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Paving the road for Energy Transition

VQ Deep Dive

Authored by

Sagar Dhawan & Ravi Dharamshi

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Image: Inside a HVDC valve hall

Source: Hitachi Energy

> *"The chip shortage may be behind us, but AI and EVs are expanding at such a rapacious rate that the world will face supply crunches in electricity and transformers next year."* ***- Elon Musk***

Electrification is the route to decarbonization as electricity is an efficient carrier of energy generated via renewables sources. On the other hand, energy consumption is also rising at a rapid pace with the advent of EVs and Gen AI. Transmission grids are the energy highways of the world and thus key enablers of energy transition as well as energy access.

The world's transmission grids are in need of a major overhaul because the energy transition is driving the need for:

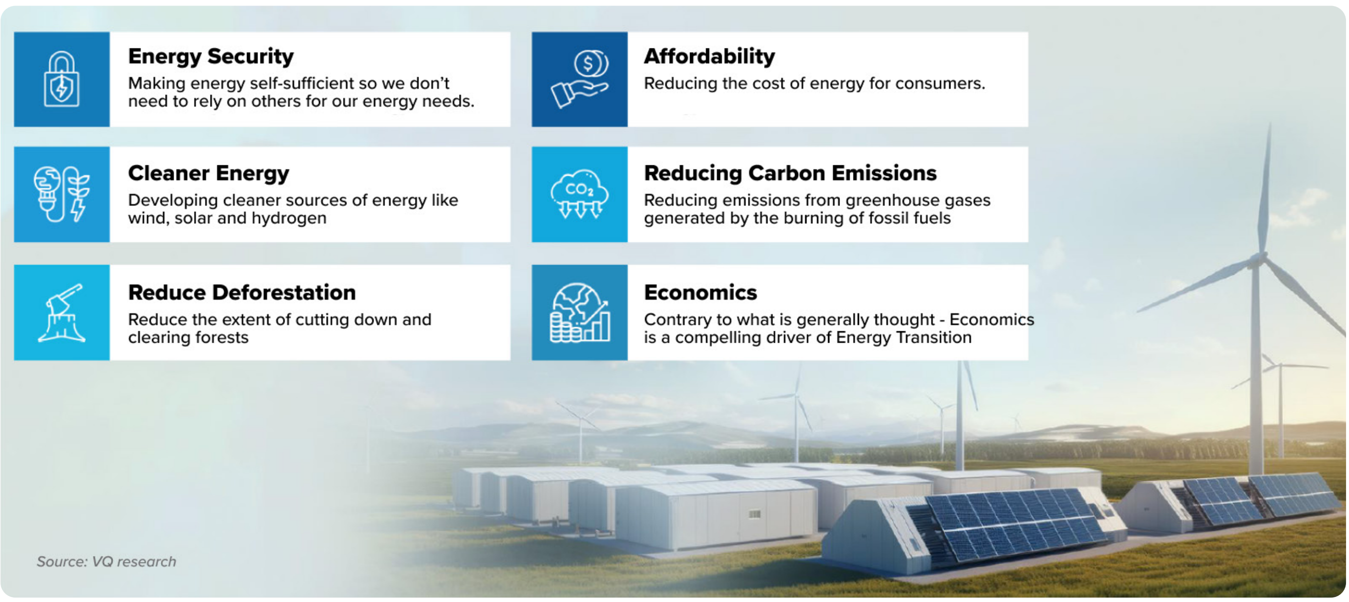
1. Building more grids,
2. Increasing the efficiency of existing grids, and
3. Developing smarter grids

We believe that these factors not only serve as growth drivers for the transmission industry but also act as key differentiating factors between incumbents from an investment positioning standpoint.

Megatrend: Energy Transition

Energy transition is a fundamental change in the way we relate to all aspects of energy generation, distribution and consumption.

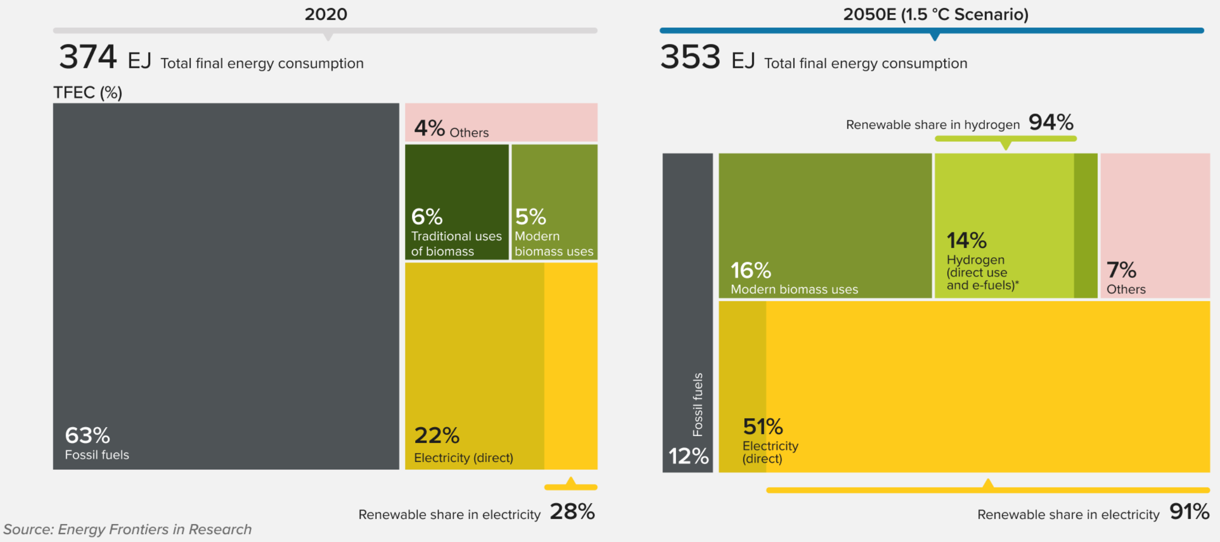
Energy transition drivers



Source: VQ research

Energy transition is not possible without transmission

Electrification demand is expected to increase by >2.5x as share of electricity in TFEC (Total Final Energy Consumption) is expected to go up from 22% to 51%.



Source: Energy Frontiers in Research

The bottleneck for electrification is the grid as RE electricity generated needs to be transmitted to the consumption centers.

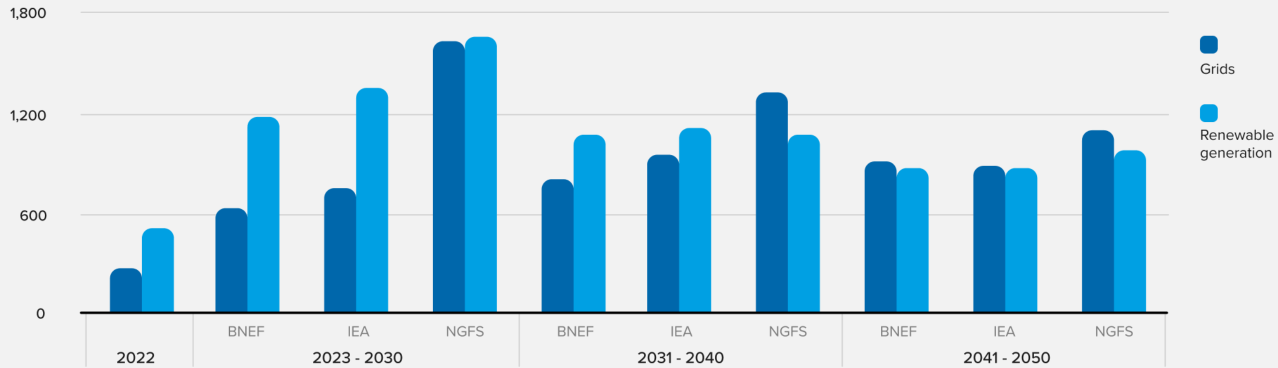
IEA (International Energy Agency) expects annual grid spends to double from US$300bn in 2023 to US$600 bn pa by 2030.

Significant acceleration in grid investments vs current levels is expected under all scenarios be it BNEF (Bloomberg New Energy Finance), IEA (International Energy Agency), NGFS (Network for Greening the Financial System) although the rate of increase expected varies greatly.

All forecasts indicate that spending on grids to not only remain elevated vs current levels but also increase as we step into the next decade 2030-2040 meaning the strong demand uptick that we are seeing right now is expected to sustain.

Comparing key capex streams under various scenario forecasts (US $bn)

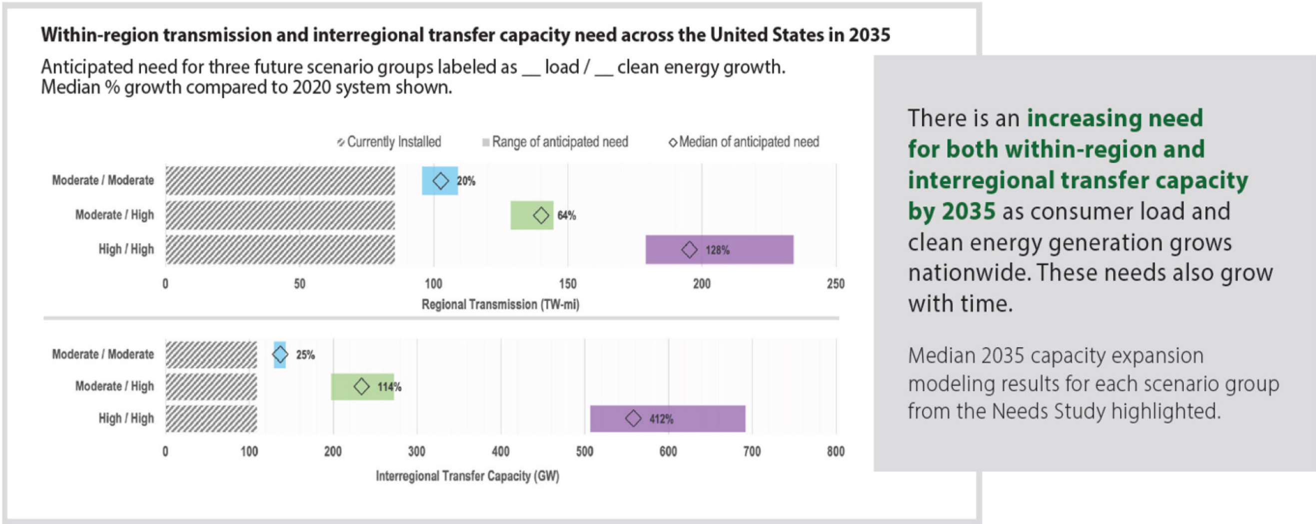
Whichever scenario "comes to pass", significant growth in capex is required



Source: BOFA report on transmission

It’s a global phenomenon

United States



Source: US National Transmission Needs Study

China

Even a country like China which has done massive investments in the grid in recent history needs to step up its spends by 50%, let alone western countries who have underinvested in the grid for decades.

Over the past decade, China has accounted for more than a third of the world’s transmission grid expansion. Globally, the country has the highest proportion of transmission lines that are less than 10 years old.

Still...
China’s capital expenditure on grids is set to rise from about $102bn in 2023 to $157bn by 2030 to overcome strains on the energy system as the country makes a rapid shift from coal power to renewable sources.

India

In India, transmission build out for RE evacuation is set to pick up with inter-state transmission bids awarded in FY24 being 3.5x higher vs FY23 at Rs 474 bn/$5.7 bn vs Rs 132 bn/$1.6 bn. Further, Rs 1 trn/$ 12 bn worth of bids are expected to be awarded in FY25 i.e ~2x of FY24 (~35% already awarded in 1QFY25).

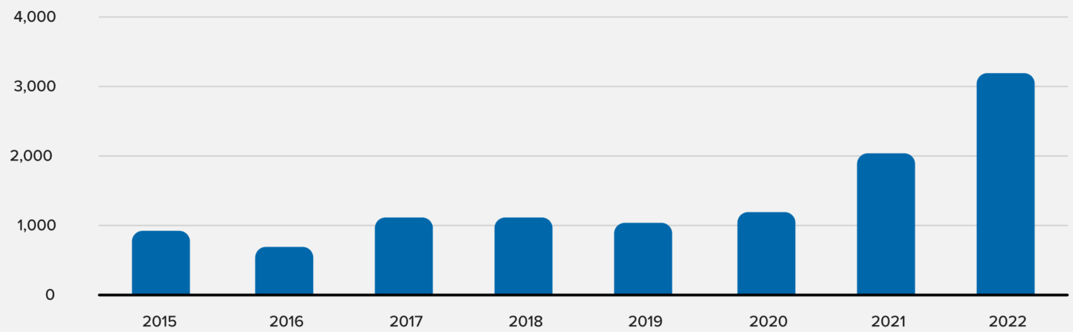
As per Central Electricity Authority (CEA), an estimated Rs 4.75 trn/$57 bn worth of investments over next 5 years would be required for implementation of additional High voltage transmission systems (220 kV and above) in India (Transmission lines, Substations, and reactive compensation etc.).

There is a sense of urgency

Costs to consumers from congestion on the U.S. power grid more than doubled to an estimated $13 billion in 2021 from the year before and was estimated to reach $21 billion in 2022. These costs will likely keep rising until the needed transmission capacity is built. Insufficient transmission infrastructure creates “transmission congestion,” effectively an electricity traffic jam, and congestion costs occur when there isn’t enough transmission capacity to deliver the lowest cost power to consumers, and the demand is then met by more expensive sources of electricity.

Congestion management costs in Germany (EURm)

Getting power from source to consumption is increasingly expensive



Source: BOFA report on transmission

Regulations are in favor

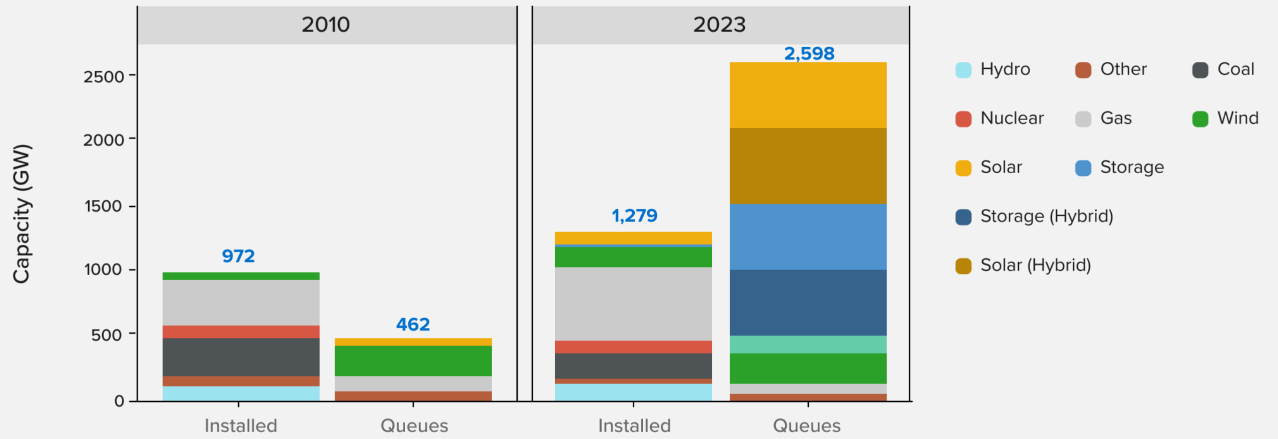
In addition to various regulatory incentives being provided for renewable energy, in US there are specific incentives for transmission grids in the form of the GRIP program. As part of the Bipartisan Infrastructure Law, Grid Resilience and Innovation Partnerships (GRIP) Program entails a total govt spending of $10.5 bn to enhance grid flexibility and improve the resilience of the power system against growing threats of extreme weather and climate change. In India, there is ISTS (Inter State Transmission System charges) waiver for Solar and wind plants coming before 30th June 2025 which will not have to pay ISTS charges for the next 25 years.

Topic Area	GRIP Program	Total Funding Amount (FY 22-26)	Approximate Total Federal Funding For All Awards - 1st Issue of FOA 2740	BIL Provision and Purpose
1	Grid Resilience Grants (Utility and Industry)	$2.5 billion	$918 million	Preventing Outages and Enhancing the Resilience of the Electric Grid / Hazard Hardening (Sec. 40101(c))
2	Smart Grid Grants	$3 billion	$1.08 billion	Deployment of Technologies to Enhance Grid Flexibility (Sec. 40107)
3	Grid Innovation Program	$5 billion	$1.82 million	Program Upgrading Our Electric Grid and Ensuring Reliability and Resiliency (Sec. 40103(b))
	TOTAL	$10.5 billion	$3.82 billion	

Source: GRIP program webinar | Webinar date: 29 Nov 2022

RE capacity commissioning timelines are shorter than conventional

A large solar plant for 500 MW capacity can be constructed within 18 months while a similar thermal or hydro plant might take 2-3 times more time, thereby leading to shortening of transmission capex timelines. The total capacity in the queue at the end of 2023, nearly 2.6 terawatts (TW), is more than twice the current U.S. generating capacity of 1.28 TW, and roughly eight times larger than the queue in 2014.



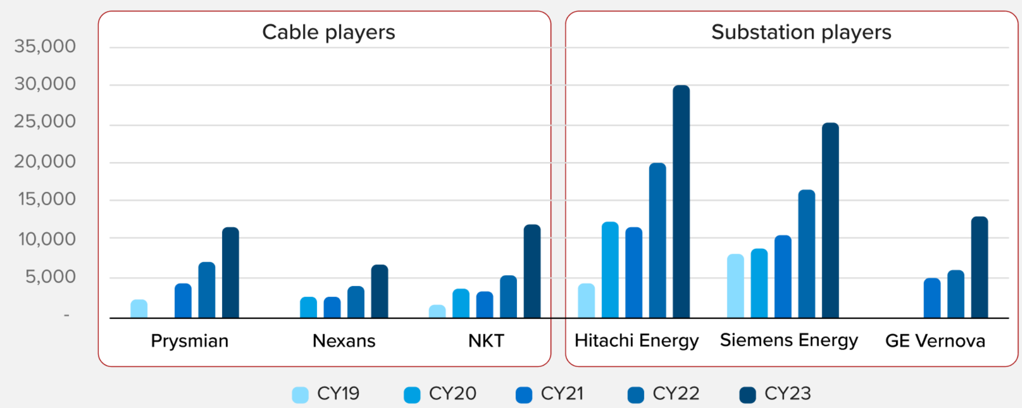
Source: Solar power world online

https://www.solarpowerworldonline.com/2024/04/electrical-grid-interconnection-backlog-grew-30-percent-2023/

As a result waiting time for transformers is longer than Nvidia's chips

A recent study in the US found that utility companies are experiencing extended lead times for transformers of up to two years (a 4x increase vs lead times prior to 2022). In comparison, lead time for Nvidia's H100 AI GPUs is 2-3 months.

Demand for high-voltage cables is also booming, with the market climbing from a typical $3bn of new projects awarded per year between 2015-20 to $11bn in 2022. This year, the estimated value of new orders is likely to exceed $20bn before settling at $18bn-$20bn per year, according to Massimo Battaini, chief executive officer of Prysmian. "We are fully booked until 2026/27," https://www.ft.com/content/c88c0c6d-c4b2-4c16-9b51-7b8beed88d75



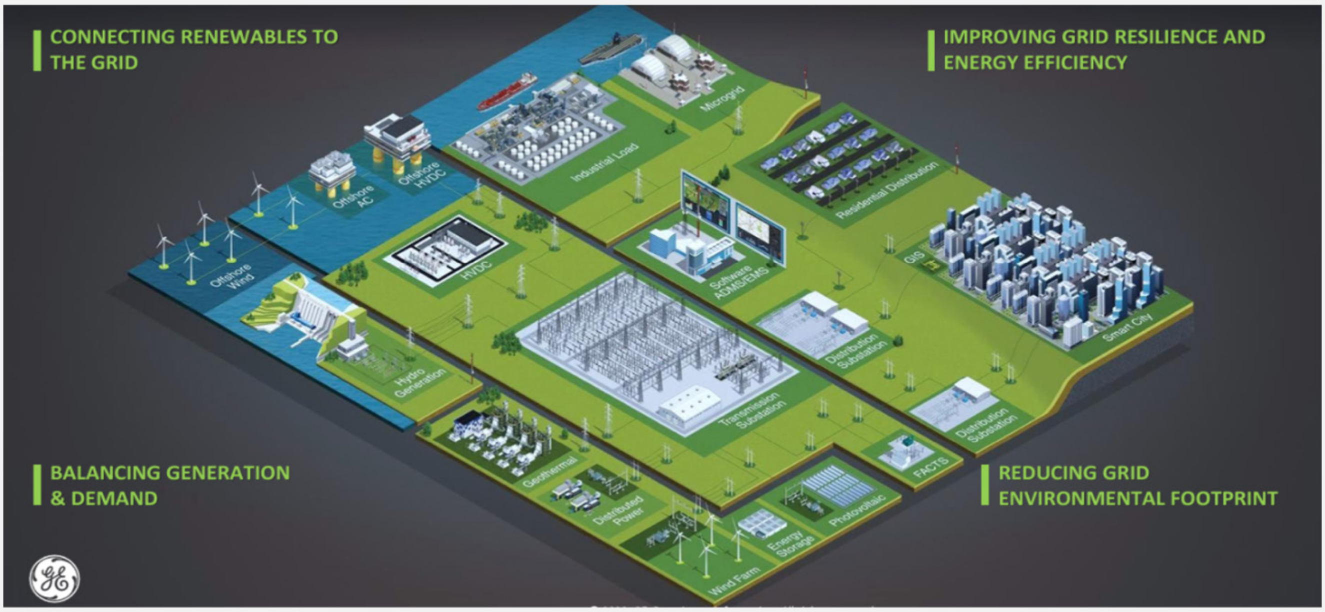
Source: VQ Research, illustrative list of OEMs, not exhaustive

How energy transition impacts transmission grids

1. Need to build new lines to transmit RE power typically being generated far away from consumption centers compared to thermal plants which could come up closer to consumption centers.

2. Need to upgrade the existing grid to handle higher loads resulting from rising electrification of energy usage, think EVs over ICE, Gen AI adoption.

3. Need to make the grid smarter to handle intermittency and bi-directional flow.

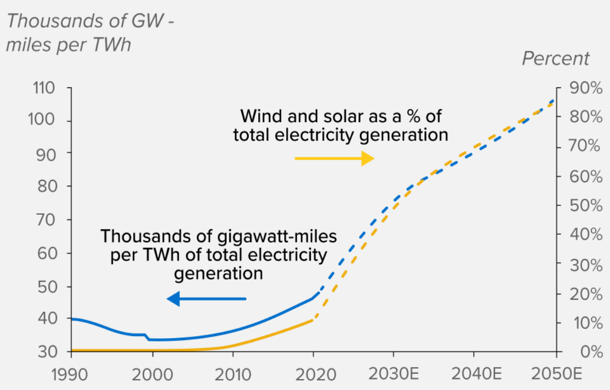


Source: GE T&D Investor Presentation

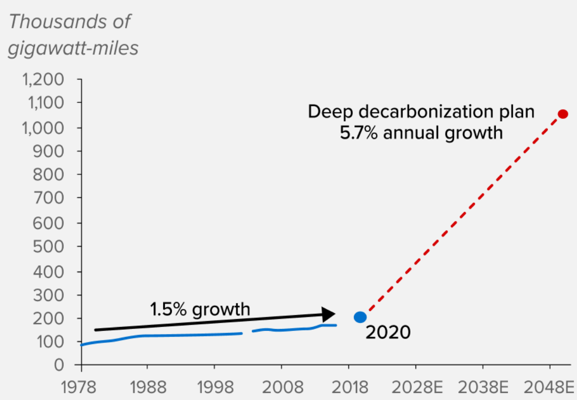
Transmission intensity of Renewables is 2x of conventional energy

For the last thirty years, the US grid operated with 35-45 miles of transmission per TWh of electricity generation. At 100% wind solar electricity generation the transmission GW miles per TWh (Terawatt hour) are 100+ which is more than 2x of historical.

Transmission intensity of a decarbonized grid



US transmission growth, history vs targets



Source: JPM Asset Management state of the energy transition report. GW-miles per TWh means Gigawatt miles per Terawatt hour.

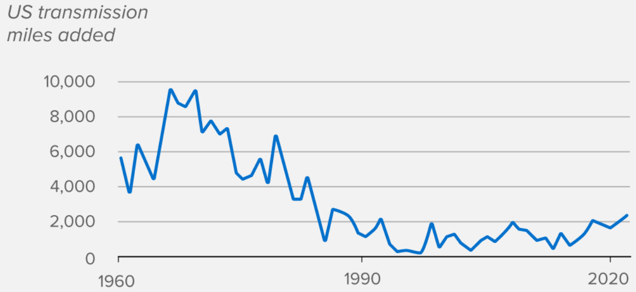
A Gigawatt-mile is the unit used when planners model needed future transmission capacity; it incorporates both a line's distance and its capacity to carry electricity. GW miles per TWh measures transmission distance adjusted for the amount of energy it is transmitting (TWh). Gigawatt miles per TWh are expected to go up because of 1) Longer distances are involved to carry RE energy from remote areas vs conventional 2) Utilization factor of RE is lower than conventional so effectively it means lower TWh per mile in RE vs conventional. But as the TWh energy requirement is not a function of supply but a function of demand, we need more miles per TWh to get to the same level.

The existing grid in the western world is old and due for an upgrade

US large power transformers are more than 40 years old, on average. The aging US grid is already having an impact, with average outages between 2015-20 more than double those of 2009-14. Less than 15% of the nation's high-voltage lines (>138 kV) were added since 2002. The greatest pace of expansion in transmission was in the 1960s and 1970s, meaning many transmission wires are over 50 years old.

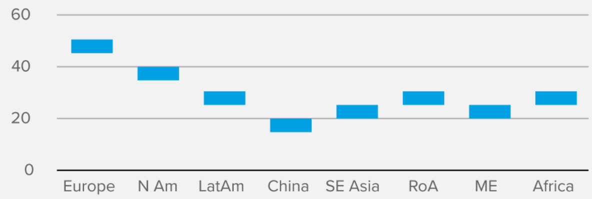
Transmission wires added to US grid by year

Less than 15% of total US transmission miles added since 2002



Age of global grid assets (years)

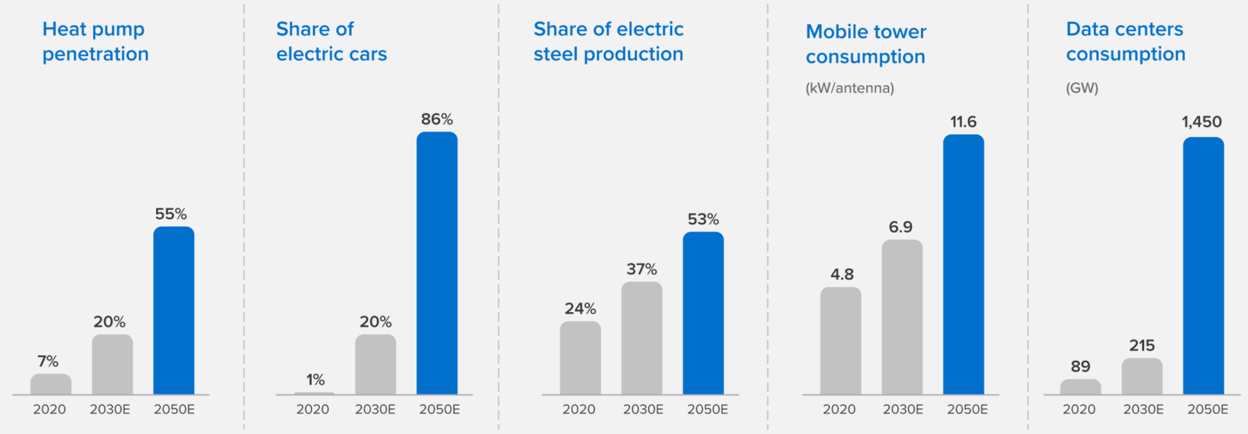
Cable avg age in Europe was 45-50 yrs 35-40 in the US... in 2020



Source: BOFA report on transmission

Grids built today need to last for another 50 years

It must take into account higher electrification as % of TFEC in addition to per capita growth. EVs, data centers, electric steel are all electricity guzzlers which were not there earlier but need to be accounted for now.



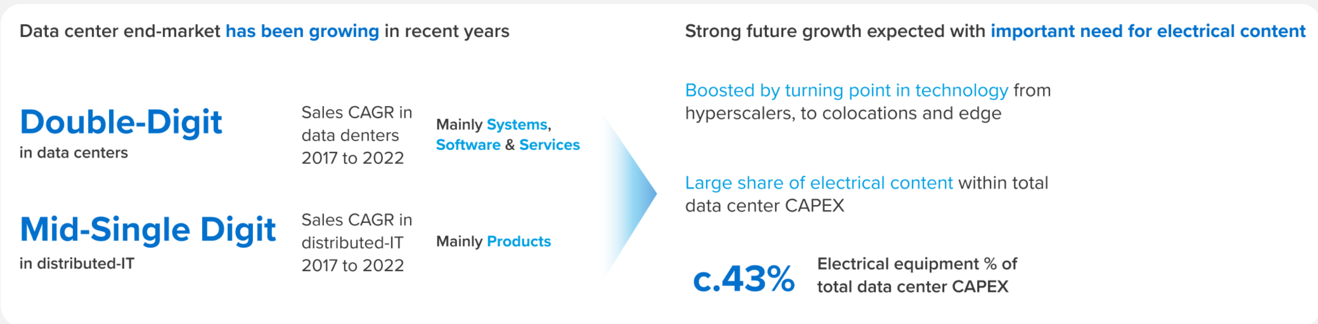
Source: Prysmian Investor Presentation

EVs will drive higher electricity consumption

Boston Consulting Group estimates that an average household without an EV has an annual capacity demand for 6-12MWh annually. This goes up to 9-17MWh for an average household with an EV, resulting in an increase of 20% - 50% in megawatt hours of electricity consumed by a household.

Data centers – ~43% of capex of a data center is electrical equipment and ~60-70% of its opex is power

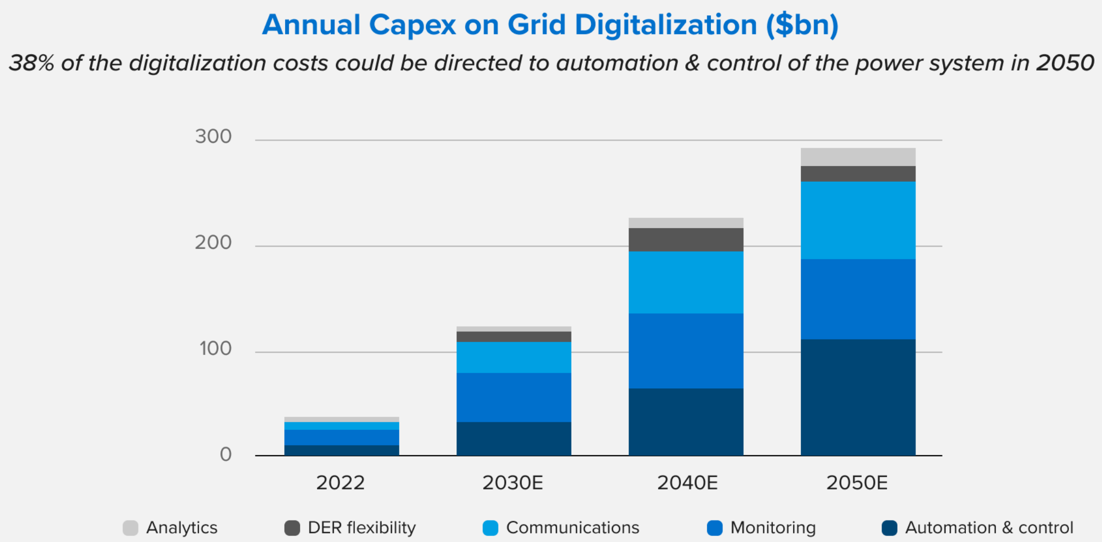
A recent study by the International Energy Agency (IEA) estimates that data centre electricity consumption could double by 2026, from 460 terawatt hours (TWh) in 2022 to more than 1,000 TWh in 2026. This demand is roughly equivalent to the electricity consumption of Japan.



Source: Schneider Electric Investor Presentation

Need smarter grids – To account for the rising complexity

A more disparate, distributed grid, variability of renewable power supply and the availability of energy storage solutions all create much greater complexity. This will require better monitoring, optimisation and control, all which can be enabled through digitalisation and automation.

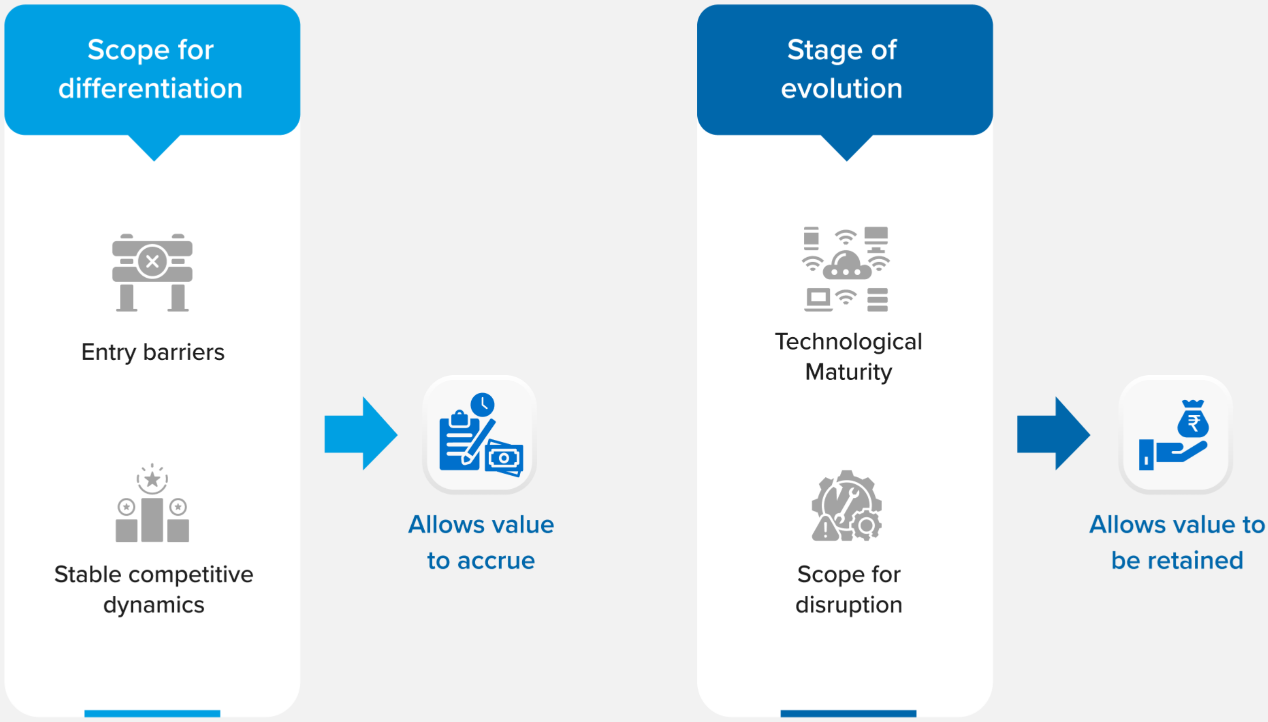


Source: BOFA report on transmission

Transmission sector offers an opportunity to invest for predictable growth

Existence of a large external opportunity is an essential condition for investing but it is not enough. Large external opportunity needs to be coupled with a predictable environment which is in turn dependent on the scope for differentiation and stage of evolution of the industry.

What lends predictability



Source: VQ Research

The existing addressable investment opportunity in the energy transition is around $1.4 trillion as of today and is expected to increase to average annual investments of $4-5 trillion up to 2050, according to IRENA (International Renewable Energy Agency). The following table shows various sub-segments of energy transition value chain, their current market size, their growth potential and our view on their stage of evolution as well as scope for differentiation altogether which help us to position ourselves in this very large investable pool for predictable growth.

Energy Transition Investment opportunity sizing and positioning

Energy Transition Investment landscape		Opportunity sizing		Rate of change		Positioning	
Value chain	Area	Current market size p.a $ bn (A)	2023-50E market size avg p.a $ bn (B)	Absolute Delta $ bn (B-A)	Growth multiplier (B/A)	Stage of market evolution	Scope for differentiation
Grid and flexibility	Electric network and grids	300	600	300	2.0	Mature	Medium
	Storage	9	170	161	18.9	Early stage	Unknown
Power generation	Bioenergy	24	93	69	3.9	Mature	Medium
	Geothermal	6	27	21	4.5	Mature	Low
	Hydro	40	138	98	3.5	Mature	Low
	Tidal	0	63	63	N/A	Early stage	Unknown
	Solar PV (Utility and Roof)	480	982	502	2.0	Mature	Medium
	Solar concentration	1	89	88	89.0	Early stage	Unknown
	Wind Onshore	57	283	226	5.0	Mature	Medium
	Wind Offshore	95	356	261	3.7	Early stage	Unknown
Energy efficiency	Building	237	935	698	3.9	Mature	Medium
	Industry	40	424	384	10.6	Mature	Medium
	Transportation	19	147	128	7.7	Mature	Medium
Electrification	EV Charging	8	314	306	39.3	Early stage	Unknown
	Heat Pump	60	230	170	3.8	Early stage	Unknown
	Transport	0	50	50	N/A	Early stage	Unknown
Hydrogen	Electrolysis and Infrastructure	0	136	136	N/A	Early stage	Unknown
	H2 Derivatives	0	34	34	N/A	Early stage	Unknown
Carbon	Carbon capture	0	107	107	N/A	Early stage	Unknown
Circular economy	Recycling and bio based products	4	18	14	4.5	Early stage	Unknown
	Total	1380	5196	3816	3.8		

Source: IRENA statistics: 2021 investments; IEA, 2022f; BNEF, 2023a

Within the energy transition value chain Transmission scores well on most counts

1. Large addressable market (~$300 bn p.a 2023).
2. 2x growth expected in market size to $600 bn by 2030.
3. Mature stage of evolution of the market in terms of leadership being established and rate of change low/manageable.
4. Scope for differentiation Medium to High depending on sub segments.

Spotlight on HVDC

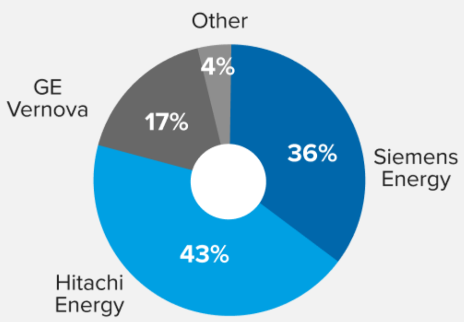
Within transmission, the largest single component in terms of the equipment is the substation which houses the transformer and the switchgear (40-45% of total transmission line capex), rest of the capex is on conductors/cables 25-30%, towers 15-20%, civil work and civil work 10-15%.

Global High Voltage transmission (substation) market has supply side entry barriers

The supply chain for equipment at the transmission end/high voltage of the grid is highly consolidated, particularly given the sensitive nature of critical infrastructure.

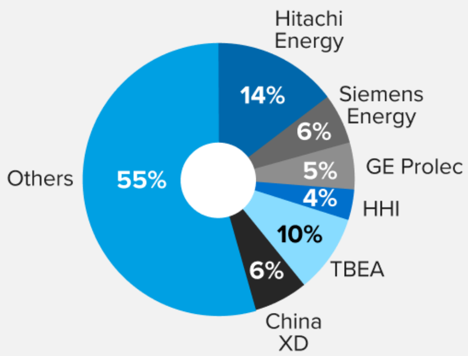
Commissioned HVDC project market share (GW)

Hitachi is the leader for HVDC converter equipment in Europe with 18GW commissioned projects



Global power transformers market share (2021)

Hitachi, Siemens Energy & GE are the largest non-Chinese suppliers



Source: BOFA report on transmission

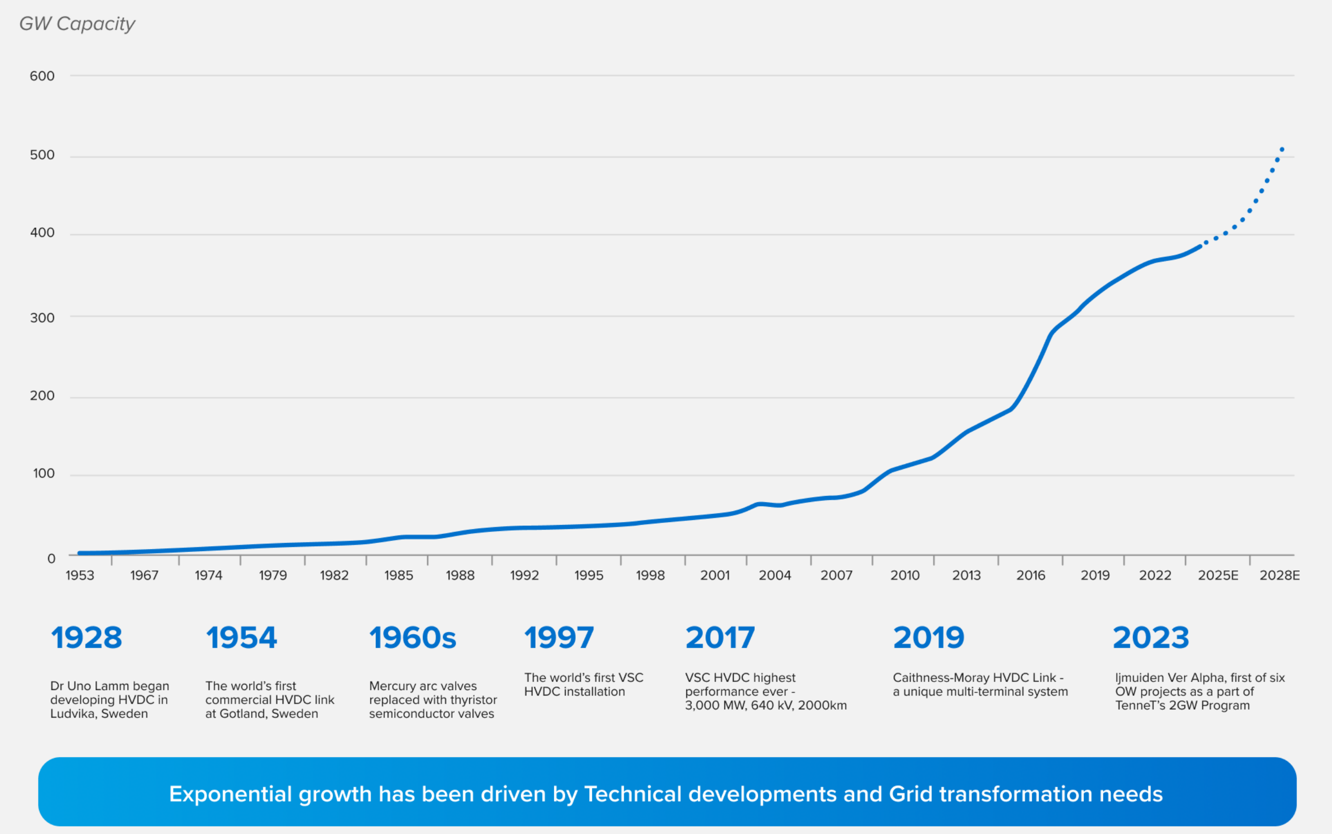
HVDC and smart grid technologies are concentrated with the top 3-4 players globally making it a highly supply constrained market

Hitachi Energy (erstwhile ABB) pioneered commercial HVDC (High Voltage Direct Current) technology 70 years ago and has delivered more than half of the world's HVDC projects.

Siemens Energy estimates that globally €950bn/$ 1 trn investments have been announced under various government stimulus programmes upto 2050 in HVDC.

Currently, HVDC global market size is $9 bn which is expected to go up to $22 bn by 2025 as per GE and $ 38 bn by 2030 as per Siemens.

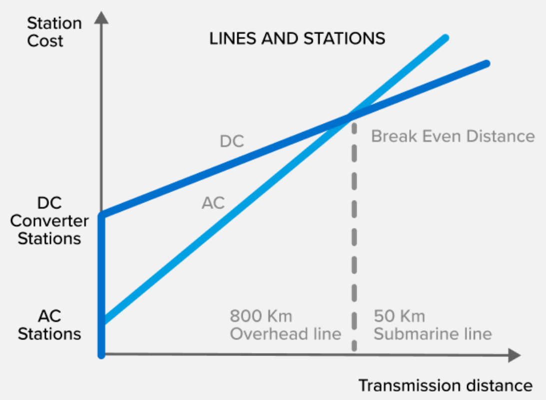
The big take away from 2023 is the sheer volume of tenders and frameworks that were announced and/or awarded throughout the year. Worldwide, this included at least 46 new HVDC projects to be installed over the next decade, equating to a 94.3 GW additional capacity on an installed base of roughly ~380 GW.



Source: Hitachi Energy Presentation - Enabling the energy transition

HVDC enables lower transmission losses for long distance power transmission

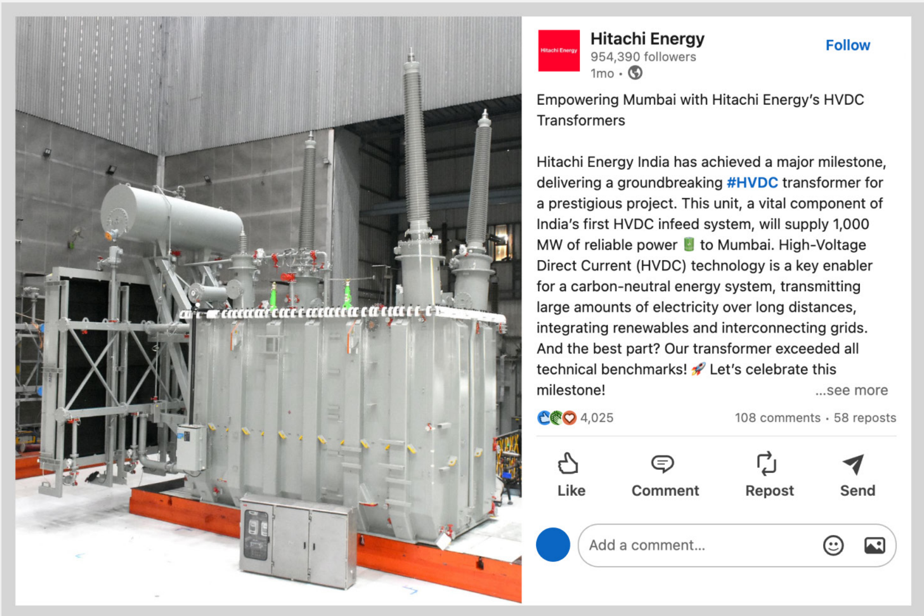
AC systems have lower capital costs than HVDC, but much higher transmission losses as you increase the distance. HVDC systems have a much higher capital cost, but as the distance increases the line losses don't increase as much as AC systems. So, there is a point where these two lines intersect, and that's the breakeven point which is around 800 kms of distance.



Source: https://electrical-engineering-portal.com/analysing-the-costs-of-high-voltage-direct-current-hvdc-transmission

But HVDC is increasingly being used for shorter distances as well

Case in point that Mumbai is in the process of building an 80 kms line on HVDC technology which will link Kudus (Palghar) to Mumbai. Mumbai is experiencing a rapid increase in electricity consumption, seeing peak demand increasing to 3,850 megawatts (MW) in 2022, of which around 2,100 MW was supplied from outside sources. The new HVDC link will supply up to 1,000 MW of electricity, increasing power from outside of the city by almost 50 percent.



Source: Hitachi Energy LinkedIn Post

Benefits of HVDC technology as mentioned by Adani Energy Solutions Ltd for their Mumbai HVDC project (Utility customer of HVDC equipment supplier)

Benefits of Technology

1. Bulk power transfer (virtual Generator) with 100% capacity utilization.
2. Less footprint requirement compared to conventional HVDC technology.
3. Independent & continuous control of active and reactive power at each terminal giving attributes of virtual generator.
4. Black start features support during Grid restoration.
5. Steady state reactive power capability can be used for voltage control.
6. Less filtering requirements & smaller foot print.
7. No impact on already stressed short circuit level of equipment.

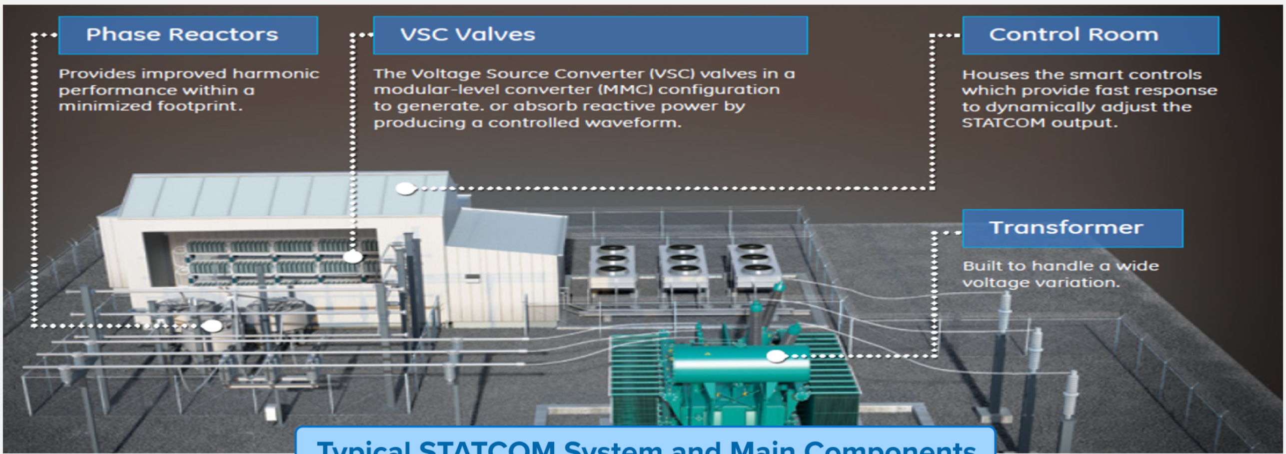
Source: Adani Preamble for Mumbai HVDC project

HVDC plays a role in grid stabilization as well

HVDC transmission systems offer enhanced grid stability and control capabilities. AC transmission networks are susceptible to voltage instability and power system oscillations, especially during contingencies or when operating across asynchronous grids. In contrast, HVDC systems provide better control over power flow, voltage regulation, and frequency stability. They enable the establishment of stable and controllable transmission corridors, allowing for efficient power exchange between different grids and facilitating grid resilience and reliability.

Grid stabilizing FACTS (Flexible AC Transmission Systems) are related to HVDC

STATCOMs (STATIC SYNCHRONOUS COMPENSATOR) are a type of FACT systems which are widely used to provide reactive power compensation and improved range of operational voltage.

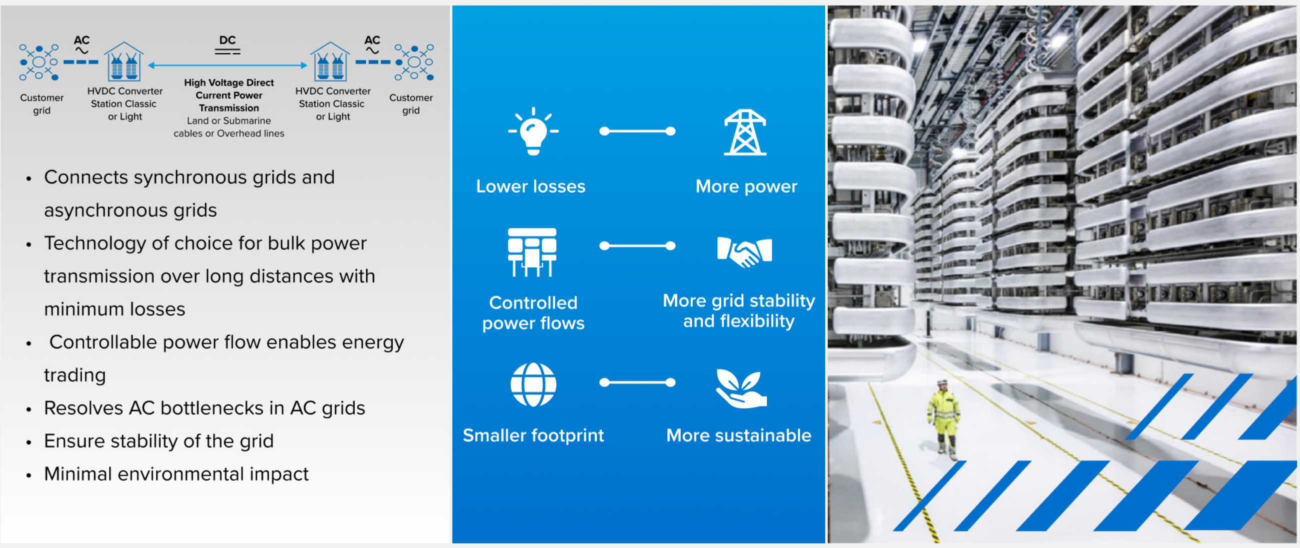


Typical STATCOM System and Main Components

Source: GE Vernova Presentation

STATCOMs leverage Voltage-Source Converter (VSC) technology which is a type of High Voltage Direct Current (HVDC) technology.

Siemens expects a 4x growth in the grid stabilization market driven by need to manage the intermittency of RE generation.



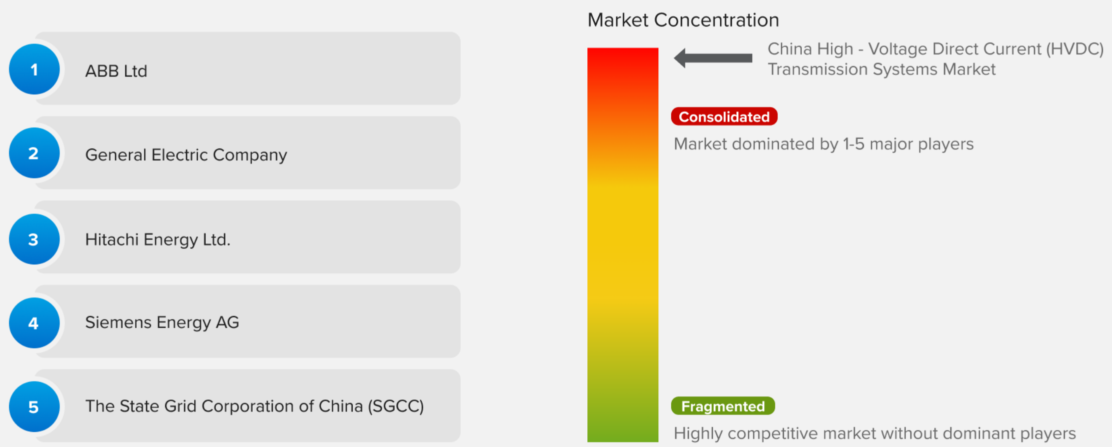
Source: Hitachi Energy Presentation - Enabling the Energy Transition

HVDC is a high entry barrier industry globally - China case study

China has built more HVDC transmission lines than anyone in the world. China accounts for 60% of the global installed capacity in HVDC. Even in China the HVDC market is highly concentrated where the same 3 players i.e Hitachi, GE and Siemens dominate the space. The State grid corporation of China also has presence in this space locally but it was a result of planned tech transfer from the global players. In the early 90s, the Chinese government implemented a policy that for Europe based HVDC OEMs, such as ABB (Now Hitachi Energy) and Siemens to be able to take part in the early HVDC projects in China, they needed to partner with local Chinese companies and transfer skills and technology to them.

Source: A review of HVDC in China by Dale Pudney, High Voltage Technology SA

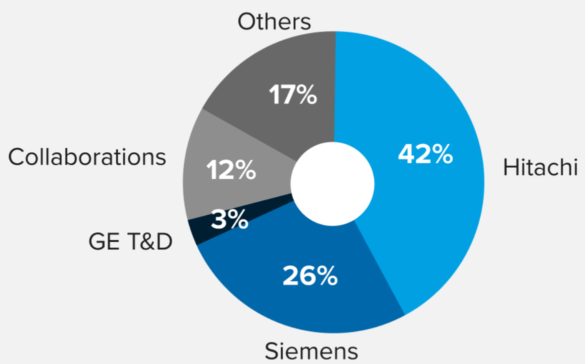
China High-Voltage Direct Current Transmission Systems Market Leaders



Source: Mordor Intelligence | Names arranged in alphabetical order

While data on China is difficult to get, our analysis of publicly available data from the global MNCs and Wikipedia list of HVDC projects in China suggests that out of 37 HVDC projects in China 28 were supported by the top 3 MNCs (75% market share by number of projects). In terms of GW capacity, the top 3 MNCs played a role in setting up ~83% of the installed capacity.

HVDC China Market share (Installed capacity GW)



Source: VQ research, Company brochures, Wikipedia HVDC projects list. Collaborations indicate where Hitachi, GE, Siemens have worked on a project together

Conclusion

- Energy Transition is a multi-decadal opportunity however the space is rapidly evolving for eg hydrogen and carbon capture technologies have not matured yet, and its difficult to identify winners as the space is in a state of flux.
- Our focus is on predictability in addition to presence of a large addressable opportunity. Low rate of change and high entry barriers lend predictability.
- Transmission sector offers an opportunity to invest in the energy transition with predictability. It's a large addressable market with 2x growth potential.
- Transmission is the bottleneck for decarbonization as RE electricity generated needs to be transmitted to the consumption centers.
- Transmission networks which were built in a different era, are already old and need to be upgraded to handle intermittency of RE and high workloads of new demand centers like EVs and Gen AI.
- Within transmission, we see the entire equipment value chain including transformers, switchgears, conductors, cables as key beneficiaries. We put the spotlight on high voltage substation equipment being one of the areas which has scope for differentiation/high entry barriers.
- HVDC (High Voltage Direct Current) has emerged as a key technology to help integrate renewables in the power grid.
- The supply chain for HVDC is highly consolidated, particularly given the sensitive nature of critical infrastructure and technological entry barriers. China accounts for 60% of the global installed capacity in HVDC. Even in China the HVDC market is highly concentrated with the global top 3 having ~83% share of the installed GW capacity.