Key Note – EV Charging and Impact on Grids

ECCE Europe 2024, Darmstadt – September 4, 2024

Christian Ebert, Global Soluion Manager Transportation, Hitachi Energy Germany

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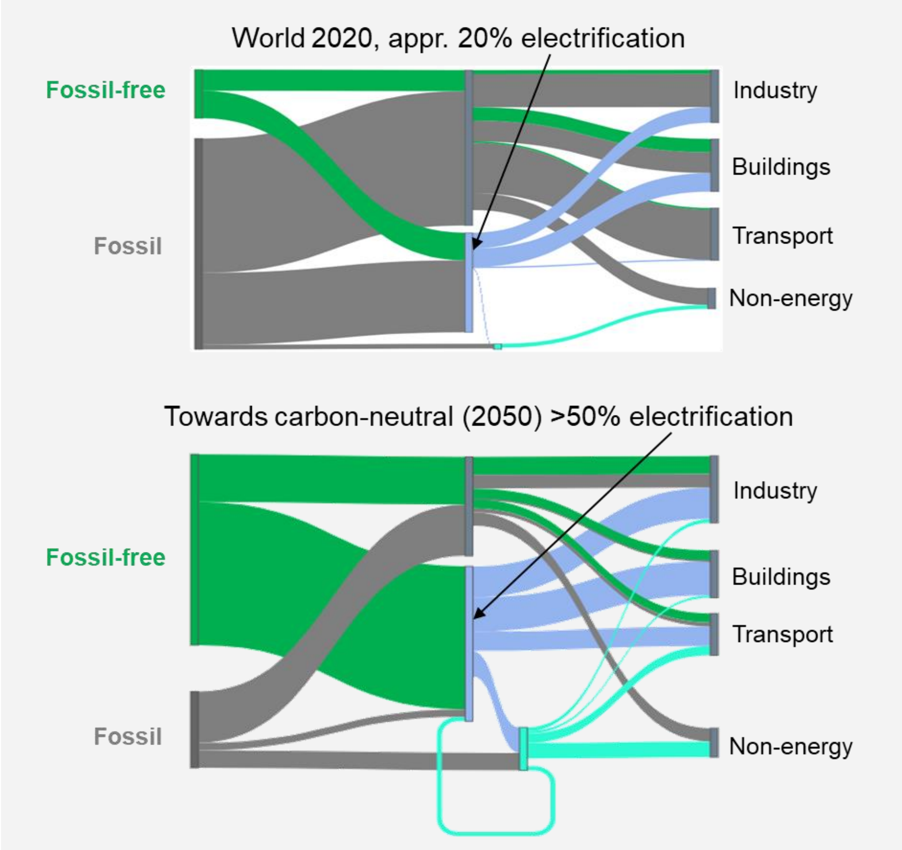
Electrification is growing like never before

Carbon emission reduction, energy security and energy efficiency are driving electrification growth

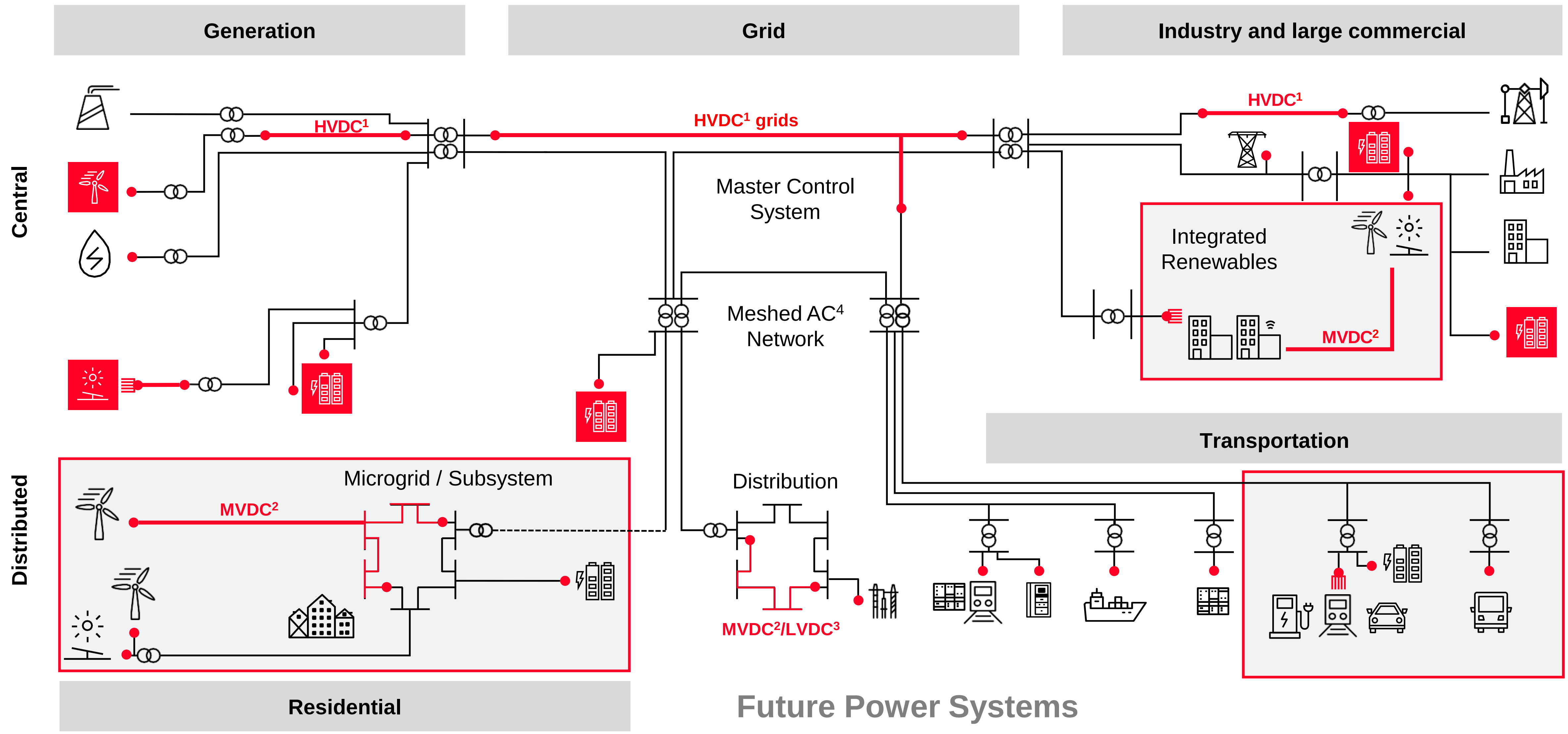
64 countries that account for 89% of global emissions have announced net-zero targets



The global power system of 2050 will require four times power generation capacity and will need to transfer three times as much electrical energy compared to 2020

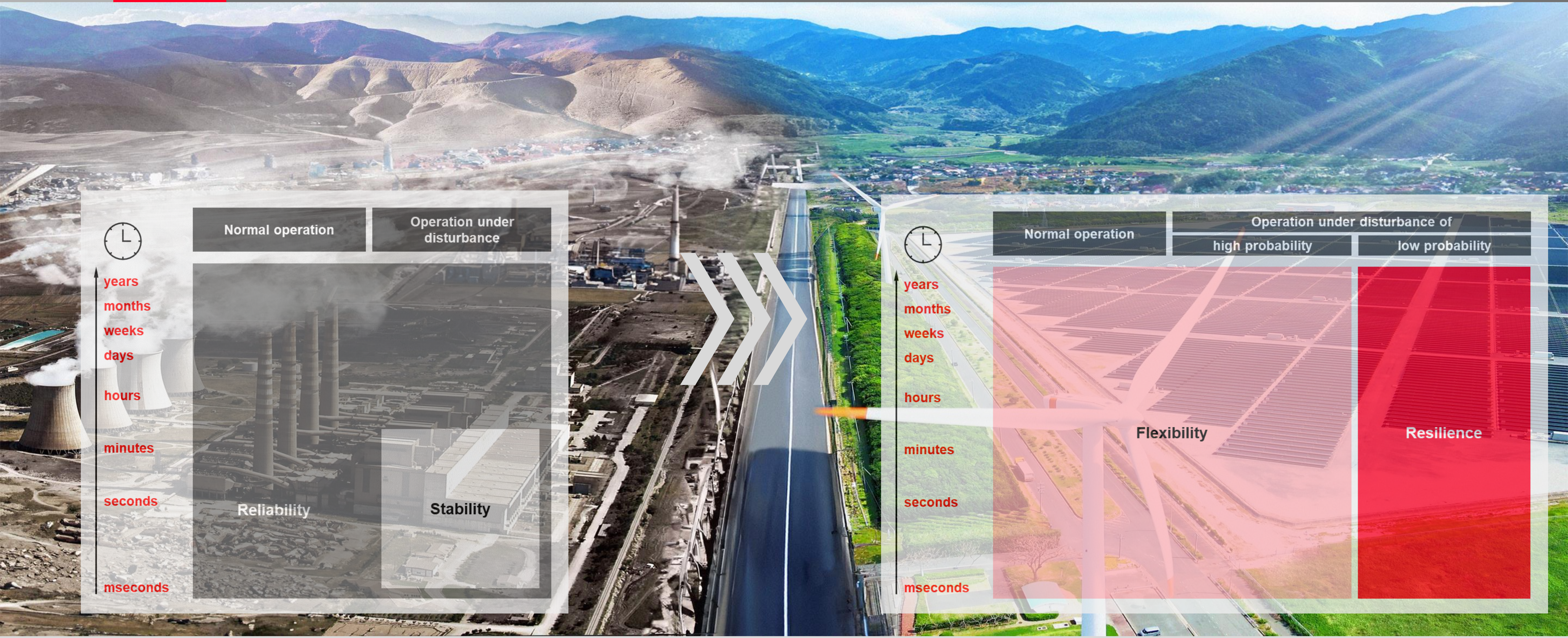
Sources: Hitachi Energy analysis of IEA Net Zero by 2050, Energy Outlook studies by IEA, BNEF, DNV and IRENA; McKinsey Energy Insights Global Energy Perspective 2023

The Power System Evolution – Future Power Systems



1. High-Voltage Direct Current
2. Medium-Voltage Direct Current
3. Low-Voltage Direct Current
4. Alternating Current

Transitioning energy landscape



While reliability and stability remain foundational principles of power system operations, the evolving energy landscape has necessitated a broader focus that includes flexibility and resilience

Four levers of flexibility with digital technology at the core

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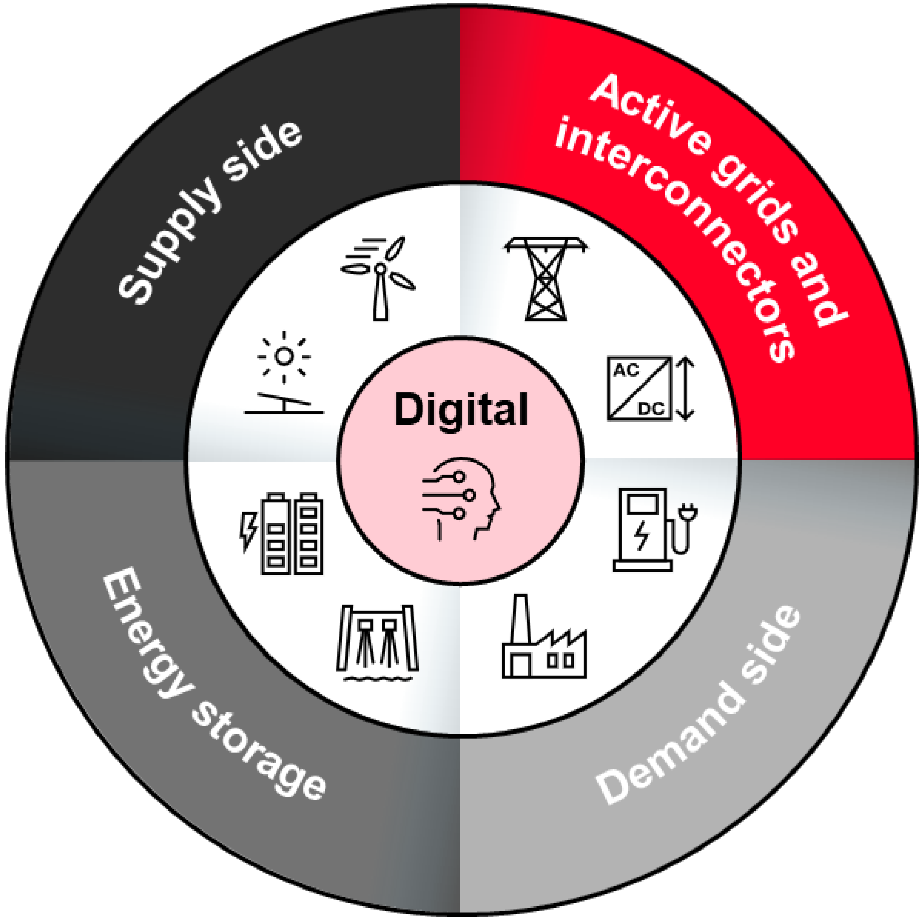

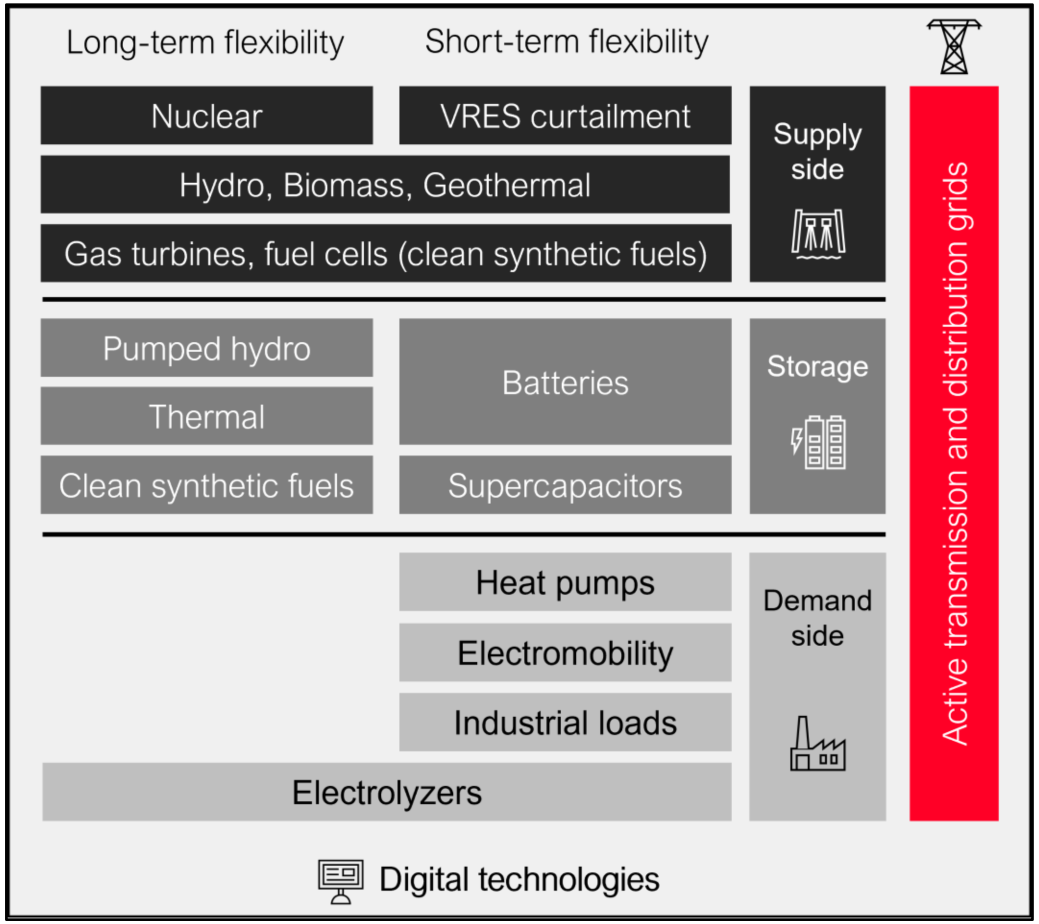

Three fundamental technology areas for the Power System evolution: Power Electronics, Digitalization and Sustainable Products and Solutions

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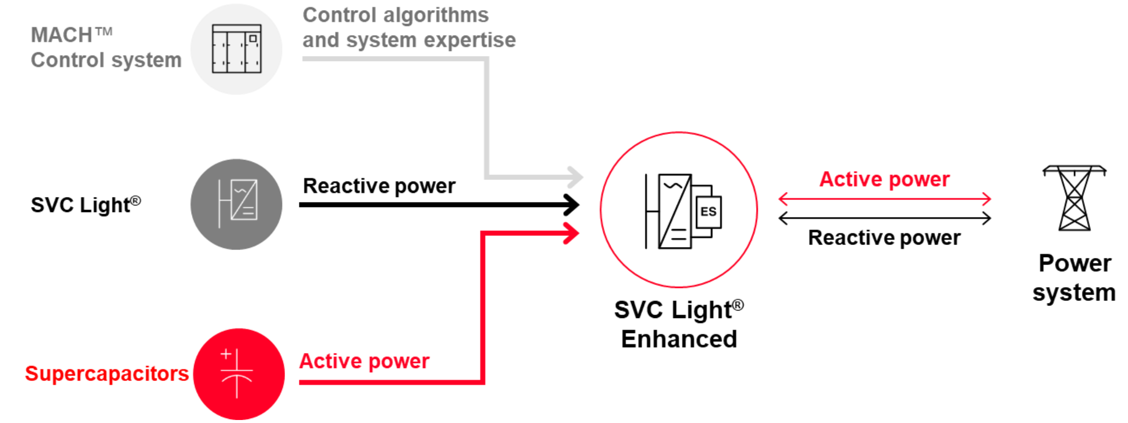
Technologies enabling the future Power System of Systems

From grid following to grid forming converters

- Creating system voltage and frequency
- Contribution to inertia and fault level
- Sink for harmonics and unbalances
- Performing black start

AC

(Enhanced) STATCOM



HVDC

DC

- Renewable integration
- Remote generation/load
- Interconnection
- DC links in AC grid & upgrades
- City center infeed
- Power from shore

AC & DC

Grid Edge

- Microgrids
- Mobility
- Industrial electrification
- Renewable integration

HVDC evolution towards Multipurpose interconnection

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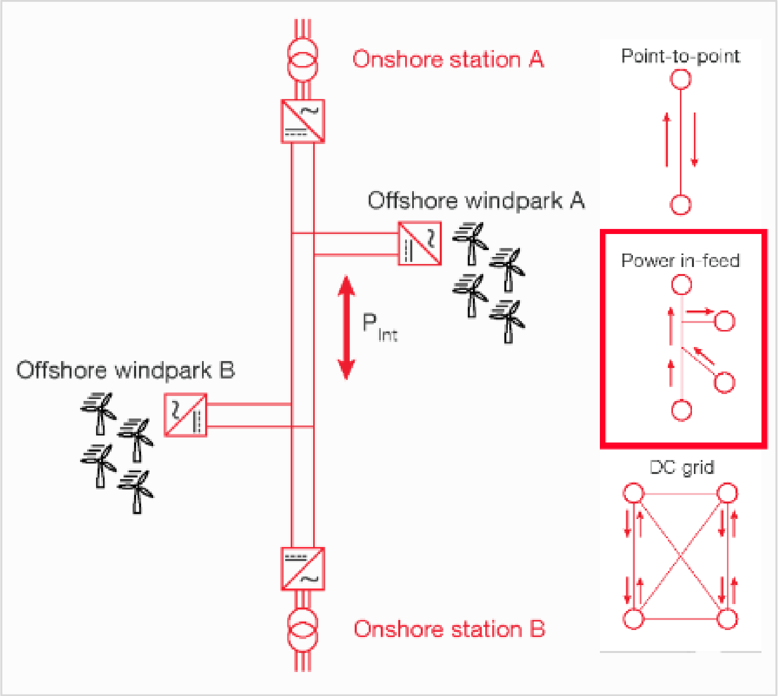
Multipurpose / Multiterminal interconnection

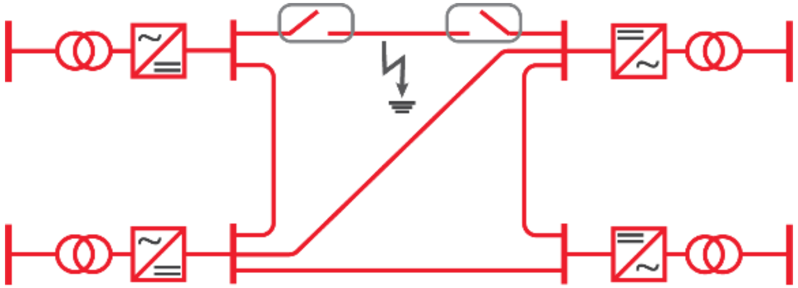
- Connects flexibly two (or more) regions or energy markets
- Integrates (renewable) power sources along the corridor
- And/or efficiently supplies load along the corridor

A regional HVDC grid is a system that comprises one protection zone for DC earth faults

Regional HVDC grids can be further extended by connecting multiple Multiterminal interconnections, and using HVDC Breaker technology for protection



HVDC grid: Multi-Multiterminal interconnections



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Record-breaking HVDC technologies – now coming to Europe

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1,100 kV
Changji-Guquan

The world's most powerful UHVDC connection

720 km
North Sea Link

World's longest subsea electricity interconnector

PFS
Power From Shore

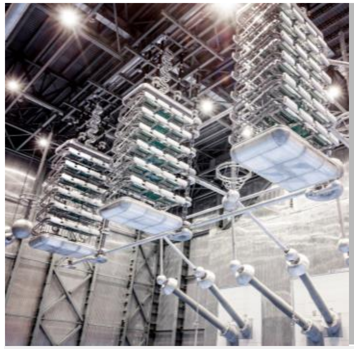
First-of-its-kind subsea power transmission network in the MENA region

3.6 GW
Dogger Bank Wind Farm

Connecting the world's largest offshore wind farm to the UK

1 GW
Mumbai city infeed

Bring almost 50 percent more power to 20 million people in India



800 kV
North-East Agra

The world's first multi-terminal UHVDC transmission link

Customer handover years: CG 1100 2018, North-East Agra 2017, NSL 2022, Dogger Bank 2023-2025, PFS 2024, Mumbai city infeed 2025

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HVDC Interconnectors in Germany – North/South-Power Exchange

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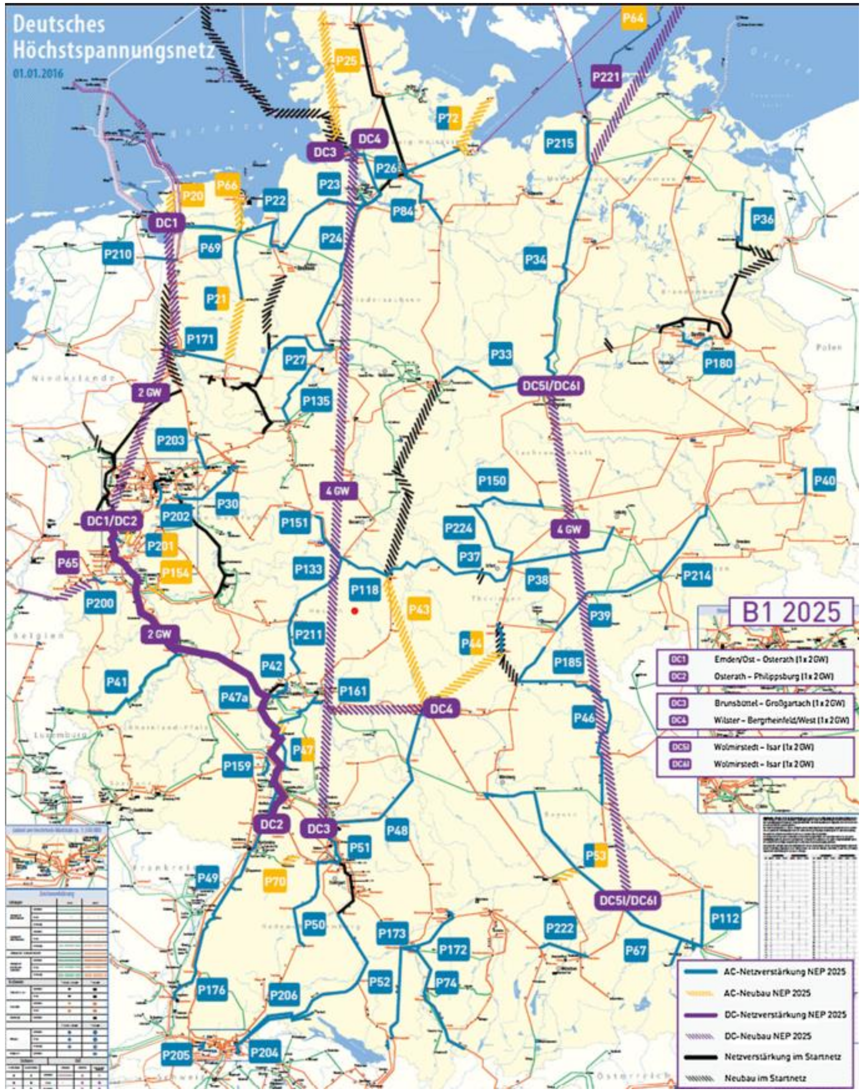
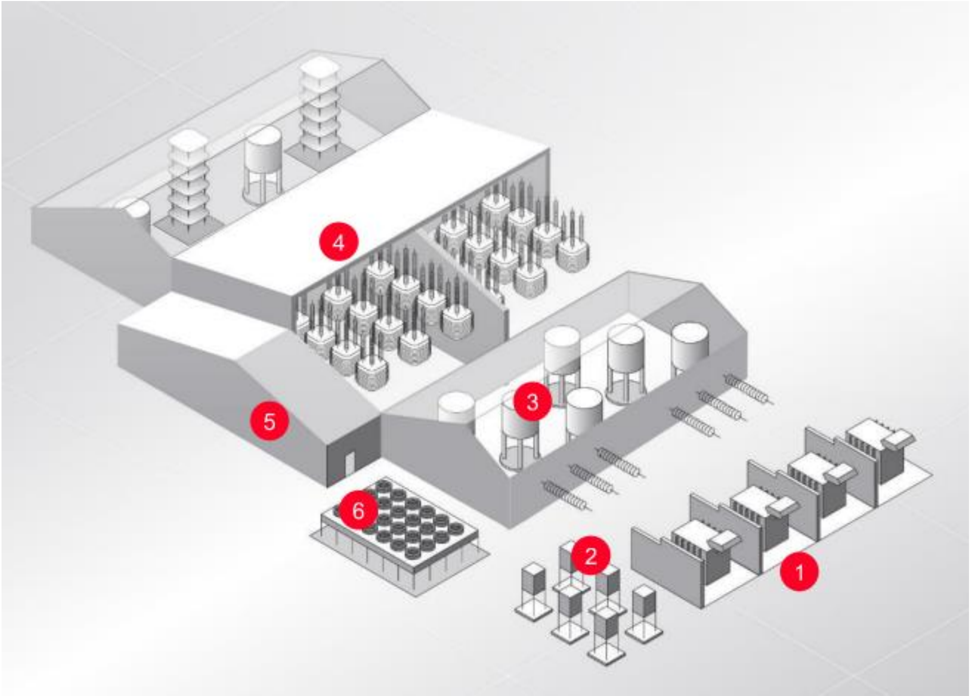


DC1	2GW	Emden/Ost – Osterath
DC2	2GW	Osterath- Philippsburg
DC3	2GW	Brunsbüttel- Großgartach
DC4	2GW	Wilster-Bergrheinfeld
DC51	2GW	Wolmirstedt-Isar
DC61	2GW	Wolmirstedt-Isar



Converter Station – Principle layout

Main equipment

1. Transformers
2. AC yard Grid
3. Converter Reactors hall
4. Valve hall and DC hall
5. Control building
6. Cooling

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Development of Installed Power Capacity (GW) in Germany from 2002 to 2024 per source

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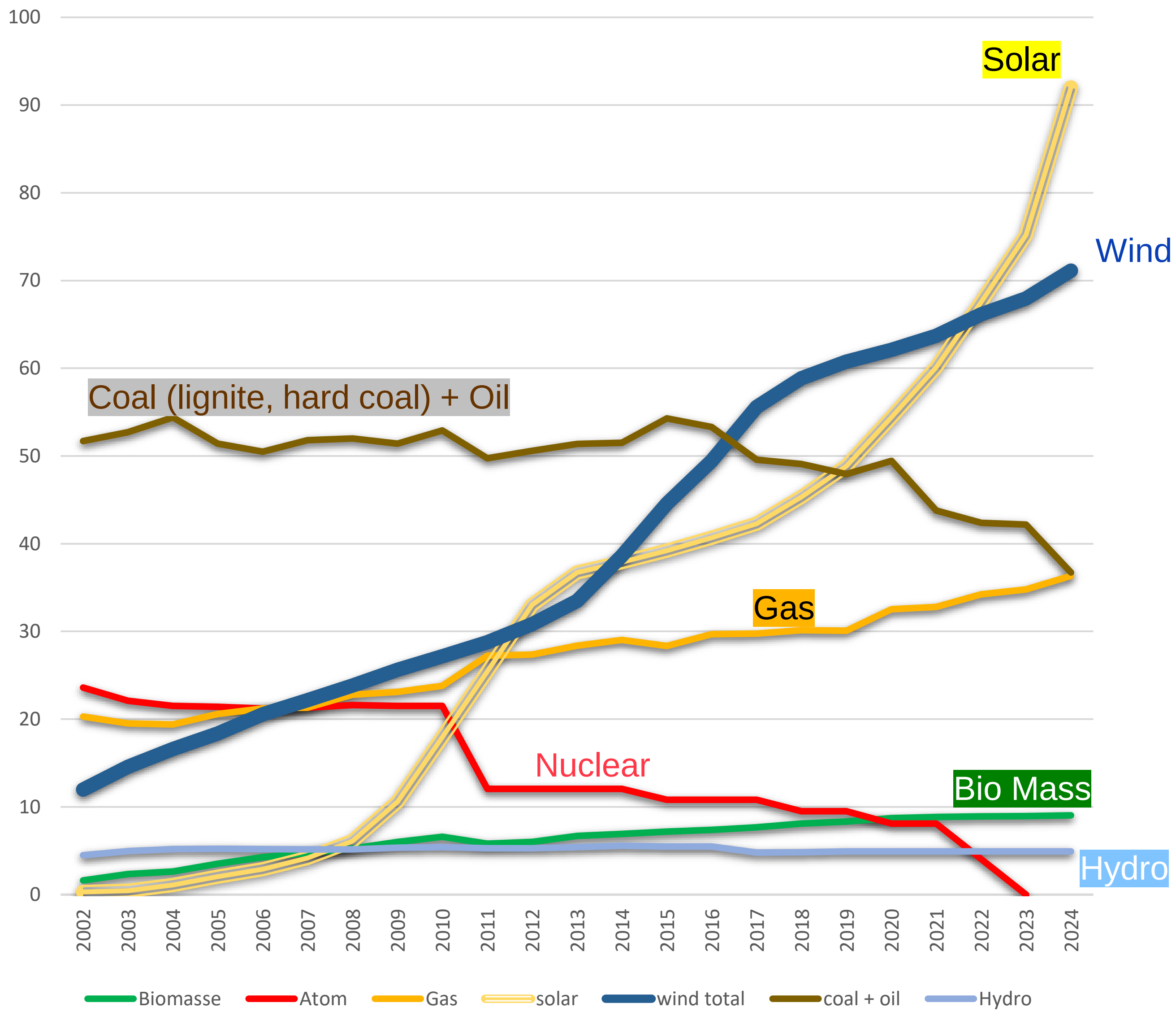


Installed power generation (Peak)

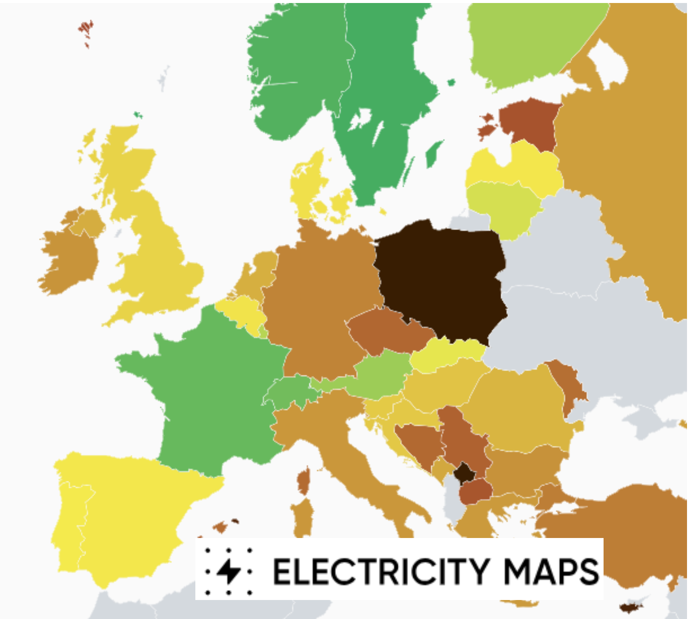
Fraunhofer ISE

CO2 low emission generation:

Solar	– more than 90 GW
Wind	– more than 70 GW (on & off shore)
Hydro	– at 4 GW
Nuclear	from 23,6 GW to Zero by April 2023

CO2-intense:

Bio Mass	– at 9 GW
Coal+Oil	from 54 GW down to 36 GW
Gas	from 20 to 36 GW – new plants foreseen



Carbon intensity per kWh generated -2023

Country	**gr CO2/kWh**
SE	21
DK	178
GB	215
DE	**425**
NL	310
FR	45
CH	53
ES	160
IT	375
PL	841

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Mix of Volatile and Controllable Energy Sources in Germany

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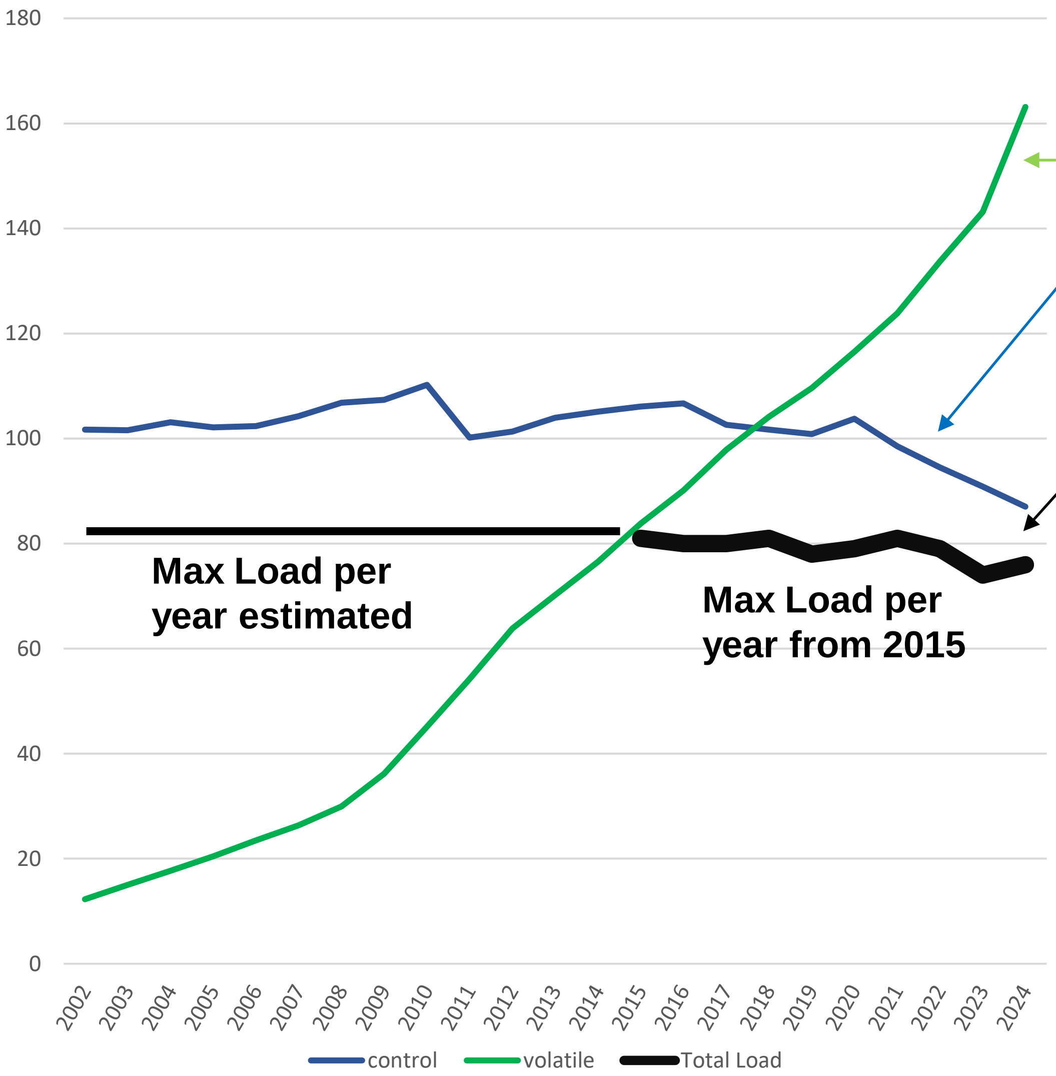
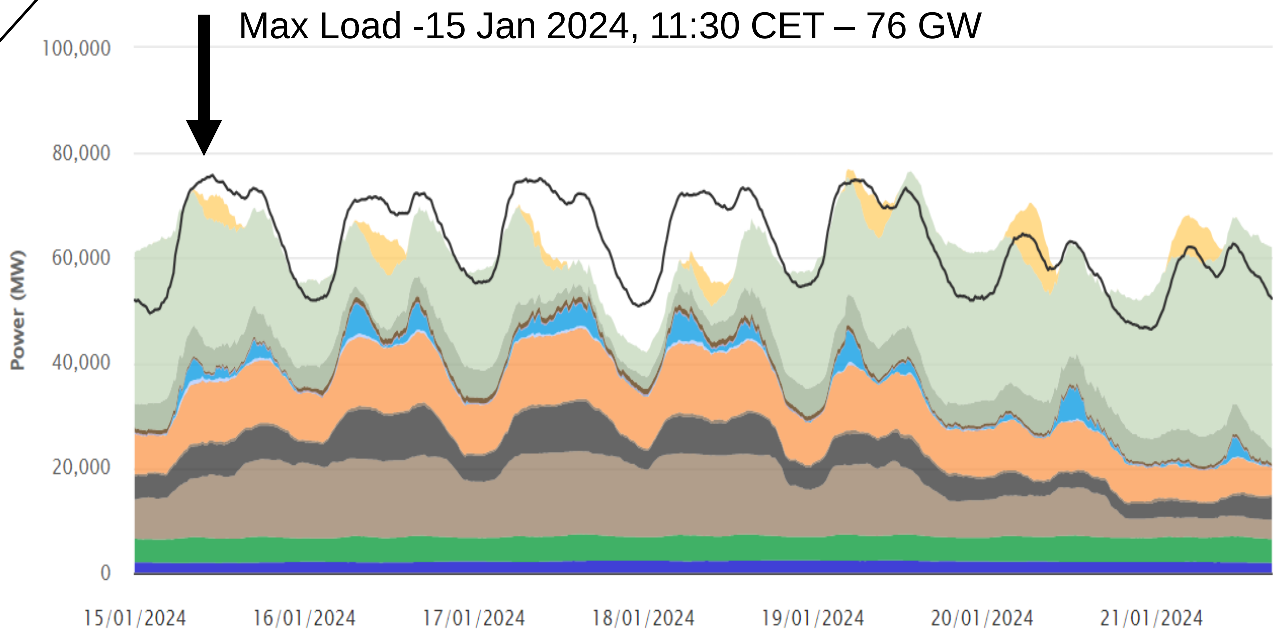


Installed power generation (Peak)

Green line: Volatile Sources – Solar + Wind at approx. 163 GW
Blue Line: Controllabel sources – Coal+Gas+Oil+Biomass+Hydro at 87 GW

Black Line: Max Power Load since 2015 per year at approx 80-82 GW



Imagine 5 Mio EVs charging simultaneously at around 6 pm at 5 kW, plus heating at 3 kW (wallbox + heatpumps) =+ 40 GW

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The Areas for Vehicle Charging DC 50 kW onwards

Typical charging needs for target markets

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Public Transport

Incremental roll-out to 100s

- **Bus depot** that operates buses (public) with total capacity of **bus of ~100 – 600**
- **Incremental roll-out of electrification** with 10 – 100 buses at each phase
- Typical charging power around **100 – 200kW. 450 – 750kW** for Pantos @ terminals

Commercial Fleet

Logistics centers by 100s

- **Medium/large-scale logistics centres** that operates Trucks & Vans, possibly cars on the side,
- **Current project nurtured by govt fundings**
- Typically **100s of Trucks / Vans** in logistics centres + parking lots for employees => need **~50-100 HP chargers**
- **High power level to enable long-range trucking** (40t) with 1hr stop => **MCS**

BEV + eTruck Charge Parks

Will replicate by 1’000s

- **Ultra fast charging roadside stations**
- Current typical site is **10-20 charging points** with **150 – 400 kW power** (e.g. DE plan to install 1’100 sites by 2025).
- **Future layout** (for customer behavior 10-15 mins recharge) with **mix of CCS** up to 400 kW for cars **and MCS** up to 3 MW MCS for long-haul e-trucks)
- Site power ranging 8-60 MW, strong case for **BESS**

Mining

X-MCS Large MegaWatt

- **Mining site (open and underground)** that operates mining trucks (private), each being 100 to 400t weight. Need **MWs of power** with higher voltage levels and charging interfaces … recharging at each stop
- Pilot phase planning, then large market opening up
- Typical layout with **10 X-MCS chargers** with capacity **up to 12 MW each**

Public

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Estimated Energy Demand for Germany for total Car and Truck Fleet

German Car Fleet - electrified

50 Mio Cars

Mileage per year: 13.000 km

Consumption: 20 kWh / 100 km

Calculations

Yearly consumption per car:

$$\frac{13.000\ \text{km} \times 20\ \text{kWh}}{100\ \text{km}} = 2600\ \text{kWh}$$

=> total fleet of 50 Mio Cars per year

50.000.000 x 2.600 Mio kWh =

= 130.000.000.000 kWh

= **130 TWh**

German Truck Fleet – electrified (40 tons)

300.000 – 40 tons (out of a fleet of 3,6 Mio trucks)

Mileage per year: 120.000 km

Consumption: 125 kWh / 100 km

Calculations:

Yearly consumption per 40 tons truck

$$\frac{120.000\ \text{km} \times 125\ \text{kWh}}{100\ \text{km}} = 150.000\ \text{kWh}$$

=> total fleet of 250 thousand Trucks per year

300.000 x 120.000 kWh =

= 37.500.000.000 kWh

= 45 **TWh**

approx. 175 TWh per year

eCars + eTrucks

130 TWh + 45 TW = 175 TWh

Yearly Generation in Germany

2018 - 600 TWh

2019 - 571 TWh

2020 - 540 TWh

2021 - 552 TWh

2022 - 545 TWh

2023 - 483 TWh (! DE importing)

Average: 550 TWh per year

175 TWh -> 32 % additional electrical energy needed

Average Power for eMobility (cars and trucks):

175 TWh / 8760h =

20 GW – constant charging power provided by the grid

Charging methods for EV fleet like buses or LCV (small trucks)

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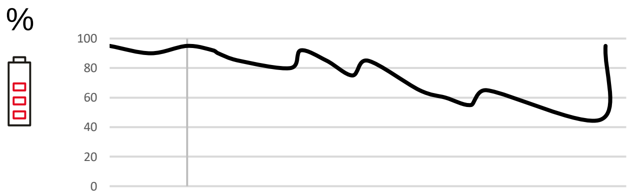
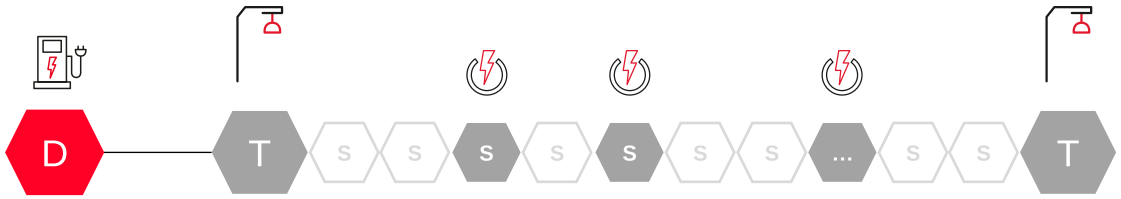
D depot · T terminal · S stops

Overnight	Opportunity and Flash-charging
50kW-150kW (plug)	150kW-600kW (pantograph)

Flash-charging at some stops for Mass Rapid Transport, Bus Rapid Transport, Mining, Maritime …

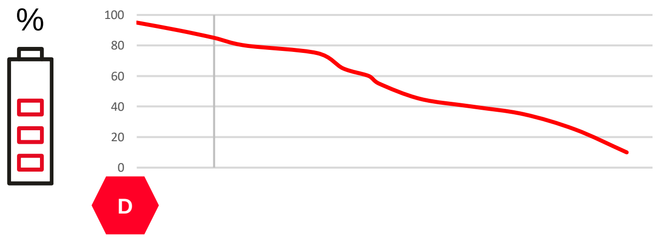


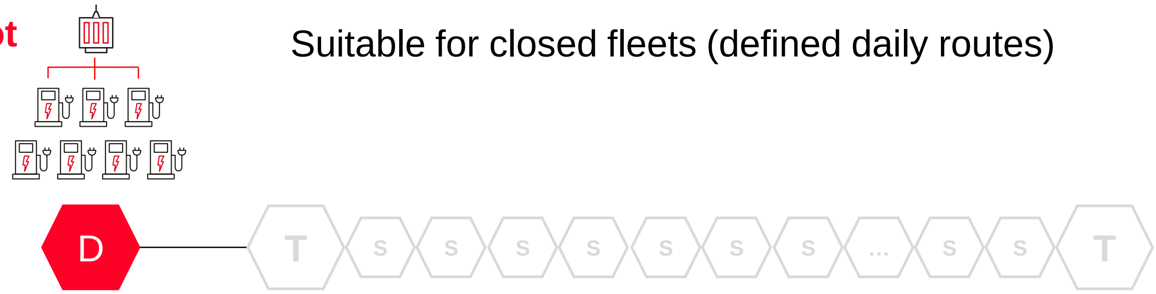


- Light and spread infrastructure
- Light batteries
- No downtime to recharge
- High frequency/capacity lines
- Best suited to big e-buses and Bus Rapid Transit (BRT)

Charging at HPC Charge Parks or Depot

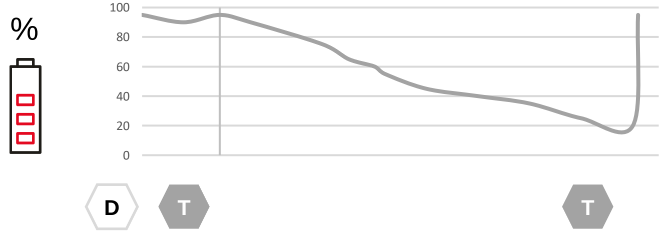
Suitable for closed fleets (defined daily routes)





- Significant footprint required
- HV or MV substation needed
- Large batteries
- Long downtime to recharge
- Usually small e-buses
- Usually charging via plug
- Interoperable with all bus and truck OEMs

Opportunity charging at terminals (eBus)



- Space needed at terminals
- Typically, 12m or 18m e-buses
- Available on PantoUp
- Available on PantoDown
- Interoperable with few bus OEMs

Grid-eMotion™ Fleet

Grid-eMotion™ Flash

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Llevels defined at CharIN plus future R-MCS and X-MCS

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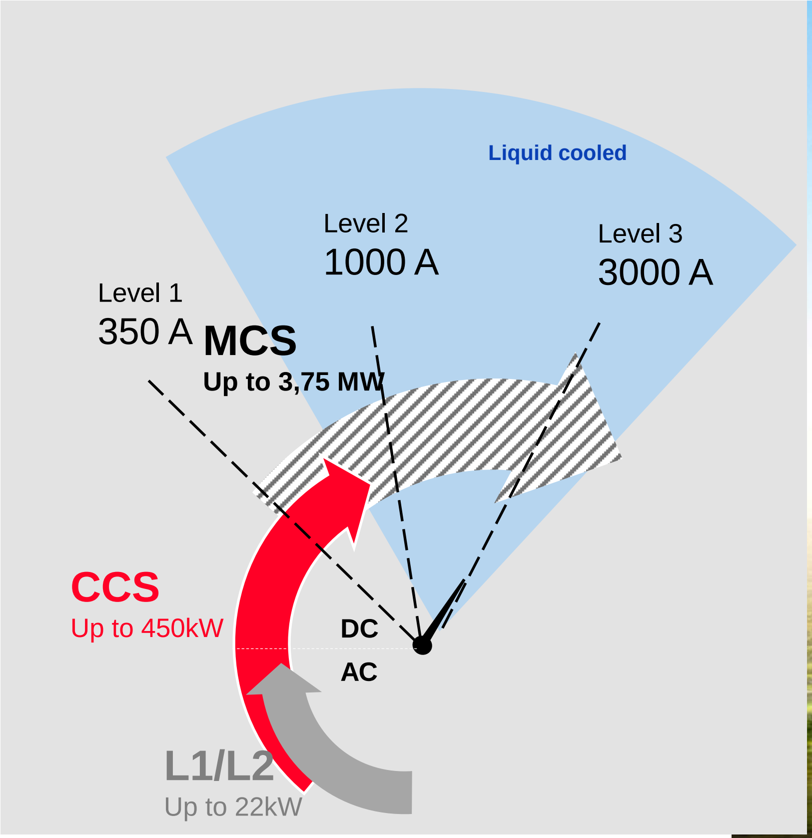

Next standards in preparation (mining industry):
R-MCS at 1,5 kV and 4 kA = 6 MW
X-MCS at 3,0 kV and 4 kA = 12 MW

R-MCS = ruggedized MCS, similar plug/socket as MCS

X-MCS = eXtreme MCS, automated coupling device needed

The following requirements for the Megawatt Charging System (MCS) are currently discussed:

- ✓ Single conductive plug
- ✓ **Max 1.250 volt & 3.000 ampere (DC)**
- ✓ PLC + ISO/IEC 15118
- ✓ Touch Safe (UL2251)
- ✓ On-handle software-interpreted override switch
- ✓ Adheres to OSHA & ADA (& local equivalent) standards
- ✓ FCC Class A EMI (& local equivalent)
- ✓ Located on left side of the vehicle, roughly hip height
- ✓ Capable of being automated
- ✓ UL (NRTL) certified
- ✓ Cyber-Secure
- ✓ V2X (bi-directional)

CHARIN

- CharIN Whitepaper Megawatt Charging System (MCS)

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By 2035 to 2340 the charger hubs along German Highways **shall be connected to the 110 kV distribution system**.

Prototype I – 140 charge points connection power: 65 MVA

Prototype II – 74 charge points connection power 40 MVA

Prototype III – 53 charge points connection power 21 MVA

Total length of the Highway System in Germany: 13.200 km, every 60 km a charging facility by 2035 – some 250 locations

Trans-European Tansport Network

Future eTruck Charging Network in Germany (354 sites)

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Announcement by NOW
June 24, 20224

Map of 354 eTruck charging sites in Germany

*Geplante Standorte für den Aufbau des Lkw-Schnellladenetz. Änderungen vorbehalten.

Bundesministerium für Wirtschaft und Klimaschutz

Bundesministerium für Digitales und Verkehr

Startschuss für das Lkw-Schnellladenetz

Launch of the eTruck High-Power- Charging-Grid (Lkw-Schnellladenetz) in Berlin – Conference on June 24, 2024

Organized by NOW GmbH and Autobahn GmbH
354 sites along the Highways
1800 MCS (1MW) and 2400 CCS (400 kW) charge points

Total installed Charging Power at 2,9 Gigawatt by 2035

Installed Power per Site: 8,1 MW

Scope could be increased to BESS and PV integration.

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Deutschlandnetz – 10.000 charge points / 1.000 Charge Parks for BEV

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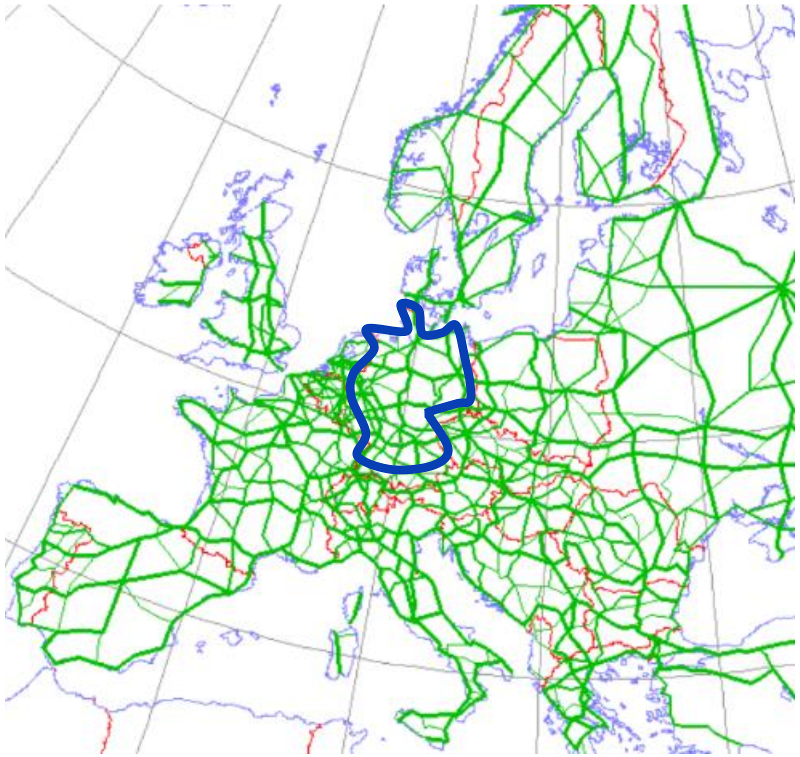
Nr.	Region	Federal States Territory involved	Mio Euro
1	North West	Bremen, Hamburg, Niedersachsen, Mecklenburg-Vorpommern, Schleswig-Holstein	279
2	North East	Berlin, Brandenburg, Mecklenburg-Vorpommern, Sachsen-Anhalt	153
3	Middle Germany	Hessen, Thüringen, Sachsen-Anhalt, Sachsen	174
4	South East	Bayern, Thüringen	205
5	South West	Saarland, Rheinland-Pfalz, Baden-Württemberg, Bayern, Hessen	370
6	West	Niedersachsen, Nordrhein-Westfalen	398
		Total estimated volume	**1579**



European Highway System

Additionally Public Bidding for 200 Charger Parks along the German Highways in preparation in 6 lots

In total 9736 charge points with 200 kW DC each.
Average Parksize at 8-10 charge points

Installed Charging Power 2 Gigawatt

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Development of Public Charging from 2017 to 2024 in Germany

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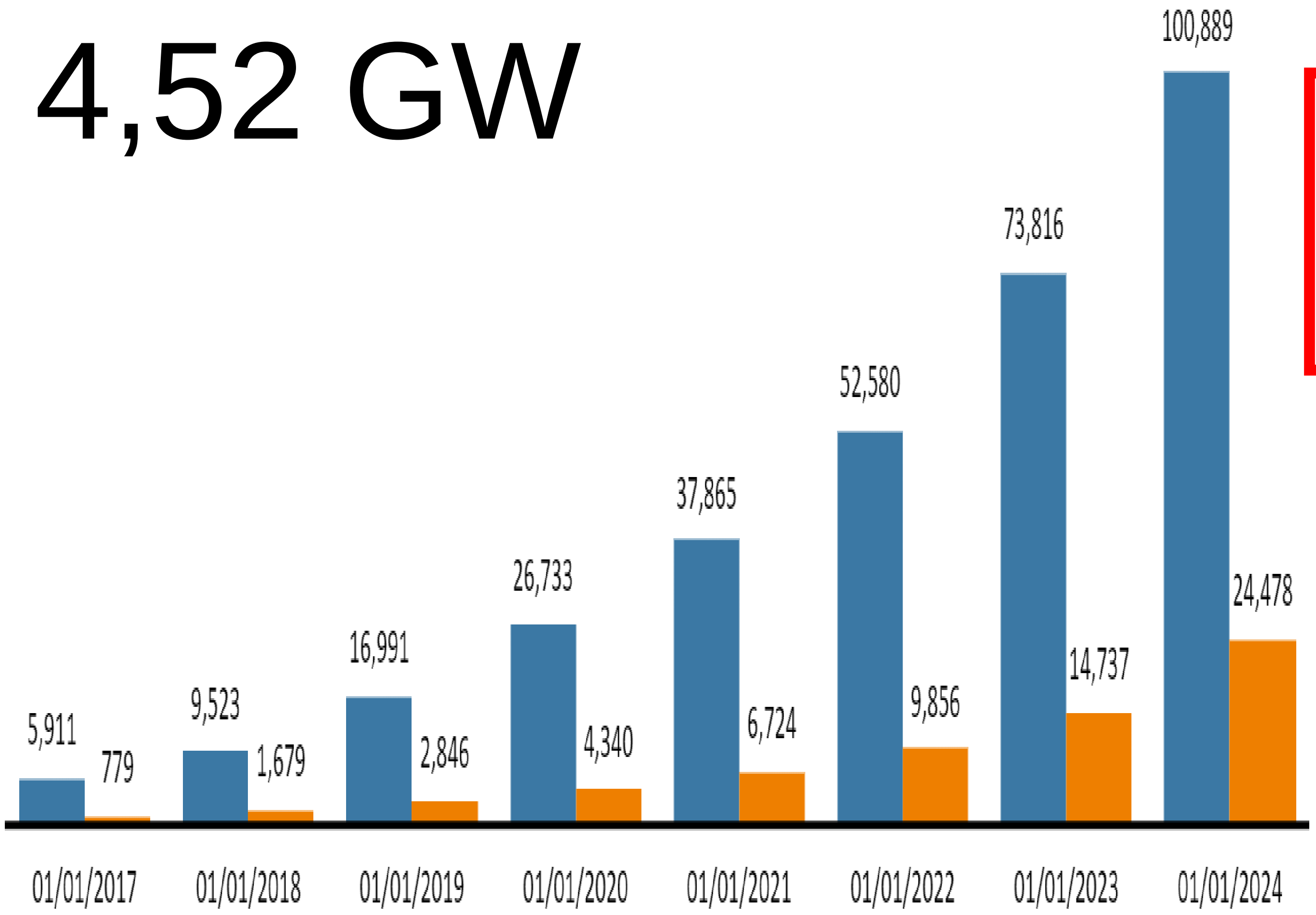
Total installed charging Power (as per March 2024)

4,52 GW



List of the Top 25 Charge Park Operators in Germany

	Status July 16, 2024	tot. Charge Power (kW)	nos of chargers	average power per charger	Increase of installed power since March 2024
1	EnBW mobility+ AG und Co.KG	603.246	7483	81	21,2%
2	T	443.850	1813	245	149,2%
3	I	279.500	824	339	78,3%
4	A	219.054	1562	140	40,8%
5	S	154.228	1083	142	18,0%
6	E	147.289	2268	65	2,9%
7	P	87.914	1383	64	36,8%
8	C	79.721	1042	77	13,2%
9	Allego	75.159	1142	66	-12,5%
10	Mercedes-Benz AG	52.734	2557	21	5,5%
11	MER Germany	50.981	1591	32	-10,8%
12	E.ON Drive Infrastructure	50.415	919	55	114,5%
13	TotalEnergies Charging Solutions	47.485	641	74	12,2%
14	E.ON Drive GmbH	45.560	2860	16	-18,3%
15	ALDI SÜD	45.187	1354	33	7,0%
16	Lidl	41.130	1649	25	18,8%
17	HEnW-Mobil	39.598	1674	24	297,7%
18	TEAG Mobil GmbH	38.218	637	60	23,5%
19	Westenergie Metering GmbH	36.762	1672	22	0,7%
20	Fastned Deutschland GmbH & Co	30.900	214	144	2,3%
21	Comfort Charge	29.544	608	49	11,7%
22	SWD AG	28.928	1111	26	18,5%
23	Kaufland	27.484	855	32	5,0%
24	Numbat GmbH	27.300	181	151	31,9%
25	N-ERGIE Aktiengesellschaft	26.926	1296	21	4,2%

2GW
installed by top 8

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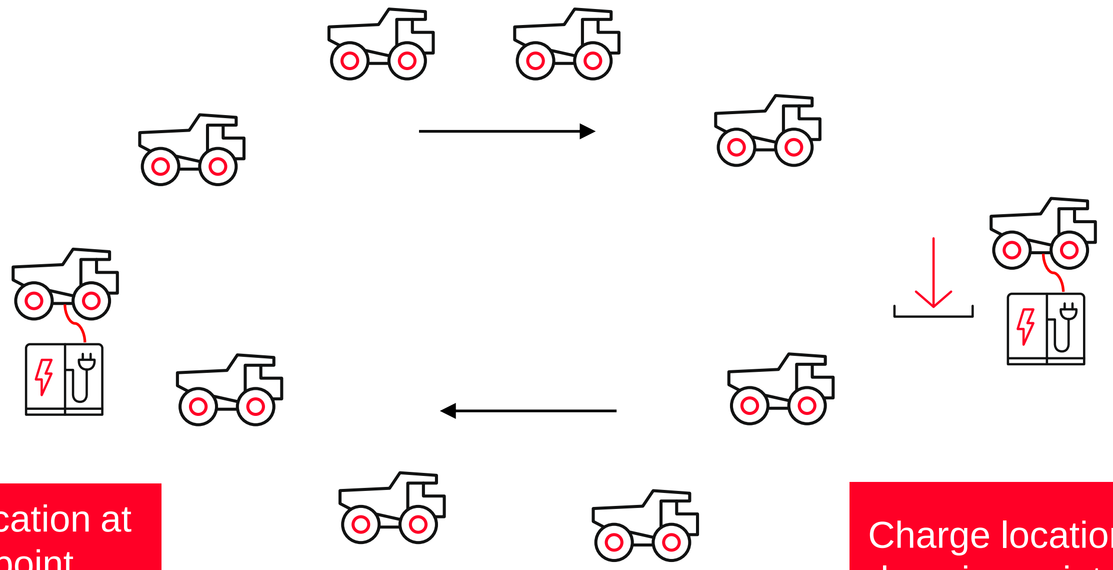
Flash Charging for Large Mining Trucks at up to 12 MW – X-MCS standard

Features

- Based on charging while stopped at queueing and dumping points
- Impose additional 2 minutes of stopping time but offset by higher truck speed. Truck will drive up to 80% faster for short periods which reduces the cycle time
- Battery on truck capable to be charged at very high rates
- Designed to be interoperable
- Interface through a simple robust connections which are mechanically guided into position
- Power supply for tethered excavator

Flash charging at 2 or 3 points

30 minute cycle
3 min charge time for 400 kWh
Charging Power: 8 MW



Charge location at queueing point before loading

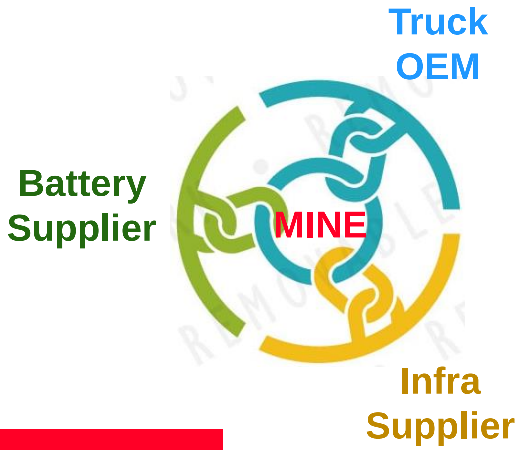
Charge location at dumping point

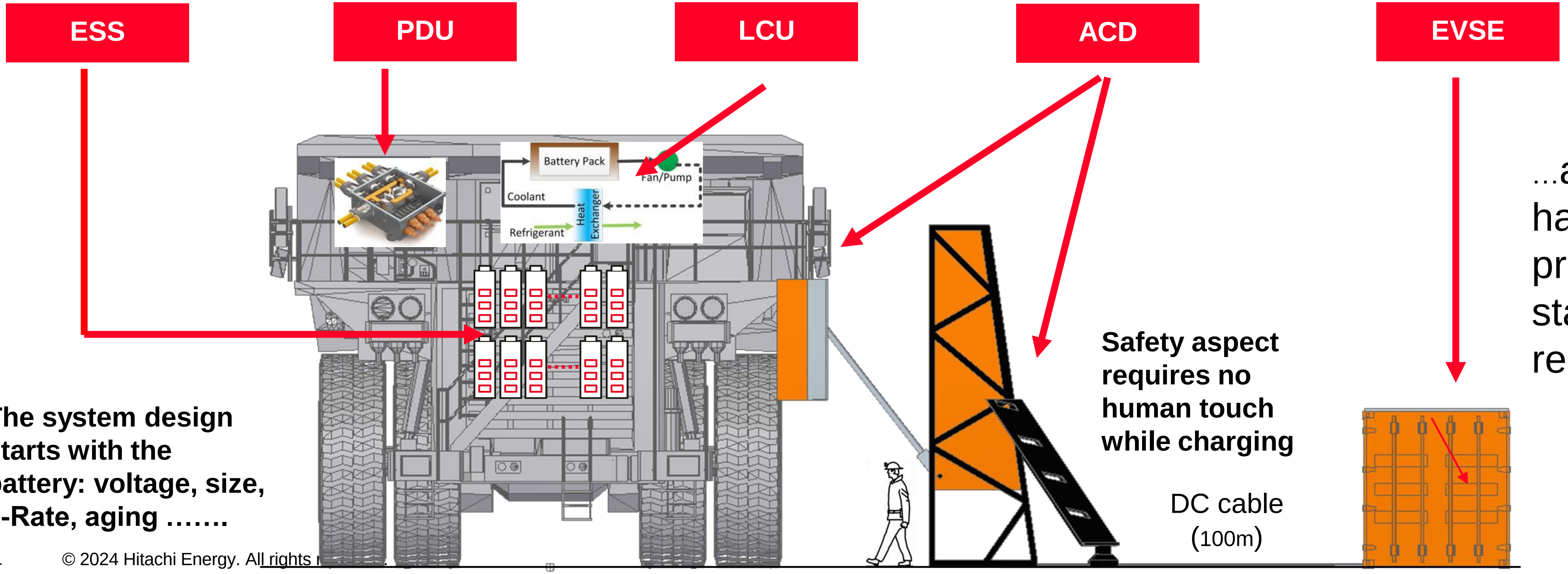
Based on stationary charging at very high charge rates

Charging is a System Approach – example EV or Truck (Train, Ship, Aircraft)

A complex & distributed system

- **ESS:** 1MWh Energy Storage System (Battery) . Water-cooled. BMS. Fuse-based DC protection.
- **PDU:** Power Distribution Unit (DC distribution & protection)
- **LCU:** Liquid Cooling Unit (to dissipate big heat generated during X-MCS charging)
- **ACD:** Automated Coupling Device (lateral arm, pantograph, 3rd-rail, etc)
- **EVSE:** EV Supply Equipment in Idc current control (battery charger)

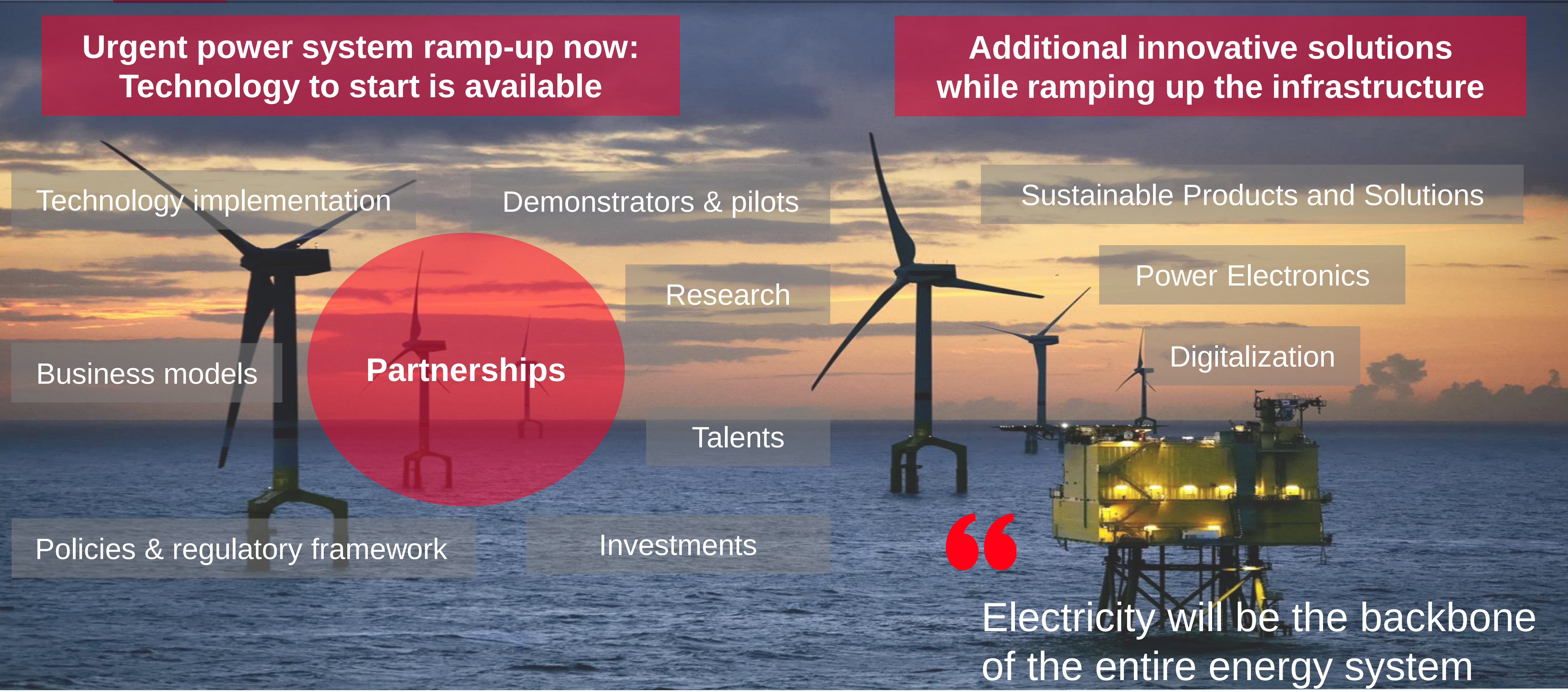




...and the power has to be provided from a stable and reliable grid

The system design starts with the battery: voltage, size, c-Rate, aging …….

Energy transition needs technologies – and partnerships



Public

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For further information for EV Charging Infrastructure, please contact
Christian Ebert
Mobile +49160 9099 5600
christian.g.ebert@hitachienergy.com
You will also find me on LinkedIn

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