CP installed per year
- Needed investments in CPs in the order of 220 USD billion per year
- Power system cost for smart vs dumb charging of around 1:10
- **Smart is the only way to go**

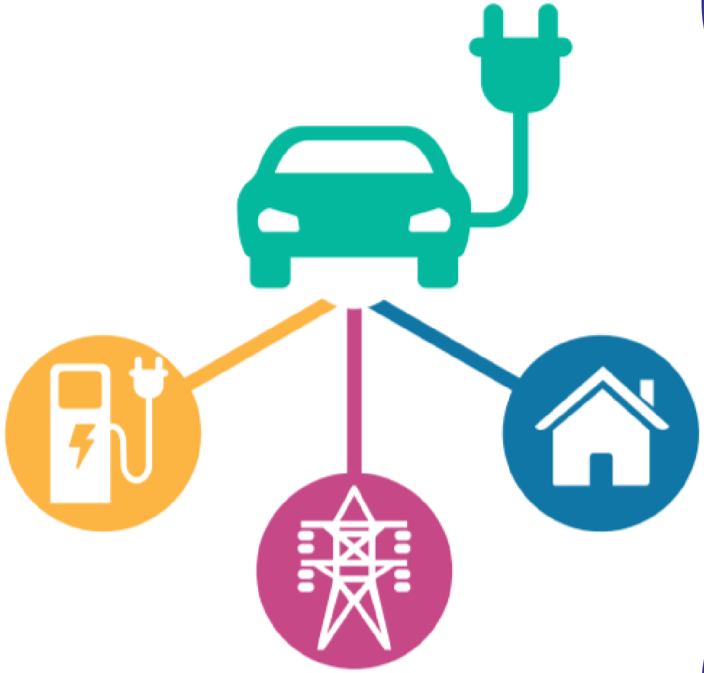
Smart charging needs a 'systemic' approach



Power-to-mobility segments

Segment	Use-Case	Charging Time	Charging Location	Parking times	Main differences
1. electric 2 and 3 wheeler	Private trips (incl. commute to work)	Anytime (day, night)	Public charging		Strategy for developing countries (high population density, low GDP per capita)
2. ePassanger Car	Private trips (incl. commute to work)	Overnight, office time, on the road	Private home, office charger, public charger	90 % of the time	Mostly developed countries; Strategy is driven by driver's experience Car is parked most of the time
3. eLDCV	Commercial trips (e.g. customer delivery)	Mainly overnight	Private depot (fleet)	Mostly overnight	Business driven; regional level
4. eHDV (eTrucks)	Logistic trips (e.g. long hub-to-hub delivery)	Overnight and on-road (public)	Private and public depot (fleet), on the road charging	Strict driving schedule, parking based on driver's official breaks	Business driven, large distances infrastructure
5. e-city Bus	Fixed public route (incl. schedule)	Overnight and on-road (public)	Public depot (fleet), bus station fast charging	Short breaks (20 min) during the day. Parked overnight	Public service, public ownership, Fixed route inside city

Impact of smart charging on solar PV and wind integration



Electric vehicles have **small impact on energy demand** but **larger impact on peak load**

Different impact of EV charging in a **wind or solar PV** dominated power system

Smart charging cuts **peak load**, reduces **curtailment** and allows higher shares of low-cost PV and wind electricity

Smart charging makes EVs a source of flexibility for power systems- facilitating integration of VRE

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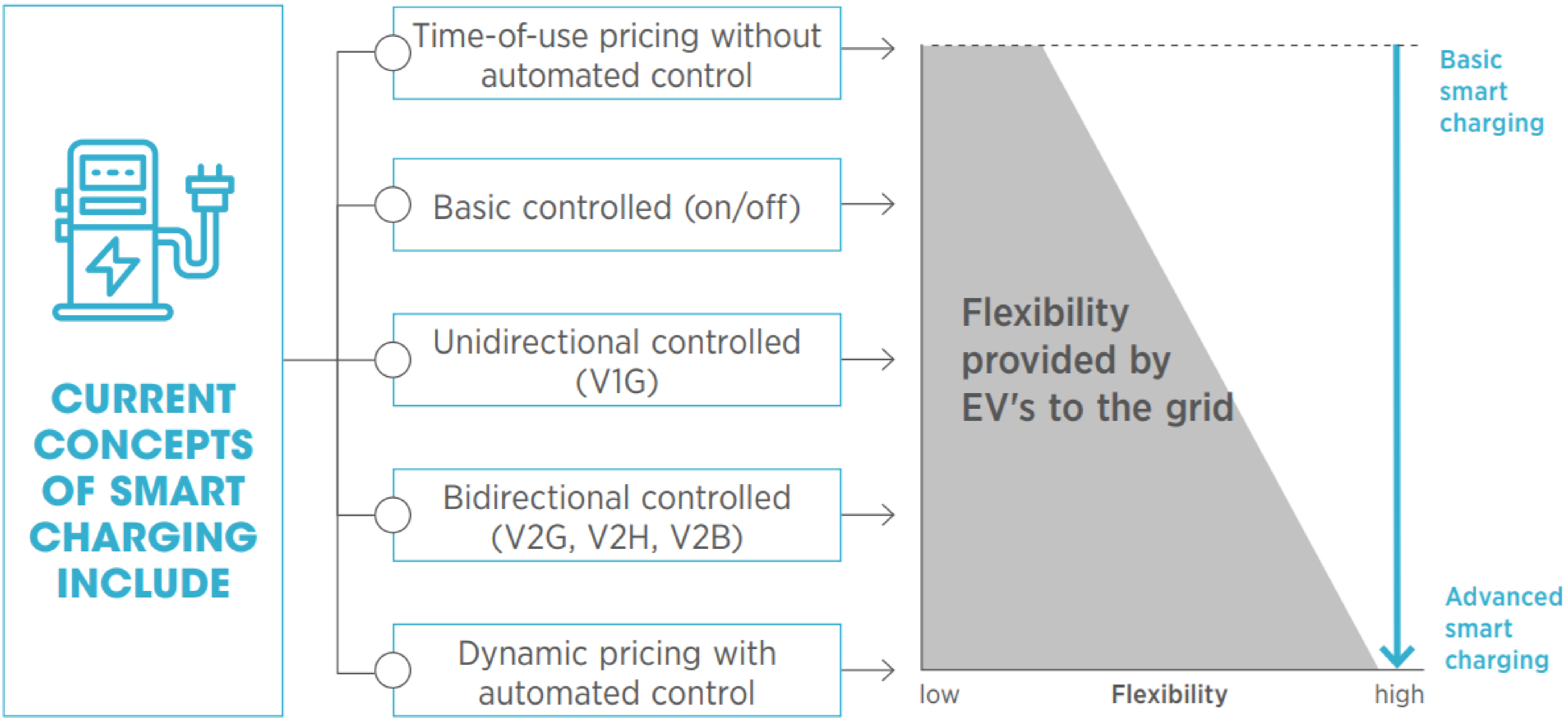

Source: IRENA (2019) Innovation Outlook: Smart charging for Electric Vehicles

Impact of smart charging on solar PV and wind integration

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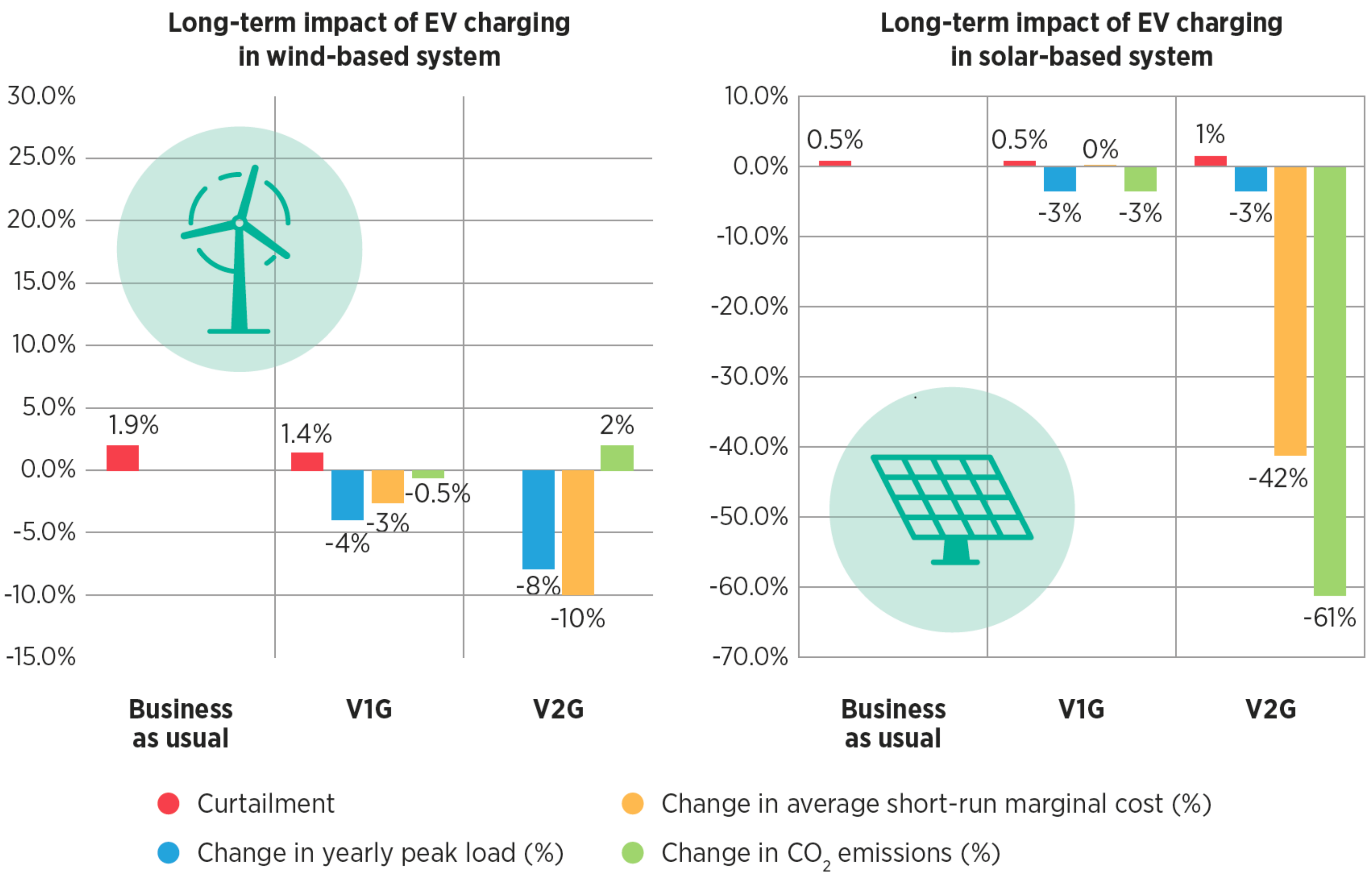

Source: IRENA (2019) Innovation Outlook: Smart charging for Electric Vehicles

Impact of smart charging – similar results in other studies

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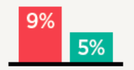
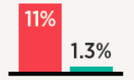
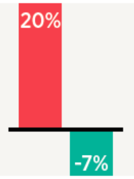
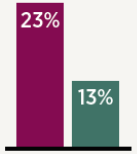
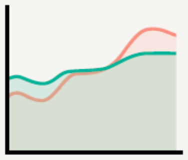
- Smart charging cuts peak load, reduces curtailment and allows higher shares of low-cost PV electricity.
- This can help to displace more expensive generation and lower electricity prices.
- Higher impact on PV than wind due to generation profiles
- Mobility-as-a-Service will reduce provision of flexibility from EVs

Study	Scenario	Uncontrolled charging	Smart charging	
IRENA	**50%** penetration in an isolated system with 27% solar share	**↑9%** increase in peak load 0.5% solar curtailment	**↑5%** increase in peak load (V2G) Down to 0% curtailment	
RMI, 2016	**23%** penetration US (California, Hawaii, Minnesota, New York, Texas)	**↑11%** increase in peak load	**↑1.3%** increase in peak load (V1G)	
Taljegard, 2017	**100%** penetration Denmark, Germany, Norway & Sweden	**↑20%** increase in peak load	**↓7%** decrease in peak load (V2G)	
McKenzie, 2016	**50%** penetration in Island of Oahu, Hawaii, US 23% VRE share	**10-23%** VRE curtailment without EVs	**8-13%** VRE curtailment with smart charging EVs	
Chen and Wu, 2018	**1 MILLION** EVs in Guanzhou region, China	**↑15%** increase in peak load	**↓43-50%** reduction in valley/peak difference	

- Peak load with uncontrolled charging
- Peak load with smart charging
- Curtailment in no EVs scenario
- Curtailment with smart charging EVs

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

Full potential of smart charging needs > 90% of charging at home and work

Question to EV owners in Norway: "How often do you charge…"

	Detached housing	Apartment buildings
At home, daily or weekly	97 %	64 %
At home, monthly or never	3 %	36 %
At work, daily or weekly	36 %	38 %
At work, monthly or never	64 %	62 %
At public charging stations, daily or weekly	11 %	28 %
At public charging stations, monthly or never	89 %	72 %
At fast charging stations, daily or weekly	12 %	18 %
At fast charging stations, monthly or never	88 %	82 %

Charging approaches more compatible with smart charging

- Full potential of smart charging -> At least **two charging points per PEV** (at home and at work)
- Influence of population density/housing type
- Most EV owners in **detached housing charge at home** or public charging stations.
- Most EV owners in **apartment buildings would charge at fast charging stations** or normal public charging stations.
- Need to understand implications on **investments at home and public charging**

Source: Norwegian EV Association (2017) Charging infrastructure experiences in Norway - the worlds most advanced EV market

Flexibility services to be provided by EVs – innovation in business models and regulation

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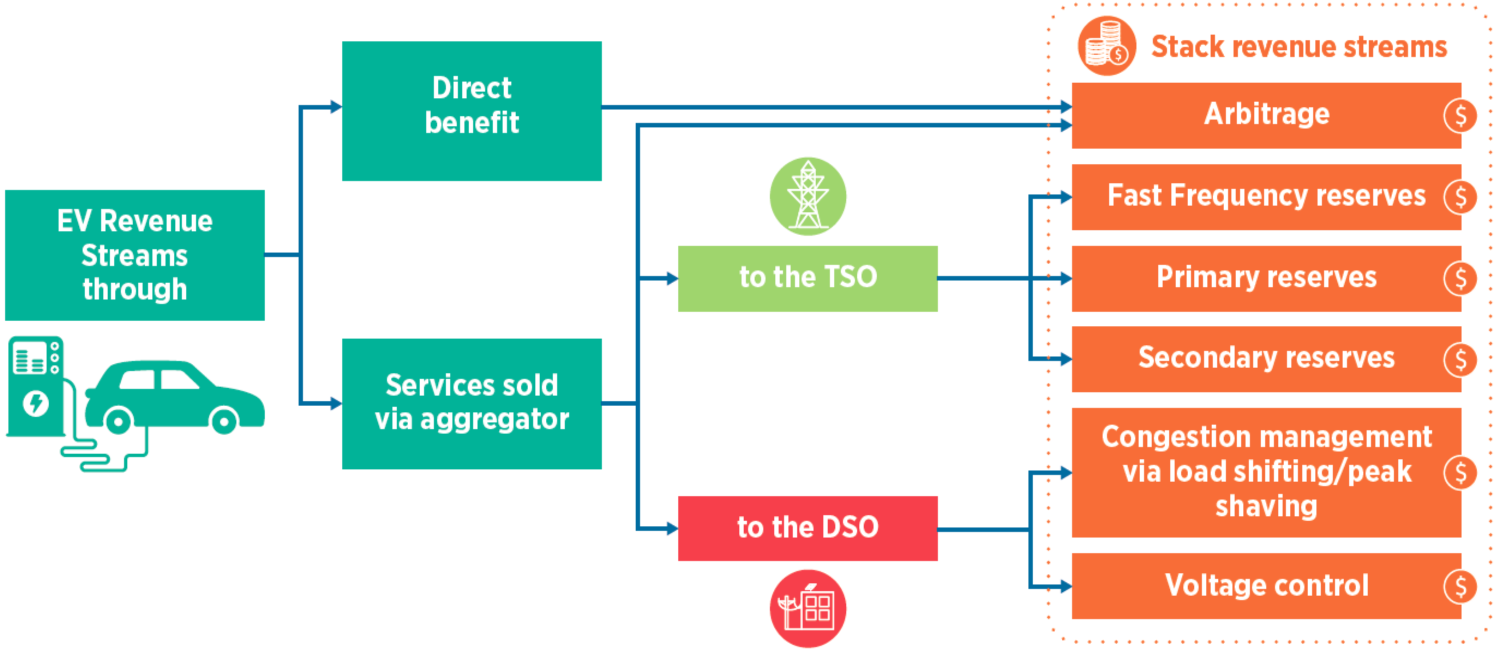
Regulation:
- Dynamic tariffs
- Need for flexibility markets at low-voltage level (e.g. congestion)
- EVs bidding multiple services in ancillary markets
- Reward performance and capacity
- Avoid double levies and fees (charging and discharging)
- Building codes (smart charging ready)

Business models:
- Aggregator business models crucial to reach trade capacity
- Consider car owner priorities - type of grid services with high revenue but also preserve car/battery ('on-call' service)



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

Impact of smart charging on grid infrastructure – digitalization is key

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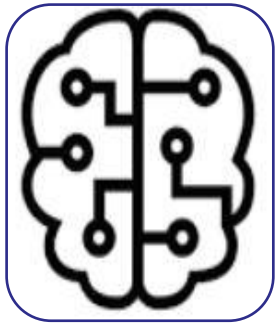
Case study: EVs impact on Hamburg’s distribution grid

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

90% grid investment savings with smart solution

Option A: Grid reinforcement solution

- Reinforcing ~ 10 000 km of 0.4 kV cable lines, replacing trasformers
- Construction works for many months, closing of roads
- Estimated investment: **20 million EUR**



Option B: Smart digital solution

- 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.
- Estimated Investment: **2 million EUR**

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

Implementing digital solution in Hamburg with "eRound"

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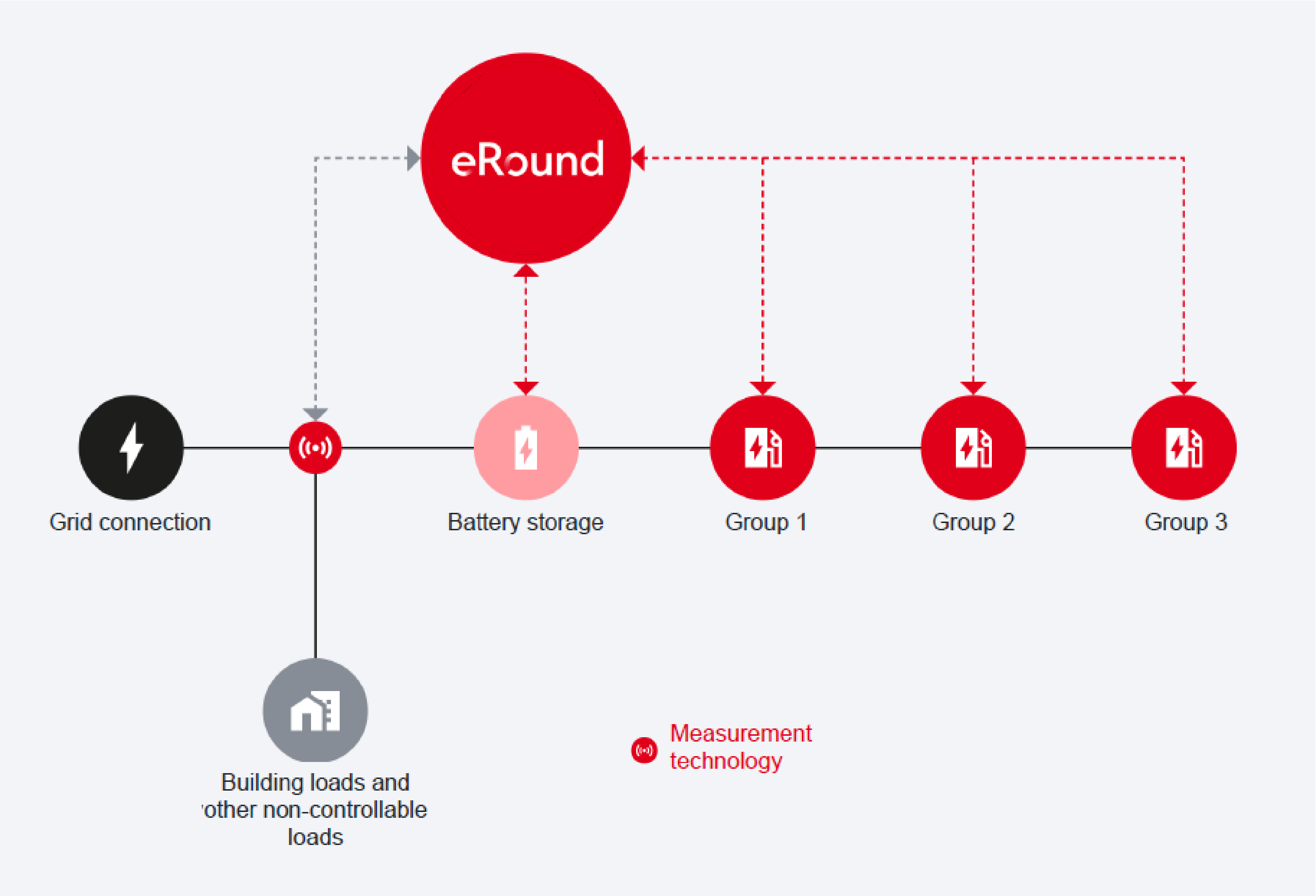
Load-side control of charging stations

- **Consideration** of building loads and other non-controllable loads to control the charging pole power.
- **Integration** of battery storage to balance the overall load
- **Control** of charging processes: Ensuring a sufficient state of charge at the scheduled departure time



Source: Counrtesy of Stromnetz Hamburg

Renewable options for road freight

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Road freight

3 options compatible with reaching zero emissions

ZERO

Battery electric vehicles

- Use electric motors powered by a battery pack, charged with renewable electricity.

Fuel cell electric vehicles

- Use electricity produced by fuel cells powered by compressed (green) hydrogen.

Advanced biofuels

- Use biomass-based fuel substitutes, such as biodiesels and renewable diesels.

Current discussion

Batteries
- Battery weight
- Drive range

ERS
- Usage factor
- High truck traffic

H2 fuel cells
- Efficiency
- Costs
- Infrastructure

Biofuels
- Feedstock availability
- Sustainability

Source: https://www.irena.org/publications/2020/Sep/Reaching-Zero-with-Renewables

E-Trucks – key considerations

- Heavy freight trucks >15 t dominate total commercial vehicle fuel use
- Bulk of European freight transport takes place over a distance of less than 500 km
- Extra weight of batteries is minor
- Continued cost reduction and performance enhancement of batteries
- Mobile batteries will dwarf stationary batteries – renewable energy integration opportunities
- Significant opportunity to contribute flexibility but need to understand how <u>‘smart charging’ for trucks</u> would look. Long-term planning is key

Impact of Charging E-trucks on Power Systems

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Charing nominal capacity: 1MW charging point for e-HDV = the peak load of 1,500 households.

Investments: Enedis - a truck service station along highways requires average > 1 M EUR investment. 400 stations in France around half a billion EUR (cables and posts)

Planning: Time needed for the work ~ 1 to 3 years

Regulation: E-trucks might not be so sensitive to changing charging behavior via compensation such as ToU tariffs

Location: Charging mainly concentrated in hubs

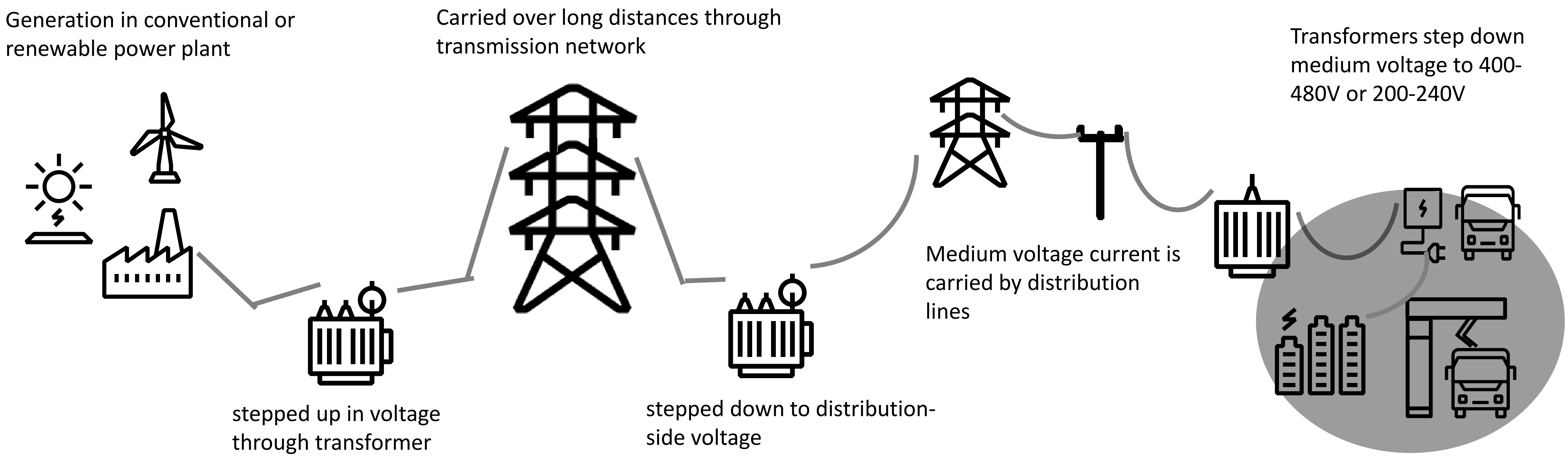
Source: IRENA Innovation Week 2020 and Regulatory Energy Commission of France

Source: https://www.irena.org/events/2020/Oct/Heavy-Duty-Vehicles-in-the-Penta-Region

Grid upgrades

Distribution systems, MV Switchgear and final transformers are the most likely candidates that require upgrading……

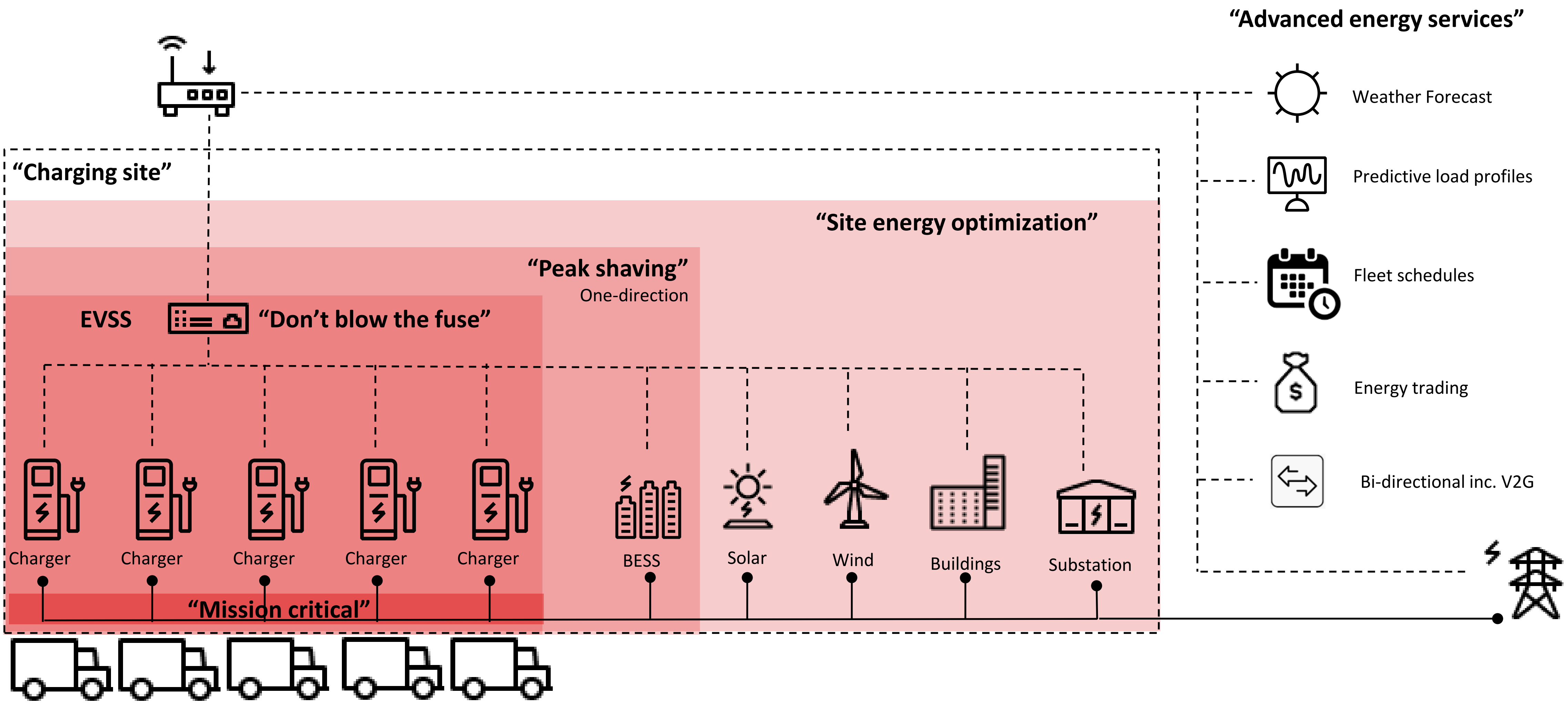
Upgrading of infrastructure will often be required, unless…



Source: Courtesy of ABB

Energy storage systems and load management reduce the need for MV grid and transformer expansion

Evolution of the EV Charging site



Source: Courtesy of ABB

Smart charging for E-trucks – how would it look?

Source: IRENA Innovation Week 2020

Considerations for smart charging of e-trucks

- Need for a better understanding on **approaches to adapt charging patterns**
- Possible solutions may rely less on price signals (tariffs) and more on **infrastructure solutions** (digital & electrical)
- Stationary **batteries as buffers** to manage peak demand
- Charging hubs combined with **on-site RE generation**, E.g.:
  - Frito Lay in California: e-trucks + on-site PV generation + stationary batteries
  - Kallista Energy in France: service stations along highways with on-site wind power generation
- **Proper long-term planning** involving CPO, utility and energy authorities is crucial

Do we need more power for charging trucks?

- New standard in development to support 3-4MW

MegaWatt Charging System (MCS)

New standard in development

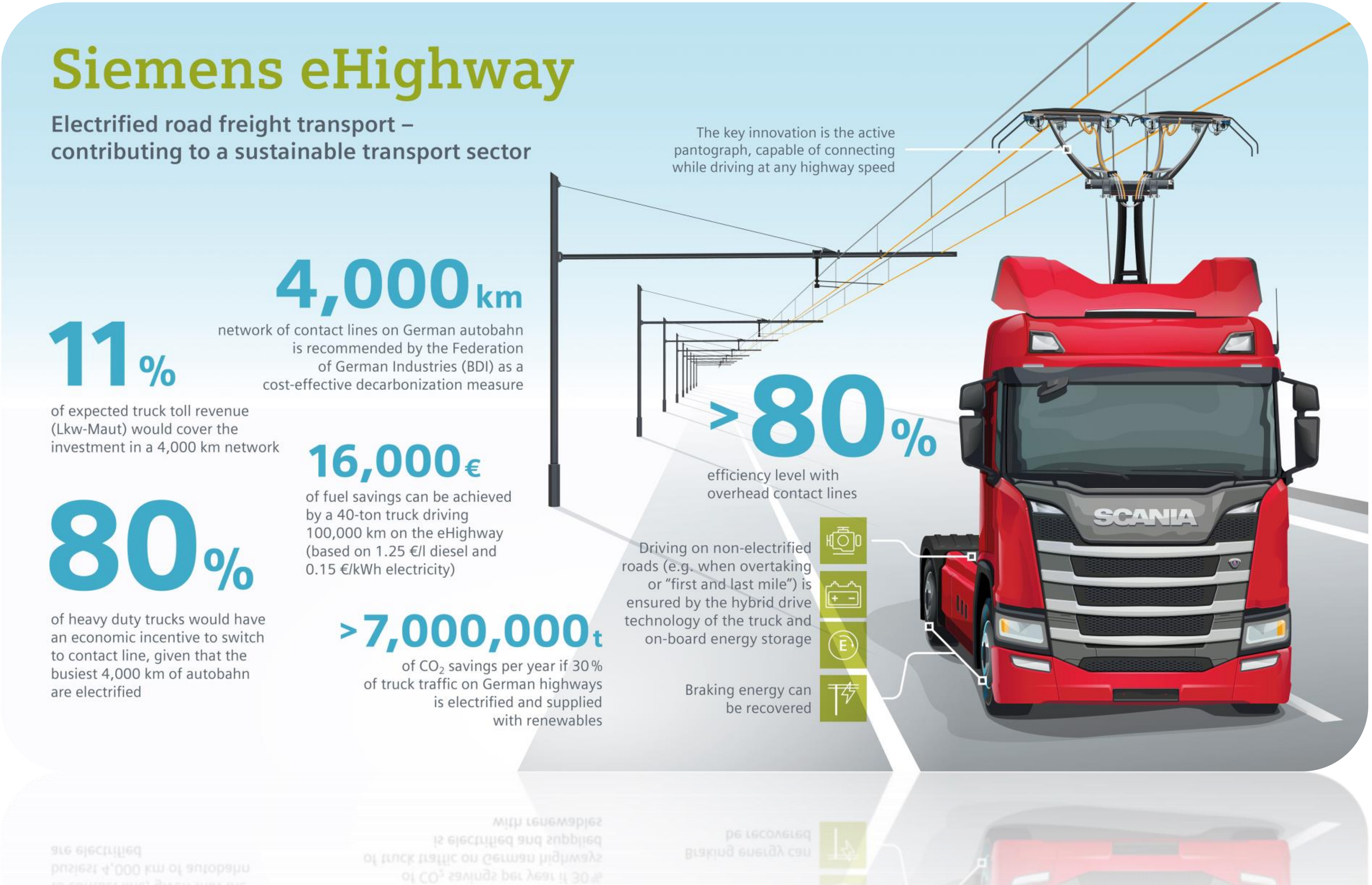
1000V and 3000A
1250V optional

CCS2 350-450kW	ChaoJi 900kW	MCS 3MW
		Under Development
920V x 500A	1500V x 600A	1000V x 3000A 1250V optional

175/350kW 500A	1MW pilot 1000A	3MW 3000A
2019	2021	2022

Source: Courtesy of ABB

Electric Road Systems



Hybrid systems:
- E-roads in segments of highways with high traffic volume
- Stationary charging points in periphery and depot

Source: Courtesy of Siemens

And how about e-buses? battery swapping could provide flexibility in addition to smart charging

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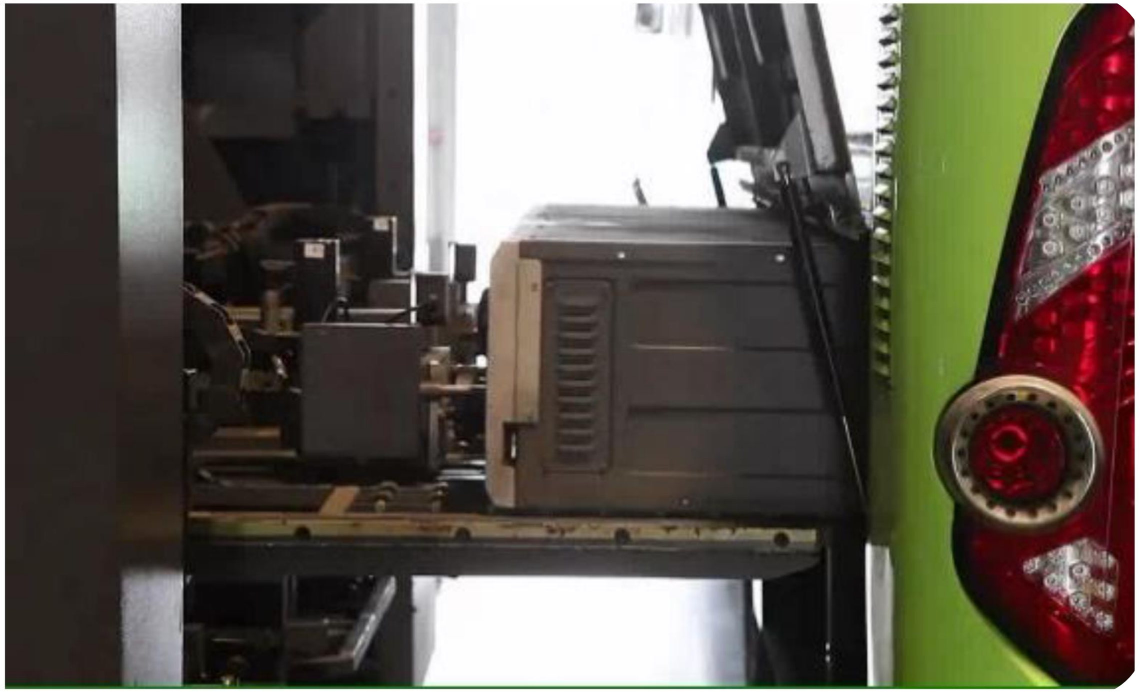
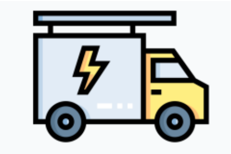
Battery swapping for e-buses in Qingdao City, China



Source: IRENA Innovation Week 2020



Smart Electrification of HDV - "Systemic innovation" Ongoing Project

Technology & infrastructure	Market design & regulation	System operation & planning	Business models
E-HDV model evolution	Electricity tariff design	Cooperation of regulatory agencies	EV aggregators
EV battery evolution	Smart charging enablement by DSOs	Cooperation to build clean highway corridors	EV load peak-shaving using distribured energy resources
Battery recycling technologies	Smart charging enablement by TSOs	Power system planning for flexible EV load	Battery second-life and end-of-life (EOL) reuse
Diversity and ubiquity of charging infrastructure	Diversity of grid-balancing services offered by smart charging of EVs	Transparency of grid data	Energy as a service
Coupling of charging infrastructure with onsite DER	Permitting procedures for charging infrastructure installation	EVs as resiliency solution	Mobility as a service
Portable and stationary V2G systems	Vehicle-to-grid (V2G) regulatory framework for Interconnection	Management of EV load to integrate intermittent renewables	Logistics as a service
Standardisation and interoperability of charging stations		Management of flexible EV load to defer grid upgrades	Scope 3 fleet electrification
Digitalisation – Transportation networks			Public charging station ownership and operation
Grid and power system enablers of EVs			

Legend
Specific for the vector
Overarching

Source: https://www.irena.org/publications/2019/May/Innovation-Outlook-Smart-Charging

13 guiding points for policymakers

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- **Promote renewable energy to decarbonise power system**
- **Promote EVs to decarbonise transport**

1. Set ambitious targets
2. Support charging infrastructure
3. Keep or introduce temporary incentives for cars
4. Deploy more renewables

- **Focus on smart charging**
- **Create incentives to tap large incremental benefits, especially from solar use**

5. Standardise and ensure interoperability
6. Implement on islands and in areas with high shares of renewable energy
7. Design smart charging strategy to fit the power mix
8. Choose optimal locations for charging
9. Market design should allow for smart charging, adjust regulation
10. Complement grid charging with storage at charging points or battery swapping

- **Study impact of long-term evolution of mobility on smart charging**

11. Support battery and charging R&D considering both mobility and grid needs
12. Study implications of mobility-as-a-service for EV flexibility
13. Integrated planning of power and transport sector

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

Thank you

Francisco Boshell
innovation@irena.org

Free download at:
www.irena.org/publications

Backup slides

Battery storage and grid services by 2050

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Utility scale

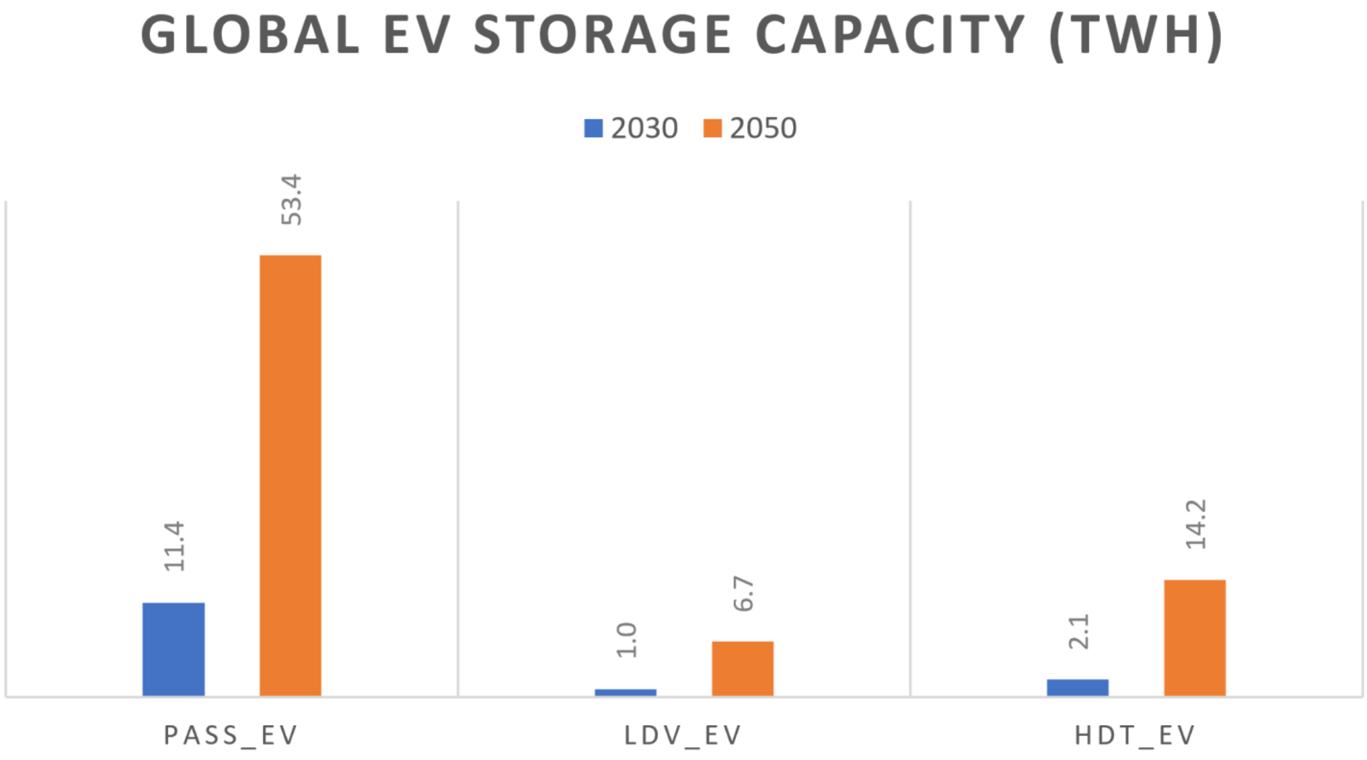
5.5 TWh

BtM Decentralised

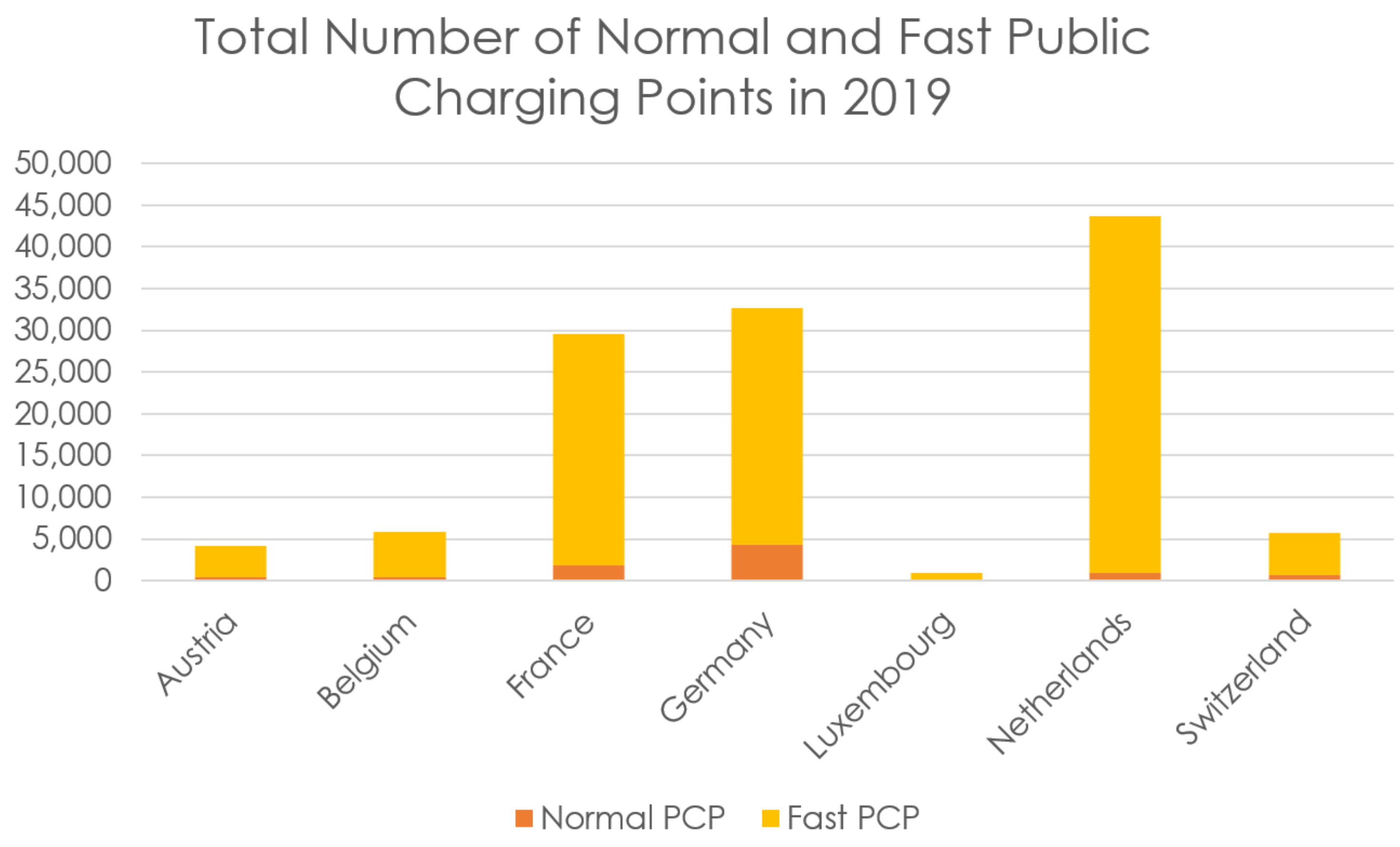
10.8 TWh

- All vehicles charge smartly either with V1G or V2G
- 2/3 wheelers can only charge with V1G
- For the other vehicles only 20% provide V2G (1:3 simultaneity) ~ 3 TWh , the rest V1G ~ 12 TWh

> 50 TWh
(pass only)



Public Charging Points gap in the Penta Region

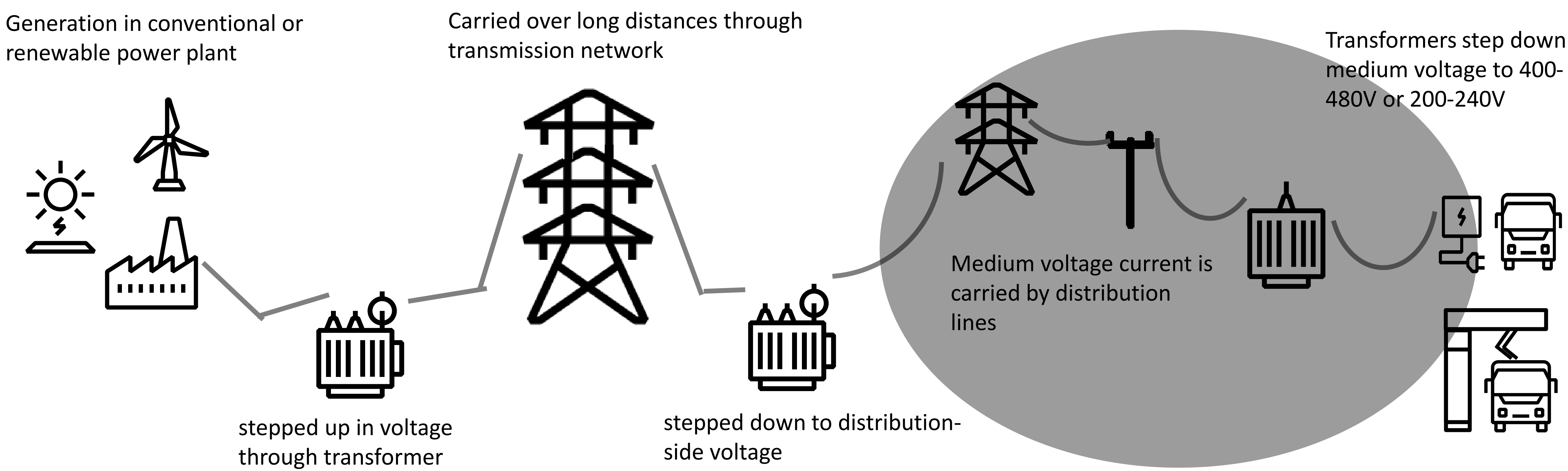


- Today around **123,000 PCP** in the Penta Region
- If 4 million PEV by **2025**, PEV/CPC ratio of 4:1. Then, **1 million PCP needed** (800k normal + 200k fast charging)
- Investment in PCP close to **14 billion EUR** (~4 billion EUR normal + ~10 billion EUR fast charging)
- Additionally, half of PEV owners may install home chargers: ~ **2,4 billion EUR more**

Source: IRENA based on data from the European Alternative Fuels Observatory

Grid upgrades

Upgrading of infrastructure will often be required: current



Source: Courtesy of ABB

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Beijing's Electrification Strategy

Beijing

Technology & infrastructure

EVs
- 16% in new registered vehicles of 2020
- 450,000 EVs on road

Diversity and ubiquity of charging infrastructure
- 210,000 chargers (public + private)
- Within 0.9 km in core area; 5 km in other areas
- Abundant in traffic hubs (e.g.≥400 in Daxing Airport)
- 100 swap stations

Digitalization
- Cellphone applications with real-time information incl. locations, charging power, V2G and cloud management systems

Market design & regulations

e-Vehicle plate
- Queue (draw lots for gas vehicle)
- No ban day

Charging infrastructure
- 25% in office buildings; 20% in commercial centers; 15% in public buildings; 100% in resident buildings

Time of Use Tariffs for EVs
- Public: Laddle-type tariff ($ 0.25/0.21/0.17 dollar/kWh), 50 kW
- Home: $ 0.077 dollar/kWh, 7 kW

System operation & planning

Management of EV load to defer grid upgrades
- Pilot project - V2G charging for office building: Beijing Renji Building, goal of reducing power consumption cost in peak hours and improving transformer load rate in low hours
- Pilot Project V1G charging for Residential site: Beijing Xibali community
- Solar-Storage-Charging pilot project (Beijing Dahongmen 4MW/25MWh DC project) - delayed the capacity upgrade of 10MW in Beijing urban power distribution network

Business models

Charging stations ownership and operations
- The charging facilities are constructed and managed by different operators (private and public).
- Sharing private charging points: State Grid Electric will provide management platform support to share charging resources. Owners need to set the idle time and will be remunerated.

Battery second life
- SGCC launched a pilot project to use retired batteries in charging station in Beijing. About 100 kWh retired batteries are applied as DC power source.

Impact of smart charging in Beijing

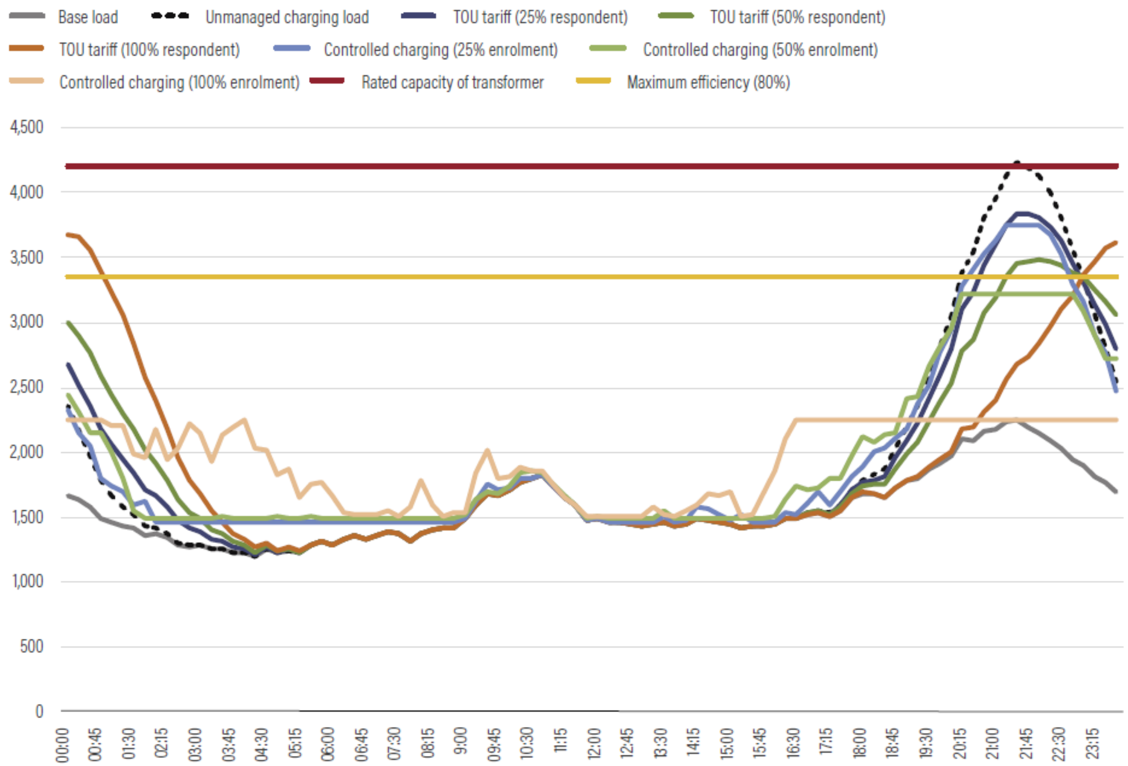
Typical residential quarter in Beijing with 100% EVs

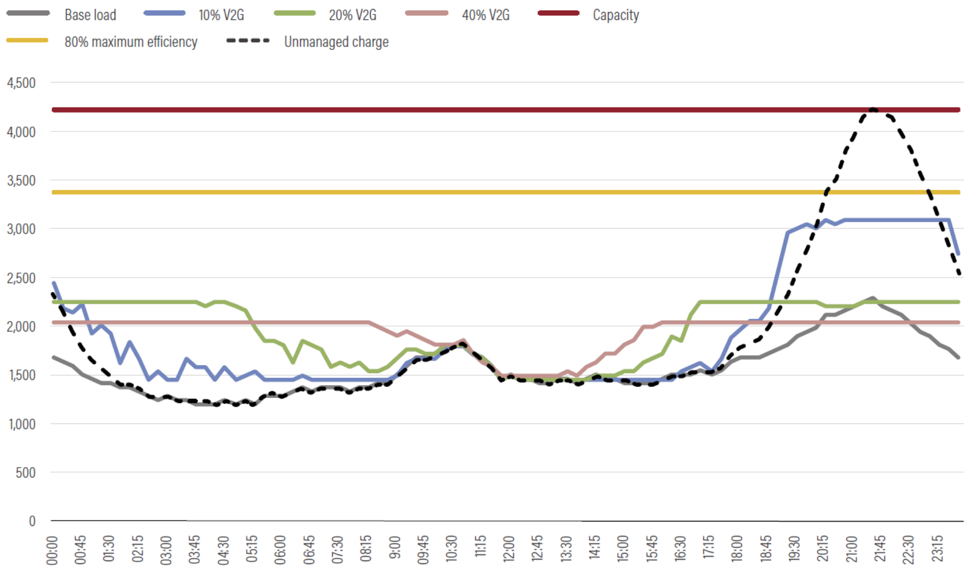
Without smart charging:

- Maximum load 4200 kW; Capacity upgrade is required

TOU charging:

- 3700 kW @ 100% respondent
- Delay the peak





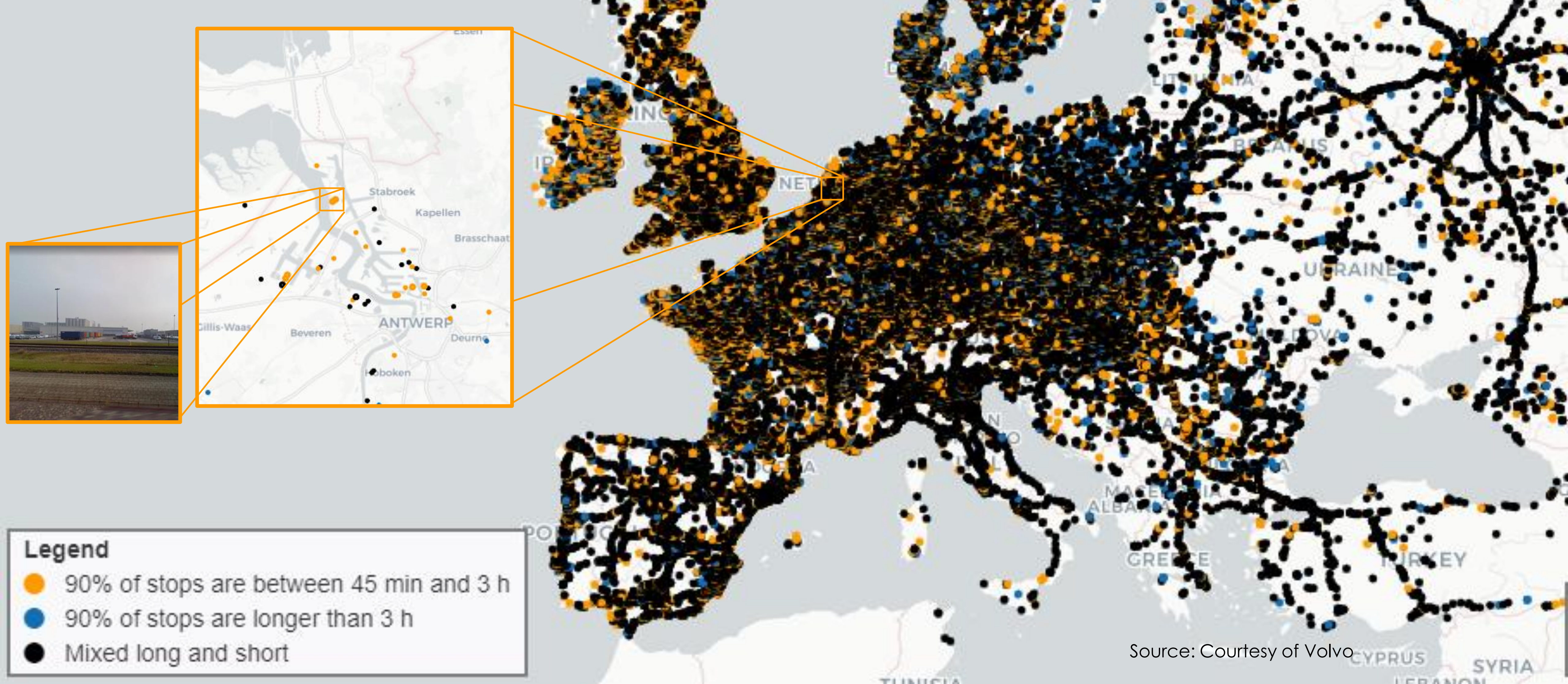
Managed charging:

- *Peak-to-valley load decreases by 2274 kW, 75%*

V2G charging:

- Capacity upgrade is not needed with10% respondent
- 20% respondent equal to 100% managed charging
- V2G is already available through cell phone application

Potential charge station locations throughout Europe



Source: Courtesy of Volvo

IRENA projections for road freight to 2050 – 1.5oC Scenario

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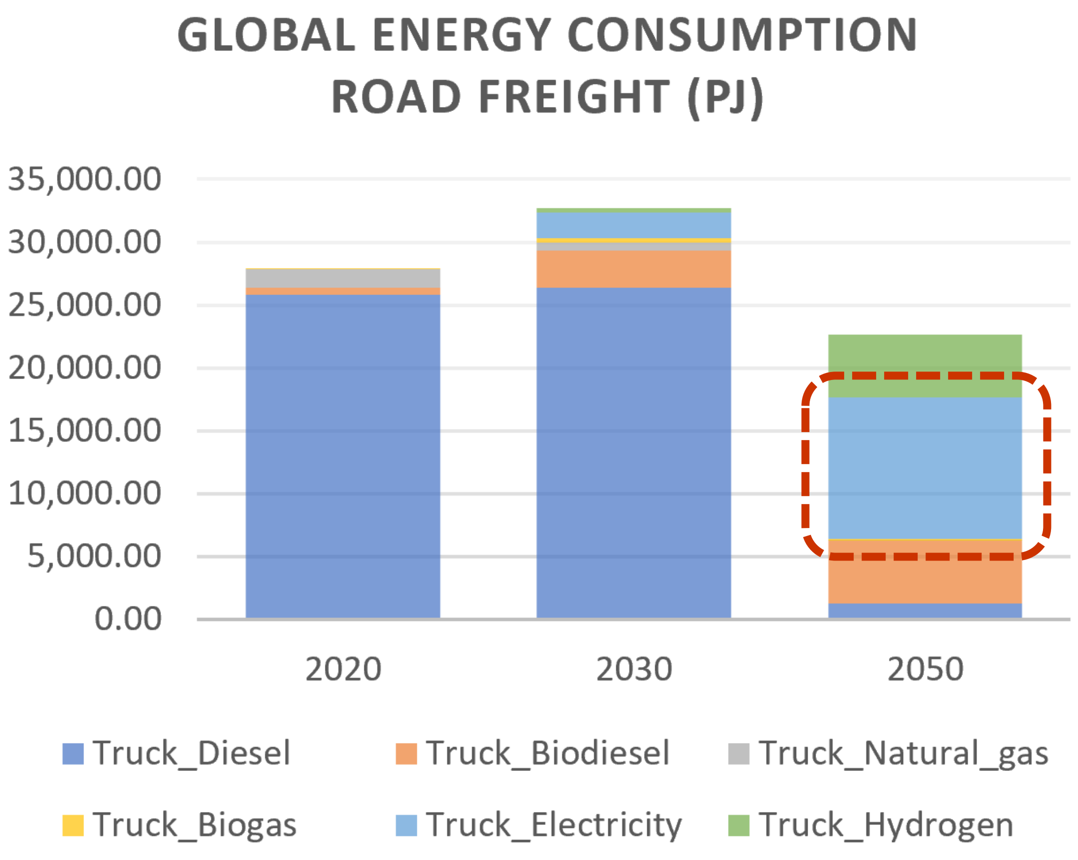

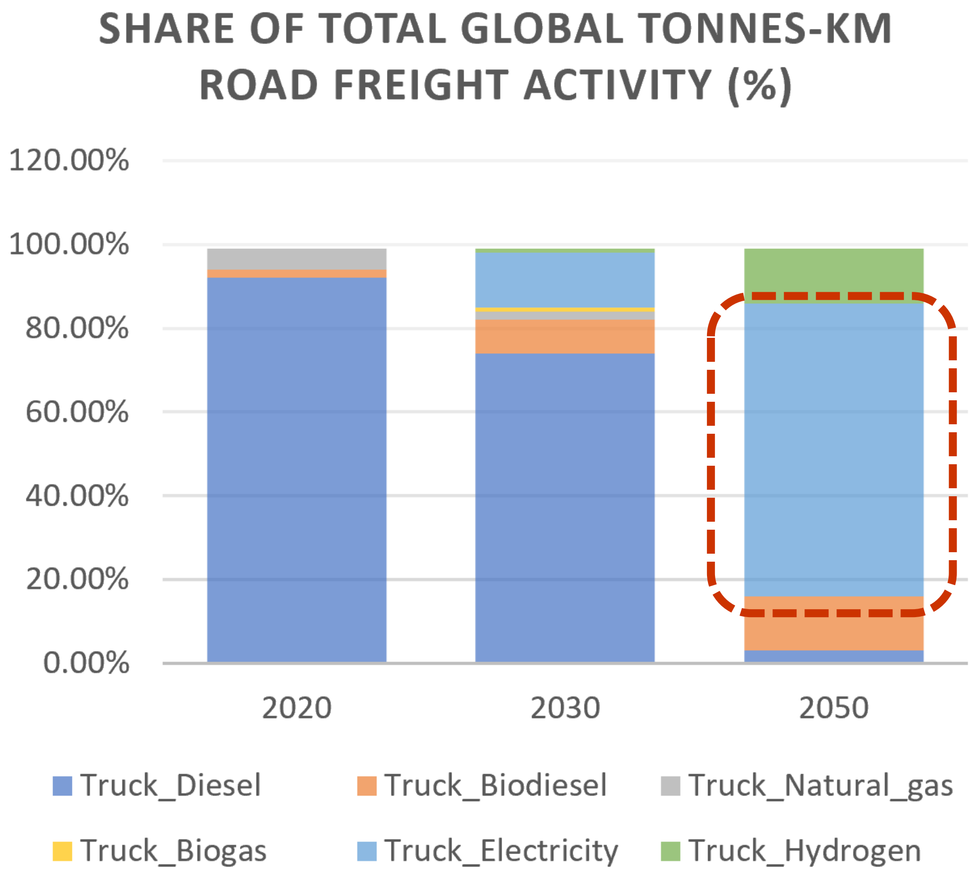

E-heavy duty trucks

- 2030: **9 million** e-trucks / ~ 3.5 TWh battery capacity / **400 billion USD in charging infrastructure**
- 2050: **60 million** e-trucks / **~ 24 TWh** battery capacity (estimated stationary utility storage 11 TWh)

Source: https://www.irena.org/publications/2021/Jun/World-Energy-Transitions-Outlook