Project Management Symposium

18 - 19 Dec. 2018 ■ Riyadh

PMI KSA

VISION 2030

Energy Highways
Large-scale DC Grid deployments

Martin Erath

Managing Director

ILF CONSULTING ENGINEERS

30+ International and Renowned Speakers

36 Seminars

4 Technical Workshops

Energy Highways - Large-scale DC Grid deployments

- **Design Development Issues**
- AC / DC Design Aspects
- Applying Technologies - limitations & selection
- DC Configurations P2P, B2B, MTDC (technical and commercial factors)
- Worldwide (U)HVDC Footprint
- System integration “Germany Energy Transition Plan, based on Large-scale DC Networks”

- **Project Implementation Issues**
- From Theory to Reality - Challenges during Execution
- PM Excellence “Suedlink Project – The DC Energy Highway in Germany”

Martin Erath

Specialized in:

- Energy, Utilities, Smart Grids, Renewables, Infrastructure, Sustainability

25+ years Professional Experience:

- Regional Director GCC: Siemens Power Transmission and Distribution – Turnkey Solutions
- CEO Middle East: GOPA-Consulting Group (Intec)
- Managing Director: ILF Consulting Engineers KSA

Highlights:

- Dubai EXPO 2020 smart grid and renewable energy
- UAE: Largest Energy Storage System Program (BESS)
- Siemens: R&D and pilots in multi-functional power links

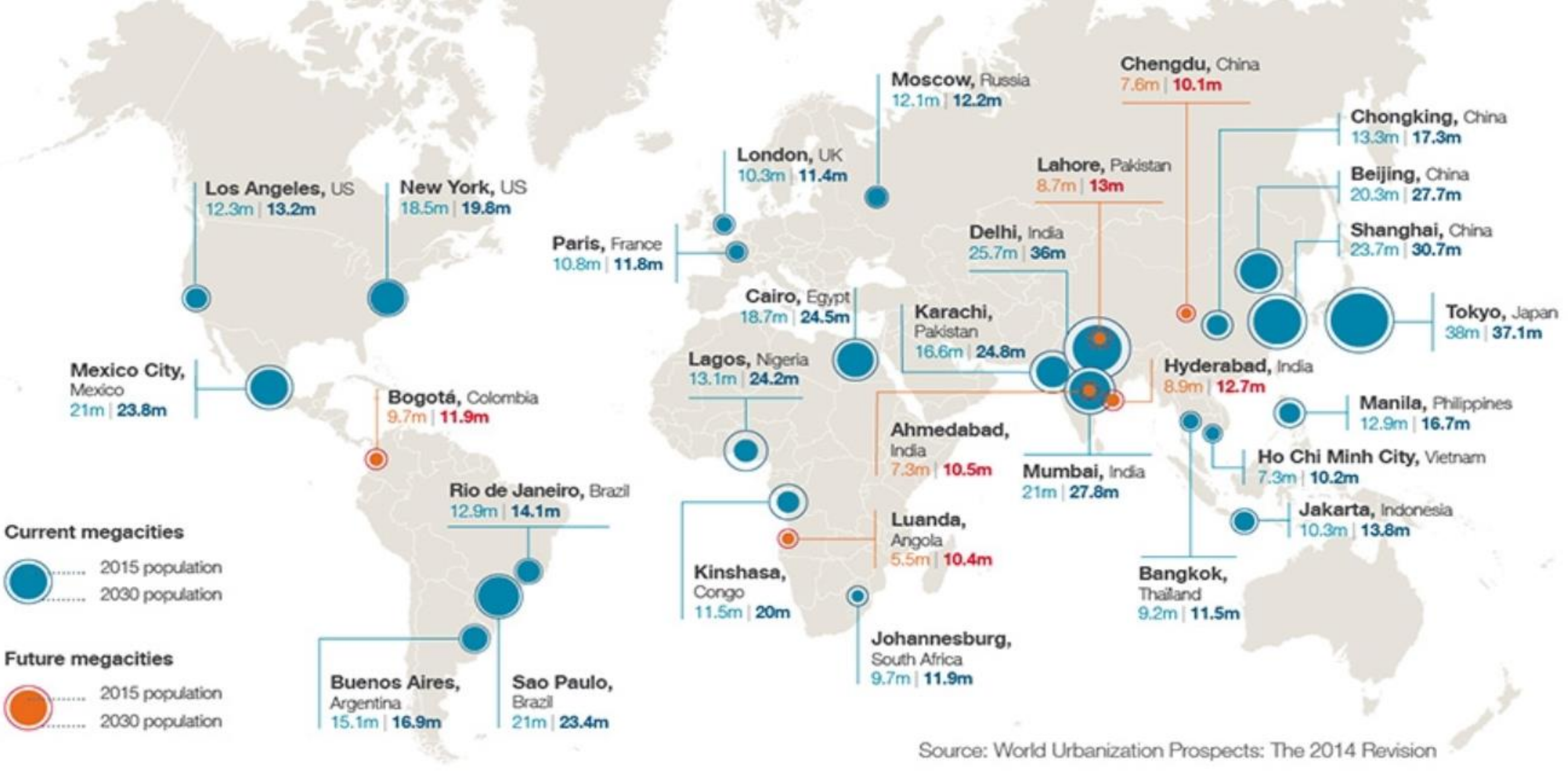
Education, Certifications and Awards:

- Master in Electrical Engineering/MBA Finance
- World Sustainability Congress 2017: Awarded 100 Most Sustainable CEOs

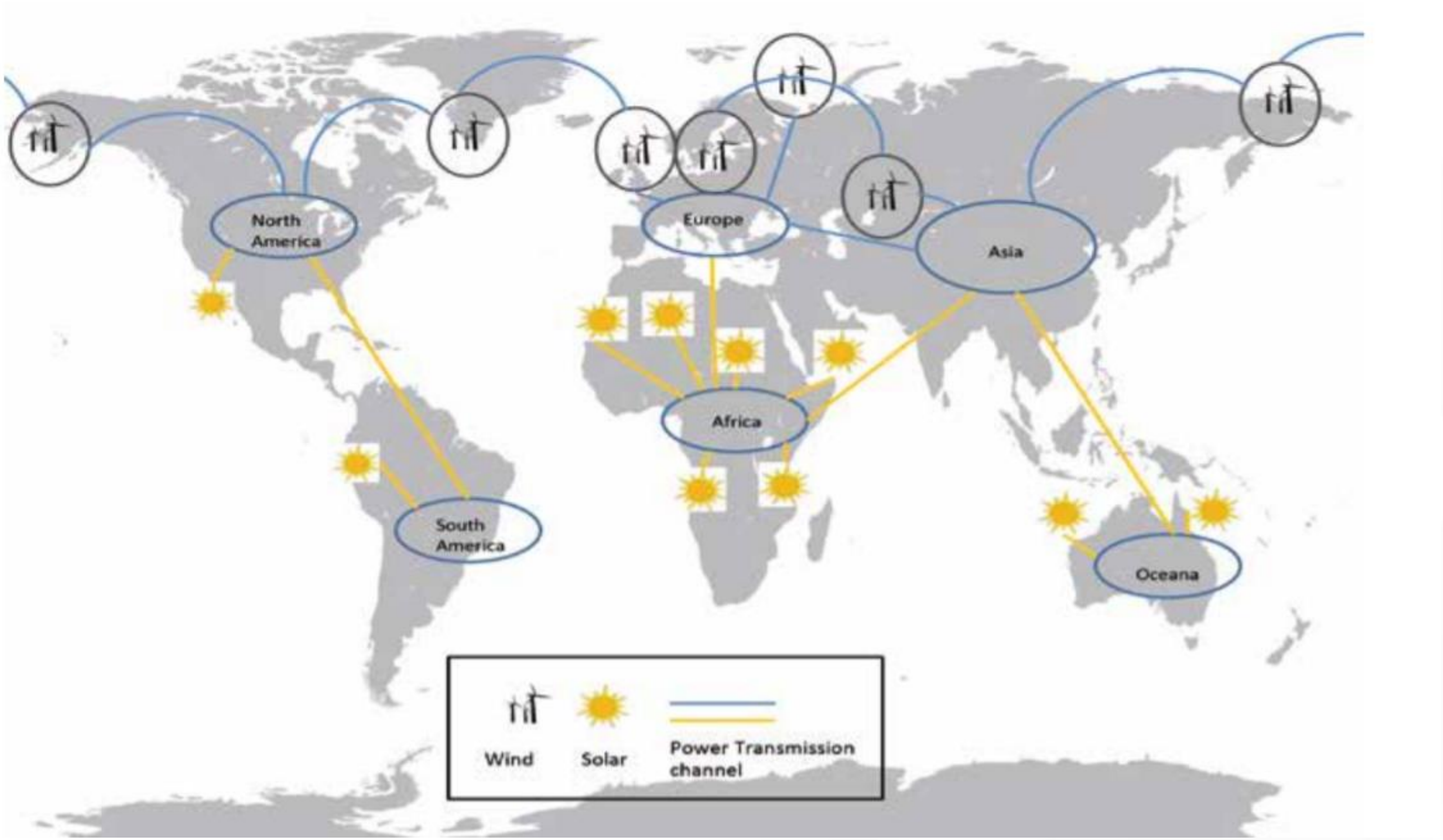
Why Energy Highways ?

by Martin Erath

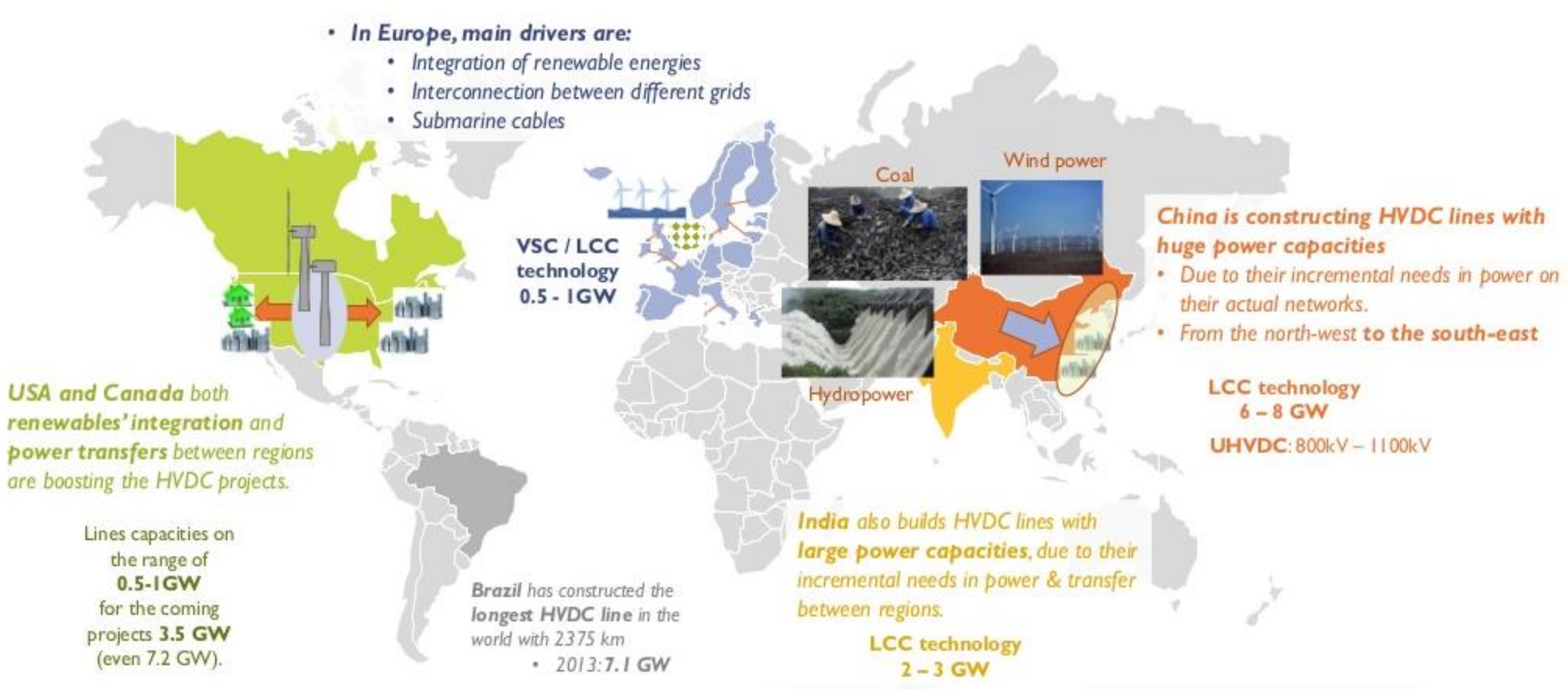
Megacities Development – Enlarging load centers



Global resources and Economics drive opportunities

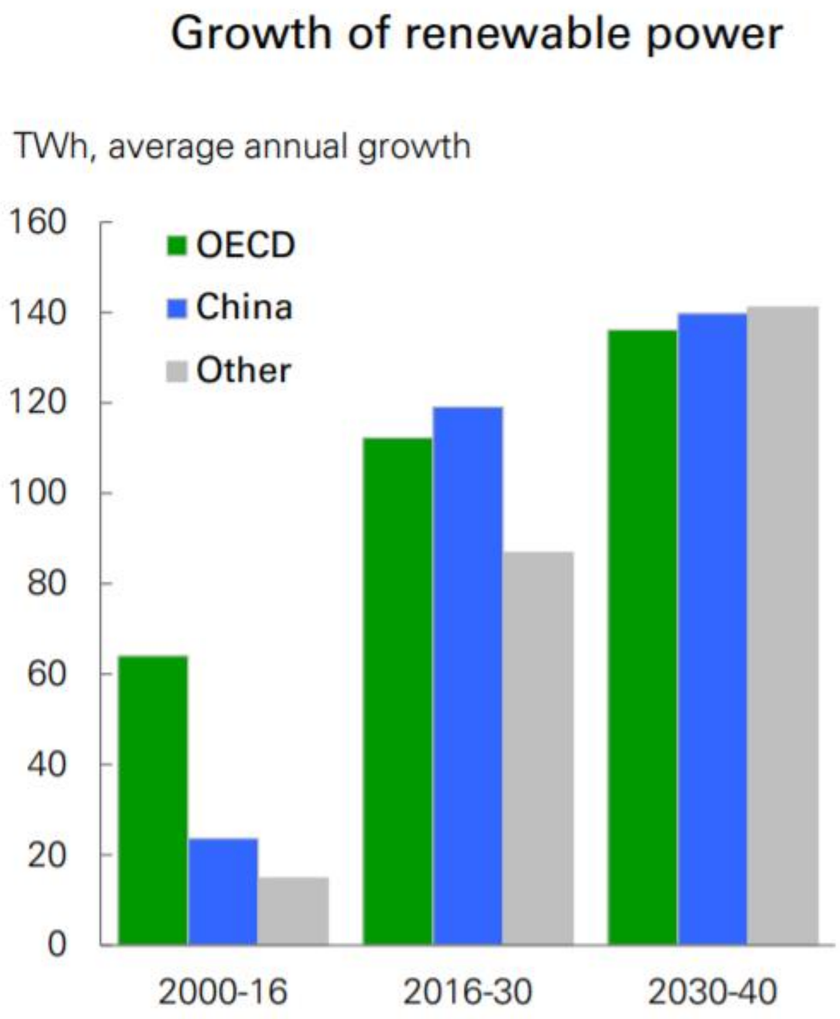


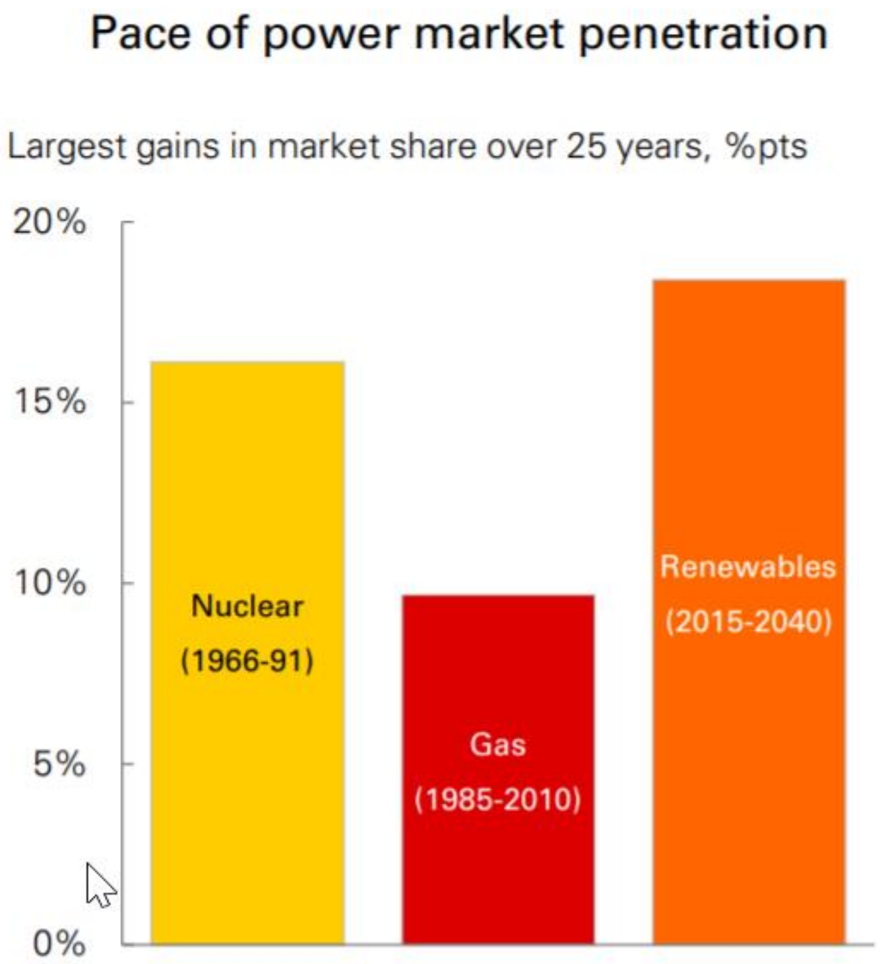
Geographical Trends and Drivers for DC Energy Highways



Source: Yole 2016

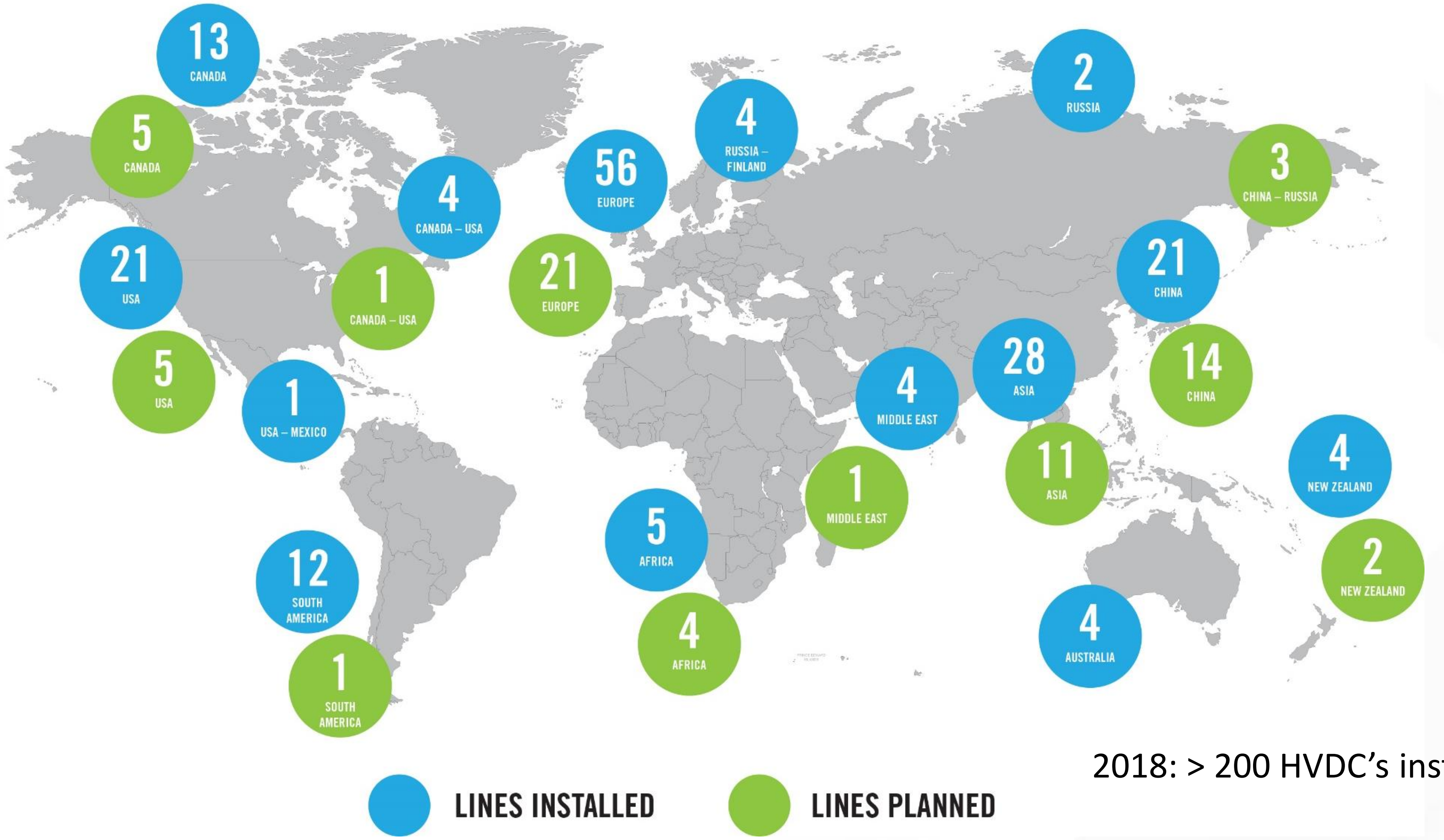
Energy Outlook - Renewable Energy taking the lead





Source: BP Energy Outlook

Energy Highways – HVDC projects since 1951

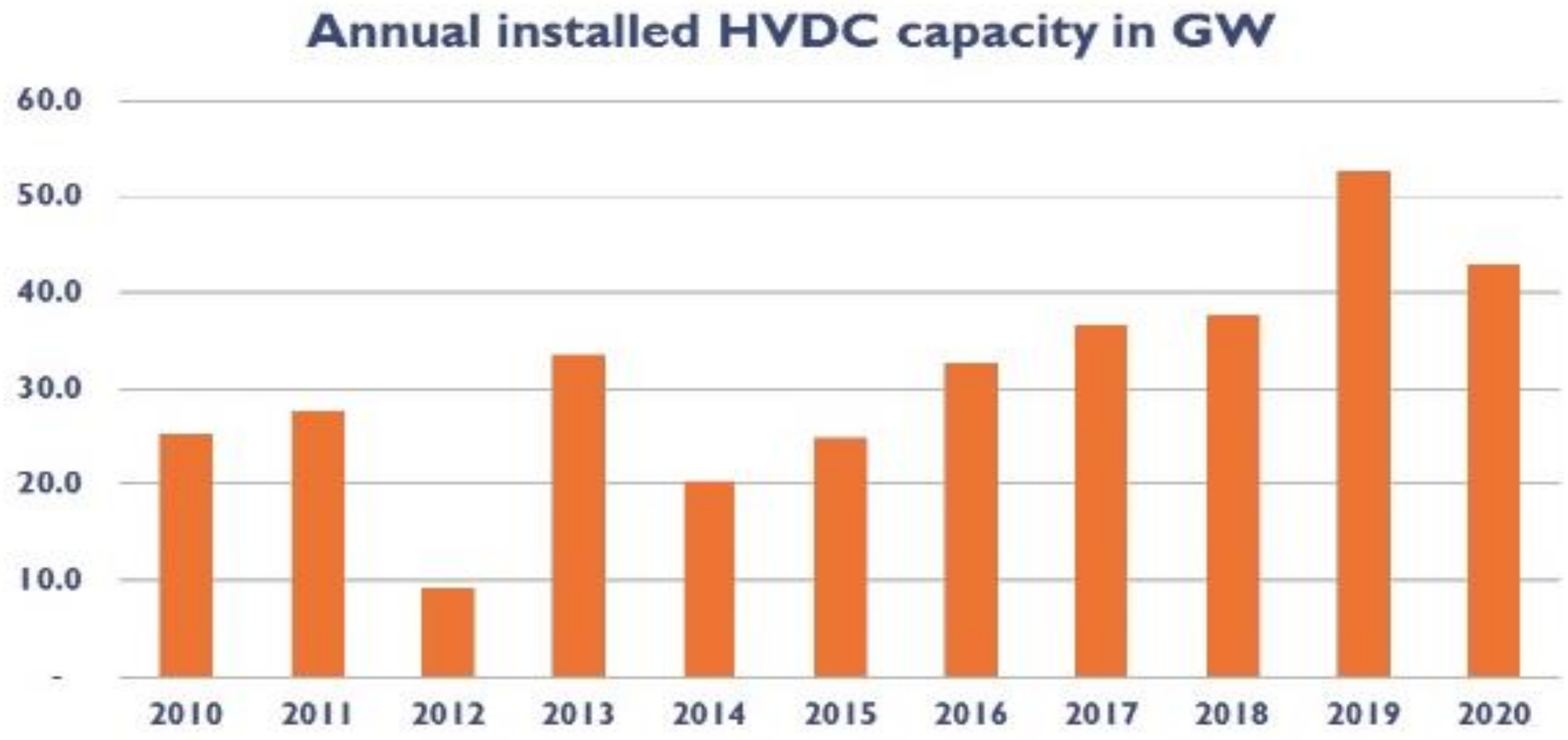


2018: > 200 HVDC's installed worldwide

DC Energy Highways – Global Growth

During the next 5 years almost **200 GW HVDC capacity** will be installed worldwide.

- Estimation of **40 GW – 50 GW transmission capacity** per year.



Source: Yole

Energy Highways AC or DC? Feature Benefits

Energy Highways – Why DC ?

Long distance bulk power transmissions: As the world's energy resources are normally decentralized from the ever increasing energy consumption, long HVDC transmissions are a particularly interesting area for the future.

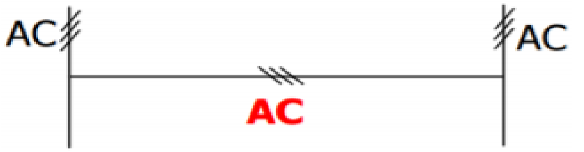
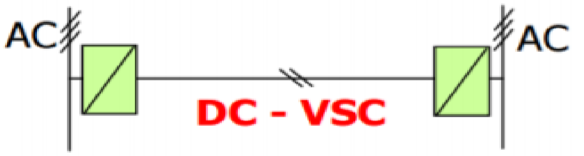
Long cable transmissions: The charging current in cables being fed with high voltage AC (HVAC) makes transmissions over long distances impractical.

Asynchronous interconnection: The HVDC technology can connect two asynchronous power systems with the same or different frequency. The interconnection is often beneficial for both of the systems and acts as a buffer between them. In case of cascading failures in one of the systems, the interconnection can serve as a ”firewall” between the systems, preventing the propagation of disturbances from continuing into the connected system

Stabilization in power systems: HVDC links can be used within synchronous AC systems to improve the control of power flow from one part of the system to another and thereby prevent large cascading failures or even blackouts in the grid. The stability can be improved, since the link provides a damping torque

Ability to connect to weak AC grids, adding less short-circuit power into existing network – no upgrade required

Energy Highway AC vs. DC Design considerations

Transmission solution	Advantages	Drawbacks/Limitations
	- simple (no conversion) - no maintenance - high availability	- heavy cable - limited to 50-150 km - rigid power control - require reactive compensation
	- less no. of cables, lighter - no limits in length - low losses - good power control - very high transmission power	- needs strong AC networks - cannot feed isolated loads - polarity reversal for reverse flow - large space occupied - special equipment (trafo, filters)
	- can feed isolated loads (oil platforms, wind parks, small islands, etc.) of medium power - modularity, short delivery time - small space and environmental impact - no polarity reversal for reverse flow - standard equipment	- higher conversion losses - limited experience - limited power

AC versus DC in Energy Highways

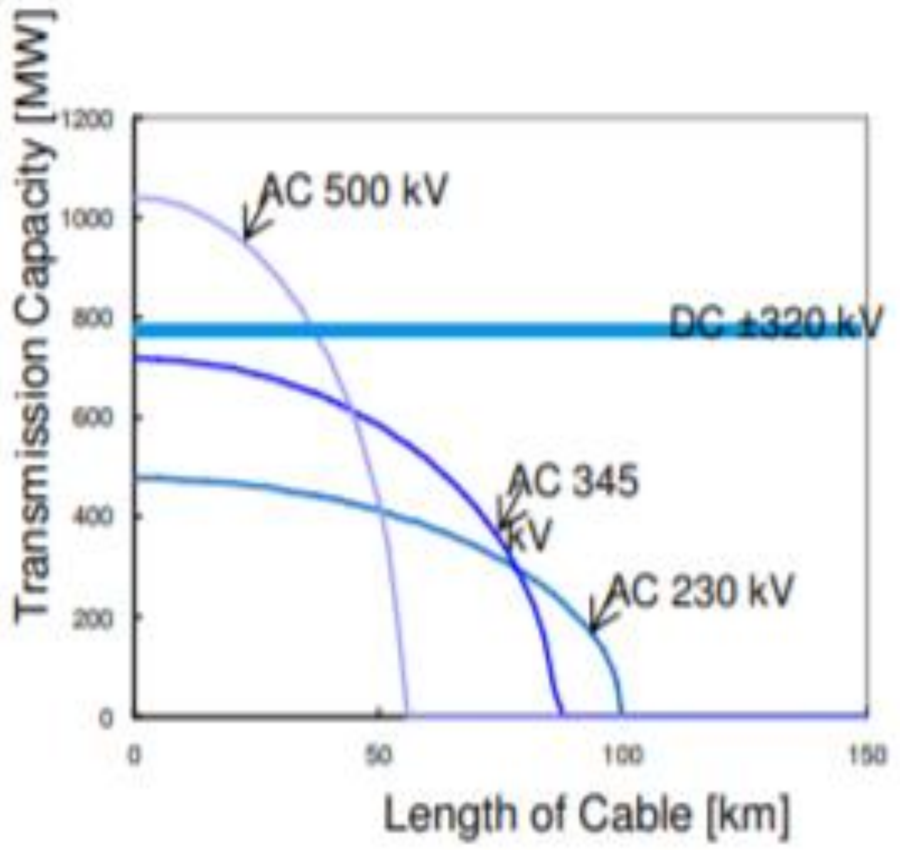
500 kV AC (Double-circuit)		1000 kV AC (Double-circuit)
2~2.4	Transmission capacity (GW)	8~9
250~800	Economical transmission distance (km)	500~2000
0.46~0.69	Line loss rate (%/100 km)	0.17~0.21
0.029~0.035	Footprint - overhead line (m/MW)	0.008~0.009
39	Footprint - substation (m^2/MVA)	29
1938	Costs (RMB/MW•km)	1346

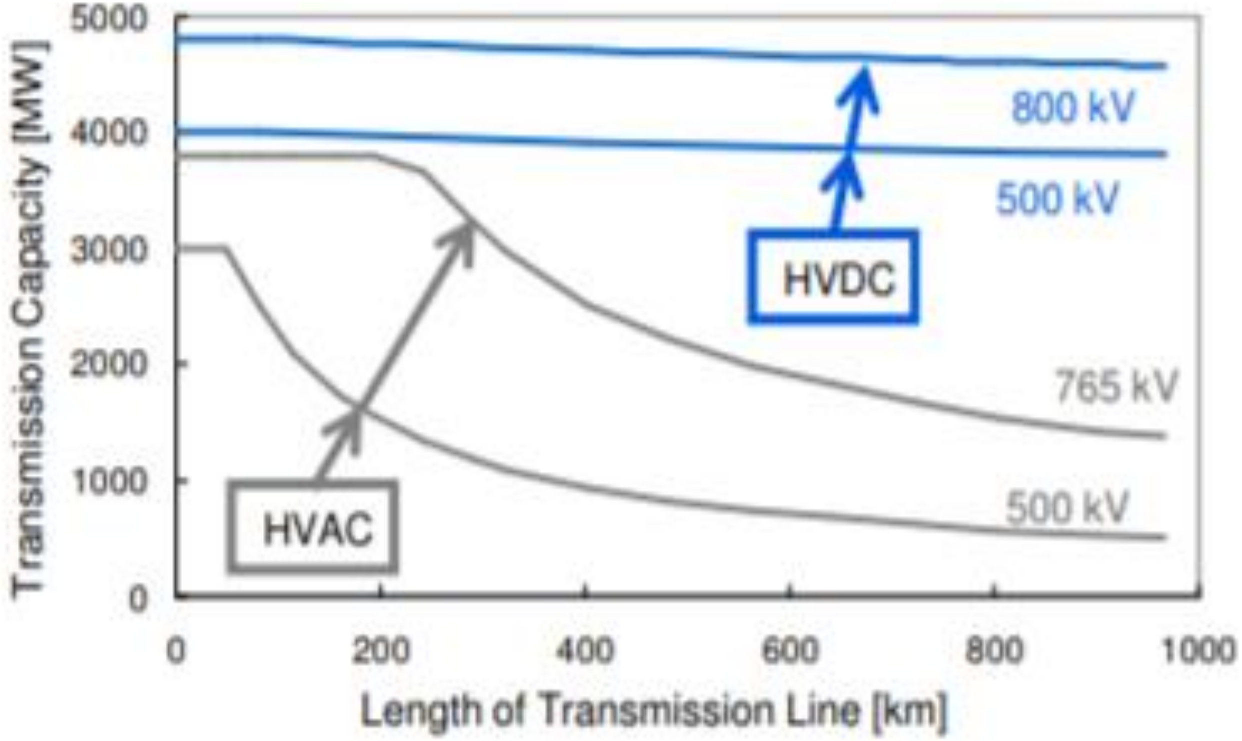
±500 kV DC		UHV DC (±800 kV/±1100 kV)
3	Transmission capacity (GW)	8~12
<800	Economical transmission distance (km)	1100~2500/2300~5000
0.28	Line loss rate (%/100 km)	0.16/0.09
0.013	Footprint - overhead line (m/MW)	0.01/0.007
60	Footprint – convertor station (m^2/MW)	20/25*
952	Costs (RMB/MW•km)	660/626

* The convertor station is connected to the AC system in two voltage levels.

Source: SGCC

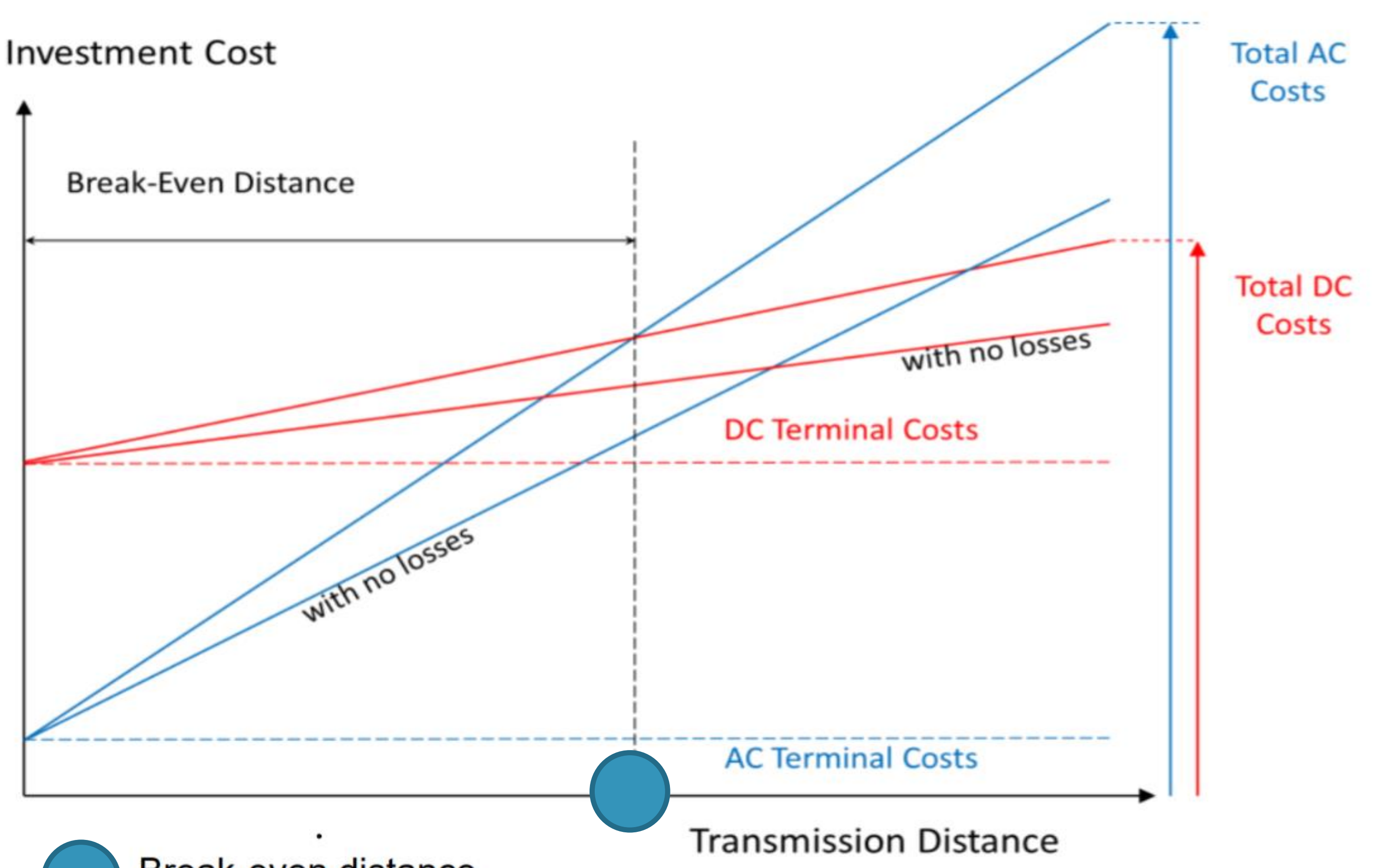
AC versus DC in Energy Highways





Source: ABB

Energy Highways – AC vs. DC Economics



Break-even distance
Overhead lines: 400 – 700 km
Cables: 25 – 50 km

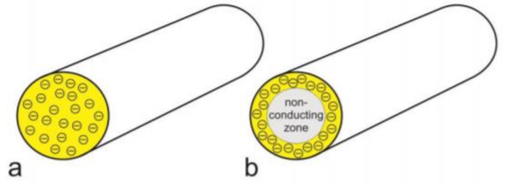


Fig. 2– DC (a) and AC (b) flow in a conductor; the *skin effect*

Two examples of HVAC and HVDC cable losses for comparable lengths and voltages are given in Table 1.

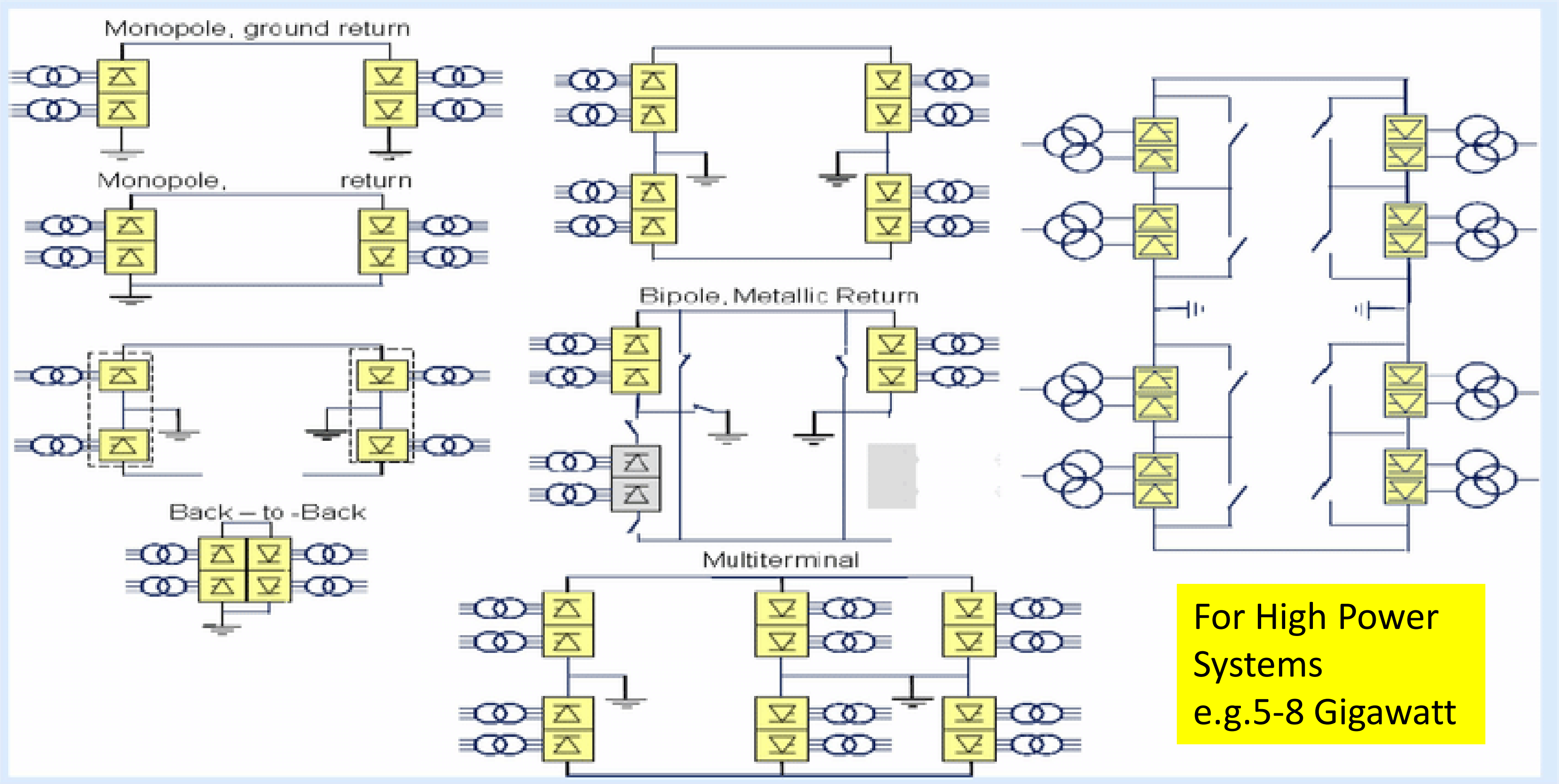
Table 1 – Two examples of losses in HVAC and HVDC power transmission cables

	Length (km)	Power (MW)	Voltage (kV)	Losses (%)
AC	1000/2000	3000	800	6.7/10
DC	1000/2000	6400	800	3.5/5

The break-even distance greatly depends on the land conditions and project specifications.

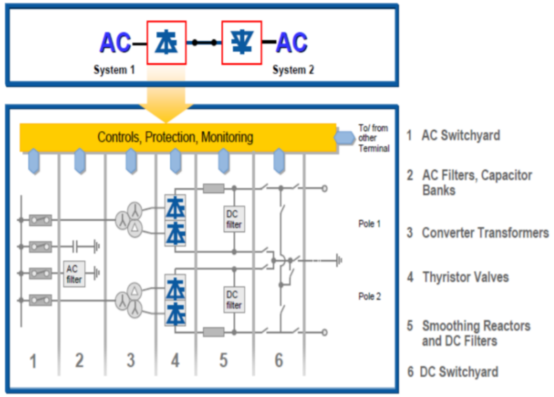
DC Energy Highways Design Development

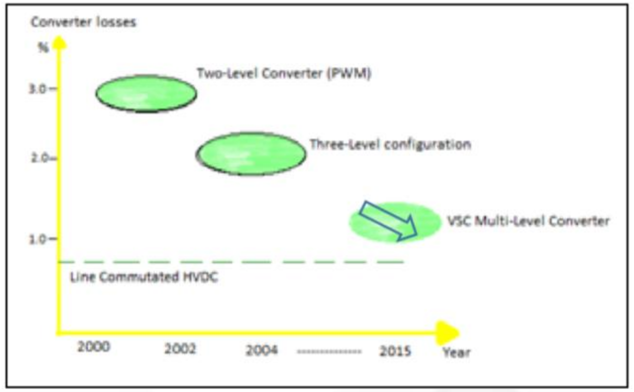
Energy Highways HVDC Configurations



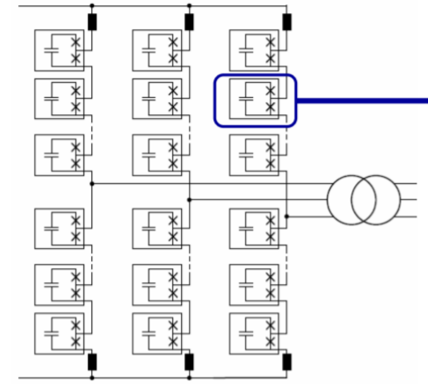
For High Power Systems e.g.5-8 Gigawatt

HVDC Converter Design Development

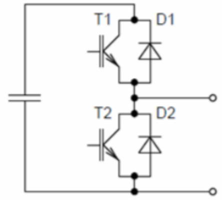


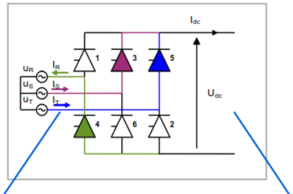


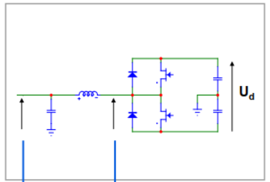
High Voltage MMC for HVDC

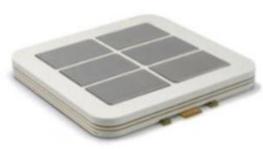


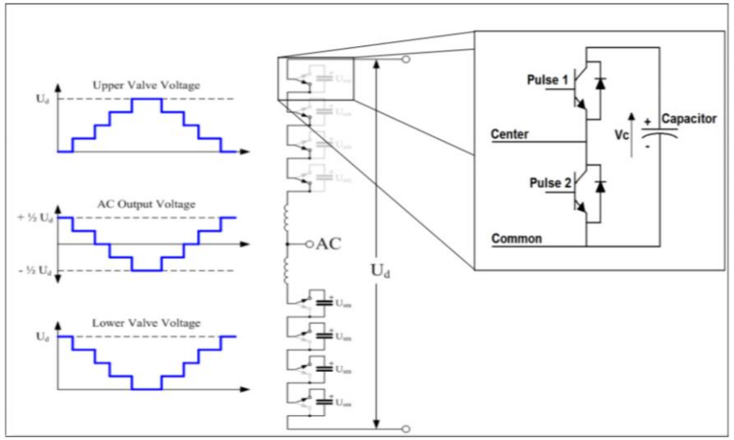
Submodule

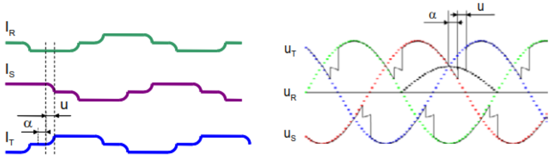




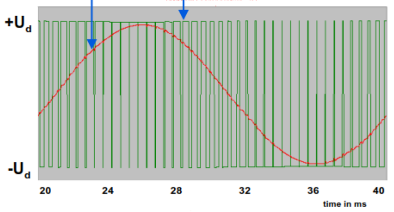






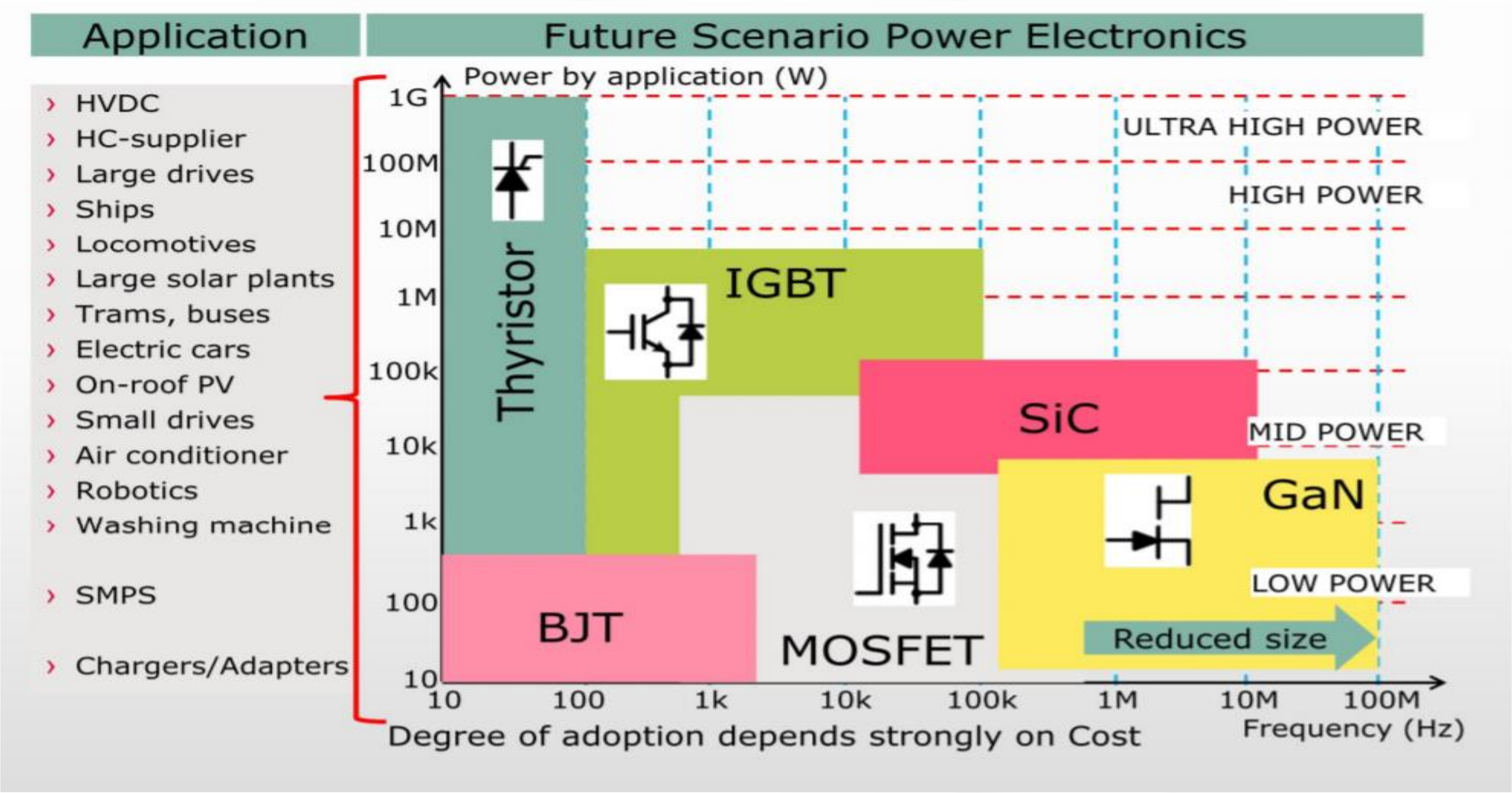


$U_d = U_{di0} \cos\alpha - d_{xr} \frac{U_{di0r}}{I_{dr}} I_d$



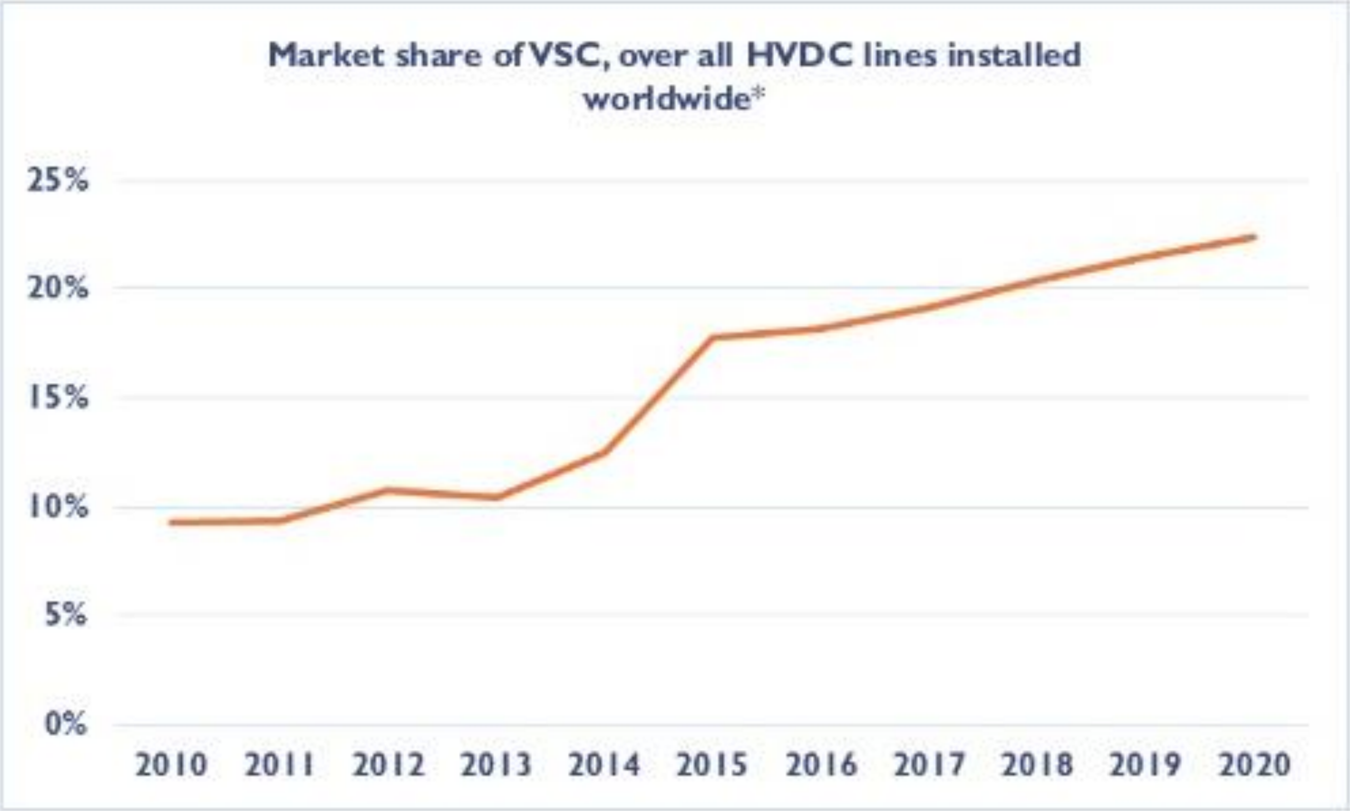
LCC (Thyristor) → VSC with IGBT → VSC with MMC

Major Power Devices Technology and Applications



Source: Empowering the Electronics Industry Power Technology Roadmap 2016

Technical Trends in HVDC

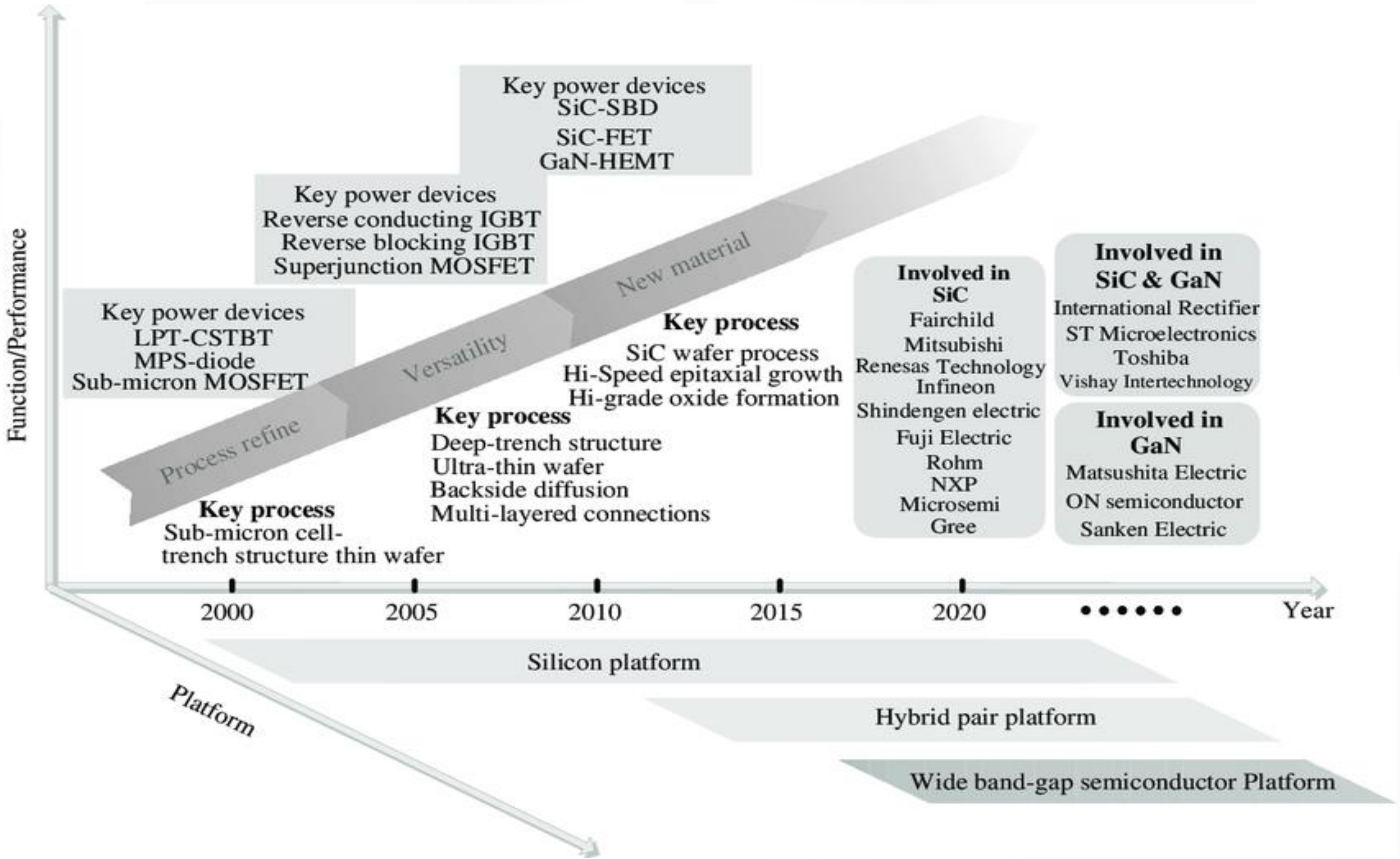


* % of cumulative HVDC line units

The use of this technology is **mostly driving by the European market** and their off-shore renewables connection to the grid.

Source: Yole 2016

Power Devices – R&D Platforms and Outlook



DC Energy Highways Applications

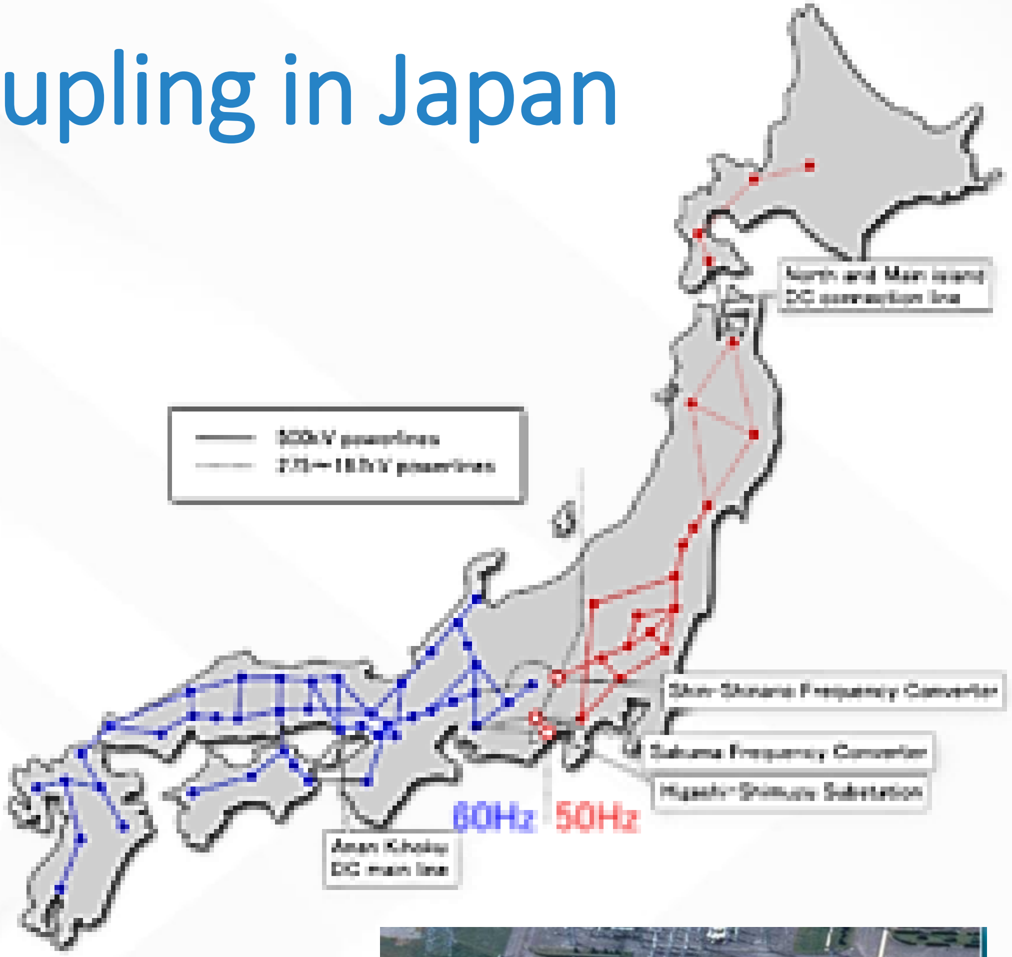
B2B Energy Highway Coupling in Japan

- Shin Shinano Hendensho

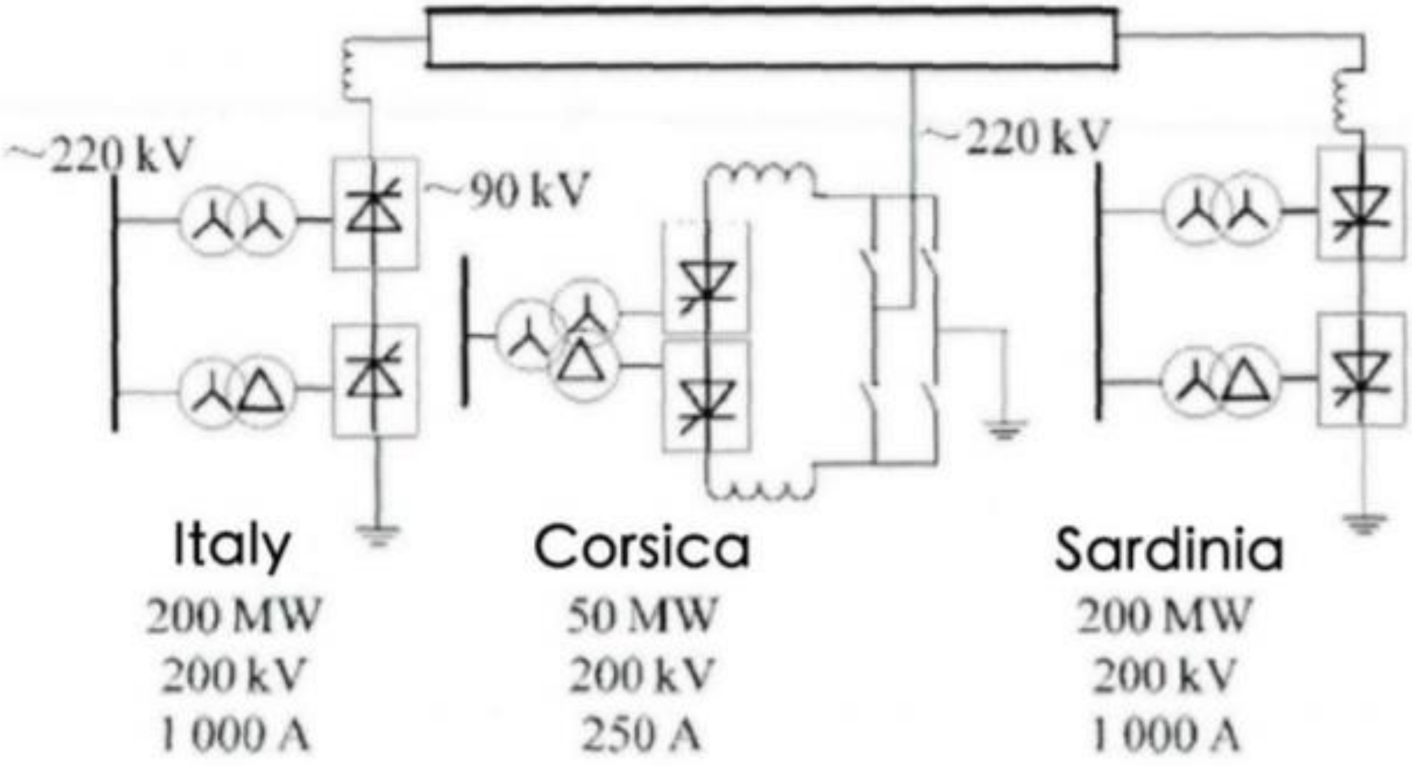
(HVDC – B2B) facility with four frequency Converter stations linking Japan's western and eastern power grids. The other three stations are at Higashi-Shimizu, Minami-Fukumitsu and Sakuma Dam.

Converter equipment

The HVDC back-to-back facility Shin Shinano uses line-commutated thyristor converters. The station houses two converters, one of which opened in December 1977,[1] the other in 1992. The original 1977 converter was one of the first thyristor-based HVDC schemes to be put into operation in the world and used oil-insulated, oil-cooled outdoor thyristor valves supplied by Hitachi (60 Hz end) and Toshiba (50 Hz end).



Islands Remote End – Energy Highway - Italy



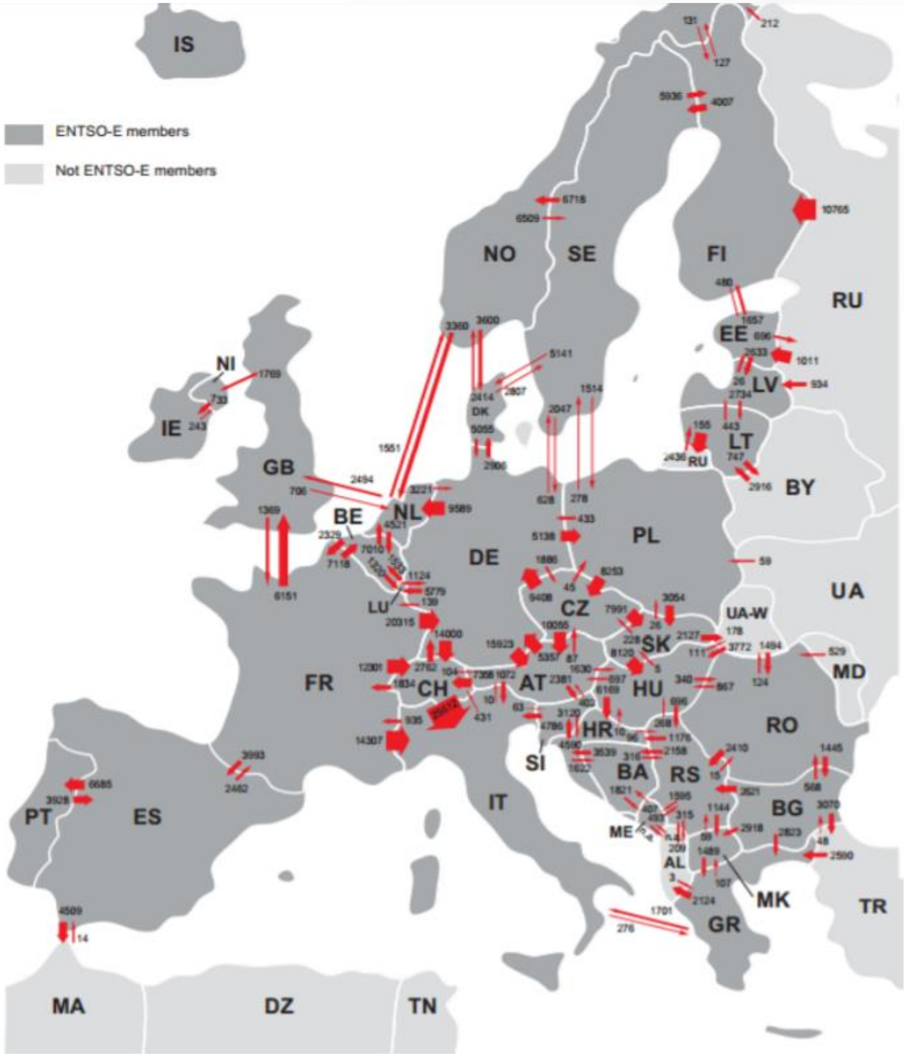
SACOI – Sardinia –Corsica – Italy Connection

Energy Highway – Island connection in New Zealand

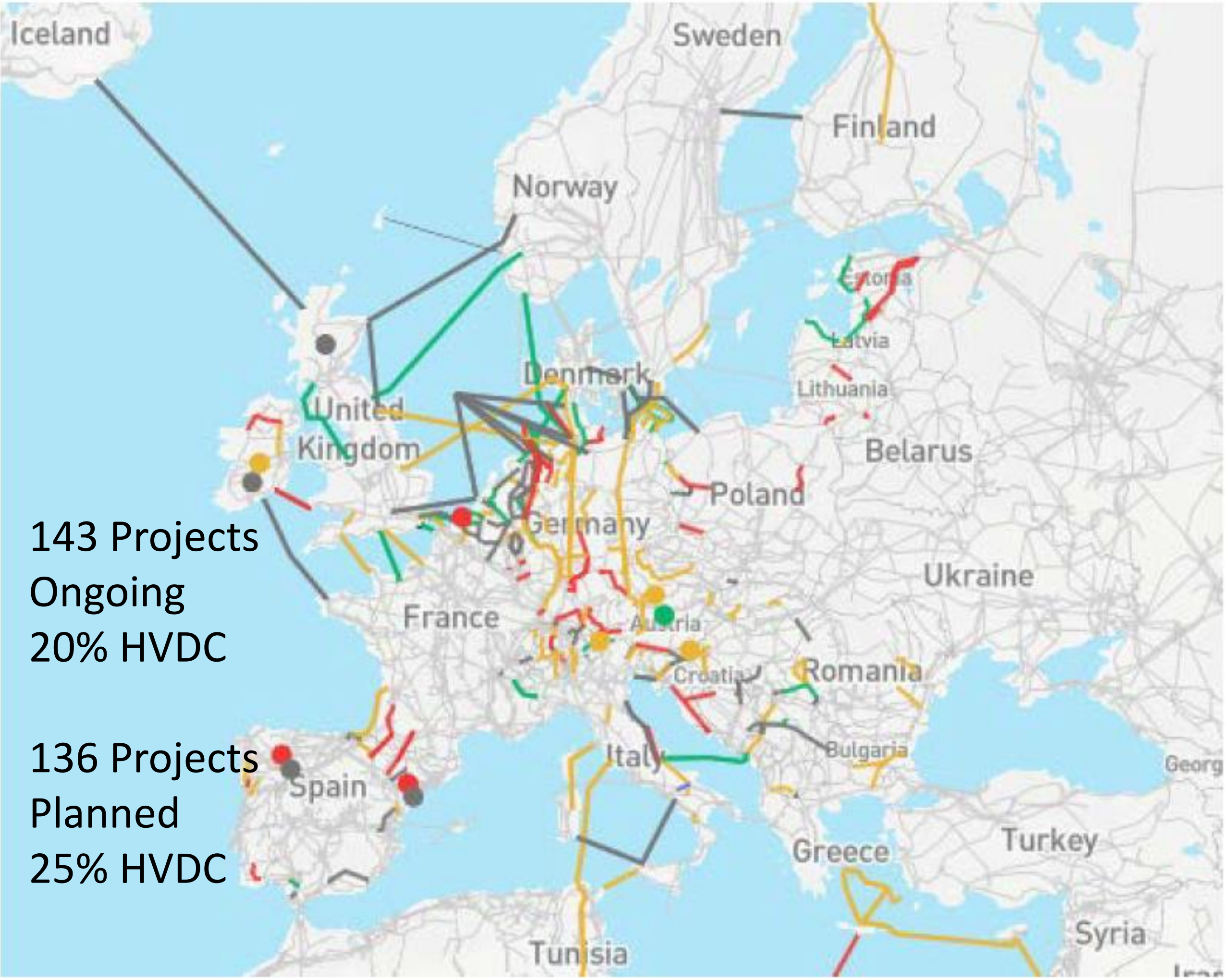
The **HVDC Inter-Island** link is a 610 km (380 mi) long, 1200 MW bipolar high-voltage direct current (HVDC) transmission system connecting the electricity networks of the North Island and South Island of New Zealand

Much of New Zealand's electricity generation is hydro-electric. The majority of this generation is from stations established on lakes and rivers in the lower half of the South Island, while most of the electricity demand is in the North Island,

Energy Highways in EU countries and Neighbors



Energy flow today between European Countries

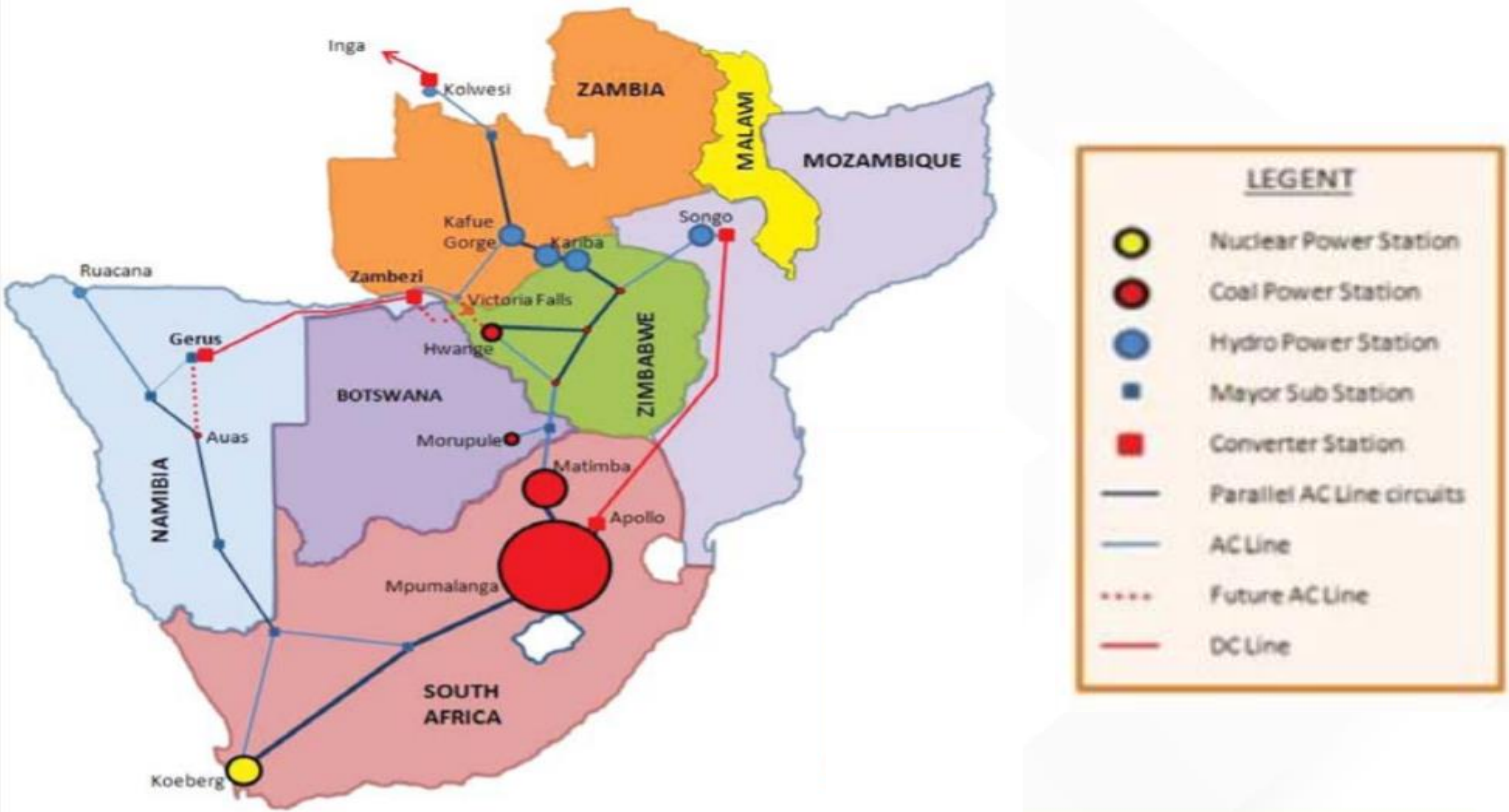


143 Projects
Ongoing
20% HVDC

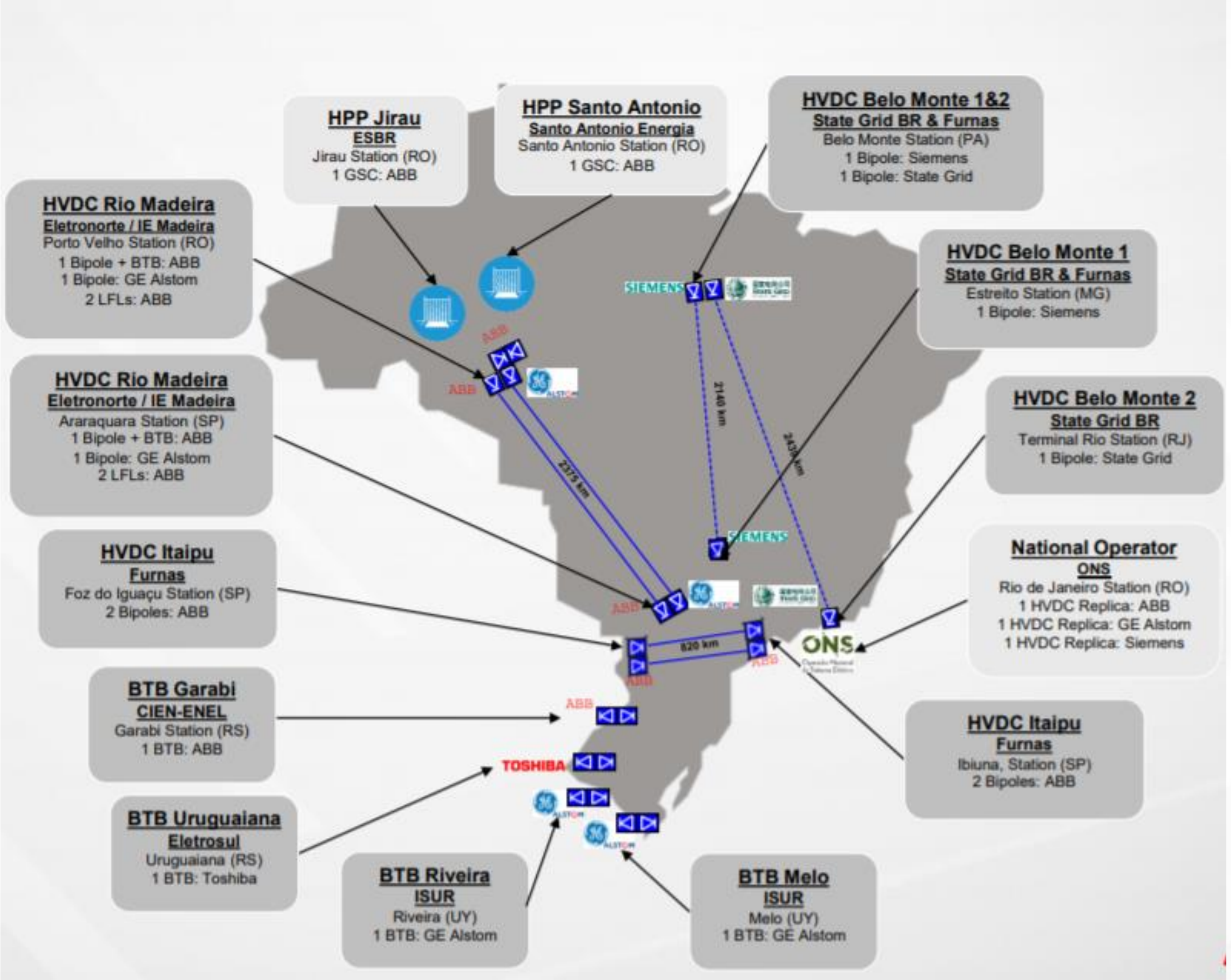
136 Projects
Planned
25% HVDC

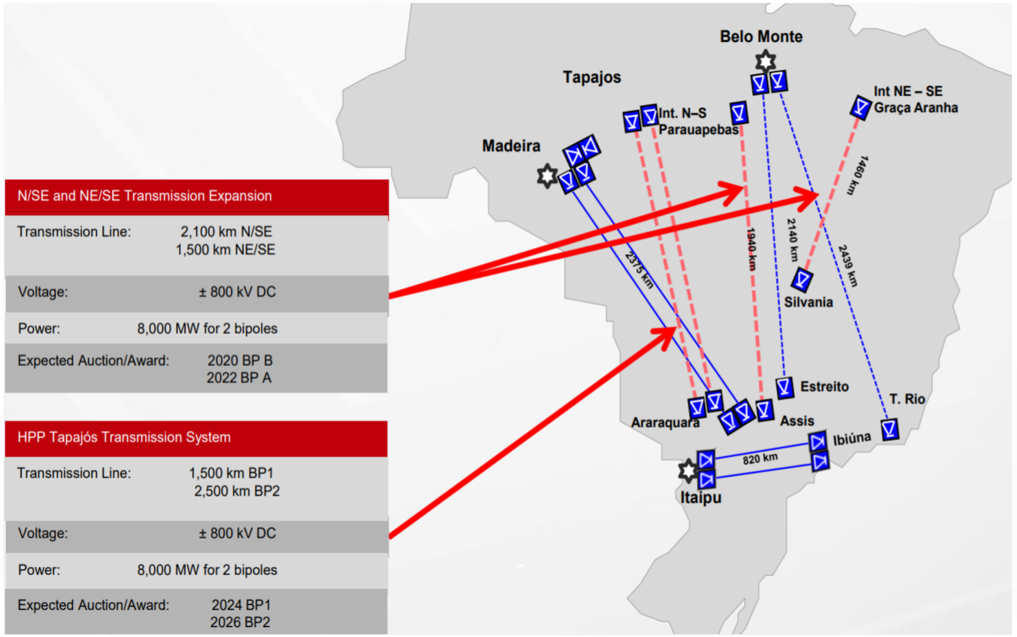
Source: Entso-e 10 years development plan 2018

African Power Pool - DC Energy Highways



DC Energy Highways in Brazil



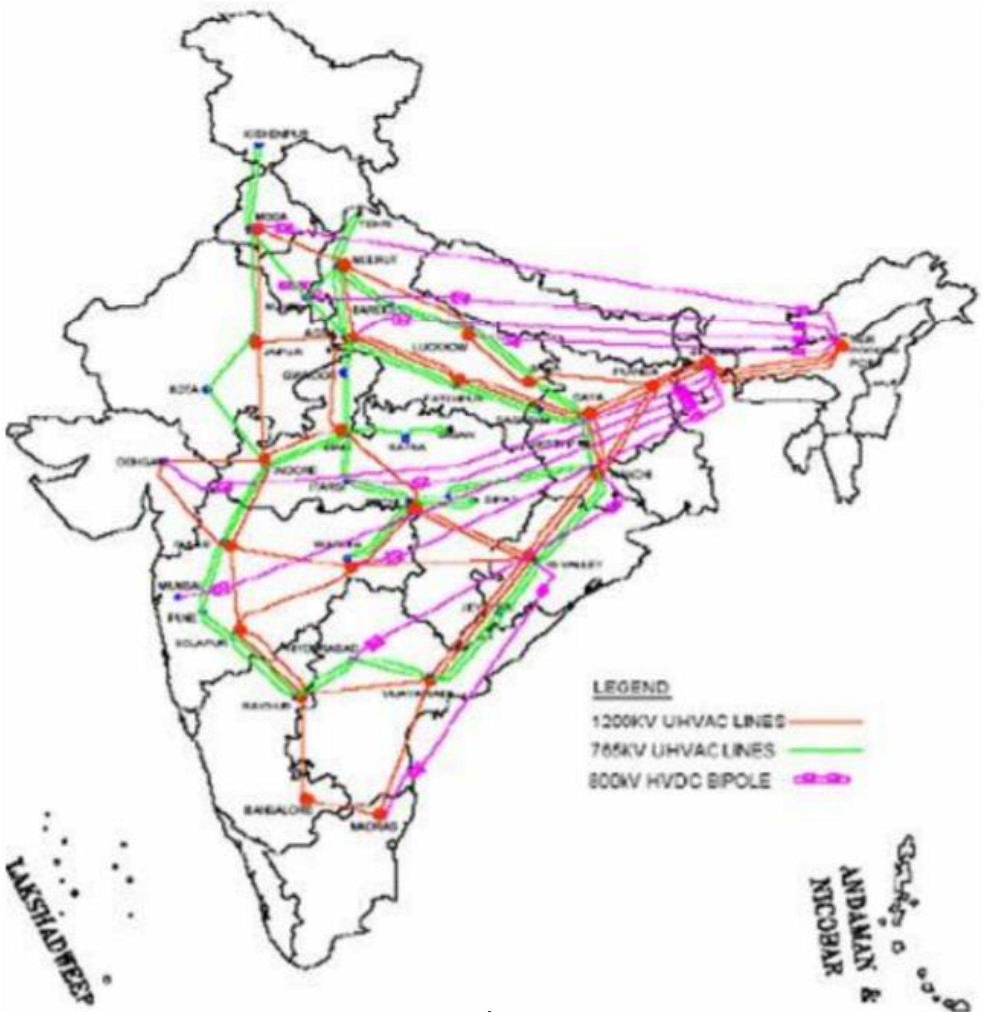


N/SE and NE/SE Transmission Expansion	
Transmission Line:	2,100 km N/SE 1,500 km NE/SE
Voltage:	± 800 kV DC
Power:	8,000 MW for 2 bipoles
Expected Auction/Award:	2020 BP B 2022 BP A

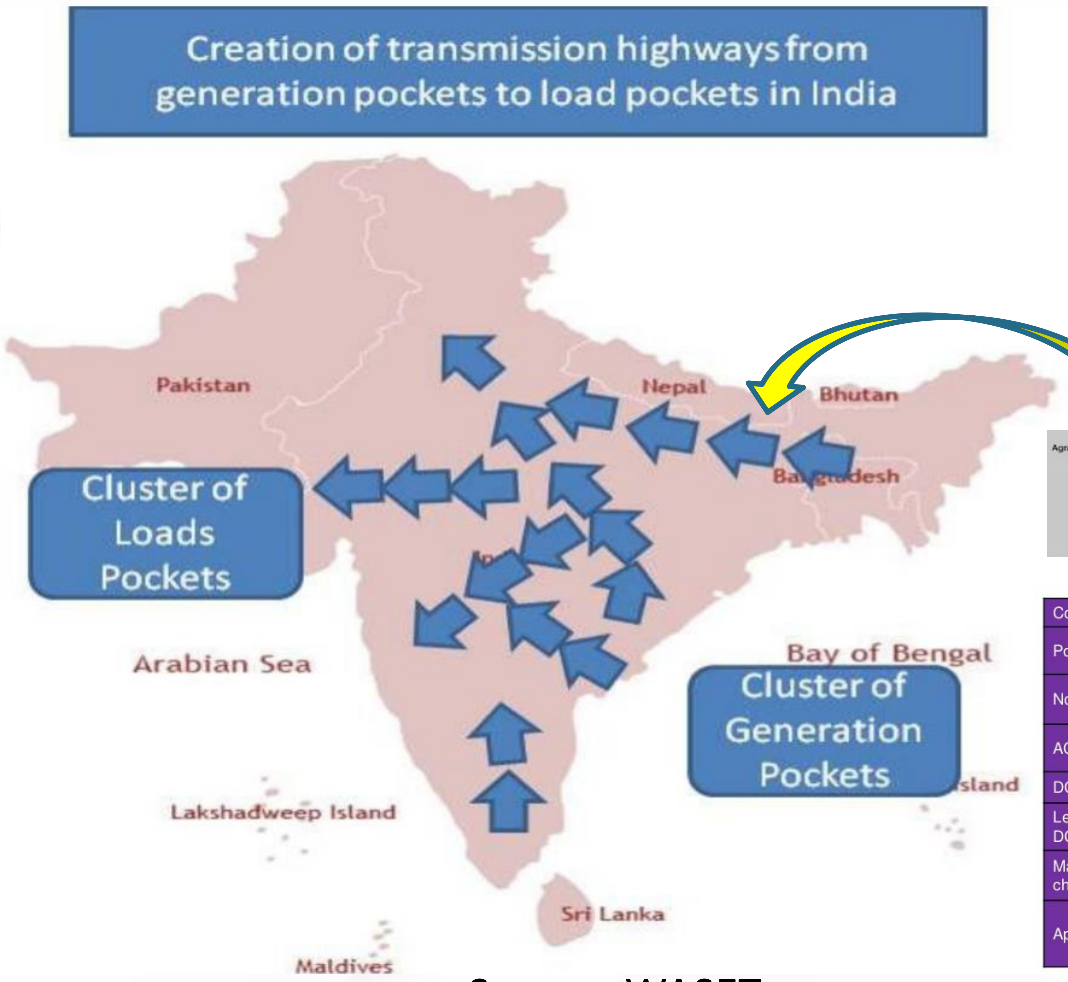
HPP Tapajós Transmission System	
Transmission Line:	1,500 km BP1 2,500 km BP2
Voltage:	± 800 kV DC
Power:	8,000 MW for 2 bipoles
Expected Auction/Award:	2024 BP1 2026 BP2

Source: ABB

Mega Energy Highways in India (UHVDC)



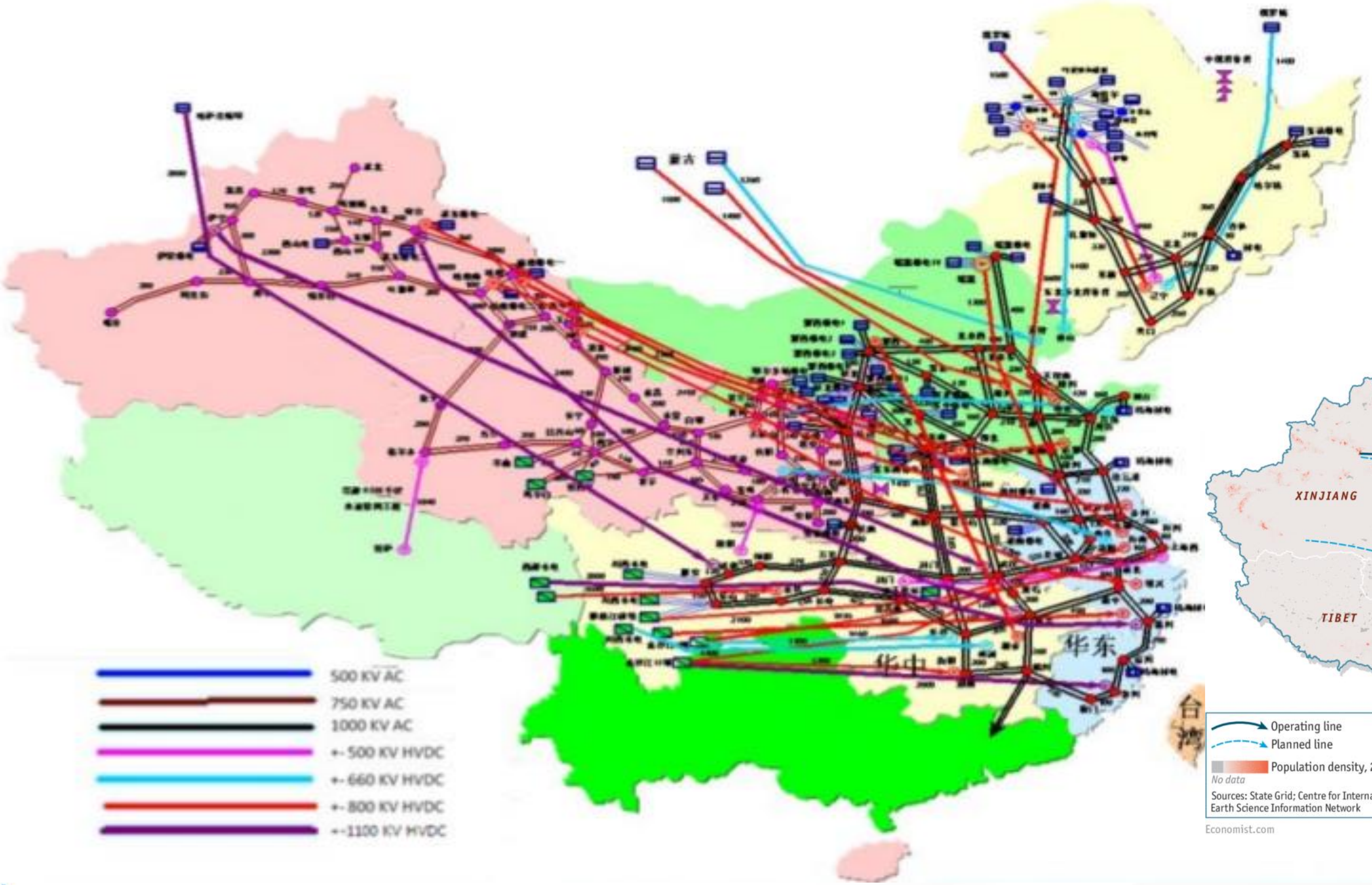
Source: CEA / Siemens
IRENA Energy Week 2016



Commissioning year:	2016
Power rating:	6,000 MW (multiterminal)
No. of poles:	Converter: 4 Line: 2
AC voltage:	400 kV (all stations)
DC voltage:	±800 kV
Length of overhead DC line:	1,728 km
Main reason for choosing HVDC:	Long distance, bulk power
Application:	Connecting remote generation

Source: WASET

Mega Energy Highways Roadmap – CHINA 2020



50 HVDC Systems

30,000 km of HVDC

The Energy Super Highways (UHVDC > 1 Megavolt)

One **"Super Energy Highway"** UHVDC transmission link could provide for about **26.5 million Chinese people**.

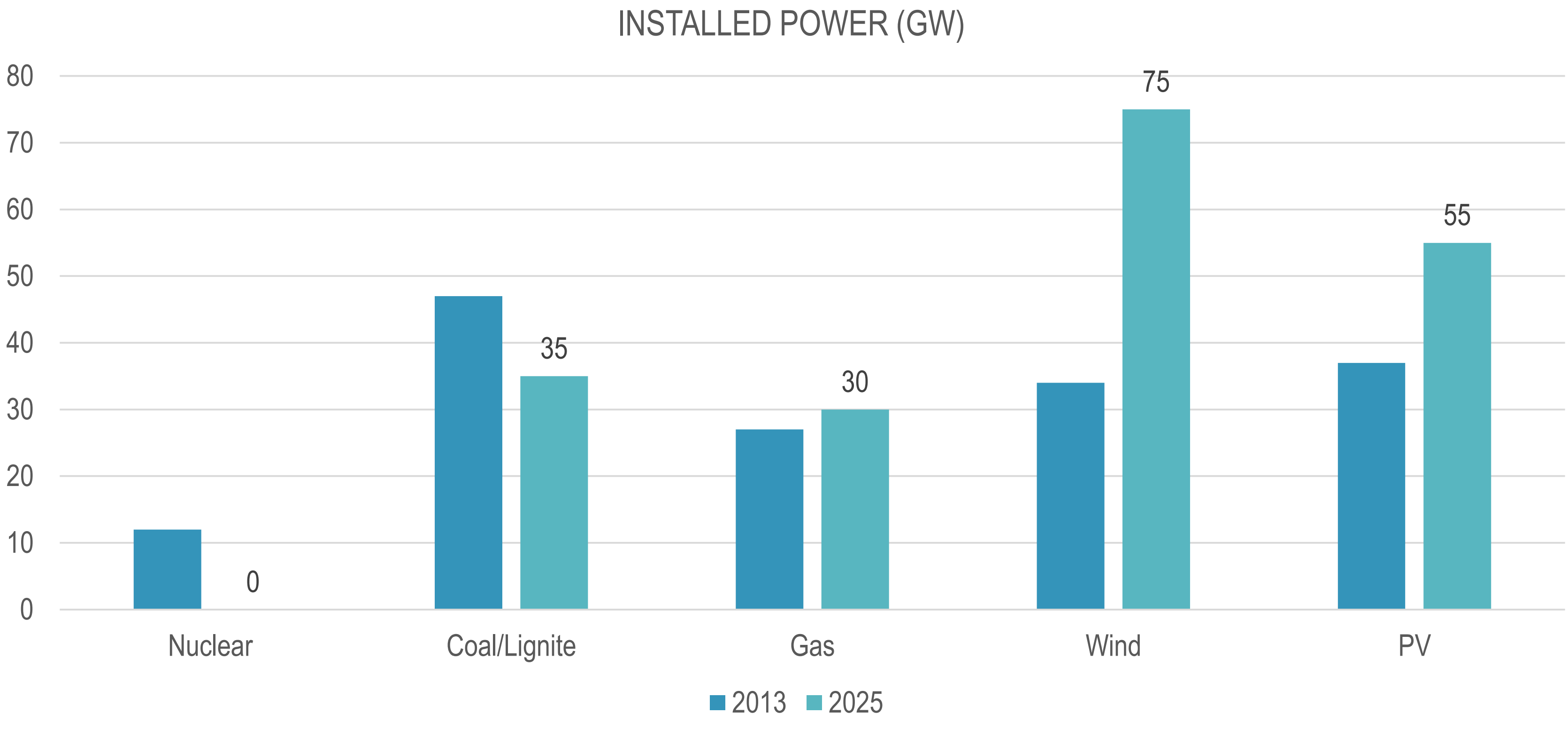
Energy Transition
in Germany
enabled by
DC Energy Highways
“a special Project”

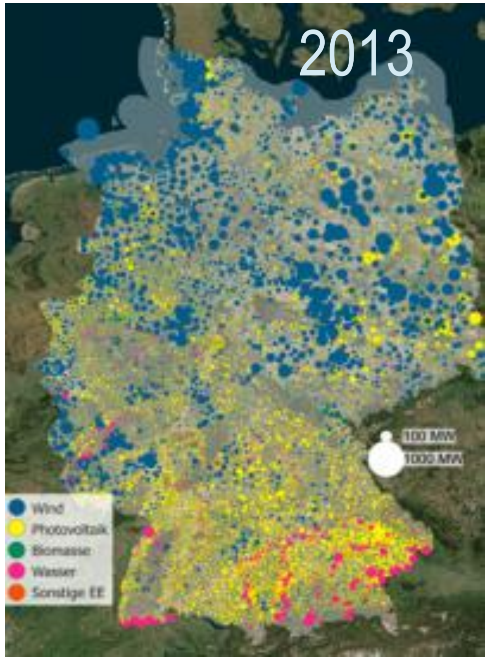
GERMAN HVDC OFFSHORE CABLE CONNECTIONS

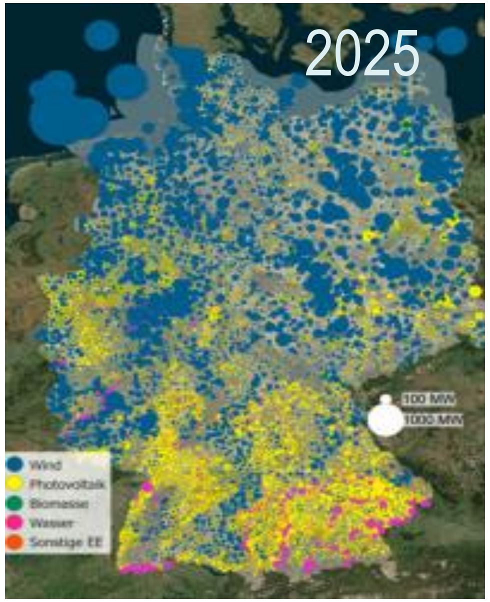
Project	On-/Offshore	Power	Year
BorWin1	75 km / 125 km	400 MW	2010
BorWin2	75 km / 125 km	800 MW	2015
BorWin3	30 km / 130 km	900 MW	2019
DolWin1	90 km / 75 km	800 MW	2015
DolWin2	90 km / 45 km	916 MW	2016
DolWin3	80 km / 80 km	900 MW	2017
HelWin1/2	2x 45 km / 85 km	1.266 MW	2015
SylWin1	45 km / 160 km	864 MW	2015
Total	**575 km / 825 km**		

GERMANY'S ENERGY TRANSITION PLAN

- Shift towards renewable energies
- **Wind Energy in the North** and **Solar Power (PV)** in the South

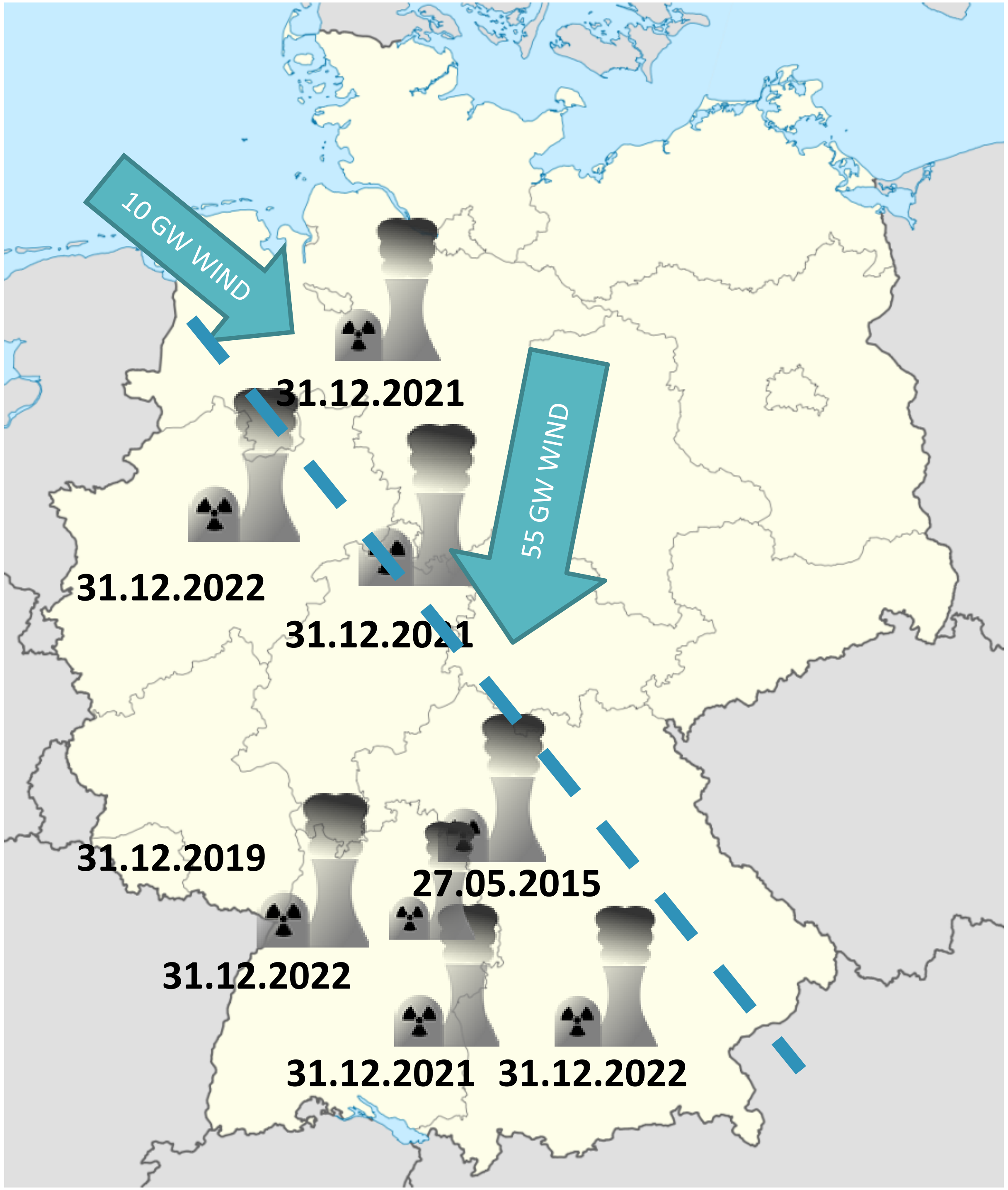






SHUTDOWN OF NUCLEAR POWER PLANTS

- Shutdown of 8 nuclear power plants until 2022
- Increase of wind power
- Power transmission North-South / East-West



PLANNED HVDC CONNECTIONS

No.	Project Name	TSO	Length
DC1*	Ultranet	Amprion	320 km
DC2	Ultranet		340 km*
DC3*	SuedLink	TenneT / TransnetBW	770 km
DC4*	SuedLink	TenneT / TransnetBW	620 km
DC5*	SuedOstLink	50Hertz / TenneT	580 km
			2.630 km

- 2GW Capacity each connection

* Priority for underground cables according to decision by Federal Government in June 2015

- Definition of projects: www.netzausbau.de (BNetzA)

PROJECT MANAGEMENT DRIVING GERMANY‘S ENERGY TRANSITION

VDE ETG Taskforce Infrastructure

2011

OVANET Study

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

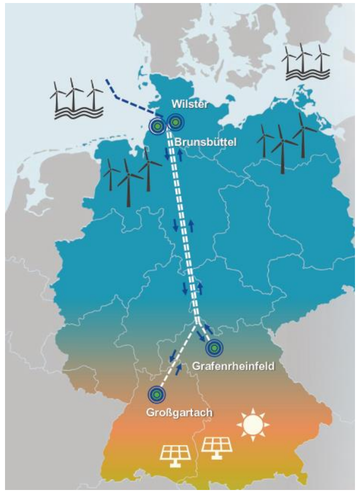
OVANET

2014

6/2015

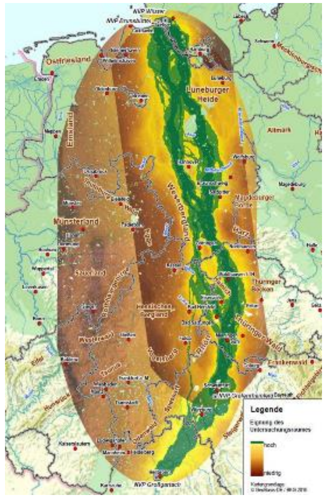
German decision for underground cable

SuedLink Feasibility Study



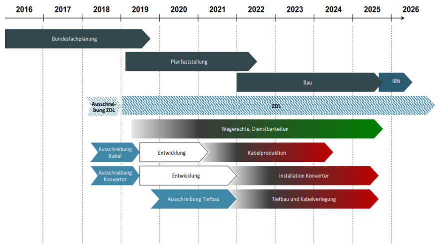
10/2015

SuedLink Regional planning Corridors 1,000m



2016-2020

ZDL SuedLink



2019-2026

Time

HVDC NETWORK AND PM EXCELLENCE

HVDC Project „Suedlink“ In Germany

DC Grid

Capacity 2 x 2 Gigawatt

Length: 500 and 700km

System Voltage: 525kV

Largest underground Cable Project

Network Planning

EIA – Environmental Impact Assessment

1 Km wide Corridor Engineering

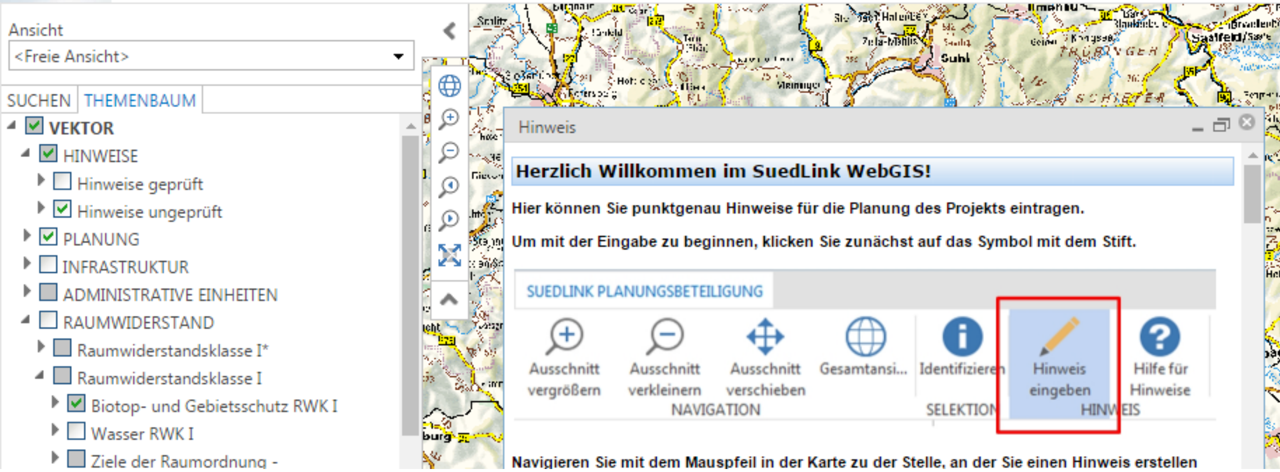
Permitting Process Management

Public Participation Coordination

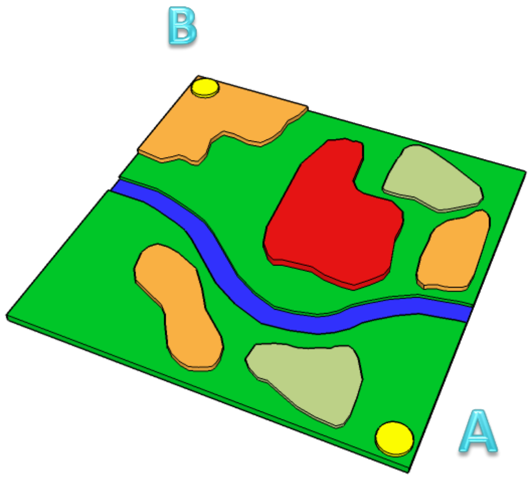
PARTICULARITIES OF HVDC UNDERGROUND CABLE

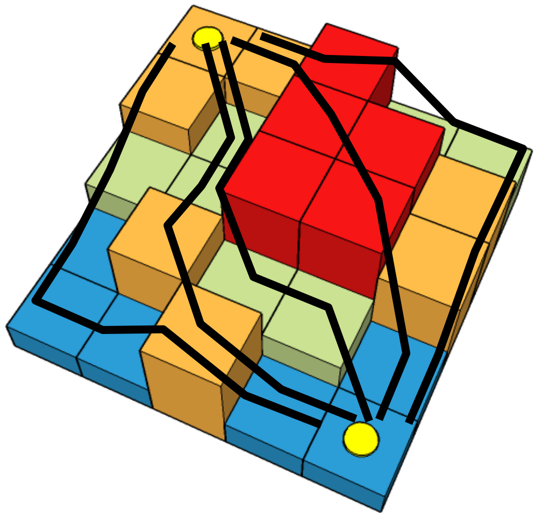
► ANALOGY OF PIPELINE AND CABLE CONSTRUCTION

► EXTENSIVE PUBLIC PARTICIPATION REQUIRED (WEBGIS)

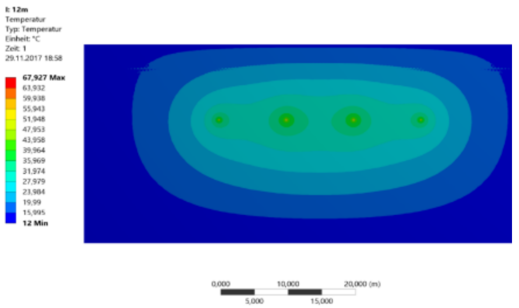


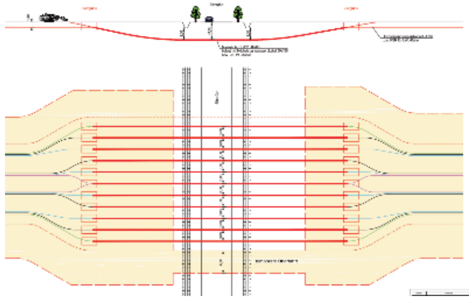
► CONSTRAINT MAPPING & PREFERRED CORRIDOR CALCS





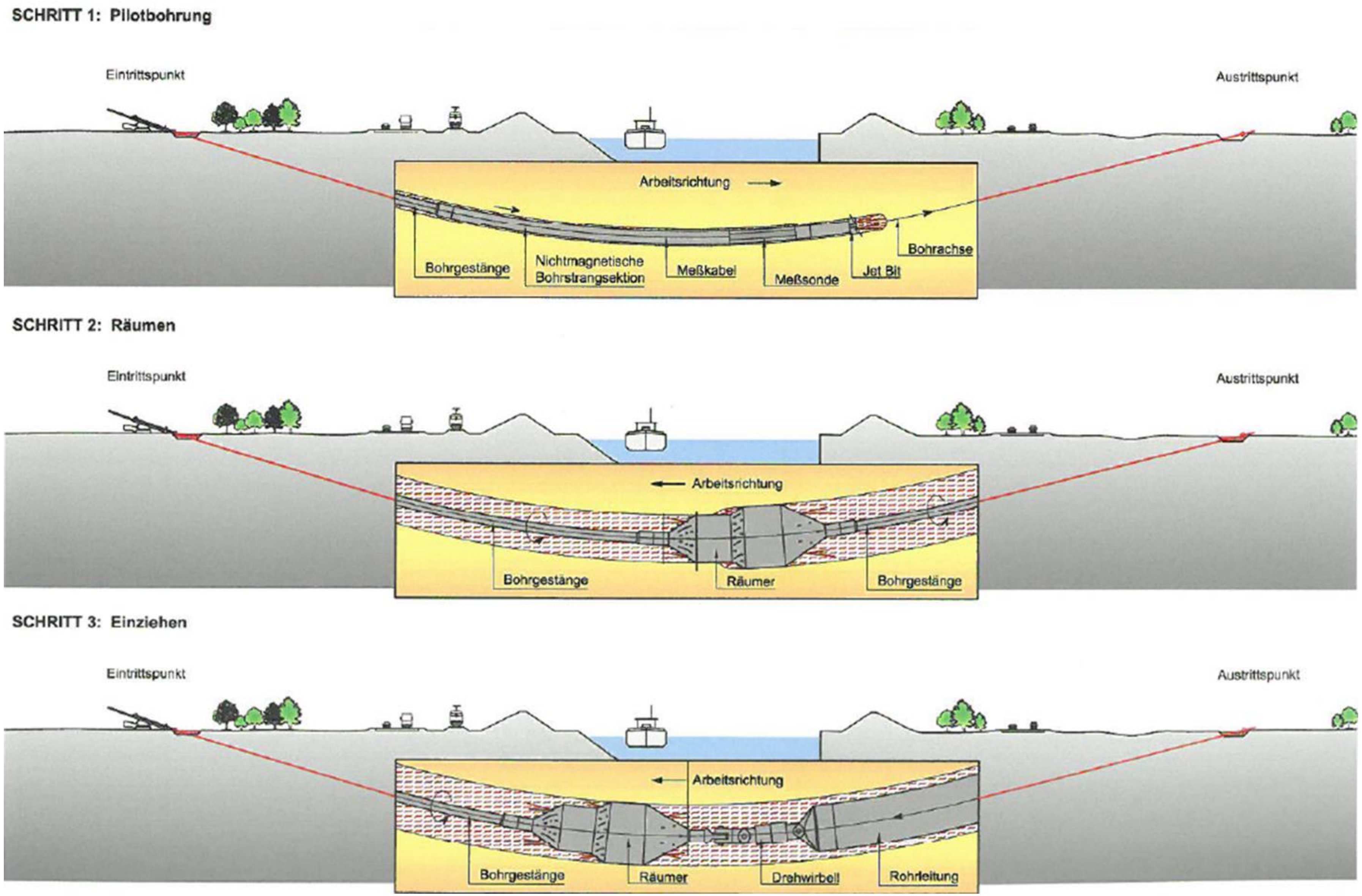
► THERMAL CABLE CALCULATIONS



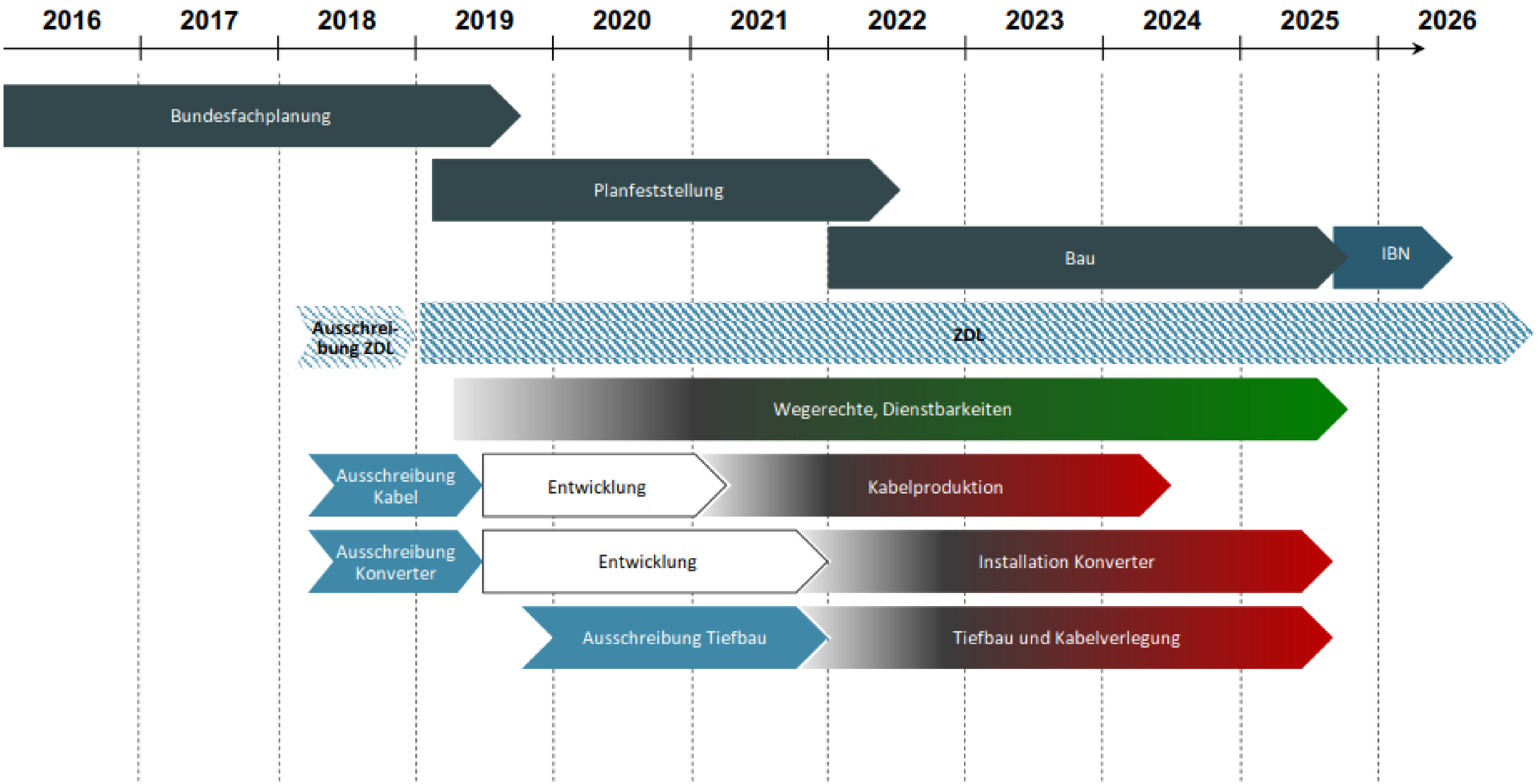


HORIZONTAL DIRECTIONAL DRILLING AND CABLE CONDUITS

- trenchless technique
- one separate cable conduit per cable
- pilot drill with steerable drill head
- bentonite as drilling liquid
- reaming and widening of drilling channel
- pulling in of cable conduit



HVDC PM EXCELLENCE



THANK YOU!

Session Feedback: https://goo.gl/zopBt8