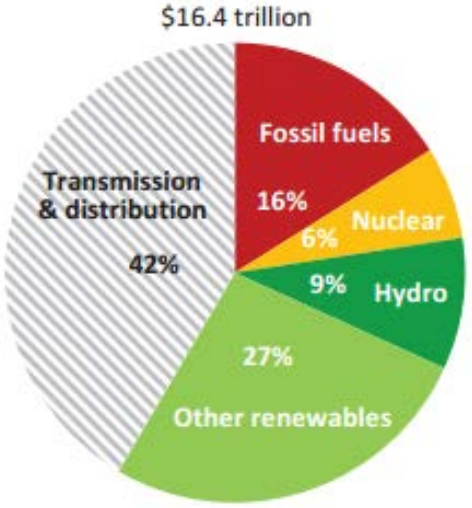
Potential gaps and barriers for energy technology development and deployment : HTS TCP perspective

IEA Technology Collaboration Program on
High-Temperature Superconductivity
(IEA HTS TCP)

Present and Potential Problems of Energy Technology: Aging Infrastructure

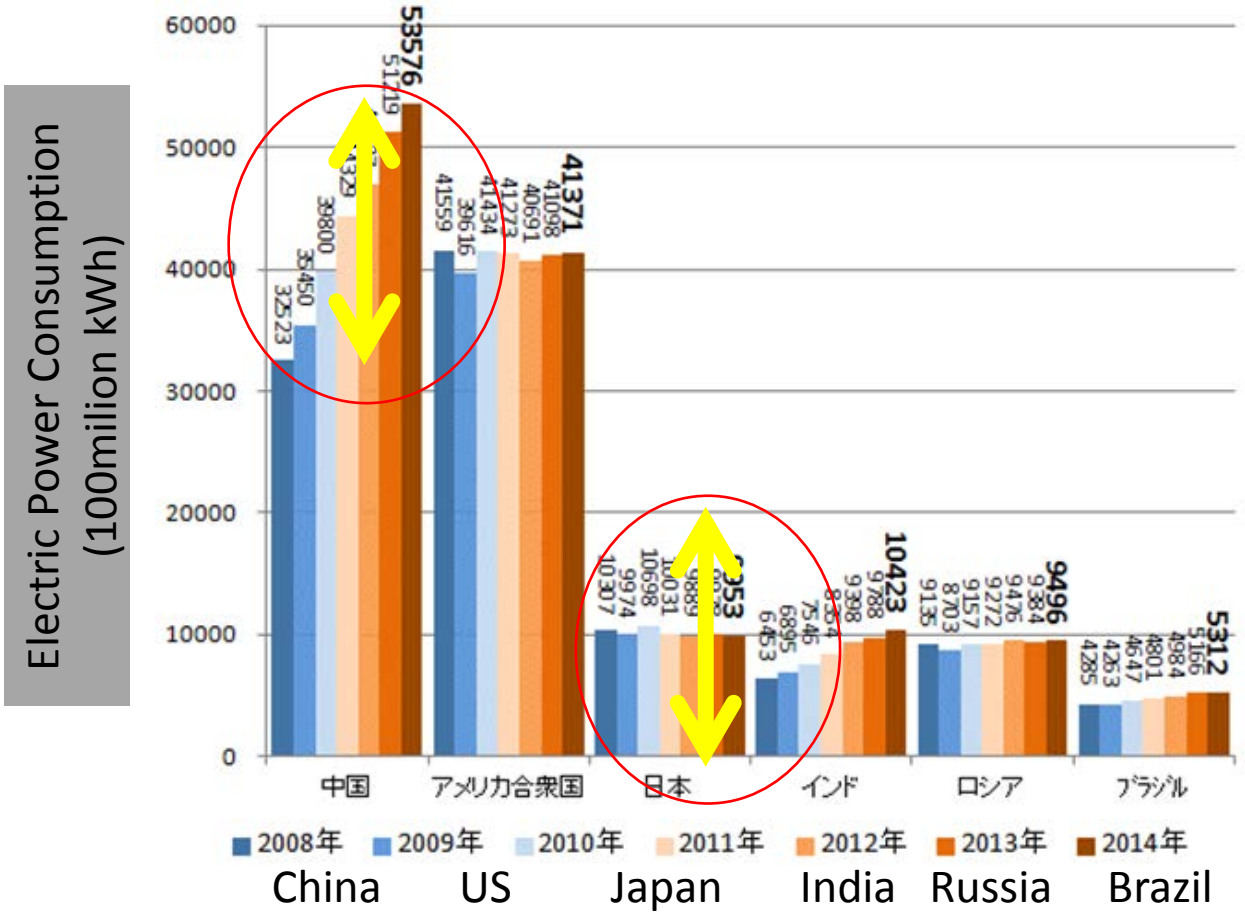
- For the global power sector, $16.4 trillion of investment will be made; transmission and distribution is expected to account for $7 trillion 2014-2035 (in 2012 US$).[i]
- The Edison Electric Institute estimated that the total infrastructure investment in the US will be between $1.5 and $2.0 trillion; transmission and distribution is expected to account for about $900 billion by 2030.[ii]
- HTS based devices have the potential to play a critical role in helping to transform the global transmission and distribution grid.



- [i] "Cumulative global power sector investment by type and selected region in the New Policies Scenario, 2014-2035" from IEA, "World Energy Investment Outlook – Special Report", OECD/IEA, 2014. https://www.iea.org/publications/freepublications/publication/WEIO2014.pdf
- [ii] Edison Electric Institute. "Transforming America's Power Industry: The Investment Challenge 2010-2030." November 2008. http://www.eei.org/ourissues/finance/Documents/Transforming_Americas_Power_Industry_Exec_Summary.pdf.

Example: 6 years electric power consumption increase in China is double the total one in Japan

- "Key World Energy Statistics 2016" in IEA - Free publications



- HTS Technology will contributes to reduce this trend.

About the IEA HTS Technology Collaboration Program

- Brings together government and funding Agencies representatives, researchers, equipment manufacturers and utility end-users to address common interests.
- Participants sponsor studies, workshops, exchange information, introduce their research facilities to other participants and guide the assessments.
- Participants also ask experts from their countries to provide input and to peer-review draft reports.
- Strategic documents, minutes of meetings, and workshop presentations are published on the website.

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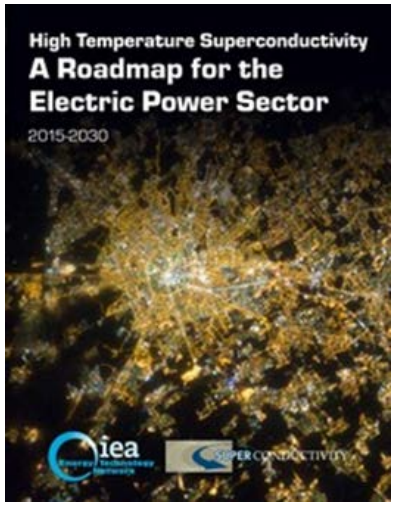
IEA HTS TCP Main activities

- Technical discussions and outreach (e.g. Exco meeting and HTS Roadmap)
- Share policy and technical information among TCP participants
- Develop website content with technical and policy information
- Stay current with HTS interest groups and IEA activities
- Organize technical Workshops
- Support in promoting TCP visibility
- Coordination with other IEA groups such as ISGAN

- Survey of present energy technology problems and HTS solutions → HTS Road Map → Define trends for world-wide energy R&D

Roadmap Purpose : To depict gap and barrier and to clarify HTS solutions

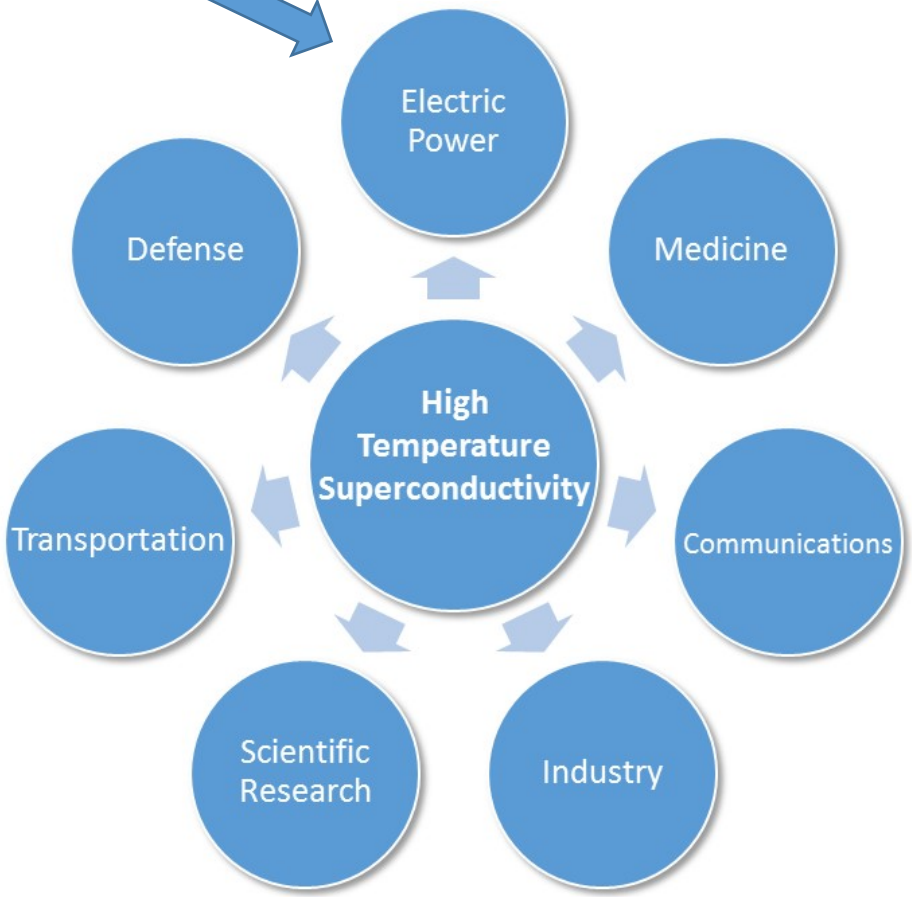
- Paints a picture of where the HTS industry is at present and what steps it should take to promote widespread adoption of HTS based devices.
- Outlines challenges and needs.
- Provides members of executive committee with info to help inform management in government and industry for future HTS R&D.
- Does not make predictions about the future nor identify specific organizations to tackle problems.



- The analysis conducted was based on the best data available at the time; it's intended to be updated in another year.

Superconductivity has Broad Applications in Energy Technology

- Focus of Roadmap
  - HTS Wire
  - Cables
  - Fault current limiters
  - Generators
  - SMES
  - Transformers

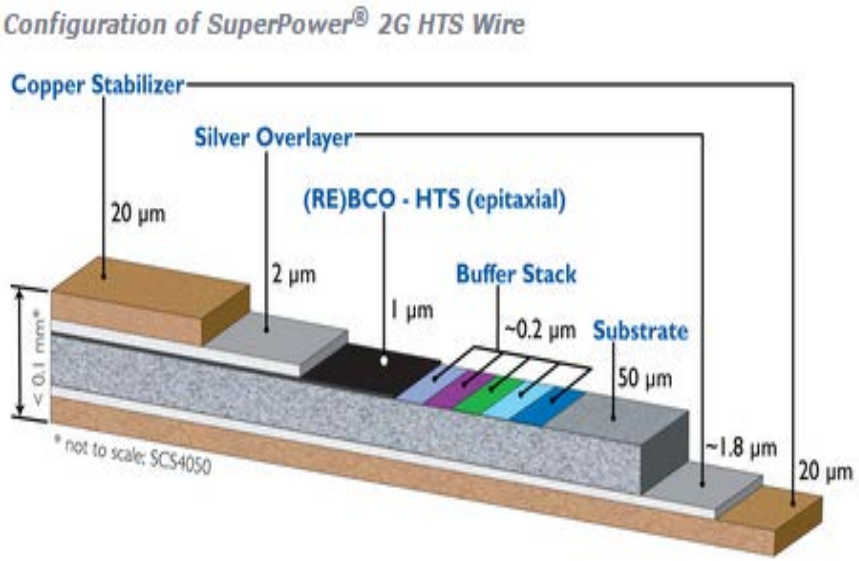


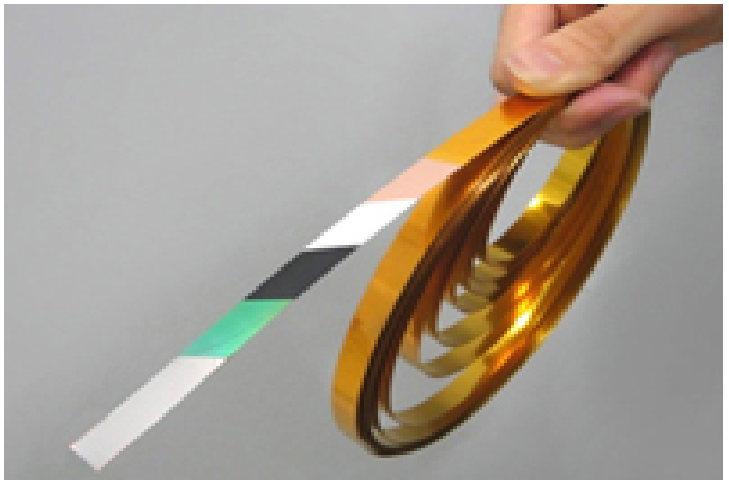
Benefits of HTS Power Applications

- Unique features of HTS
  - Highest engineering current densities
  - Zero DC resistance even at high magnetic fields
  - Fast transition from zero to high resistivity
- Impact on Power Applications
  - Improved energy efficiency
  - Higher power density
  - New technologies (e.g. FCL)
  - Higher power quality
  - Environmentally friendly
- Superior parameters and complete new systems are possible

Example: HTS Wire

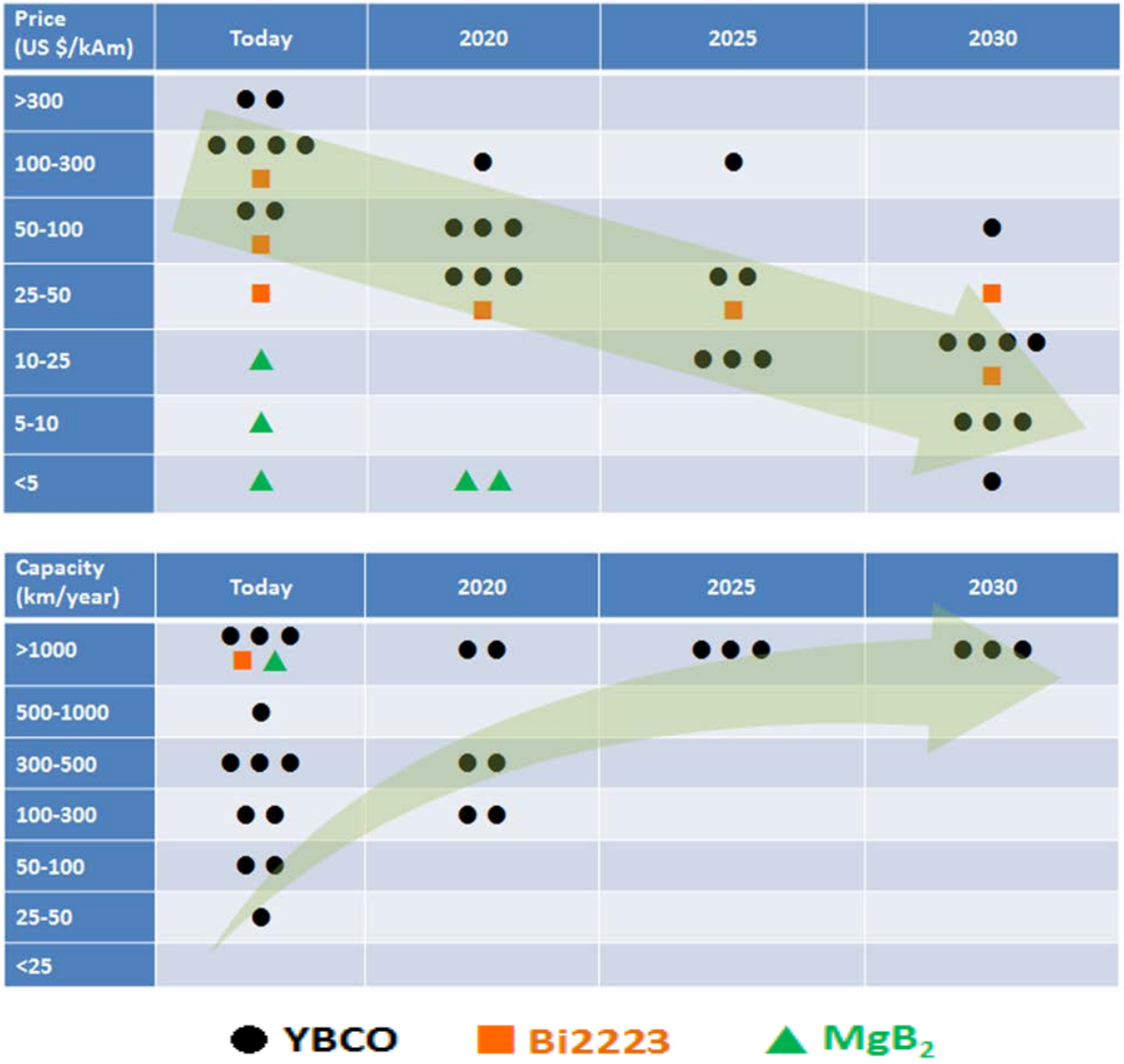
- Gap, Barrier and Solutions
  (TCP survey and discussion +Road Map)





- Cost and Capacity in Mass-production

Price and Capacity for HTS Wire



Coated Conductor Manufacturers 2016

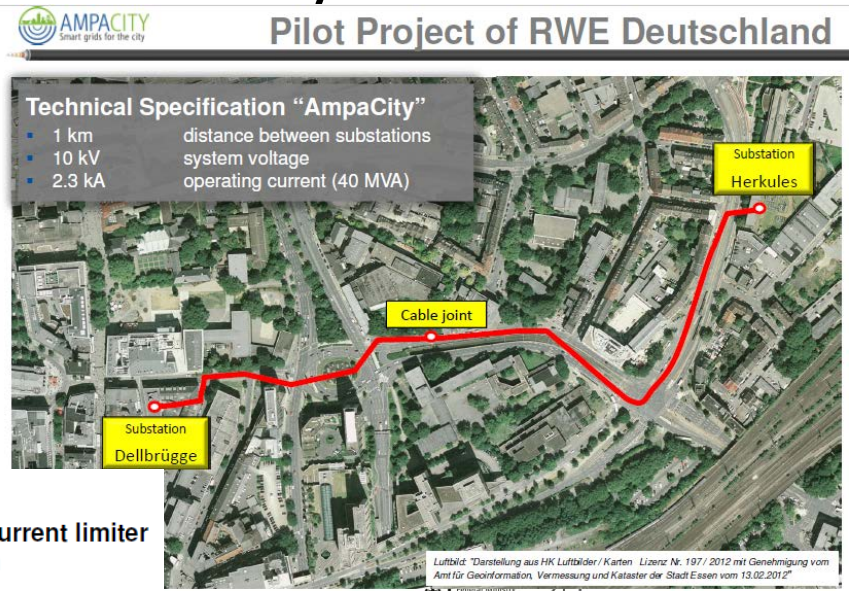
- **there are several established companies that offers wire quotes**
- **the range of specifications is increasing**

- **the issue is cost and mass manufacturing at industrial scale**

Example: HTS Cable

- Cost of wire, cooling system and system
- Long term reliability

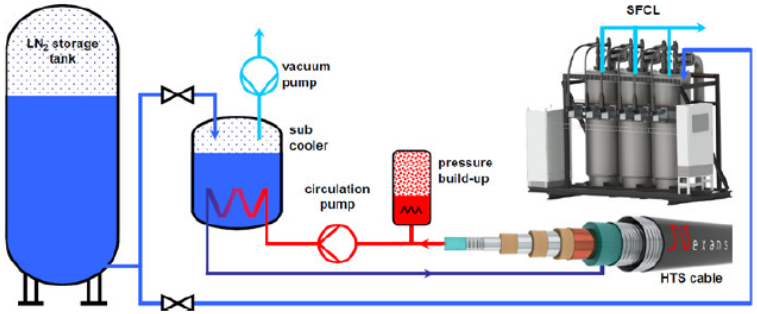
- **RWE AmpaCity (10kV Cable)**



Cooling system (in substation Herkules)

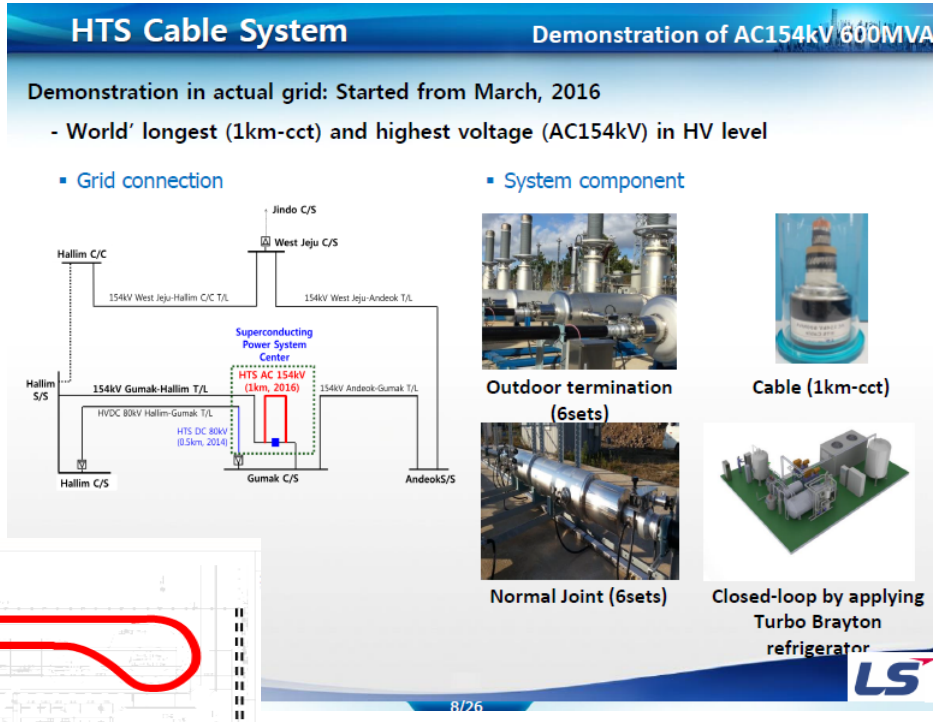
> **Cryogenic technology for the HTS cable system and the fault current limiter**

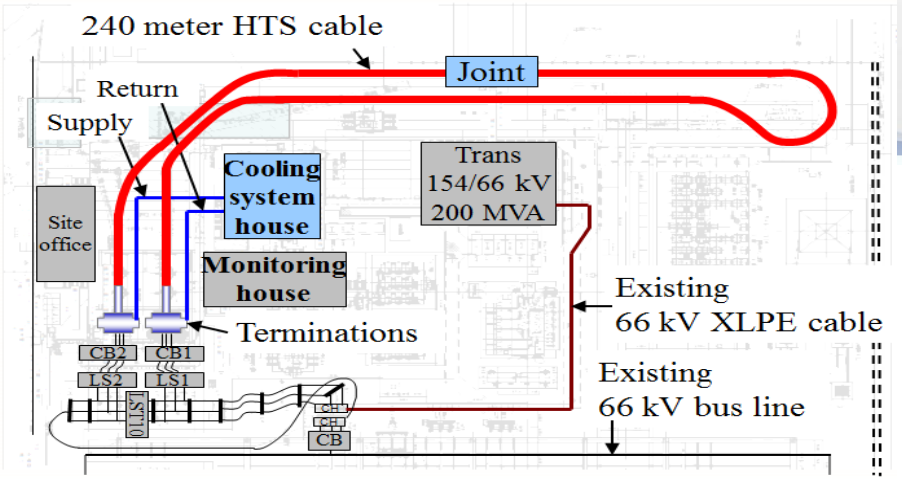
- Liquid nitrogen (LIN) is circulated as a coolant in a closed system
  → no release of LIN
- LIN is cooled down in sub cooler (-206 °C)
- LIN evaporates at 150 mbar(a)
  (produced by vacuum pumps)
- Temperatur of LIN drops to -209 °C
  (expansion via expansion valve)



Cable – State-of-the-Art 2016

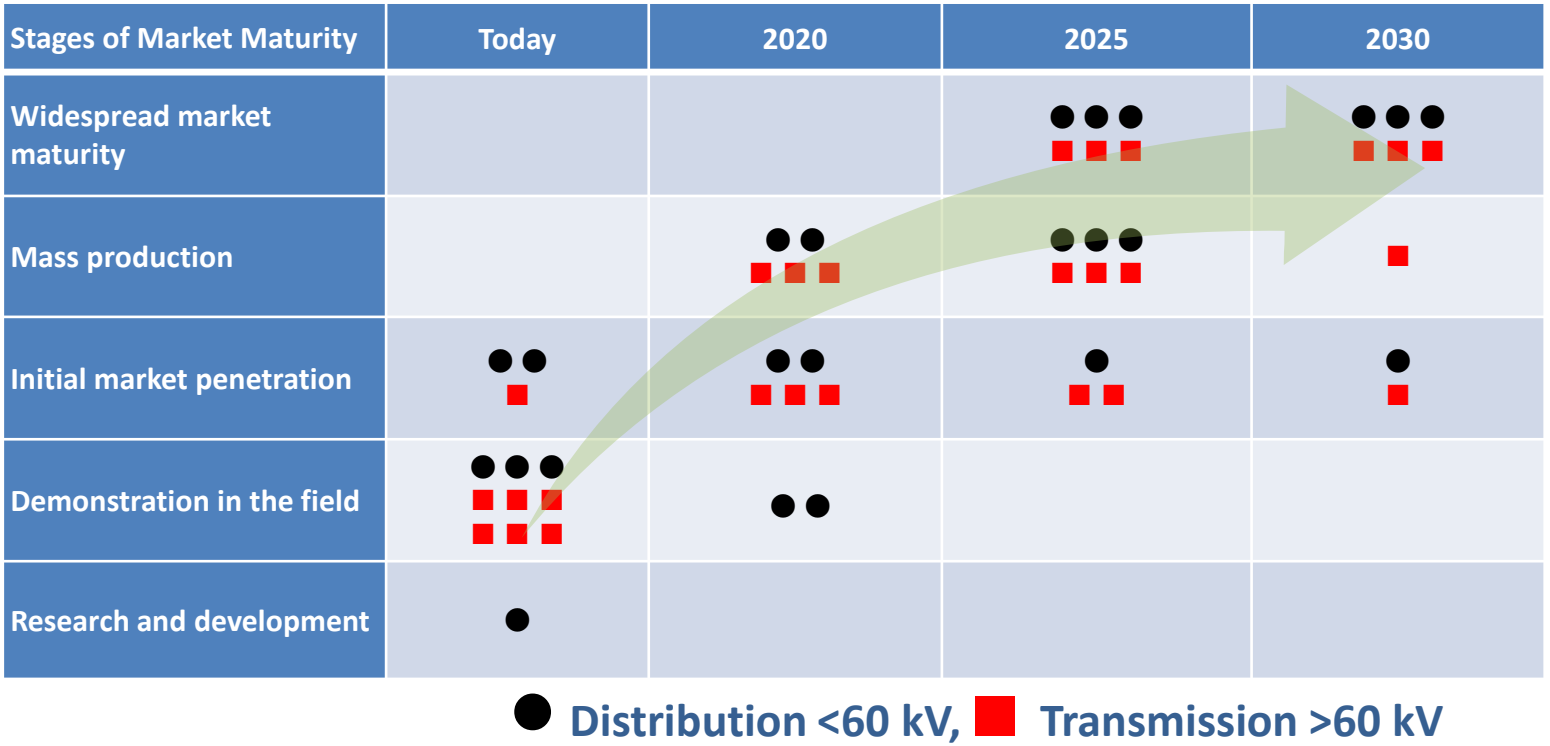
- KEPCO Jeju (154kV Cable)





- **TEPCO Asahi (66kV Cable)**

Stages of Market Maturity Cable



- We are now at “Initial Market Penetration Stage”

HTS Cables – Future Directions

- Applications
  - More real application studies with utilities
  - Long term grid application
  - Towards higher voltages
  - More DC applications
- Technology
  - Lower system cost and less maintenance
  - Lower AC and cryostat loss
  - R&D on high voltage issues

Example: SFCL

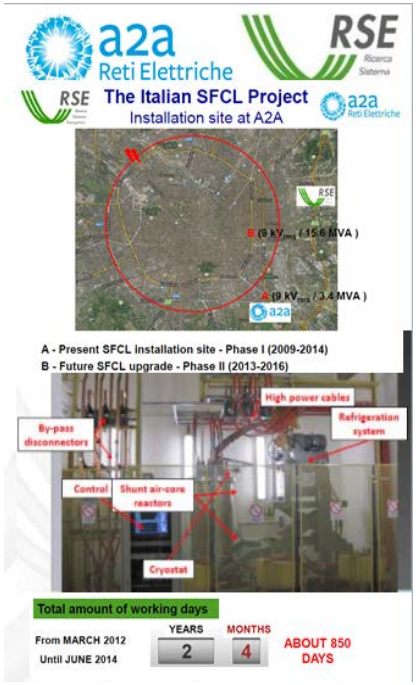
- Cost of cooling system, HTS wire, HTS coil, and reliability at faulting events (for high voltage)

Nexans

Resistive type, YBCO
12 kV, 1600 A
Installed 11/2015

Siemens

Resistive type, YBCO
12 kV, 815 A
Installed 3/2016



Resistive type, Bi, YBCO
9 kV, 250 A(Bi), 1000A(Y)
Bi 2.4years tested in 2014
Y tested in 2016

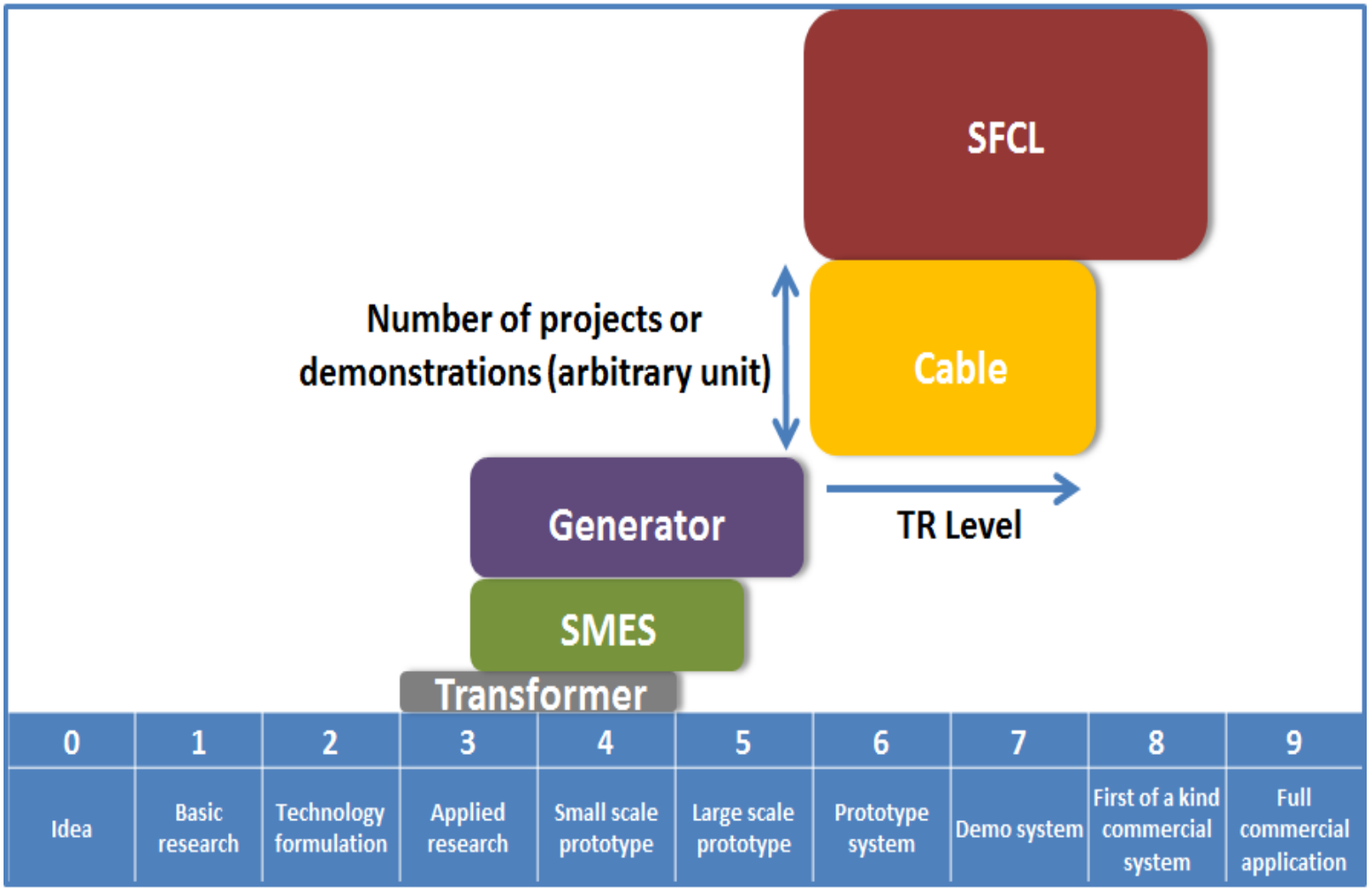
- TRL Level 8 - system complete and qualified

SFCLs – Future Directions

- Applications
  - More commercial applications
  - More field operational experience
  - More diversity in applications
- Technology
  - System improvement
  - Demonstrators and prototypes for new types and higher voltages
  - DC Limiters

Present Status (2016)

- TRL (Technology Readiness Level)



Summary of Gap and Barrier for HTS Applications which are being solved.

Device	Gap/Barrier
HTS Wire	Cost, Capacity
Cables	Cost of wire and cooling system, Low AC loss Long term reliability in a power grid, High voltage
Fault current limiters	Cost of system including cooling system, HTS coil (fabrication), Reliability at faulting event, High voltage
Generators	Cost of HTS wire and coil, Reliability at coil quenching, Long term reliability for cooling system at rotating state
SMES	Cost of HTS wire and coil, Low loss and Reliability at switching, Long term reliability
Transformers	Low cost, high reliability, comparable to conventional one

Challenges and needs
Common to all devices

Economics. Cost of wire, devices → Because of the unique attributes of HTS devices, a system cost analysis should be conducted.

Fabrication Process Control (QA/QC) → QA/QC and process control tools that can meet the requirements of high-yield manufacturing in high volume.

Long term reliability → Accelerated lifetime testing is essential to confirm reliability and guide product improvements

More information:

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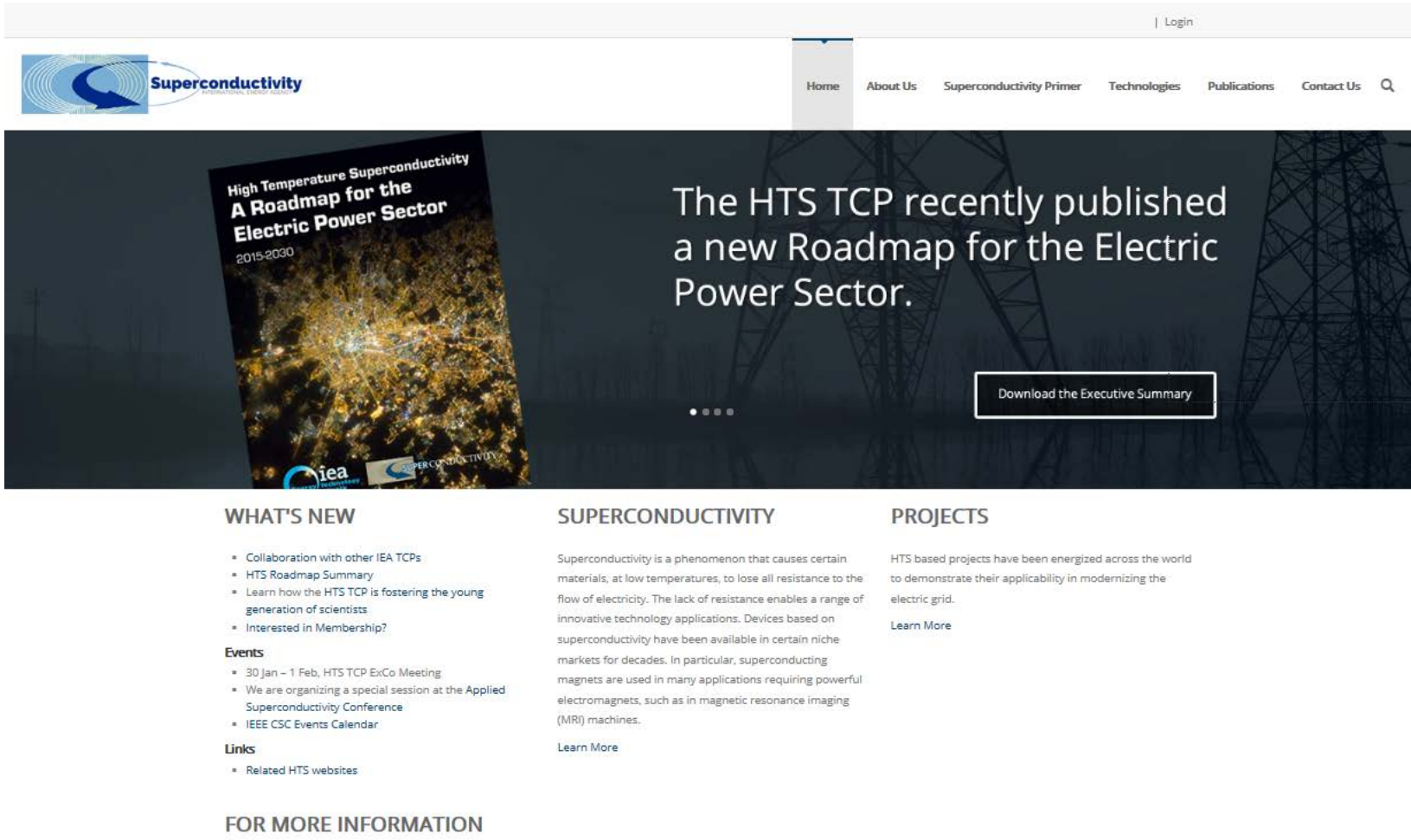

World Projects at a Glance

- Technical monitoring of HTS projects:
  - Covers EU, US, Korea, Japan, China, Russia, …
  - Focus is on electric power projects
  - Updated periodically

Thank you for your attention !