

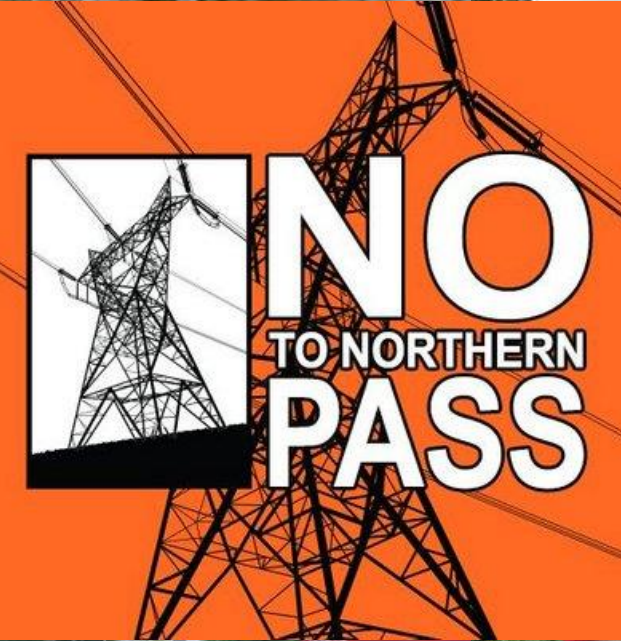


The Cool New Thing in Superconducting Transmission Capacity at Distribution Voltage

Stephen Conant – VP Commercial for VEIR

August 21, 2023

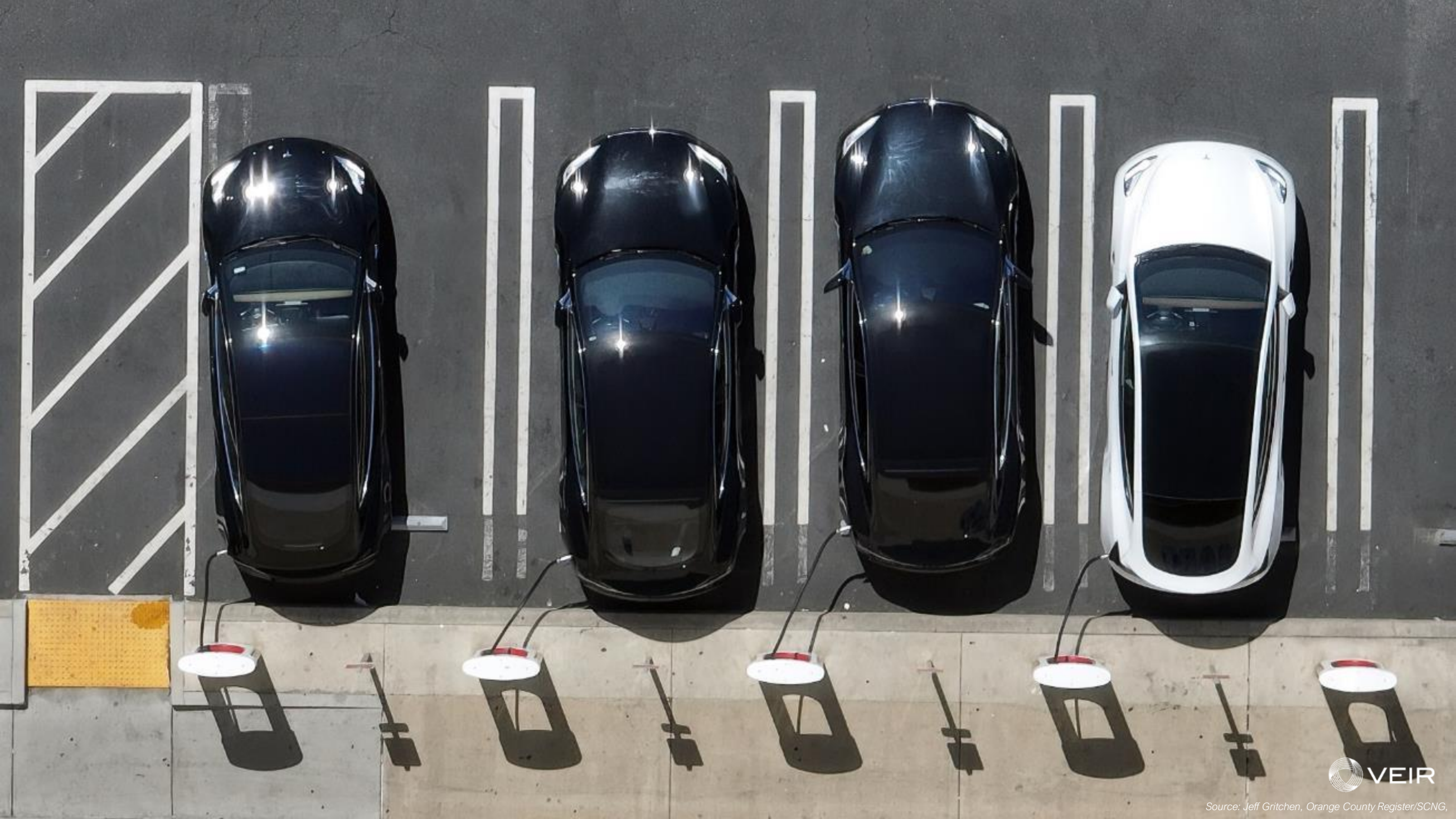




NORTHERN PASS
NO HIGH-TENSION LINES IN NH







US transmission grid growing at just 2% per year since 1978, Thousands of gigawatt-miles

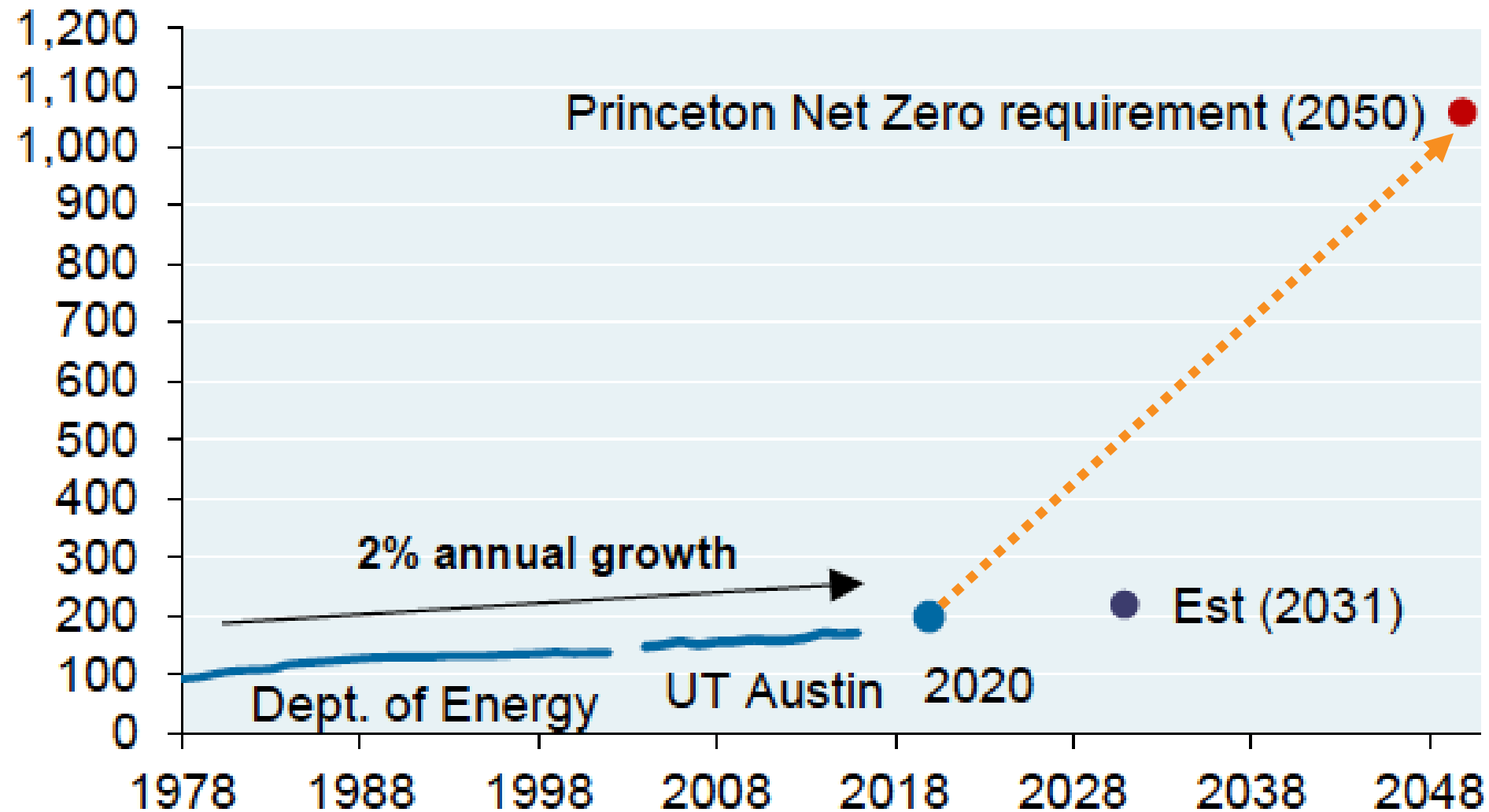




Photo Source: Joe Raedle / Getty Images





The Secret is Superconductivity

- In 1911, the Dutch physicist Heike Kamerlingh Onnes discovered superconductivity (*zero resistance to the flow current*) during his search for absolute zero
- Found in Mercury at 4.19 Kelvin
- Temperature of liquid Helium
- Of some scientific interest, but no commercial application
- Availability of Helium is limited

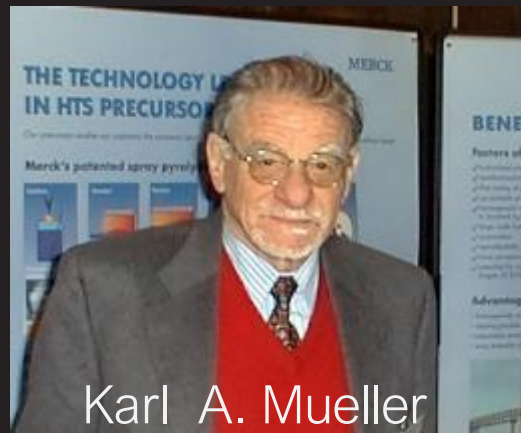
“On the Sudden Rate at Which Resistance of Mercury Disappears” 1911 Paper



The Woodstock of Physics New York -1987



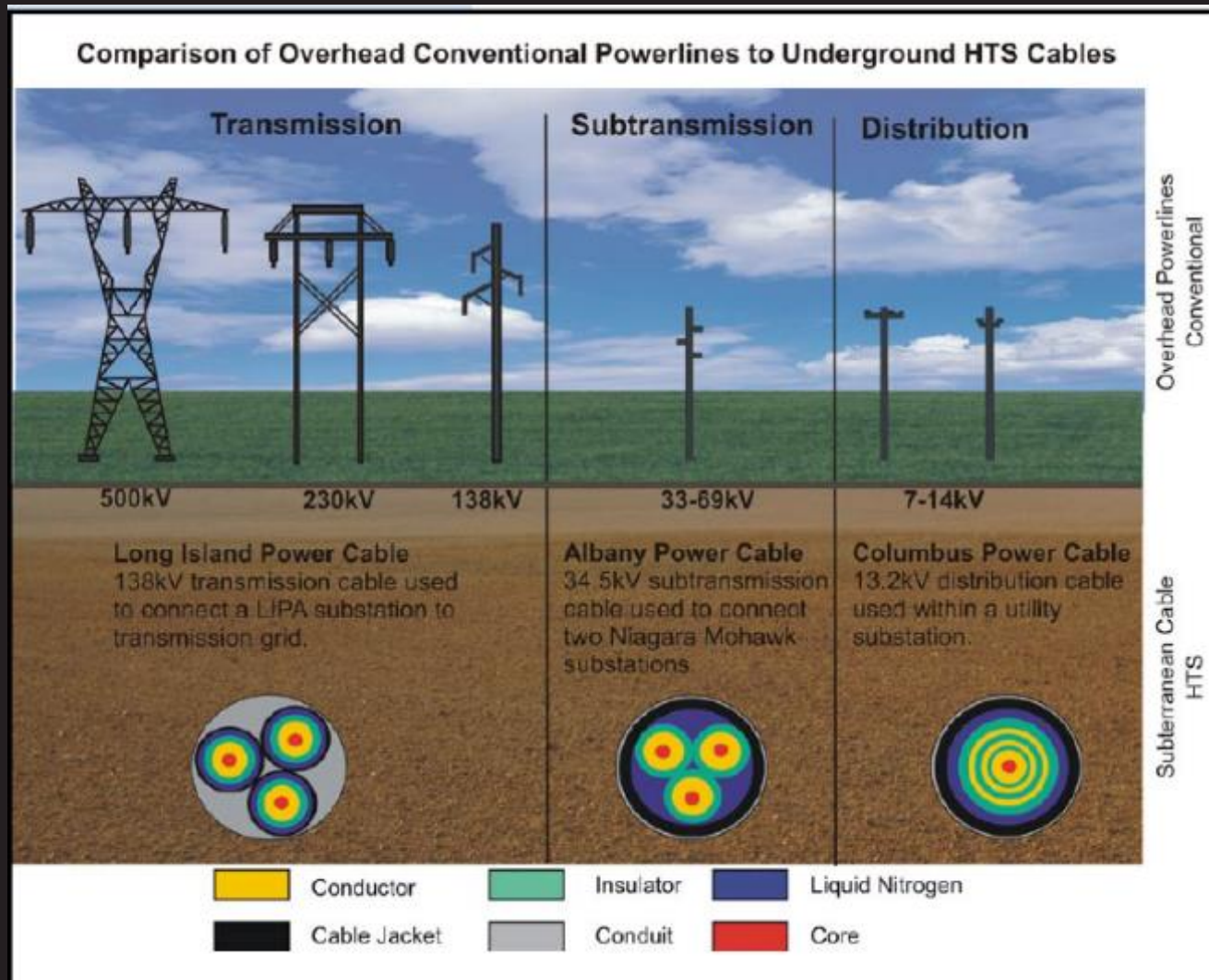
George Bednorz



Karl A. Mueller



Benefits of Superconductors for the Grid - 2008



- “Eliminate the need for new rights of way
- “Enable power flow as low voltages, significantly reducing permitting requirements
- “Enhance overall system efficiency as a result of exceptionally low losses
- “Increase utility system operating capacity and flexibility”*

Image from “A National Effort to Introduce New Technology into the Power Delivery Infrastructure”
DOE Office of Electricity Delivery and Energy Reliability - 2/16/2007

*“Basic Research Needs for Superconductivity”, DOE Office of Science, May 2006

Other than VEIR's, all other superconductor systems use closed loop cooling.



Columbus, OH (2006)

Utility: *AEP*
Cable: *Southwire/AMSC*
Distance: *200m (0.1 mile)*
Capacity: **51 MVA @ 13.2kV**



Albany, NY (2006-2008)

Utility: *National Grid*
Cable: *Sumitomo/SuperPower*
Distance: *350m (0.2 mile)*
Capacity: **48 MVA @ 35kV**



Long Island, NY (2008)

Utility: *LIPA*
Cable: *Nexans/AMSC*
Distance: *600m (0.4 mile)*
Capacity: **574 MVA @ 138kV**



Utility: *KEPCO (South Korea)*
Cable: *LS Cable/AMSC*
Distance: *700m (0.5 mile)*
Capacity: **50 MVA @ 23kV**



Yokohama, JP (2012)

Utility: *TEPCO (Japan)*
Cable: *Sumitomo (SEI)*
Distance: *250m (0.2 mile)*
Capacity: **200 MVA @ 66kV**



Essen, DE (2014)

Utility: *RWE (Germany)*
Cable: *Nexans*
Distance: *1km (0.6 mile)*
Capacity: **40 MVA @ 10kV**



Jeju Island, KR (2014)

Utility: *KEPCO (South Korea)*
Cable: *Nexans*
Distance: *1000m (0.6 mile)*
Capacity: **600 MVA @ 154kV**



Chicago, IL (2021)

Utility: *ComEd*
Cable: *AMSC*
Distance: *200m (0.1 mile)*
Capacity: **62 MVA @ 12kV**

Closed loop cooling falls short.



Long Island, NY (2008)

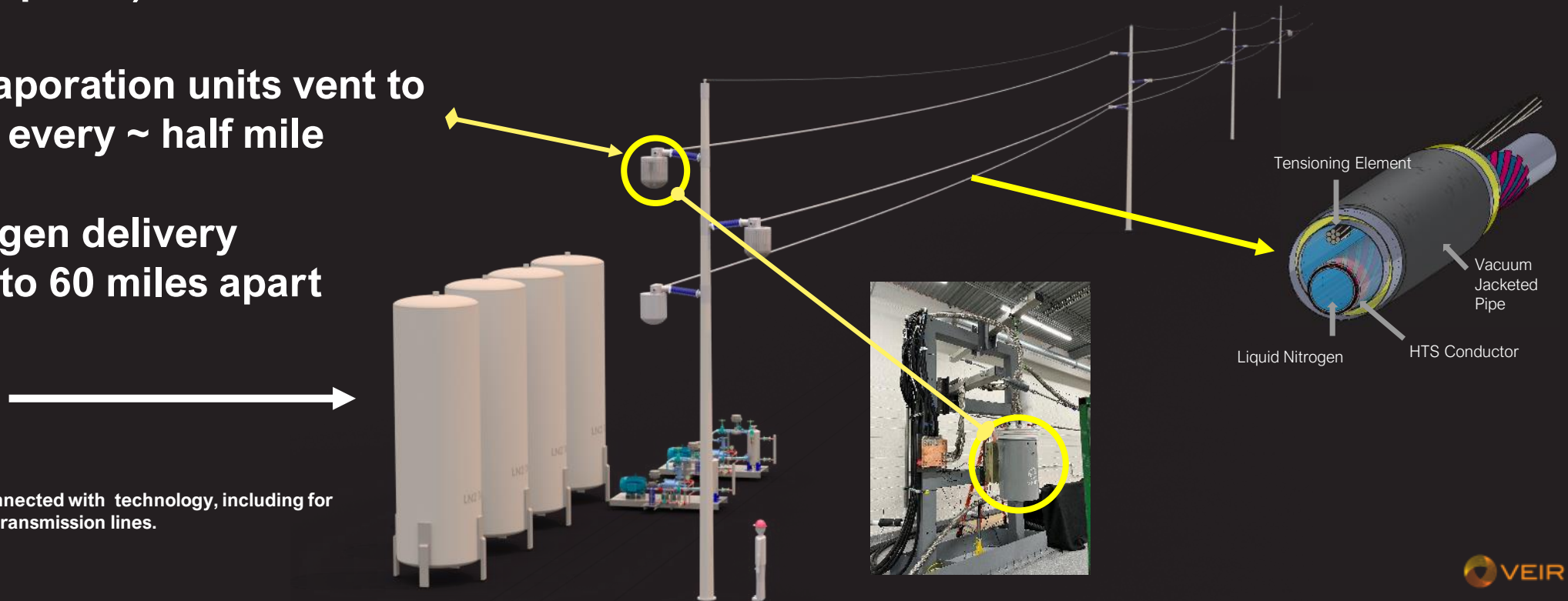


Yokohama, JP (2012)

VEIR's cooling goes the distance*.

Distributed evaporative cooling enables overhead, long-distance installations.

- Uses the latent heat of vaporization that delivers 20 X the cooling power as sensible heat.
- Overhead installation with vacuum jacketed pipes at line voltage (no dielectric insulation required)
- Nitrogen evaporation units vent to atmosphere every ~ half mile
- Liquid nitrogen delivery stations up to 60 miles apart



* VEIR holds three patents connected with technology, including for suspended superconducting transmission lines.

December 15, 2022

4000 Amps – Single Phase DC



Overhead Superconductor demonstration April 2023



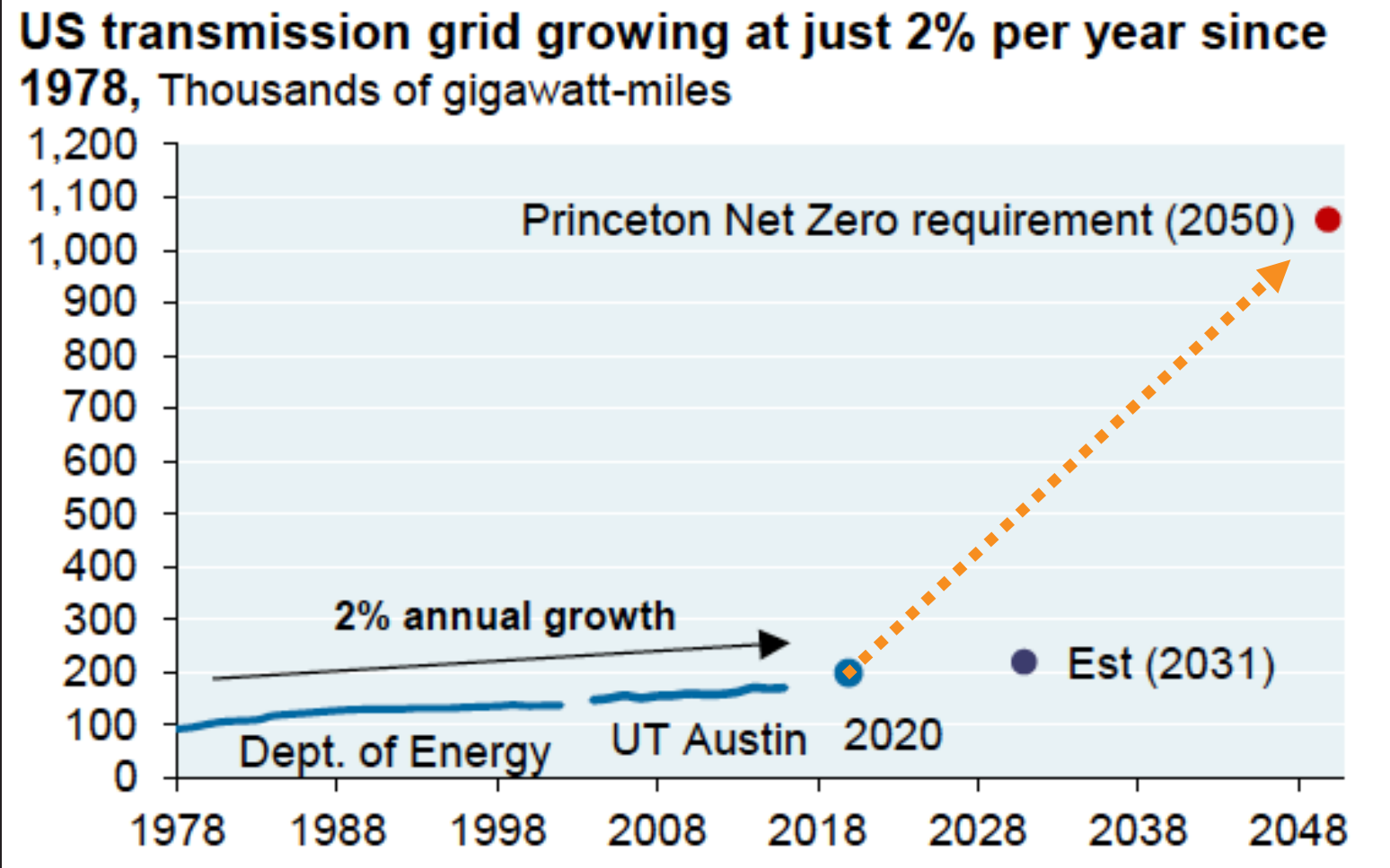
VEIR – Overhead Superconductor Demonstration



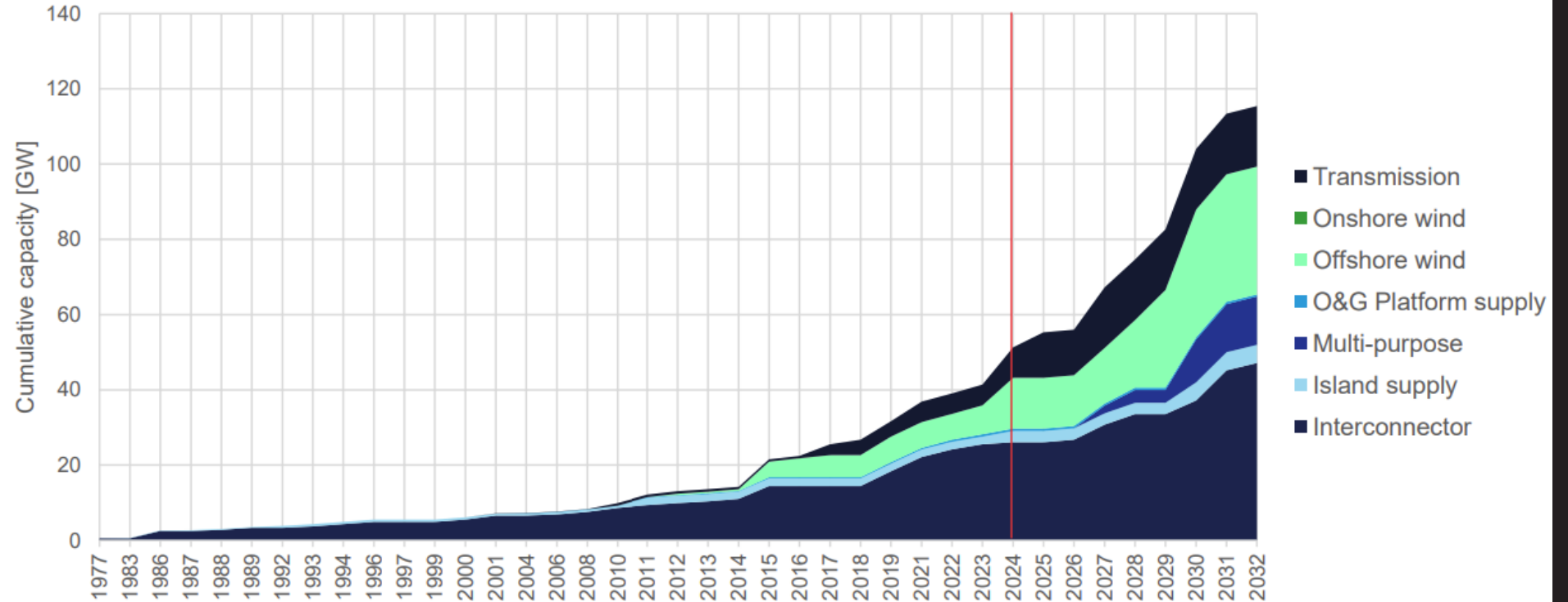
VEIR – Overhead Superconductor Demonstration



How quickly can we move?

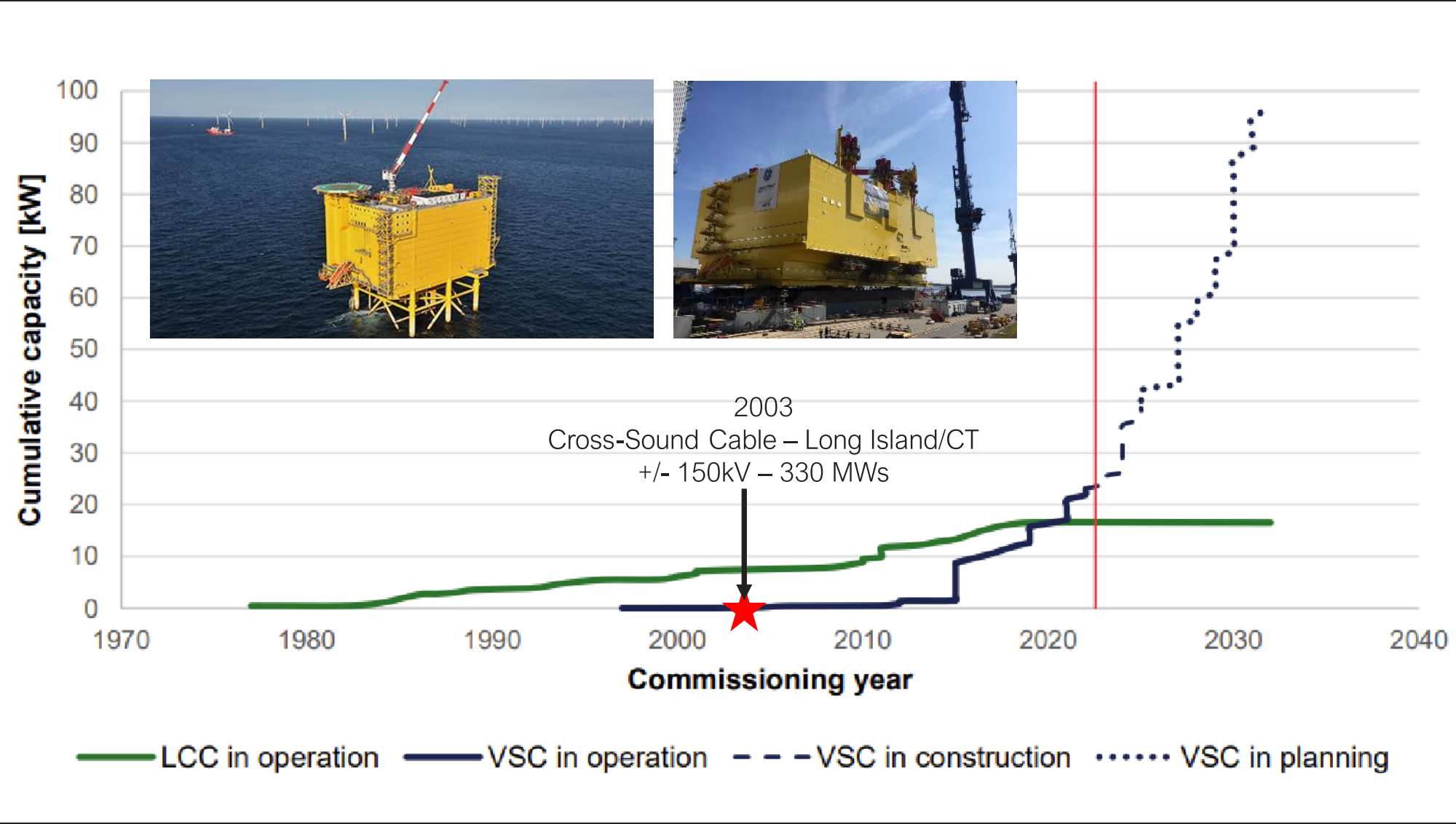


HVDC Capacity Growth

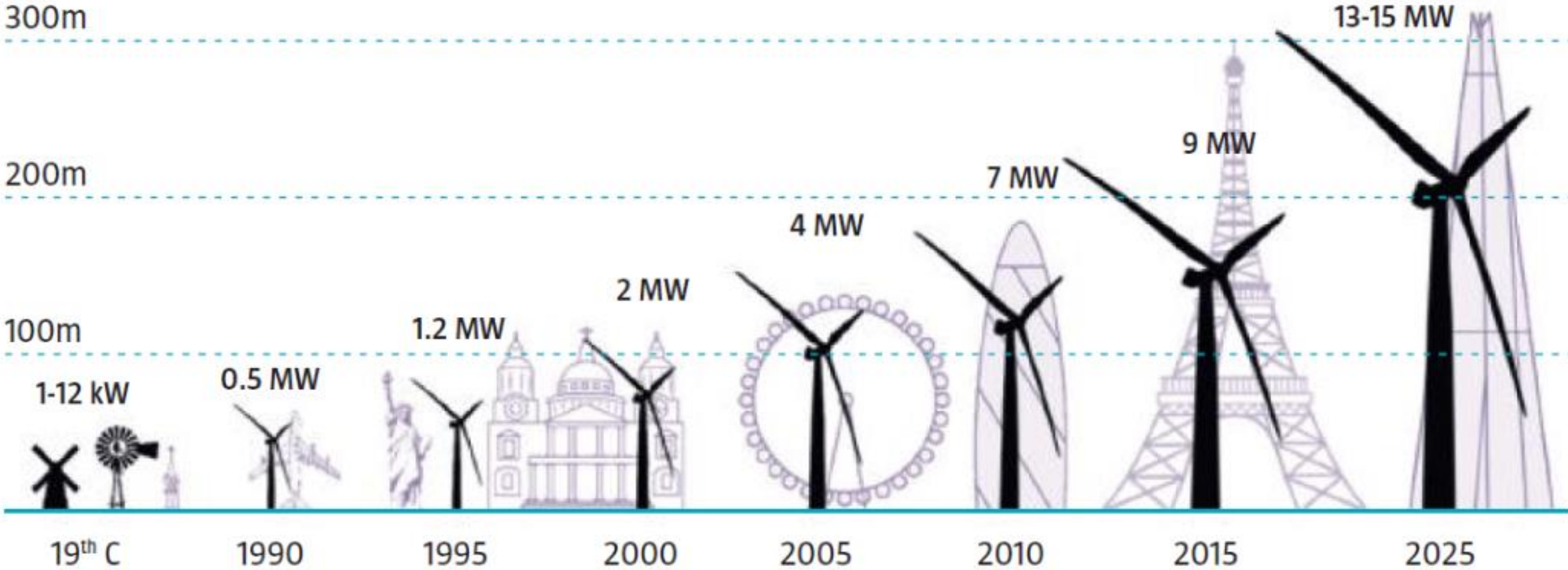


- Total installed HVDC capacity will more than triple in the next decade.

Voltage Source Converter (VSC) Growth



Growth of Wind Turbine Size and Capacity



Source: Bloomberg New Energy Finance

From Superconductivity to Overhead Transmission



1911

Superconductivity
Discovered

1973

First Cell
Phone Call



1986

High Temperature
Superconductivity
Discovered



2008/2010

Closed Loop cooled
Underground
Superconductors
for the grid.
1st /2nd generation
HTS tapes.



2022

VEIR – 4kA
Overhead –
Distributively
Cooled
Demonstration



2027

VEIR – 1st
Commercial
Products

75 years

22 years

12 years

5 years



MORE POWER, LESS TOWER.



MORE POWER, LESS TOWER.