HTS Transmission Network will be the key of 21st Century's Power Grid

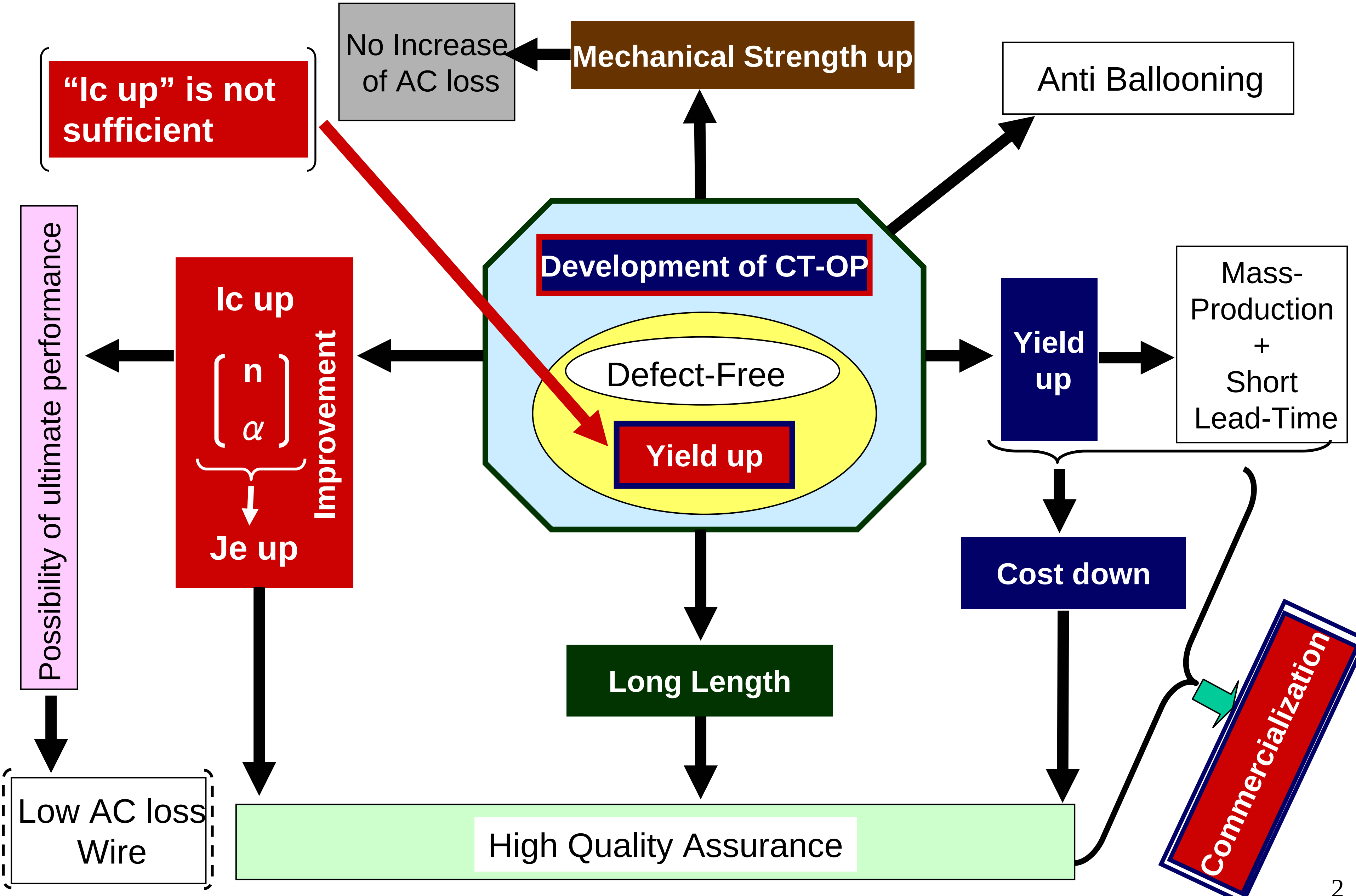
June 24-25, 2004

昆明(Kunming), China

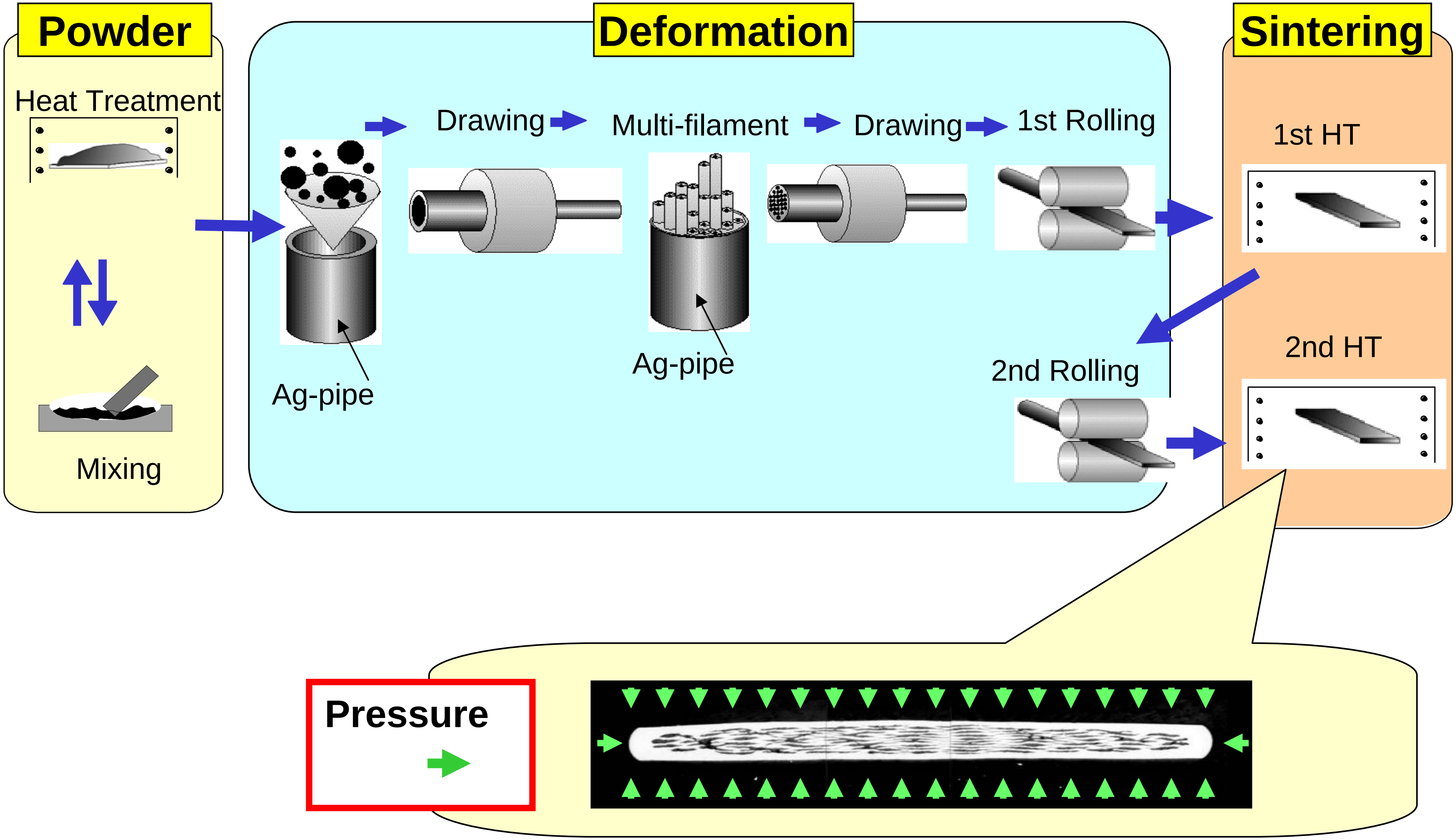
Ryosuke Hata

SUMITOMO ELECTRIC INDUSTRIES, LTD.

Improvement Policy of BSCCO wire



CT-OP (ConTrolled Over Pressure)

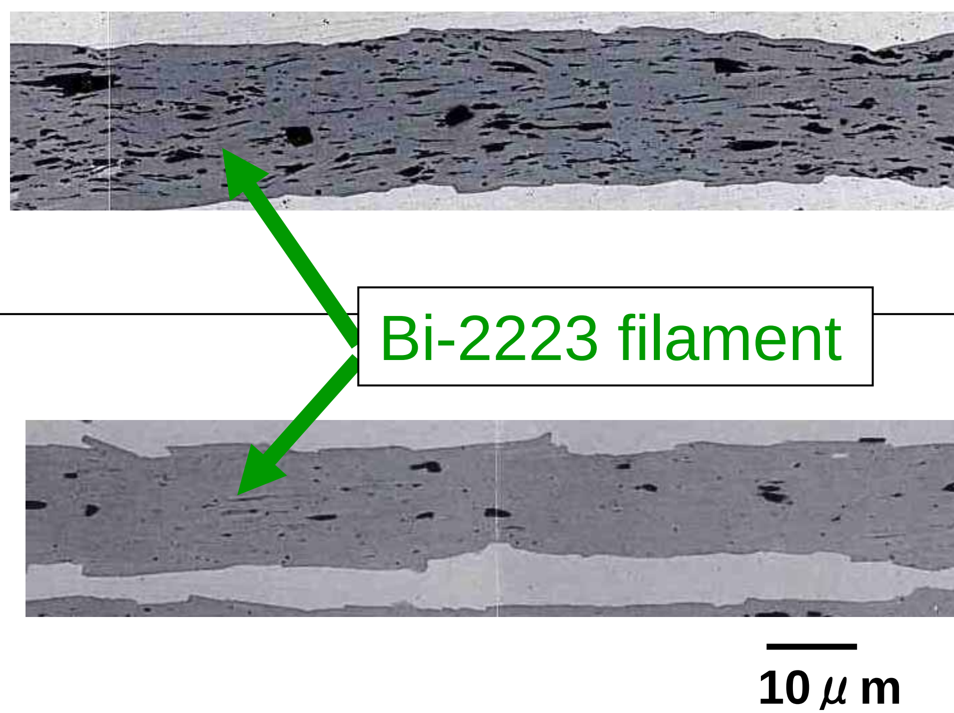


SUMITOMO ELECTRIC

Drastic Improvements on Bi-2223 by New Innovative Process: CT-OP
- 100% density of filament -

Conventional Process

New Innovative Process



Density：80~90%

Large and lots of Non-SCs and Porosities

Density：~100%
Ic Improved by 30% or higher

Small and little Non-SCs and Porosities

Effects achieved with CT-OP (1)

●High Yield and Long Length by exterminating Defects During Sintering

●Improved Jc & Ic by Increased Density up to 100% and Decreased Non-superconducting Phases

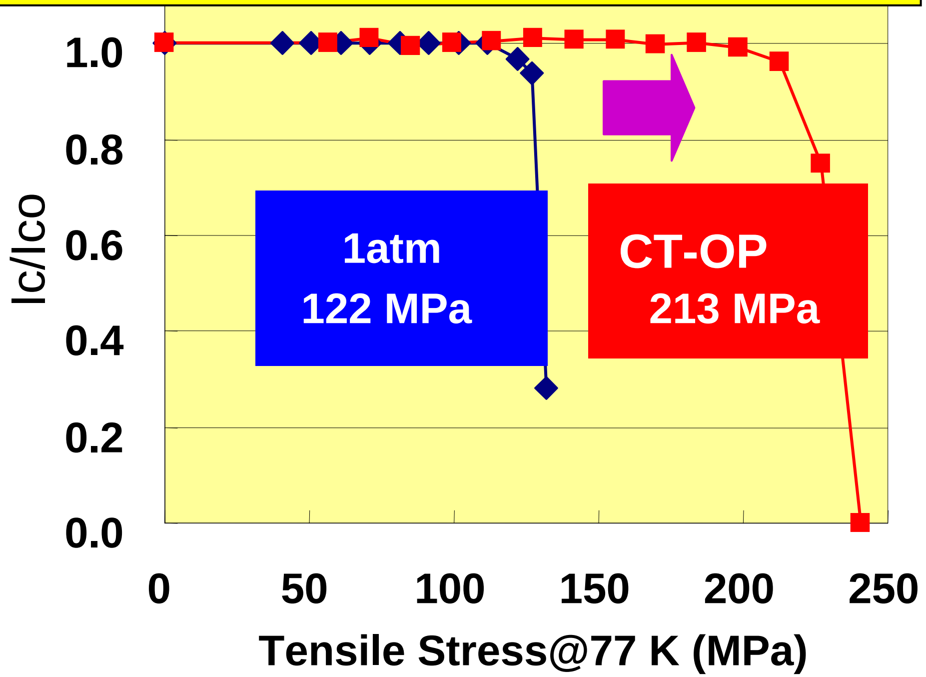
	1atm	CT-OP
Critical Current (Ic)	99 A	~130A ~1,000m
Critical Current Density (Jc)	26 kA/cm^2	37 kA/cm^2

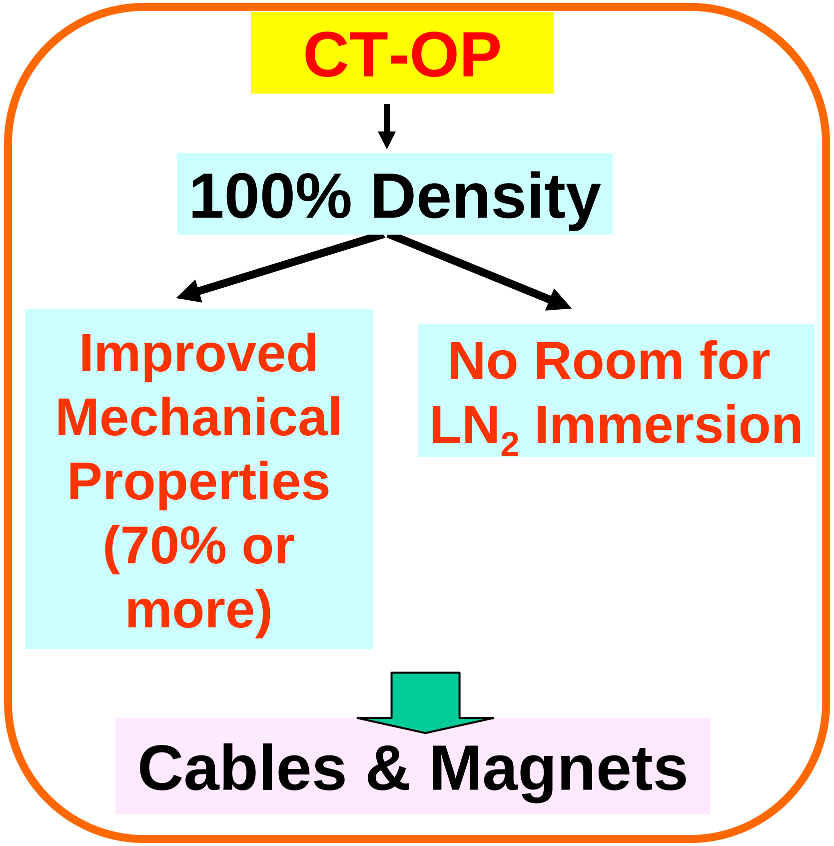
～30% UP

～40% UP

Effects achieved with CT-OP (2)

●Increased Tensile Strength by 70%





No Need for Additional Metal for Mechanical Properties

●Anti-Ballooning when immersed in LN_2

Ballooning : zero in 1,000m CT-OP Wire

Cost Down and Merit Figure of BSCCO wire

$$M = \frac{\$}{A \cdot m} = \frac{(\$ / m)}{A} \qquad \frac{(\text{Cost} \downarrow)}{(\text{Ic} \uparrow)}$$

Cable	A × # of wire	➪ A・m
Magnet	A × Turn	

Cost reduction by CT-OP

$$C_{cost} = \partial D \frac{1}{\alpha \beta} + X$$

- ∂ : Available Ic(A)
- D : Merit Figure($/A・m)
- α : Yield (Long Wire)
- β : Ic Increment Ratio
- X : Cost of CT-OP($/m)

(A) Non CT-OP (Old Process)

$$C_1 = \partial D \frac{1}{0.2 \times 1}$$

(B) CT-OP (New Process)

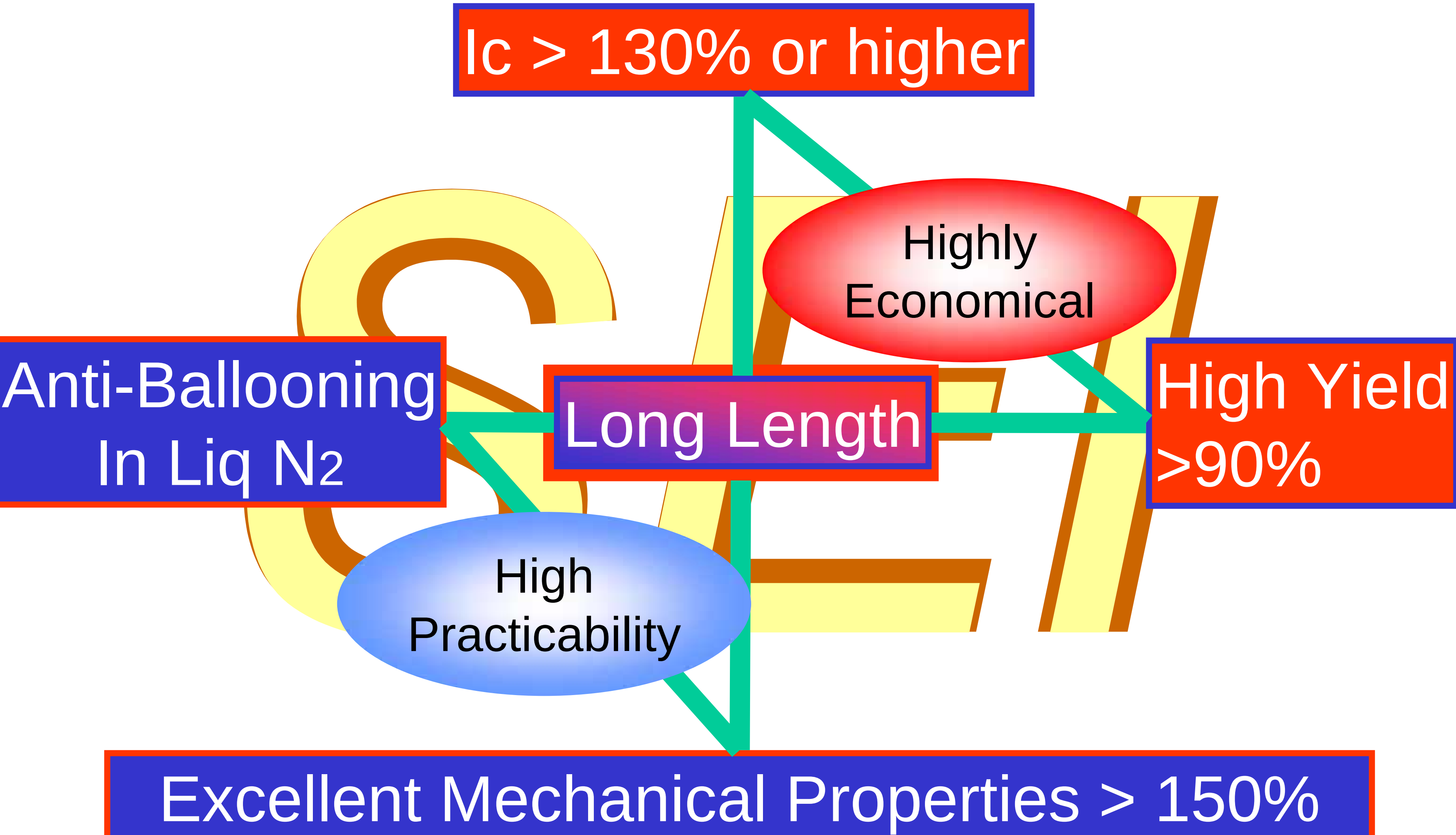
$$C_2 = \partial D \cdot \frac{1}{0.9 \times 1.3} + X \fallingdotseq \partial D \frac{1}{0.9 \times 1.3}$$

Expectation of Cost Reduction

$$Z = \frac{C_2}{C_1} = \frac{\partial D \cdot \frac{1}{0.9 \times 1.3}}{\partial D \cdot \frac{1}{0.2}} = \frac{0.2}{0.9 \times 1.3} = 0.17 \approx \mathbf{0.2}$$

Long-length(>500m) BSCCO wire is expected to be lower than $100／KA・m as a price.

Summary: Improvements Achieved by CT-OP Process



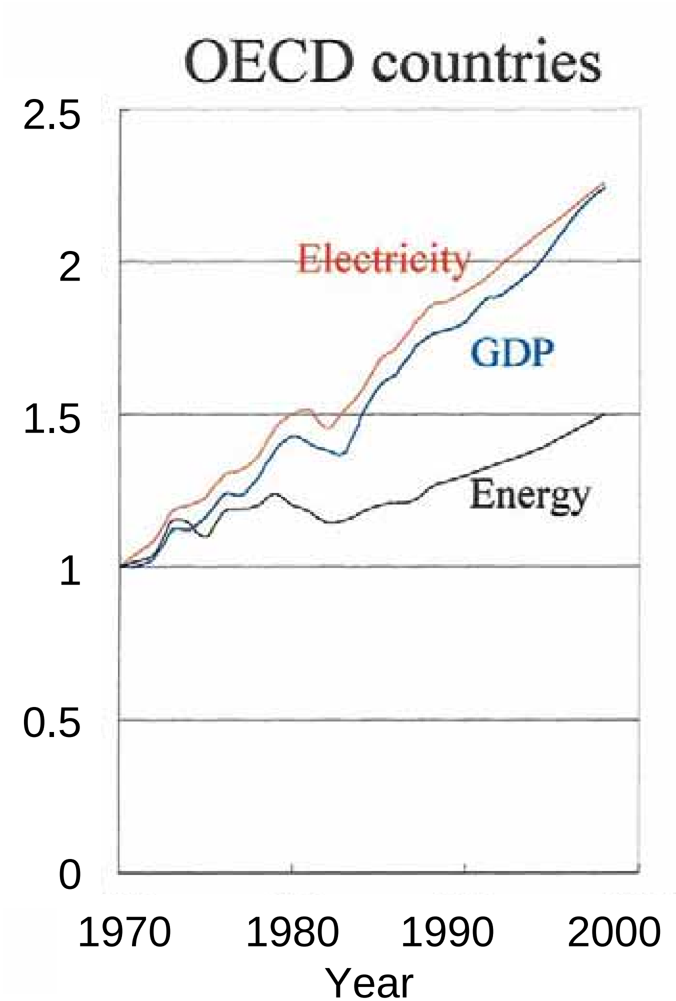
(No Additional AC Loss by Metallic Sheath)

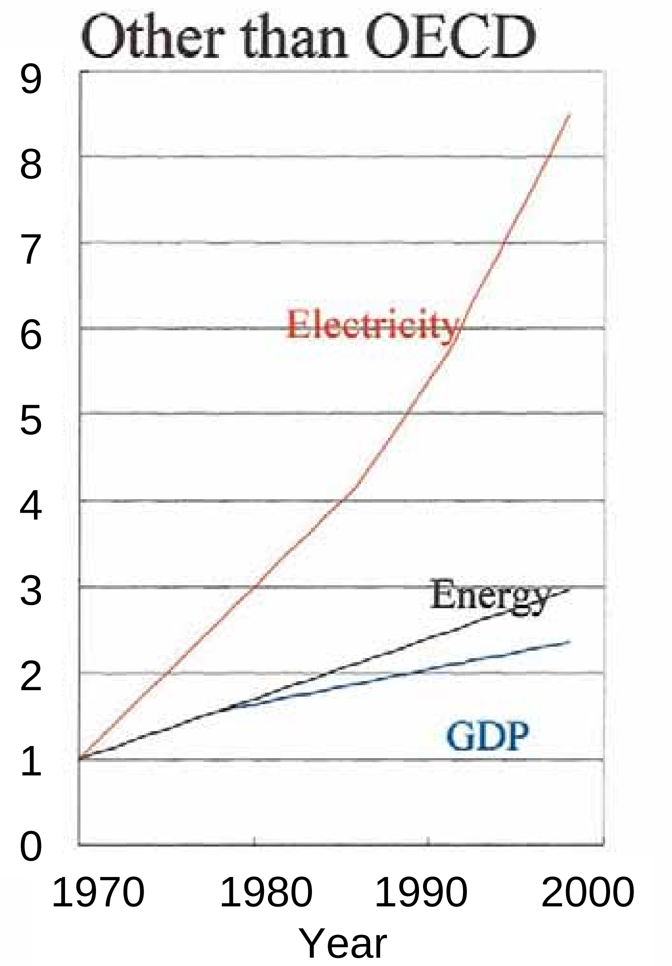
Comparison of Japan, US, EU, China and Russia

		Japan 2004 (2000)	US 2004 (2000)	EU	China 2004 (2000)	Russia
Population	Million	127 (126)	281 (273)	456	1270 (1275)	146
GDP	Nation's Currency	465 (500) Trillion-Yen	11.0 (8.9) Trillion-USD	8.0 Trillion-EUR	10.2 (8.2) Trillion-Yuan	13.0 Trillion-Rouble
	Trillion-USD	4.23 (4.43)	11.0 (8.90)	9.70	1.23 (0.99)	0.45
	USD/capita	33,000 (35,000)	39,000 (33,000)	21,000	970 (780)	3,000
Electric Power Generation	GW	260 (200)	860 (800)	650	320 (240)	210
	kW/capita	2.0 (1.6)	3.1 (2.9)	1.4	0.25 (0.18)	1.44

<Investigated at 2004>

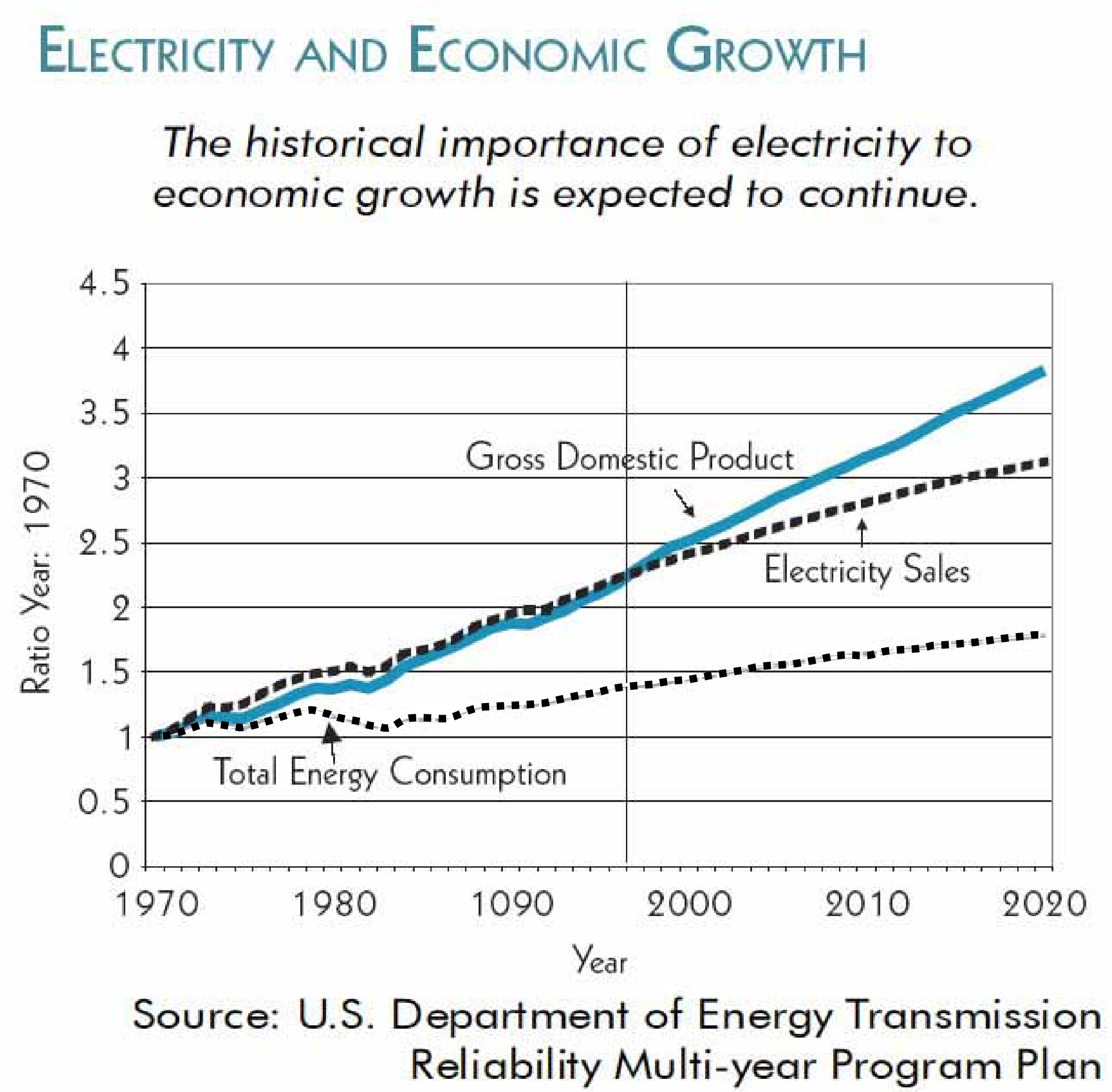
Electricity and Economic Growth





Source : Mohan Munasinghe – World Energy Council Journal (Dec 1991)
www.oecdtokyo.org

Electricity is Increasing in US

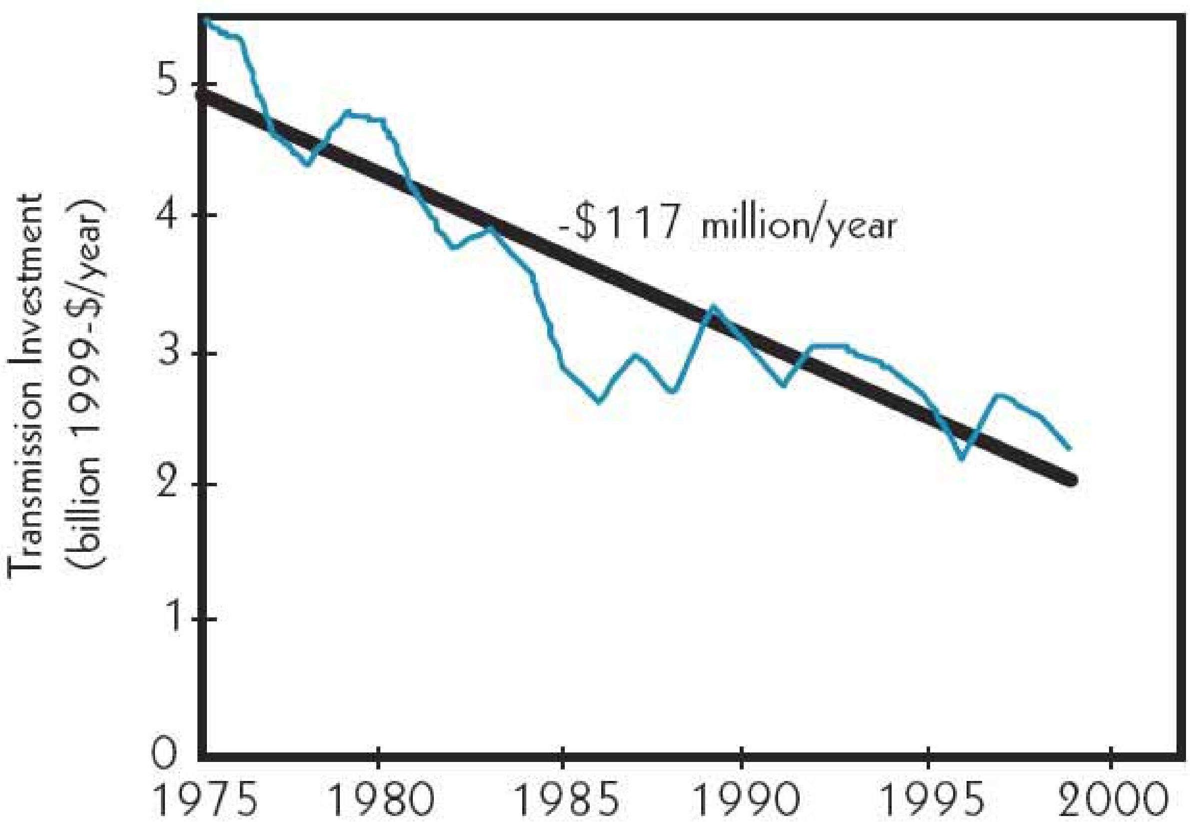


Growth (%/year)	Doubling Year
1	70
1.5	47
2	35
2.5	28
3	23

Transmission Investments are Decreasing in US

U.S. Transmission Investments

Annual investment in transmission facilities has been declining since 1975.



Source: U.S. DOE National Transmission Grid Study May 2002

Note

California Blackout

⇩

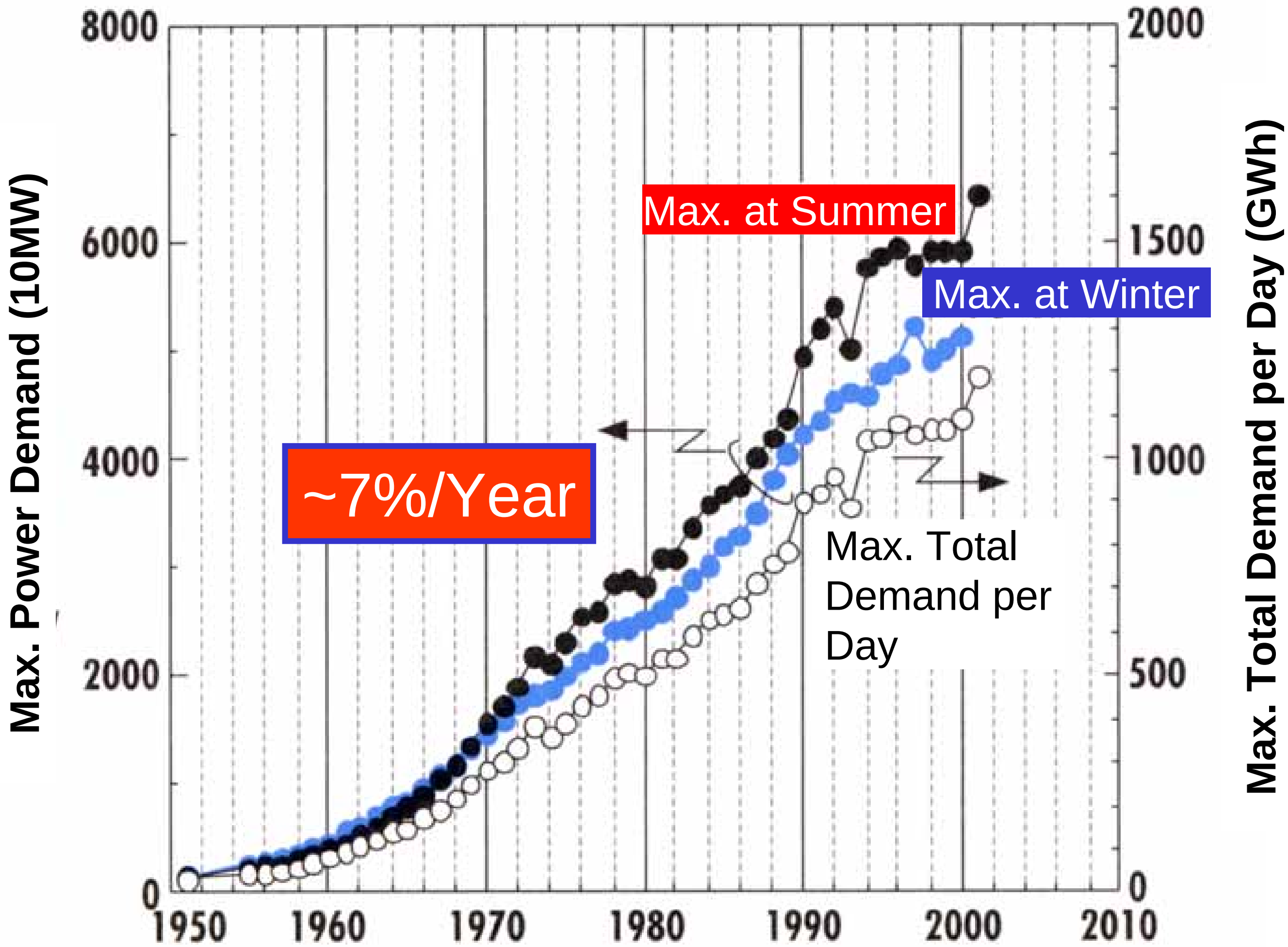
◎ Numerous Power Generations

⇕

× Few cables

Trend of Maximum Electricity (TEPCO in Japan)

<Average Electricity Growth of Japan : 1~2% in Coming 10 Years >

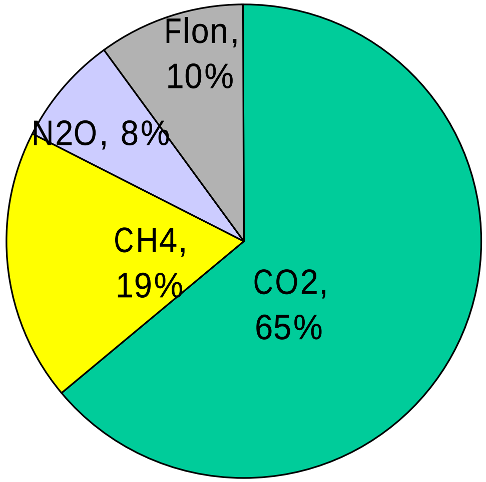


Trend of Maximum Demand of Electricity (TEPCO)

Electricity Supply Must Satisfy Max. Demand !

Influence of Electricity on Green House Gas Emission

Effect of Various Gas on Climate Change



CO_2 Emission in Japan(2000) :

1,200 Million-ton(CO_2)

or 337 Million-ton(C)

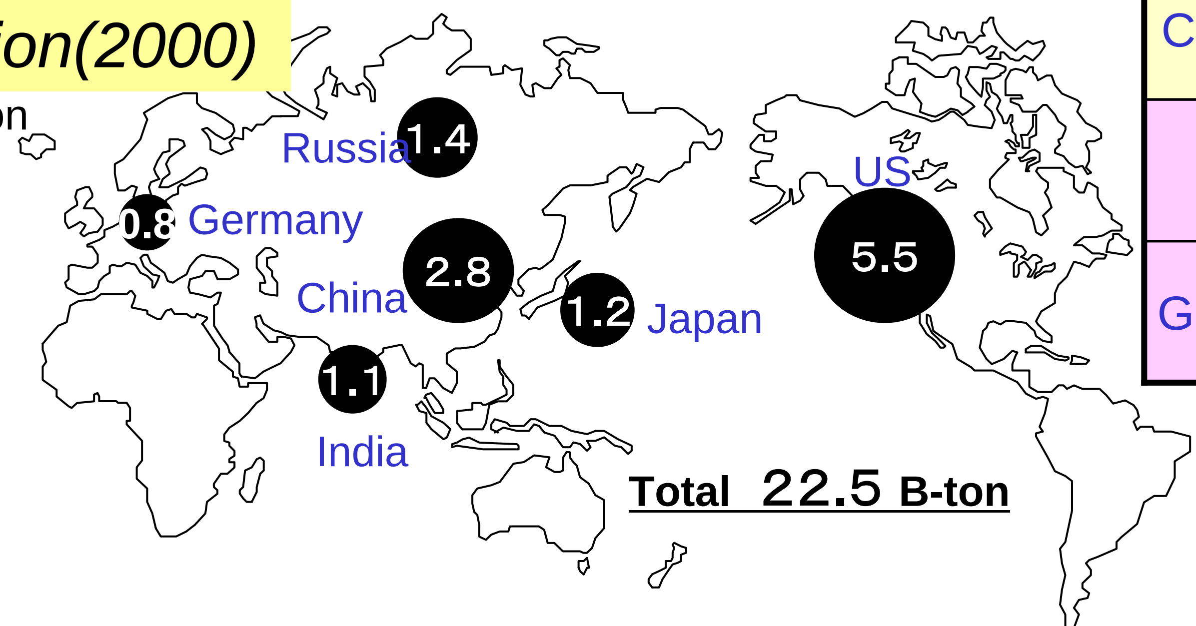
1/3: Electricity

1/4: Transportation

	CO_2/GDP (B-ton/Tri.$)
US	0.55
Russ.	4
China	2.4
JP	0.28
Germ.	0.43

CO_2 Emission(2000)

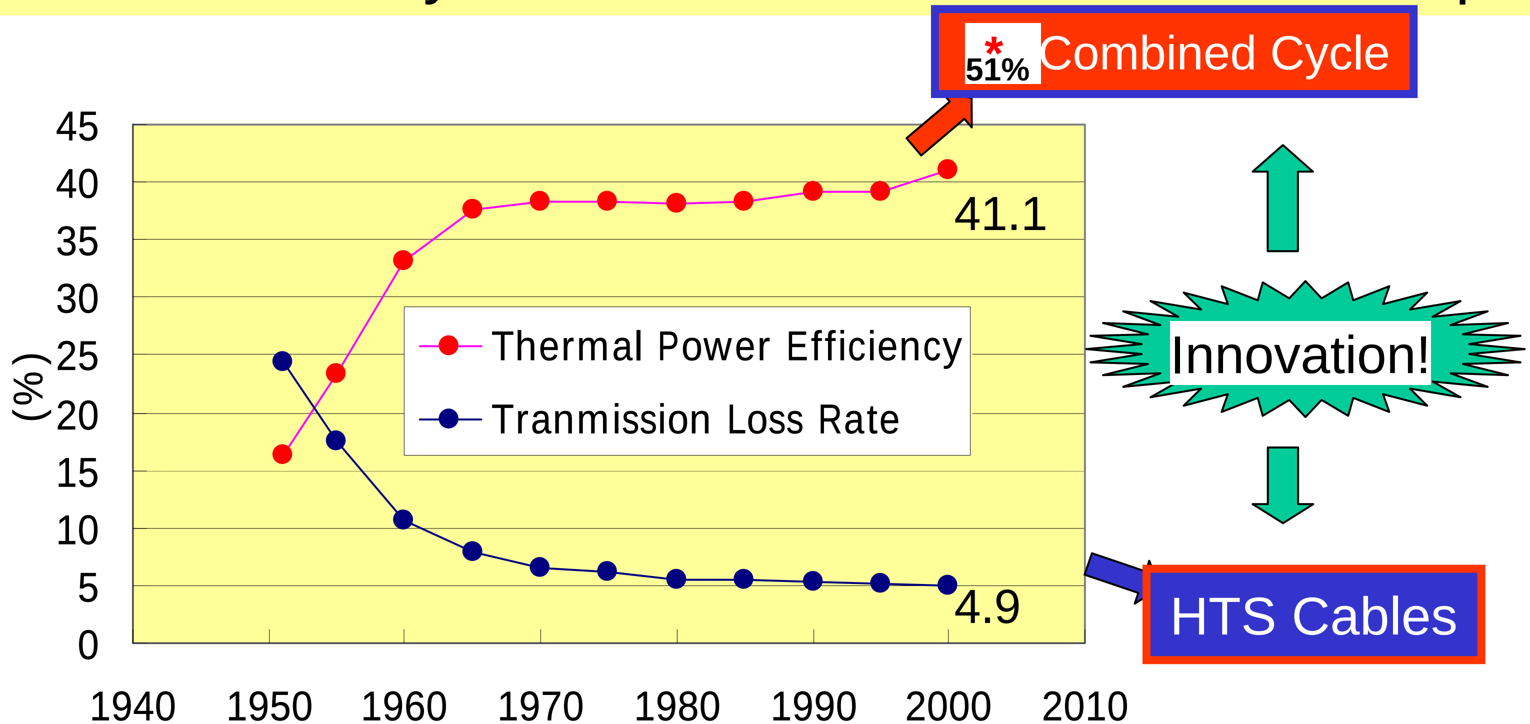
Billion-ton



Total 22.5 B-ton

Influence of Electricity on Green House Gas Emission

Thermal Power Efficiency and Transmission Loss Rate in Japan



Demand：1 Trillion kWh/Year

Transmission Loss reduction of 0.1 point

➡ 120,000 ton-C, Saving of 100 Million$

HTS cable is indispensable

Environmental and Economic Comparisons between HTS and Conventional Cable Systems

cable system	Conventional	HTS
Transmission capacity	1000 MVAx3 circuits	750 MVAx2 circuits, 2 routes
Transmission voltage (line to line)	275 kVrms	66 kVrms
Transmission current	2 kArms/phase	6.6 kArms/phase
Cable type	Single-core XLPE (1x3000mm^2)	Triple-core in one cryostat, Cold dielectric
Cable size	Approx. 170 mm	Approx. 135 mm
Number of cables	9	4
Installation	Installation of newly constructed 2700mm diameter tunnel	Replacement of existing duct
Cooling	Indirect cooling system in tunnel	Liquid nitrogen circulation cooling system
Transmission loss	740 kW/km (Transmission loss 113 kW/km/cct, Cooling system power 400 kW/km/tunnel)	200 kW/km (Transmission loss 3 kW/km/cct, Cryostat invading heat 2 kW/km/cct, Cooling efficiency 10%)
CO_2 Emission *1	778 ton-C/km/year	210 ton-C/km/year
Transmission loss cost *2	¥64,800,000 /km/year	¥17,520,000 /km/year

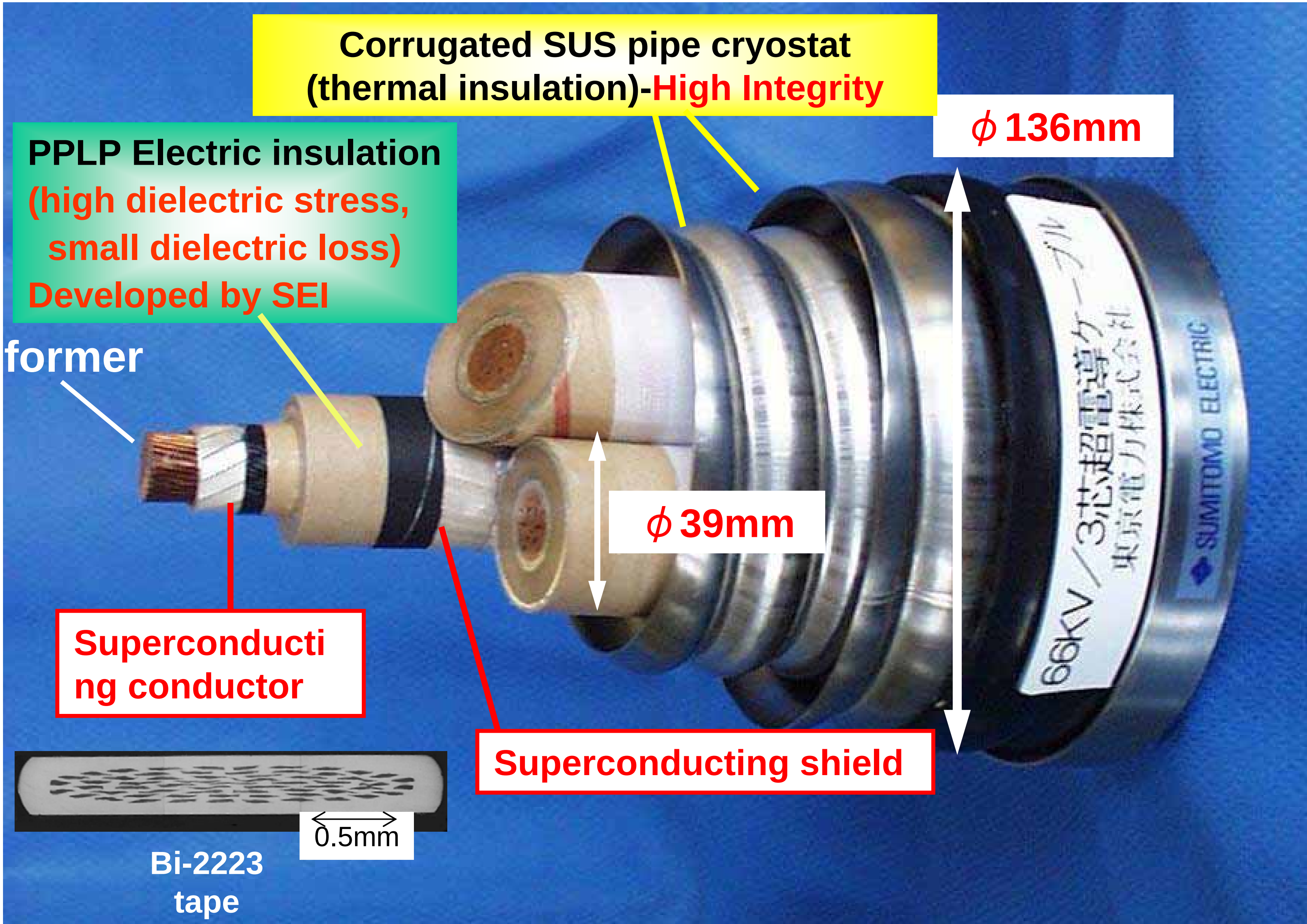
¼ →

*1 Calculated at carbon conversion rate of 0.12 kg-C/kWh

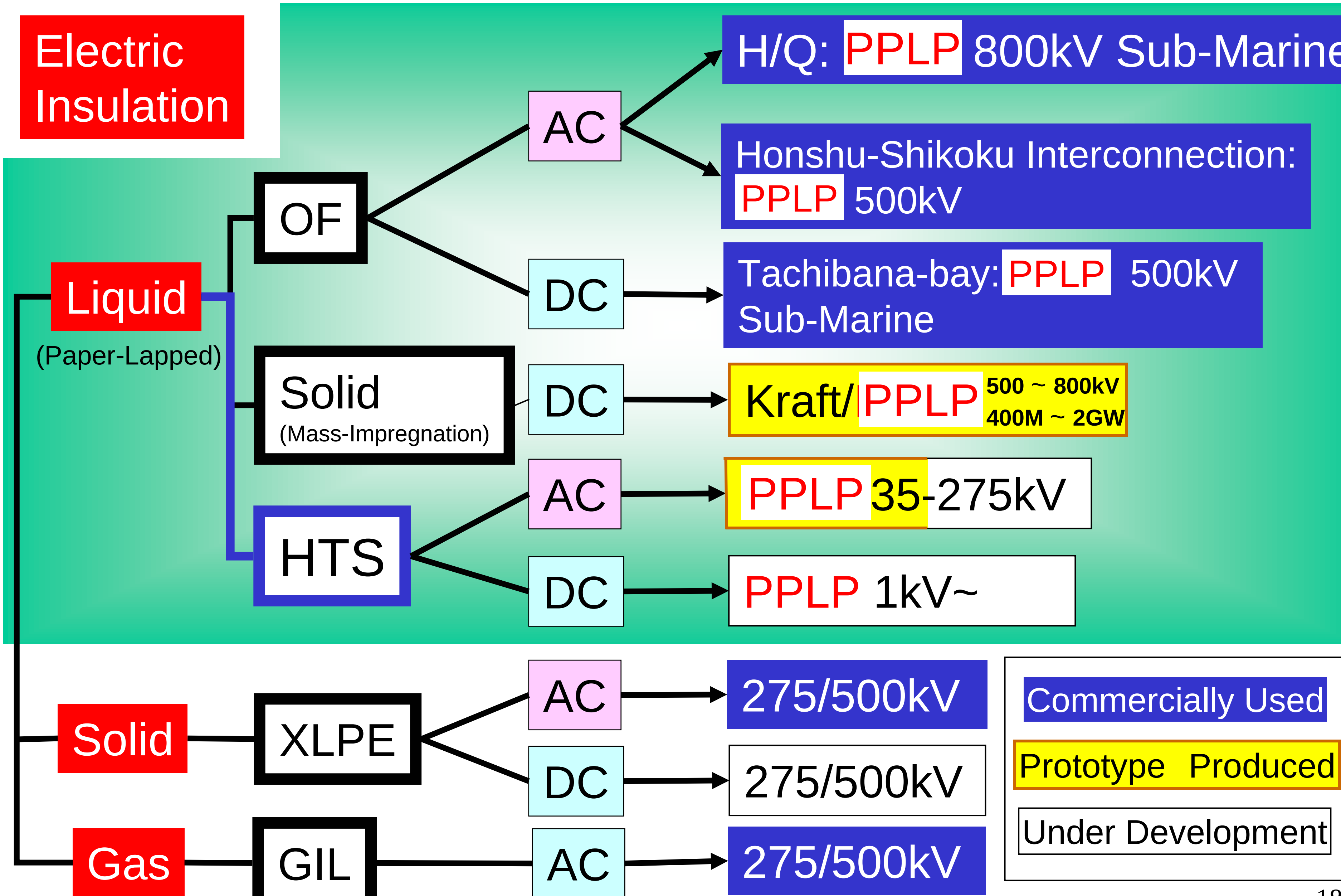
*2 Calculated at per kWh generation cost of ¥10

100m-114MVA-1000A Cable

Cold dielectric designed 3-Phase in One Cryostat



Underground Transmission Cable



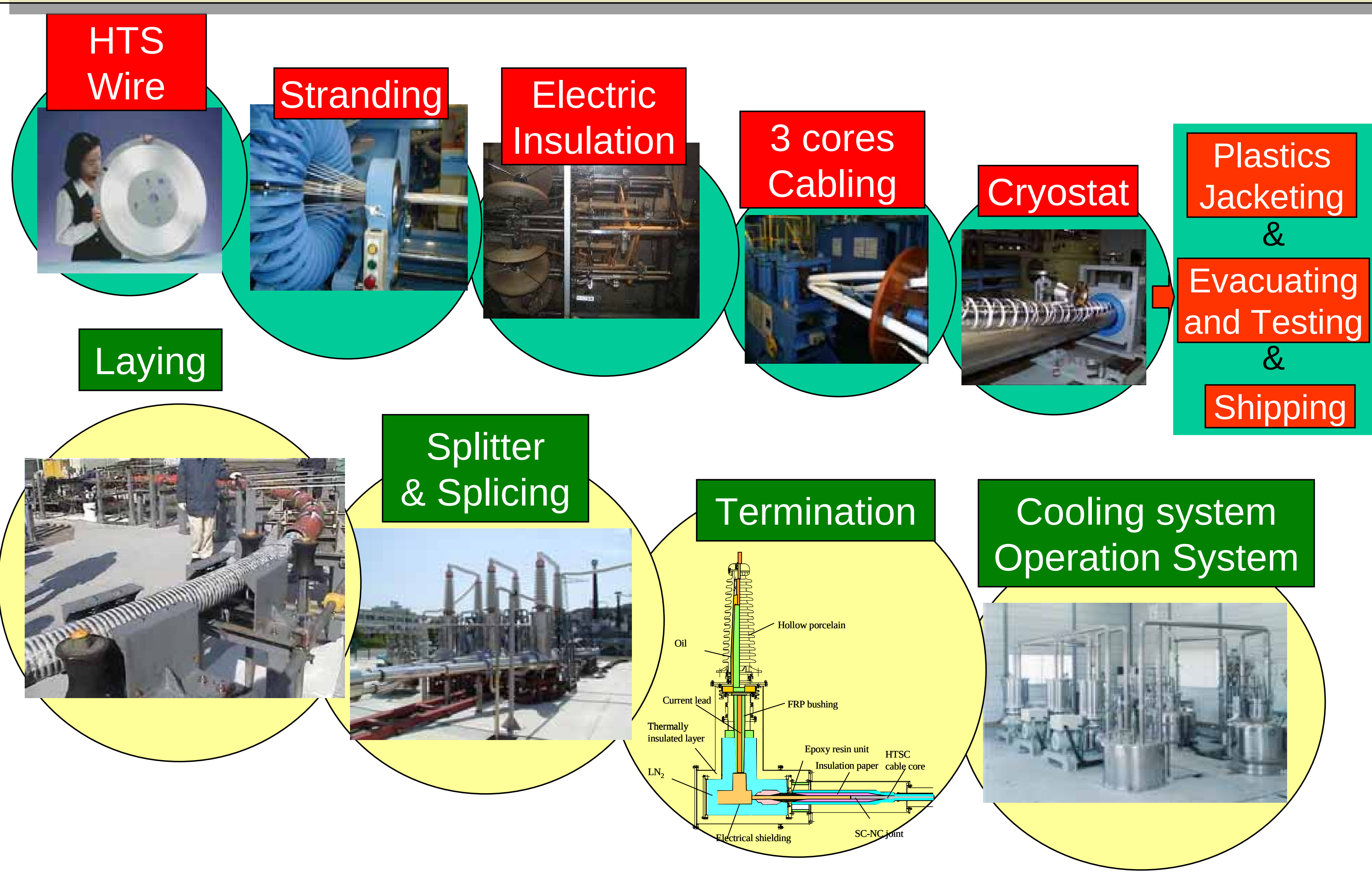
HTS Cable is One of OF Cable Family

		OF Cable	HTS Cable
Number of Core		Single or 3-Core	
Insul-ation	Liquid	Oil (Flammable/Not Green)	Liq N_2 (Inflammable/Green)
	Dielectric	Lapped PPLP (Kraft) Tapes & Oil Composite	Lapped PPLP Tapes & Liquid Nitrogen Composite
Metal-Sheath		Al / Pb (Corrugated)	SUS Cryostat
Liquid Circulation (Forced Cooling)		Oil-Pressure-Tank or Oil-Pumping-Station (Oil-Piping, Valves…)	Liq N_2 Cooling-Station (Liq N_2-Piping, Valves…)
Manufacturing		Very Similar	
Installation		Under Oil-Pressure	Under Vacuum
Operation		Oil-Feed-Control (Oil-Circulation-Control)	Liq N_2-Circulation-Control

↓

Technologies and Experience of OF Cable Are Indispensable!

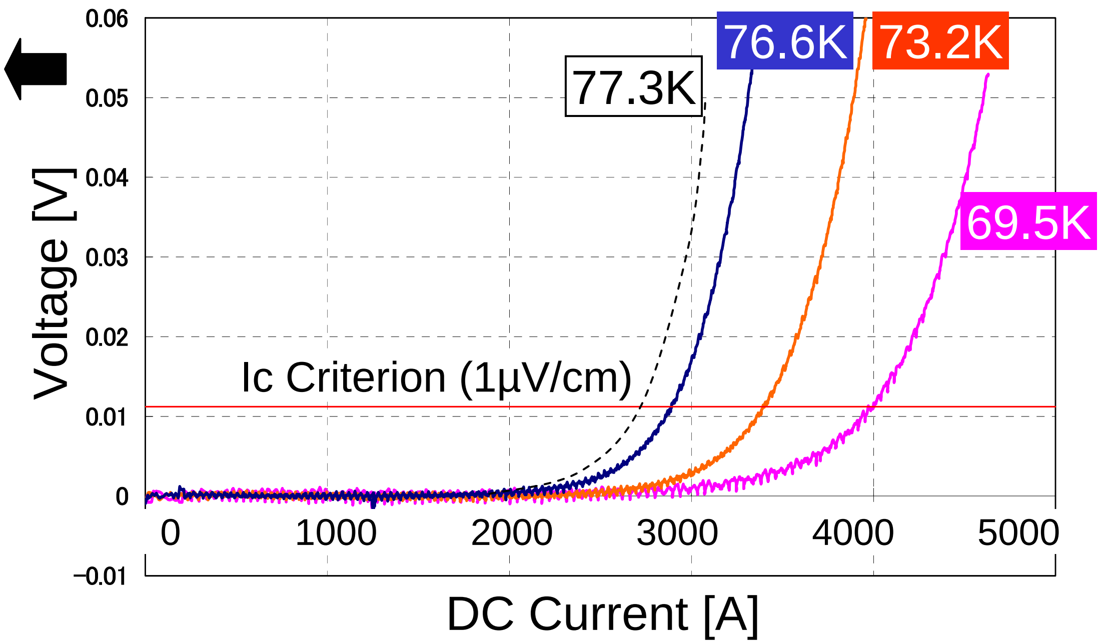
Wide Range of Technologies for HTS Cable Manufacturing, Installation & Operation

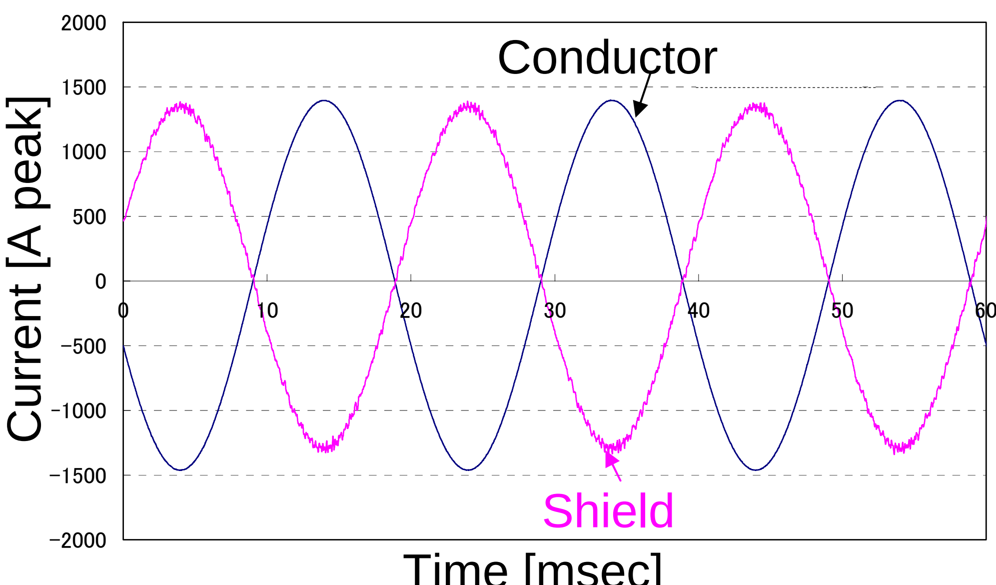


Merits of HTS cable

2.7kA(77K) →4kA(69.5K)

Ic can be increased "Largely and Easily" by "Controlling Liq-N2 Flow"



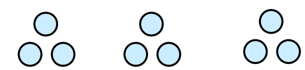
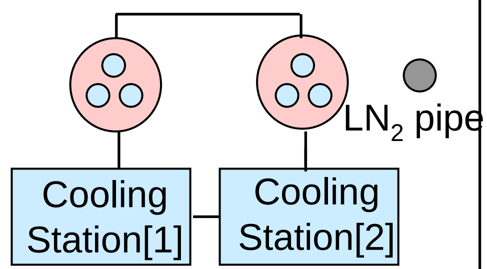
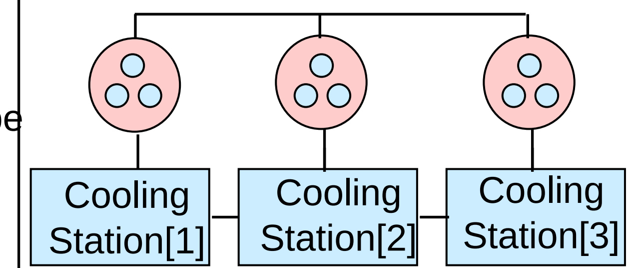
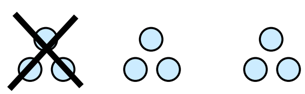
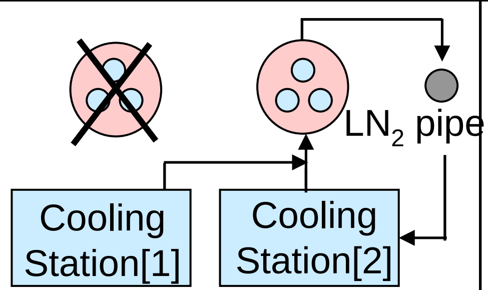
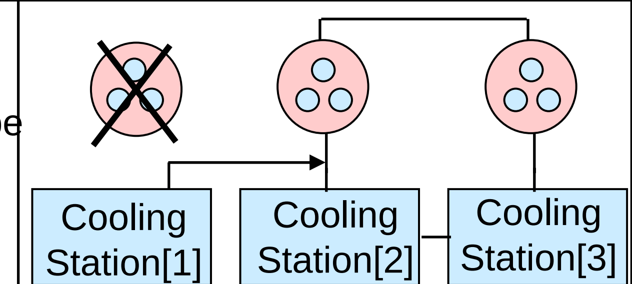


Shielding Current with Opposite Phase

***No Loss in Cryostat & Outside**

***EMI-Free**

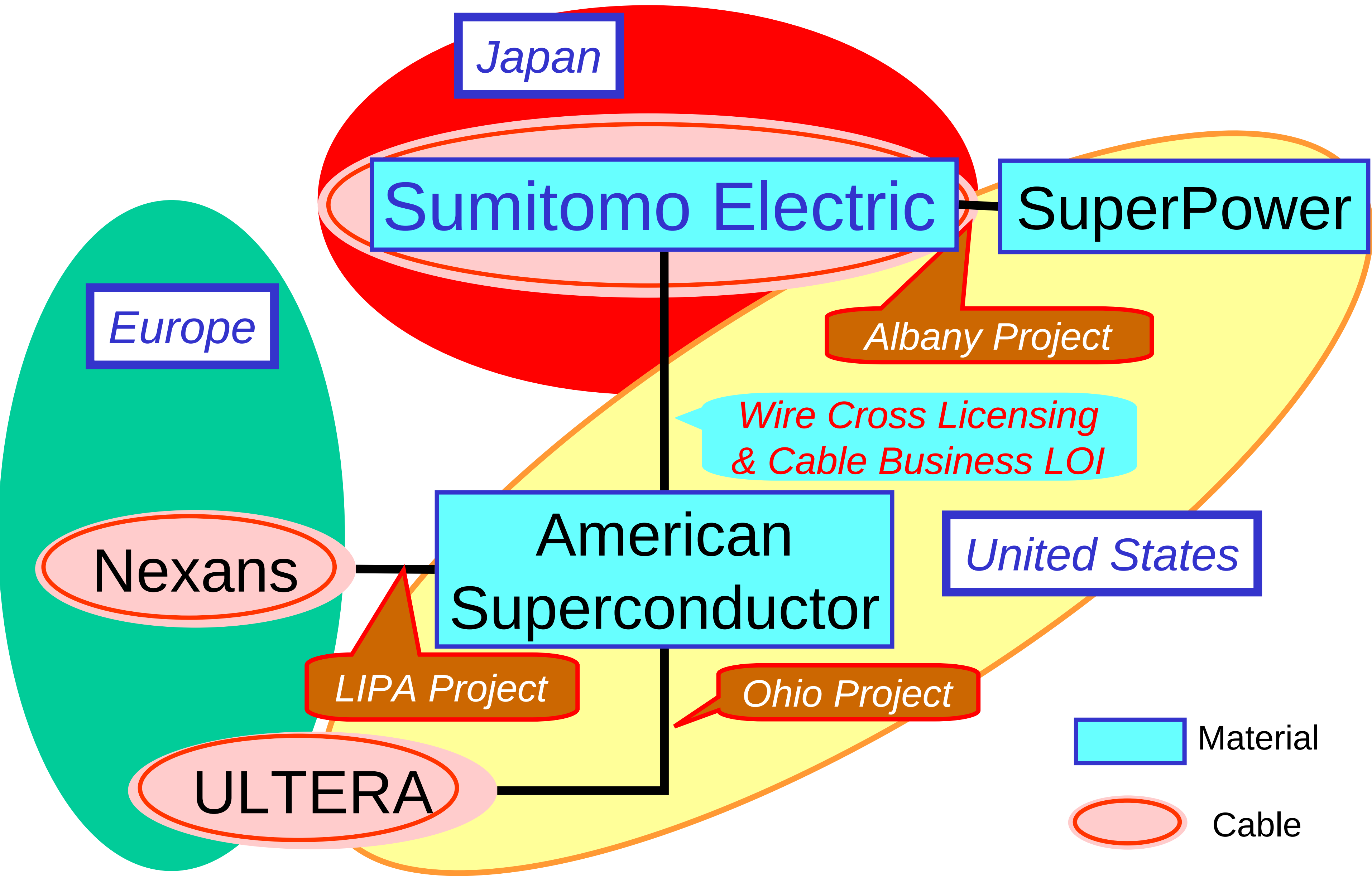
Establishment of Transmission System Reliability

	Conventional Cable (OF／XLPE)	HTS Cable	
	"3-2"	"2-2"	"3-3"
Circuit Configuration per Route			
Normal Condition	3cct. 2/3 Load Each **(67%/cct.×3=200%)**	2cct. Full Load **(100%/cct.×2=200%)** <Capacity/Route:1> →	3cct. Full Load **(100%/cct.×3=300%)** <Capacity/Route:1.5>
In case of Emergency (Failure on One Circuit)	 **Full load on 2cct.** **(100%/cct.×2=200%)**	 **Overload on 1cct.** **(200%/cct.×1=200%)**	 **Overload on 2cct.** **(150%/cct.×2=300%)**
Economy	**Over-redundancy** (High reliability Less Loss But high cost)	**Reliability and Not costly in Initial Investment.** **(Less Right of Way,** **Reduction of Civil and Cable Cost)**	

Status of Major HTS Cable Test Projects in Japan and Overseas

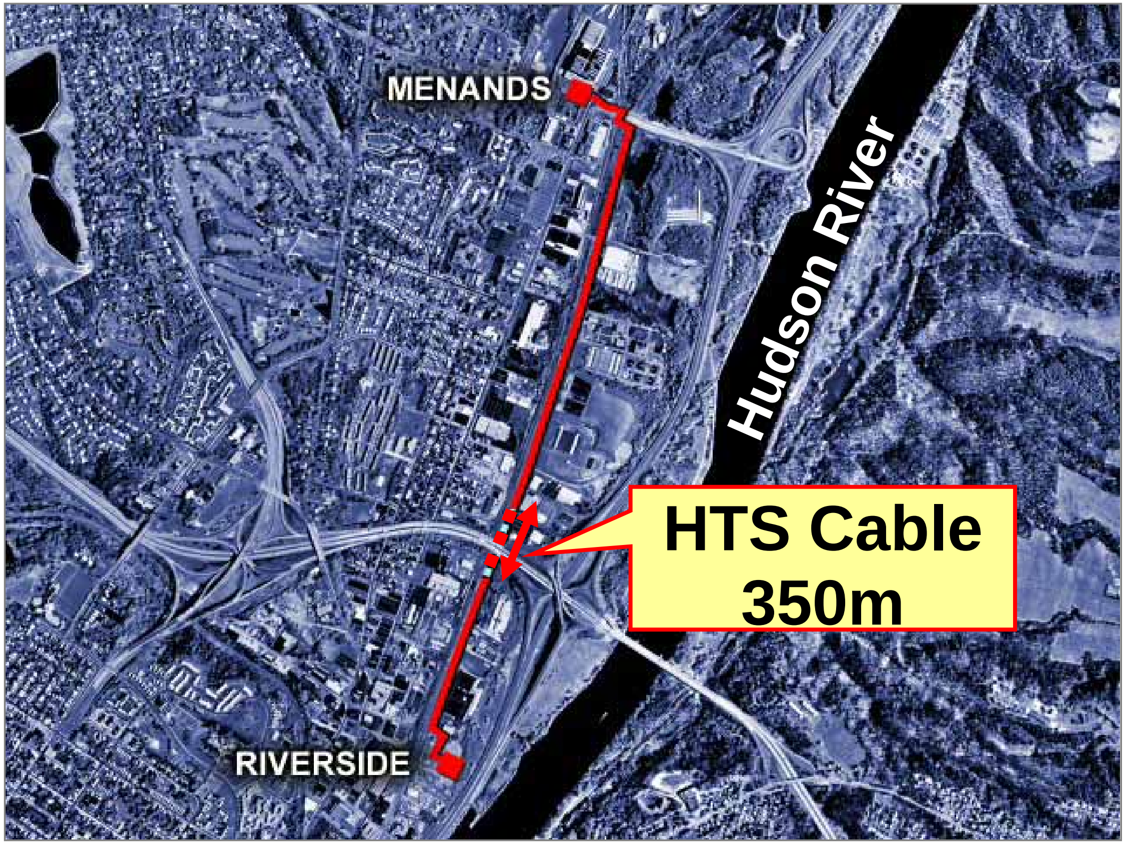
	TEPCO-SEI	Southwire-IGC	NKT-NST	Pirelli-AMSC
Government Funding	None (100% Private)	DOE	Denmark Gov.	DOE
Ratings	66kV/1kA 114MVA	12kV/1.25kA 27MVA	30kV/2kA 103MVA	24kV/2.4kA 100MVA
Length (m)	100	30	30	120
Type of cable test	In-plant test (Yokosuka)	Internal power transmission line (Carrollton)	Internal substation line (Copenhagen)	Internal substation line (Detroit)
Dielectric type	Cold dielectric	Cold dielectric	Warm dielectric	Warm dielectric
Features	Triple-core in one cryostat/ flexible type	Single-core/ rigid type	Single-core/ flexible type	Single-core/ flexible type
Test status	Laid:Feb.2001 Started: June 2001 Ended: June 2002	Laid: 1999 Started: Jan. 2000	Laid: 2001 Started: May 2001 Ended: 2003	Laid: 2001 Not Started.

International Collaboration



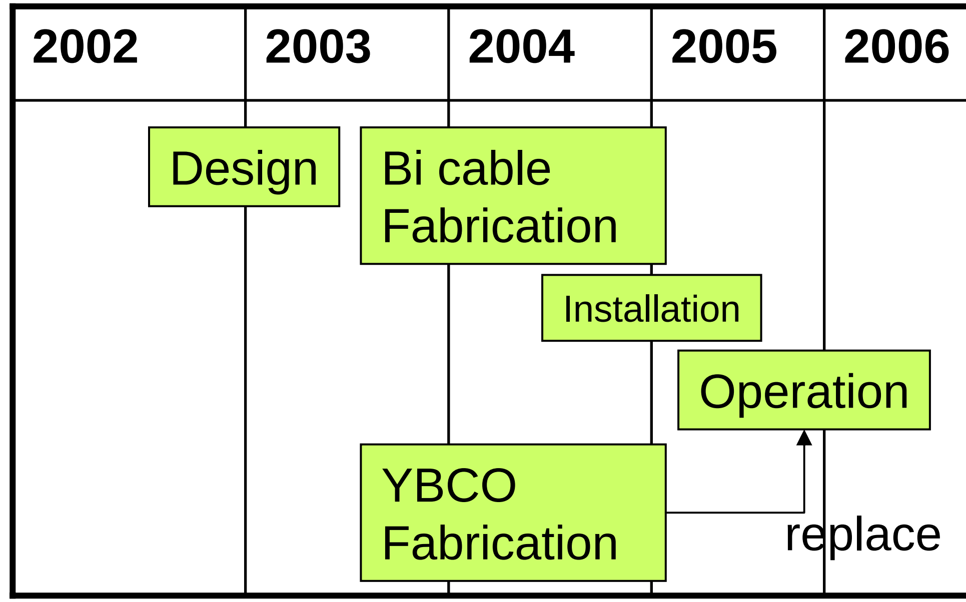
Albany Project

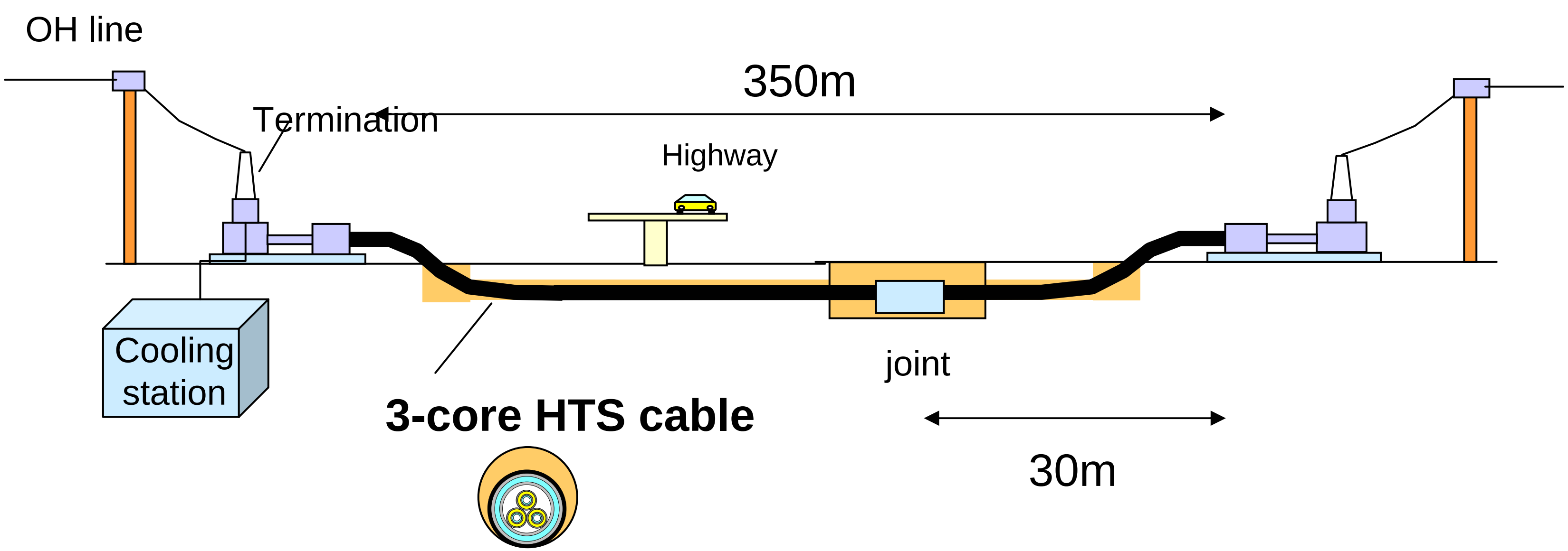
Purpose: Demonstration of the long length HTS cable in the real net work in US
Members: Super Power / SEI / Niagara-Mohawk /BOC
Project cost :26M$ including NY (6M$) and DOE(13M$)



Albany Project Outlook

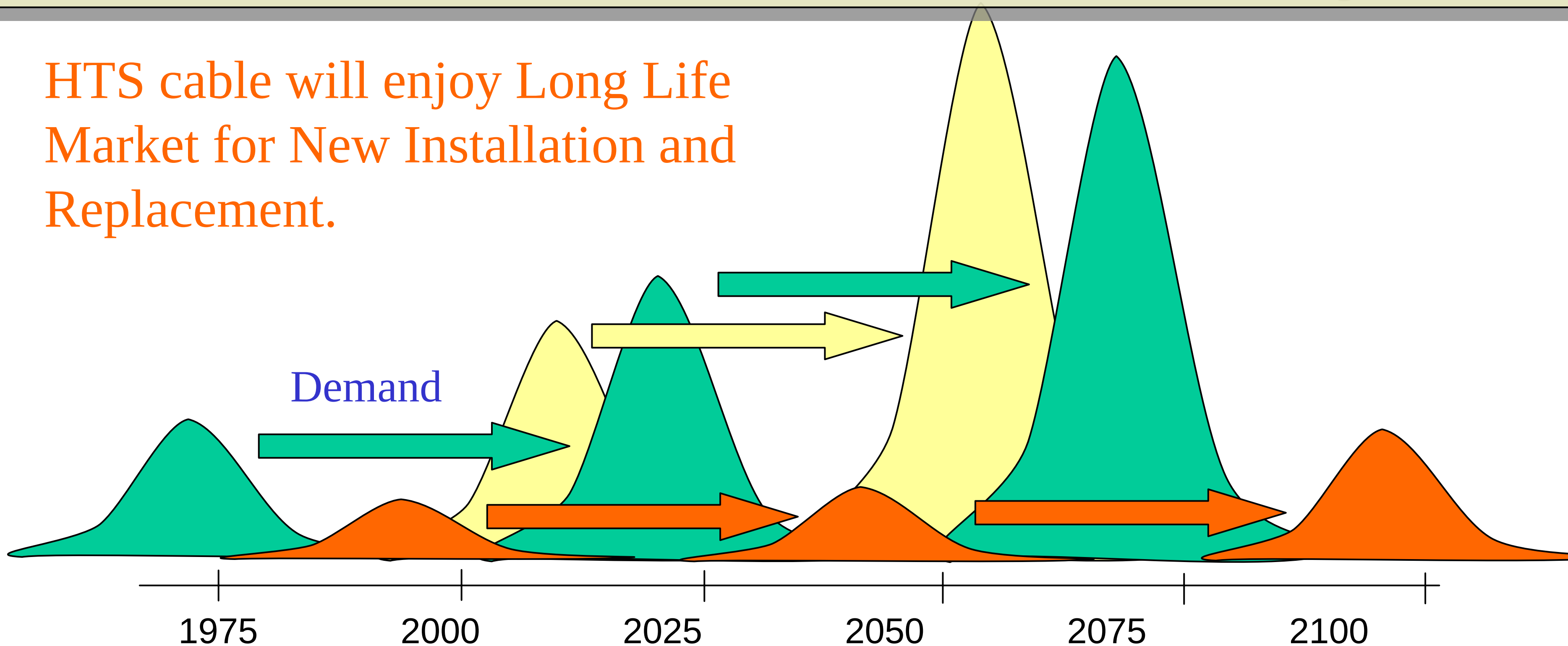
Length :350m
Voltage: 34.5kV
Current: 0.8kA





Power cable market of 21th Century

HTS cable will enjoy Long Life Market for New Installation and Replacement.



	Capacity of Generation*	Demand growth rate (%/yr.)	Demand doubling year	Peak of renewal	Capacity ratio (2020/2003)
Japan	260GW	0.7%	100	~2040	1.1(286GW)
USA	860GW	2.0%	35	~2010	1.4(1200GW)
Korea	50GW	9.0%	8		3.7(185GW)
China	320GW	6.0%	12		2.7(860GW)

* (investigated at 2003)

Conclusion

(I) 3 HTS Cable Demonstrations in Yokosuka (Japan), Copenhagen (Denmark) and Carrollton (US) were successfully implemented.

(II) 3 Bi-based Cable projects have started in US under international collaborations. Also, HTS cable Projects are on-going in Korea and China.

(III) Big Innovation of Bi-based wire has been achieved. Ic, Mechanical Properties, Anti-Ballooning Properties and Yield of Bi-Based wires are simultaneously improved greatly.

(IV) HTS Cables with Large Transmission Capacity and Low Loss are Environmentally Friendly, hence Indispensable for 21st Century's Power Grid.

↓

HTS's Era is about to dawn !