PV R&D trend in Japan and Sahara Solar Breeder plan

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1, Global energy and environmental problem is a matter of oxides

2, Recent trend of PV R&D in Japan

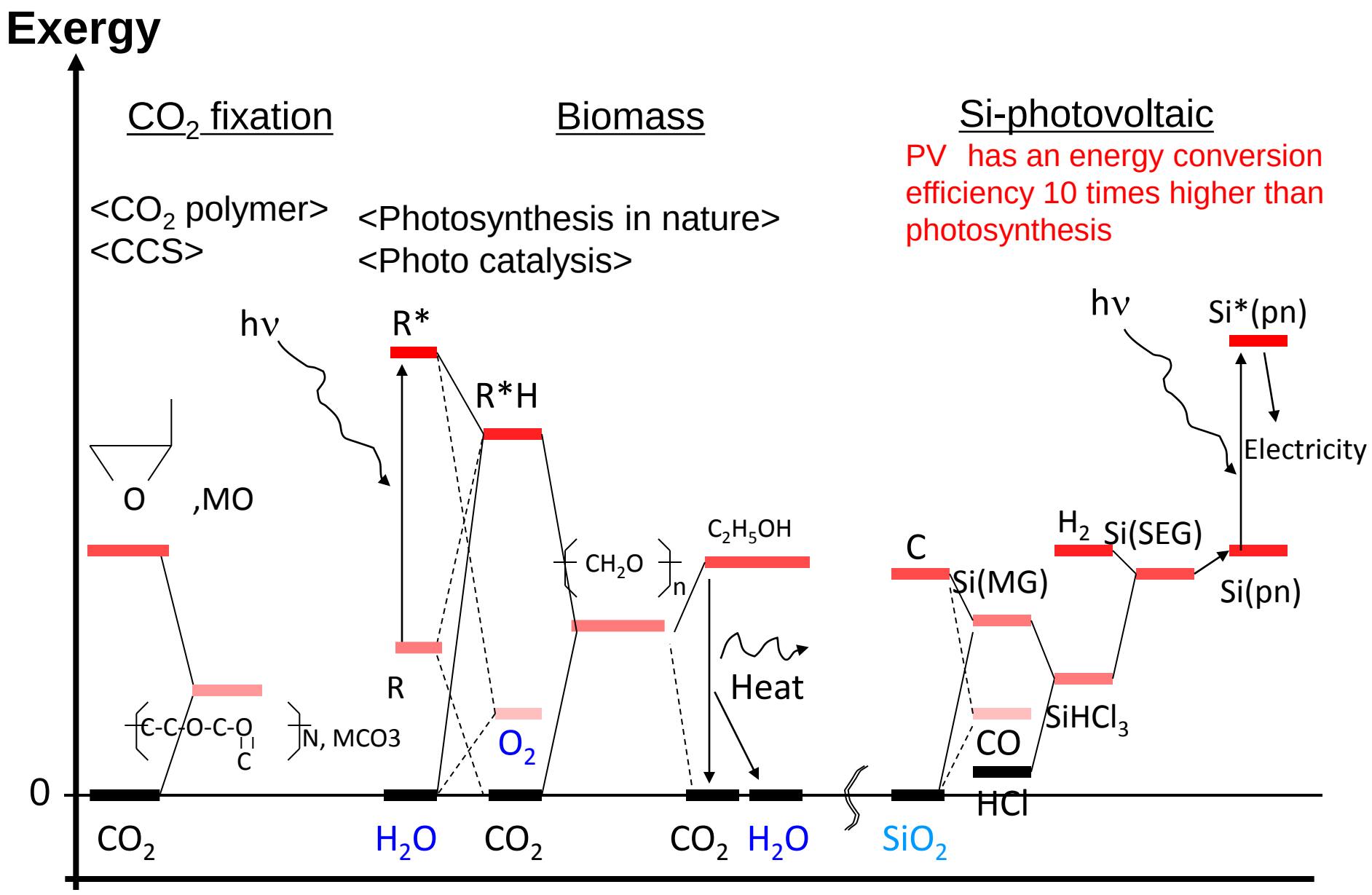
NEDO sun shine project to push up Japan as world leader in PV till 2006

FIT and Si Shortage shock

Current R&D direction of PV research and industry in Japan

3, Sahara Solar Breeder plan

Is it a crazy fiction or the dream of Super Apollo Project ?

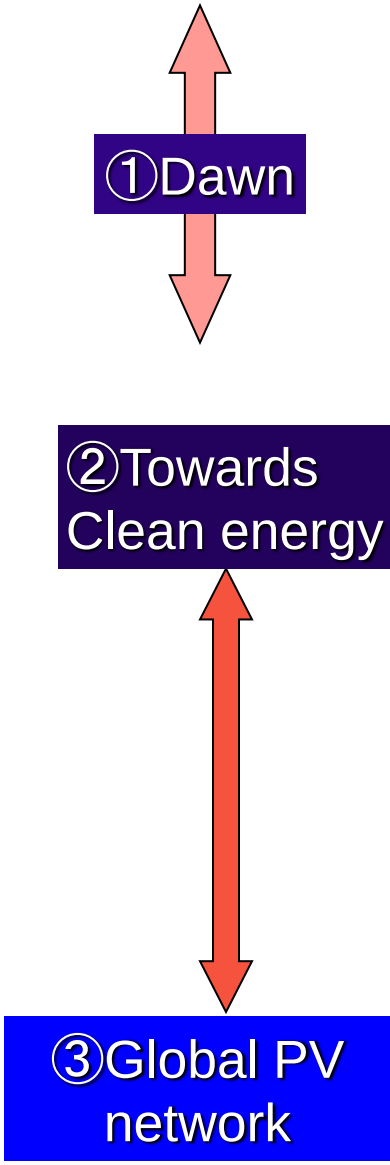


Global energy problem is resulting from accumulation of zero-exergy oxides

(H. Koinuma, IAC-WS061216)

History of solar cell

1954 sc-Si solar cell（Pearson）
1973 1st Oil shock
1974 Start PV National project in US, Europe, and Japan (Sun shine PJ)
1975 Discovery of valence control in a-Si:H (Spear)
1979 2nd Oil Shock → 1st PV boom
1980 Production of a-Si solar cell (for calculator, Sanyo)
1986 Discovery of HTSC
1988 Realization of global environmental problem
1989 Genesis plan (proposed by Kuwano)
1992 NEDO starts supporting for private PV houses
PV field test for public facilities
1996 New energy promotion guide lines
2002 Kyoto protocol (CO2 reduction guideline)
2004 PV Road map towards 2030（PV2030）
(FIT started in Germany) → 2nd PV boom
2005 Reaching GW scale PV annual production
2007 Sahara solar breeder plan (HK and KK)
Si shock hit Japan
2010 Present
2030



Various types of solar cells

1. Bulk semiconductor

c-Si : High efficiency and reliability

(Sharp, Kyocera, Sanyo-HIT, Mitsubishi, etc)

2. Thin films

a) Group IV: a-Si:H, μ c-Si系、a-SiGe

(Kaneka, Fuji, Mitsubishi, Sharp, etc.)

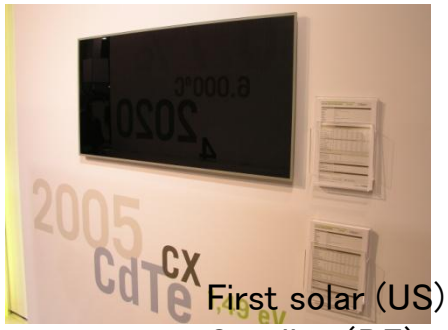
b) Compounds : InP/GaAs/Ge, CdTe, CIGS

(Sharp, Showa Shell, Honda)

c) New materials : InGaN , Dye、Organic

d) New concept : Quantum dots

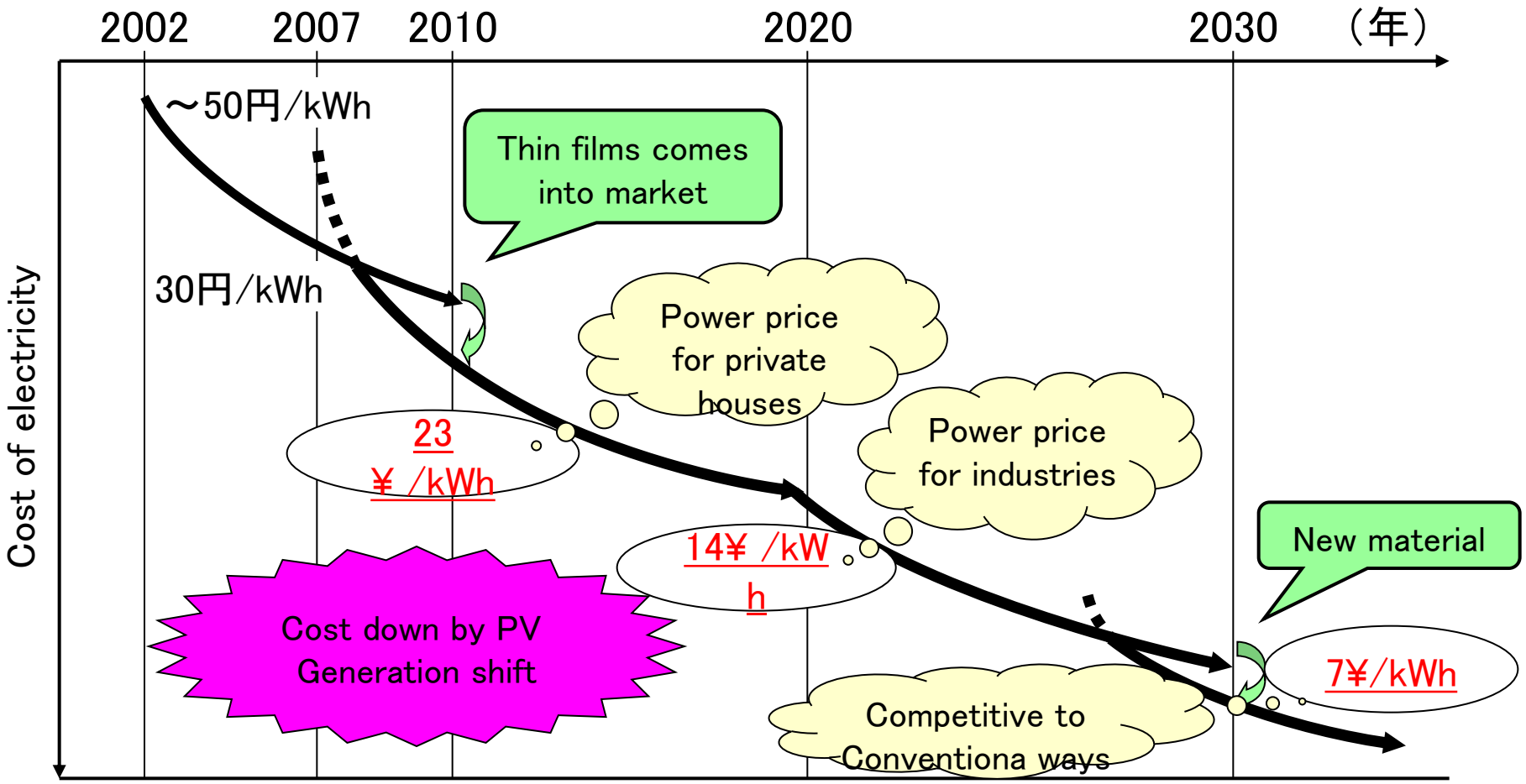
In general, c-Si cell has twice as high conversion efficiency as current thin film cells



First solar (US)
Q cells （DE）

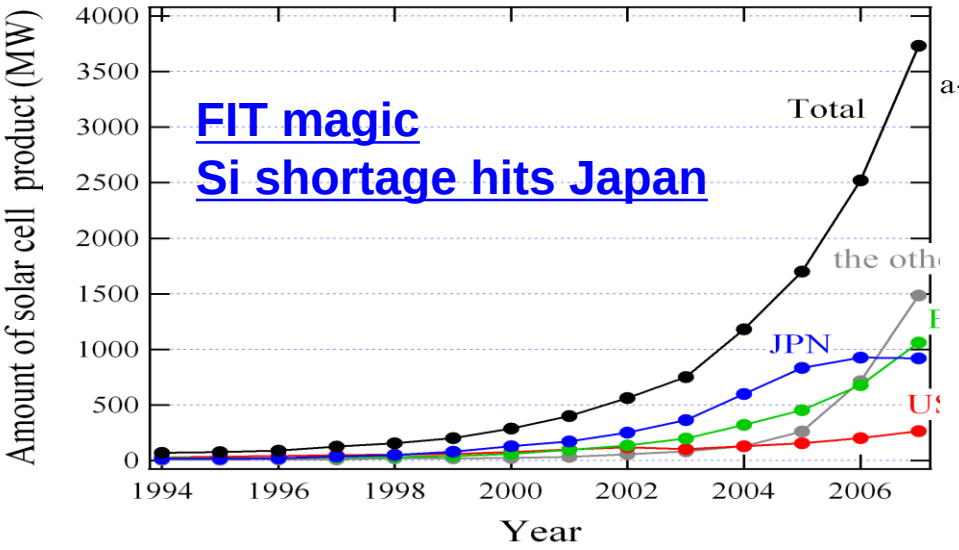
有機太陽電池
Konaruka(US)

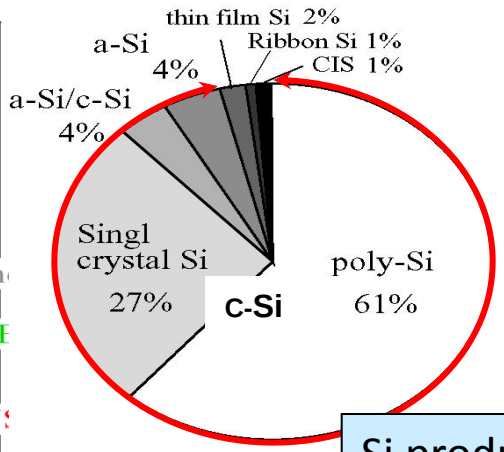
Road map of photovoltaic power generation (2003, NEDO)



出典：NEDO「2030年に向けた太陽光発電ロードマップ（PV2030）」
経済産業省「第2回評価検討会経済産業省提出資料」

Technology initiative and priorities





Si dominates PV material

Si production in the world
9 kt (1985), 36 kt (2006)

Key points to think about energy : Quality, quantity, cost
→What is the material to solve global energy crisis ?

Si weight to electricity
10g→ 1 W
1 t → 100 kW
10 kt → 1 GW（10 km²)

Solar cell resources vs. maximum PV energy

材料	形態	厚さ [um]	変換効率 [%]	希少元素	Wp/g	資源量 [10^3t]	エネルギー生成可能量[GW]
c-Si	Wafer	200	20	Si	0.1	∞	∞
	Film	20	15		0.75		
a-Si	Film	0.7	10	Si	19	∞	∞
CdTe	Film	2	15	Te	24	22	526.0
Ge	Wafer	200	15	Ge	0.14	4.4	0.6
	Film	0.5	15		60		250.0
$CuInSe_2$	Film	2	15	In	38	1.68	64.0
GaAs	Wafer	200	25	Ga	0.49	110	53.9
InP	Wafer	200	25	In	0.33	1.68	0.6

Only Si can afford
> 100 GW/yr. PV

Catastrophe in PV situation of Japan

Main factors:

1, Feed-in tarif

2, Global warming by CO_2

3, Oil supply drop and price jump

4, Shortage of SEG-Si production

9,000 t/ y (< 1,000 t for PV) in 1985

36,000 t/ y (>20,000t for PV) in 2006

-Semiconductor device market increased more than 10 times during this period, but demand for Si is not as much due to higher integration

-Large surface coverage (area) is essential for PV

Si ~100 kt/y for PV in 2010 (world) →10GW solar cell

This amount is still far below the scale of steel production

Fe ~ 100 Mt/y in Japan, 2010: 4-orders of magnitude higher than Si

5, Japan's option to innovation

→ Thin film, High efficiency (Escape from Si crystal ?)

Japan's current strategy to overcome Si feedstock shortage

7 yrs. Program (2008-): *International R&D centers for innovative solar photovoltaics*

- Target: η>40 % by 2050 at a cost competitive to conventional electricity
- 3 key centers for industry-academia collaboration: AIST, Tokyo Univ., and Tokyo Inst. Tech.
- Funding : about 7 M$ each annualy
- Focused on multi-heterojunction thin films and quantum dots (using concentrators)
- No funding for Si crystal feedstock

3rd Symp. on innovative PV @Tokyo Tech. 101007-8

October 7, Thursday

10:30-10:45 Opening: M. Konagai, Tokyo Tech. and S. Watanabe, METI

Session 1 (10:45-11:15)

(Invited) "Renewable Energy Policy in Japan" by T. Kashiwagi, Tokyo Tech.

Session 2 (11:15-12:45)

- "Recent Progress in Thin-Film Full Spectrum Solar Cells" by M. Konagai
- "Post-silicon Solar Cells for Ultra-High Efficiencies" by Y. Nakano, Tokyo U.
- "High eff. thin film solar cells using a smart-stack technologies" by M. Kondo, AIST

Session 3 (14:00-16:00)

-*(Invited)* "Building blocks for high eff. c-Si Solar Cells" by J. H. Werner, Stuttgart U

-*(Invited)* "Thin-film crystalline silicon solar cells at imec" by I. Gordon et al., imec, Belgium

-*(Invited)* "Design and characterization of a plasmonic back reflector" by D. Bagnall, Southampton U.

-*(Invited)* "Ultrathin silicon solar cells with nanopatterned plasmonic back contact" R.E. Schropp, Utrecht U.

16:00-16:15 "Development of c-Ge Heterojunction Solar Cells"

16:15-16:30 "Type II Si Clathrate as a Novel Semiconductive and Photosensitive Material"

16:30-16:45 "Development of multi-cell interface junction layers in thin film solar cells",

16:45-17:00 "Fabrication of p-type TCO thin films with high conductivity"

17:00-18:20 **Poster session**

October 8, Friday (9:00-17:00) Sessions 4-7

What to do with Energy and Environment crisis

UN and Summit: 1997 Kyoto protocol, 2009 COP-15@Copenhagen

Commitment of Academia

G8 (US, UK, Fr, Jp, Ge, It, Can, Ru) + 5 (China, In, Br, S-Af, Mx) Academies'

Year	Country	・・・・・Global issues discussed ・・・・・・・・・・・・・・・
2005	UK	1) Global action against climate change,
		2) Science & Technology for Africa
2006	Russia	1)Energy sustainability and security,
		2) Bird influenza & infective diseases
2007	Germany	1) Energy efficiency and climate conservation,
		2)Innovation
2008	Japan	1) Climate change : Adaptation and Change to low-C society,
		2) Global health
2009	Italy	1)New technologies for energy,
		2)International migration

<Policy> of Science Council of Japan (SCJ)

Proposal @Rome meeting (Mar.26-27, '09)

Let's move forward for future and sustainable earth by

"Sahara Solar Breeder Plan

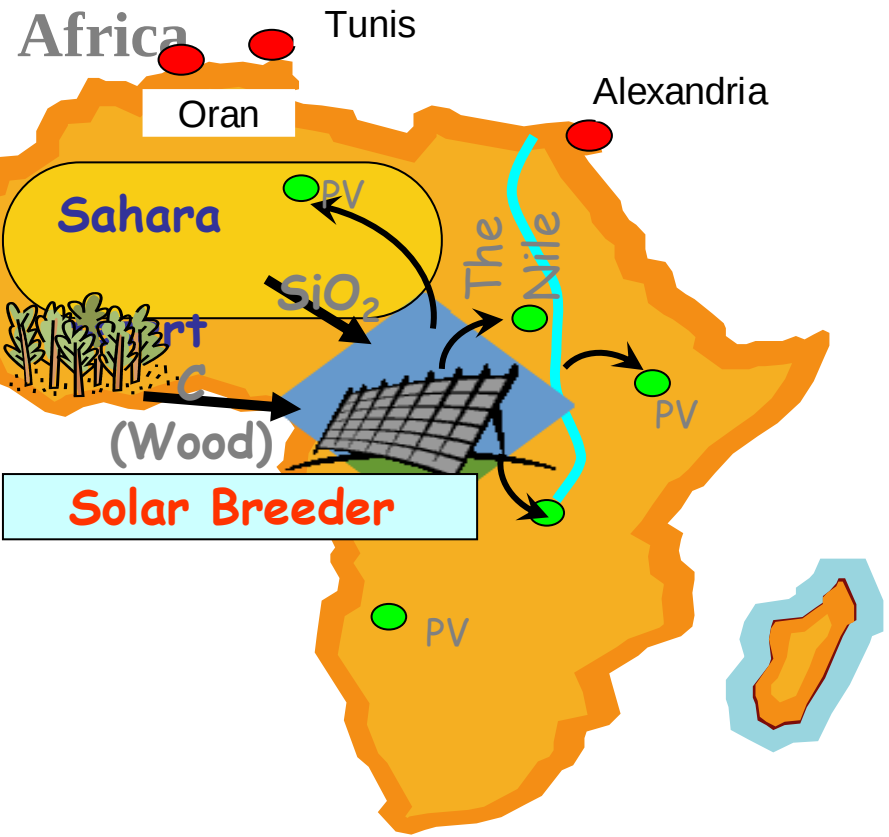
directed towards global clean energy superhighway"

Sahara solar breeder plan

(Solar Tunisia Int'l seminar 091211)

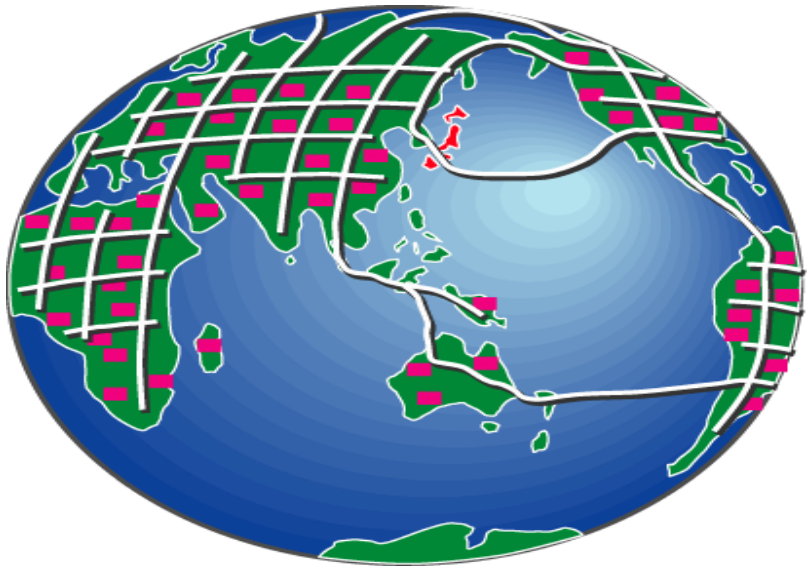
directed towards global clean energy superhighway

H. Koinuma (Tokyo Univ.) and colleagues in SCJ, JST,JICA, TITEC, NIMS, PVTEC



towards
Global dc transmission Network with HTSC cable

World wide energy network: A dream to come true



PV plants to make SOG-Si and solar cells using resources (SiO_2, etc.) and solar power in the desert
Eg.
Start from e.g. 2MW/2 yrs (Si 10t/yr)

JAPAN as an advanced problem solution country

Preceded by many energy and environmental crises

Japanese high technologies evolved from problems

- **Shinkansen: Bullet train (1964-) and Super-MAGREV (in progress)**
- **Hybrid car**
- **Catalyses to minimize chemical pollution (1960s-)**
- **Sun-shine project to promote PV research (1974-)**
- **Discovery of various new superconductors (1986-)**
  (LSCO, BSCCO, MgB2, CoO based Oxide, Fe-As-O)
- **Superconductor (Alloy and High-Tc) cables**

Proposals of Africa and intercontinental Solar systems

- **1, GENESIS: Global Energy Network Equipped with Solar cells and International Superconductor grids (Kuwano 1989)**
- **2, IEA's PVPS Task (Kurokawa et al., since 1996)**
- **3, MSP: Mediterranian solar plan (Paris, 2008)**
- **4, ICSU Regional office for Africa Science plan:**
  Sustainable energy in sub-Saharan Africa (2007)
- **5, Desertec: Solar thermal electricity for EU**

Sahara solar breeder plan (SCJ, 2007; G8+5@Rome, 2009)

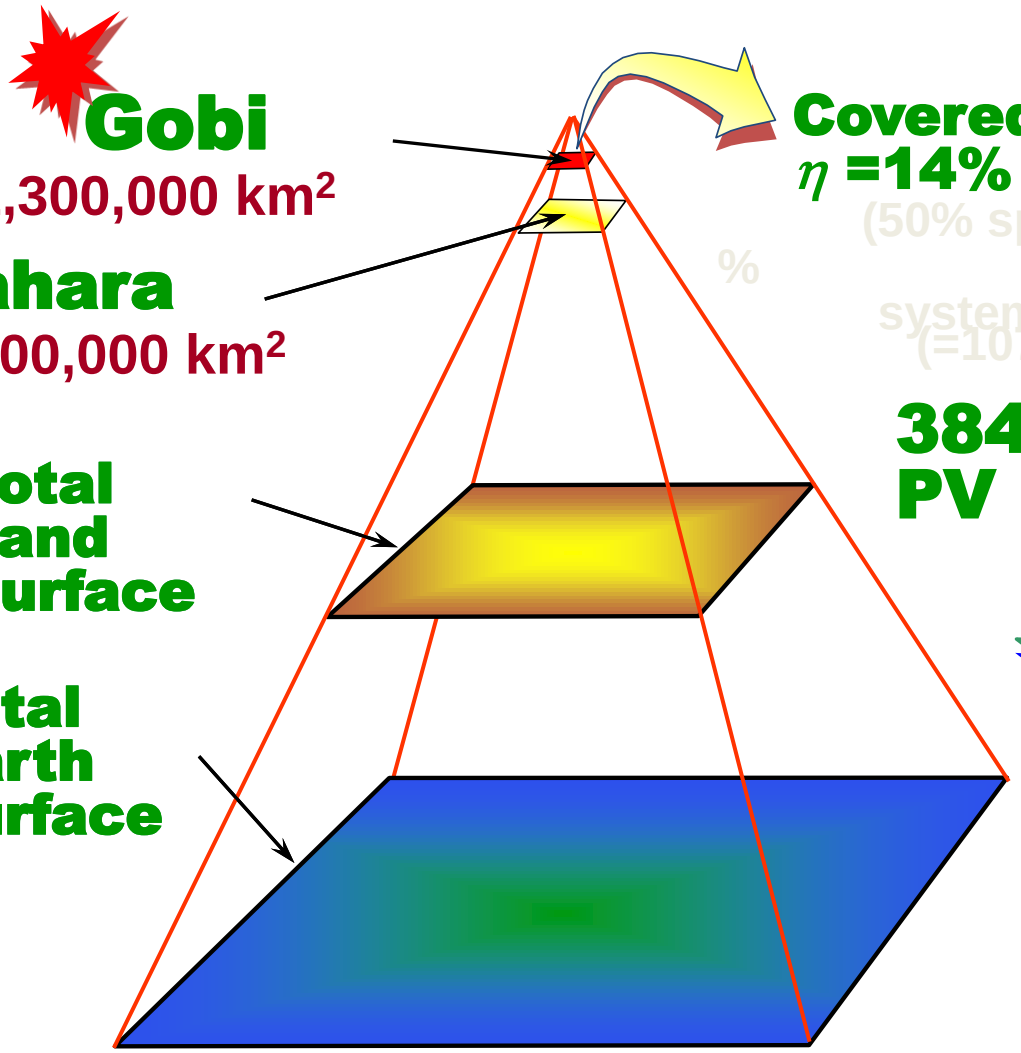
- Not an assembly of known technology, but start from basic R & D
-Coupling of PV and HTSC for clean energy generation and energy-saving transmission
-Education and training for science and technology of African people
-For solving global crisis by international cooperation by grid-parity PV

HK.@TU & NIMS0912

Solar Pyramid: PV Systems for 21st Century

IEA PVPS Task 8 Activities（Kurokawa et al.)

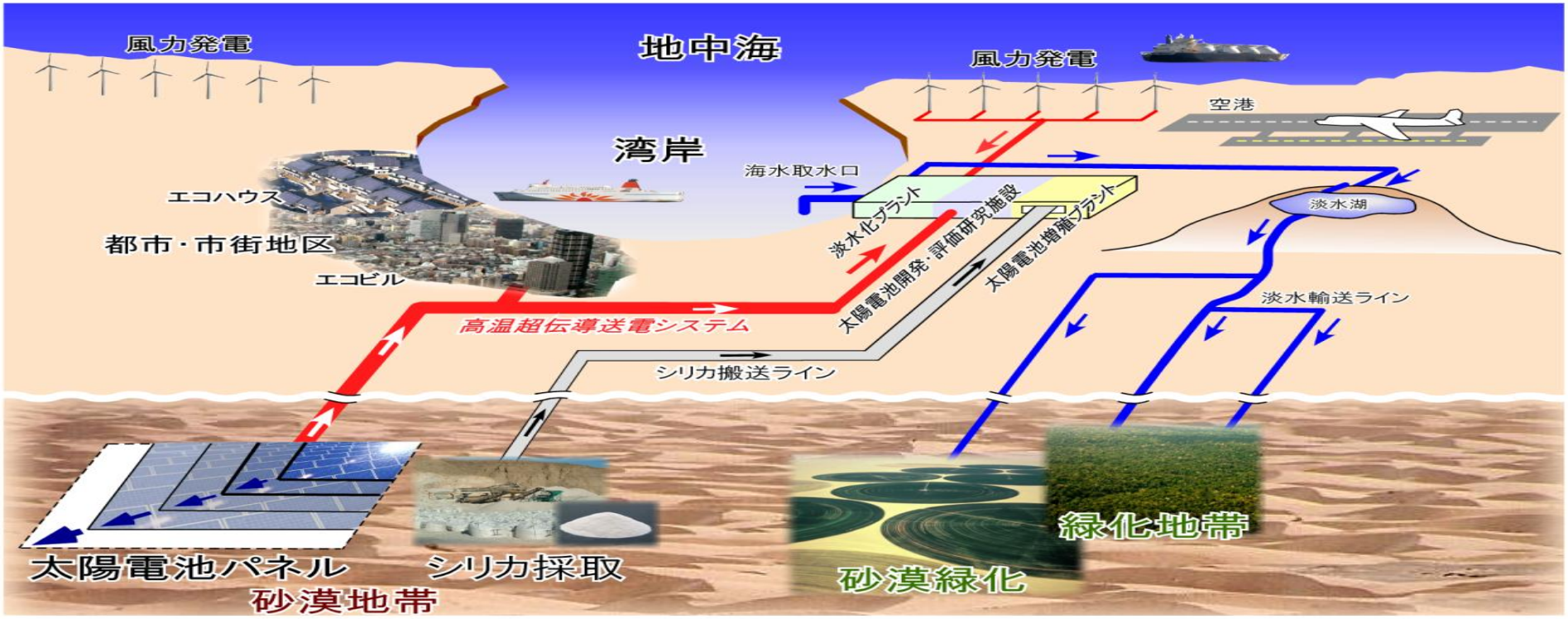
Study on Very Large Scale Photovoltaic Power Generation Systems

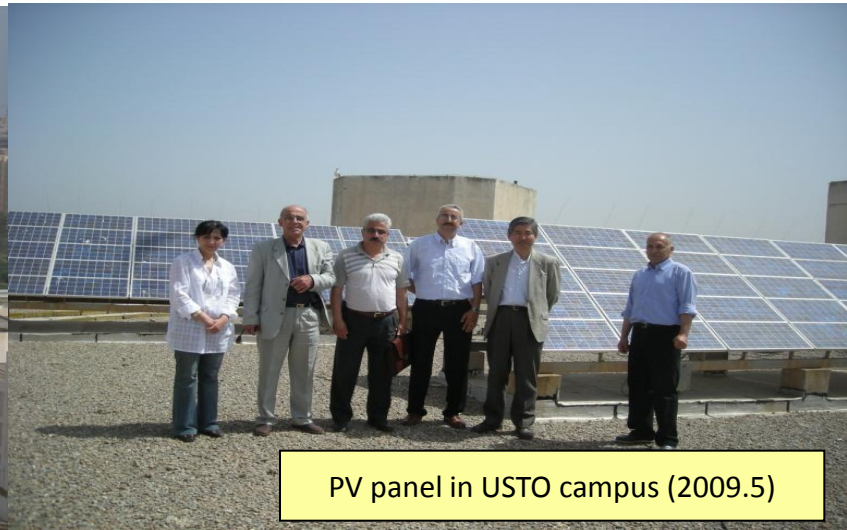


Desert is a treasure island of energy resources

SSB initiative in North Africa by JST/JICA support for SSERC project

Materialize the 3rd value of the desert



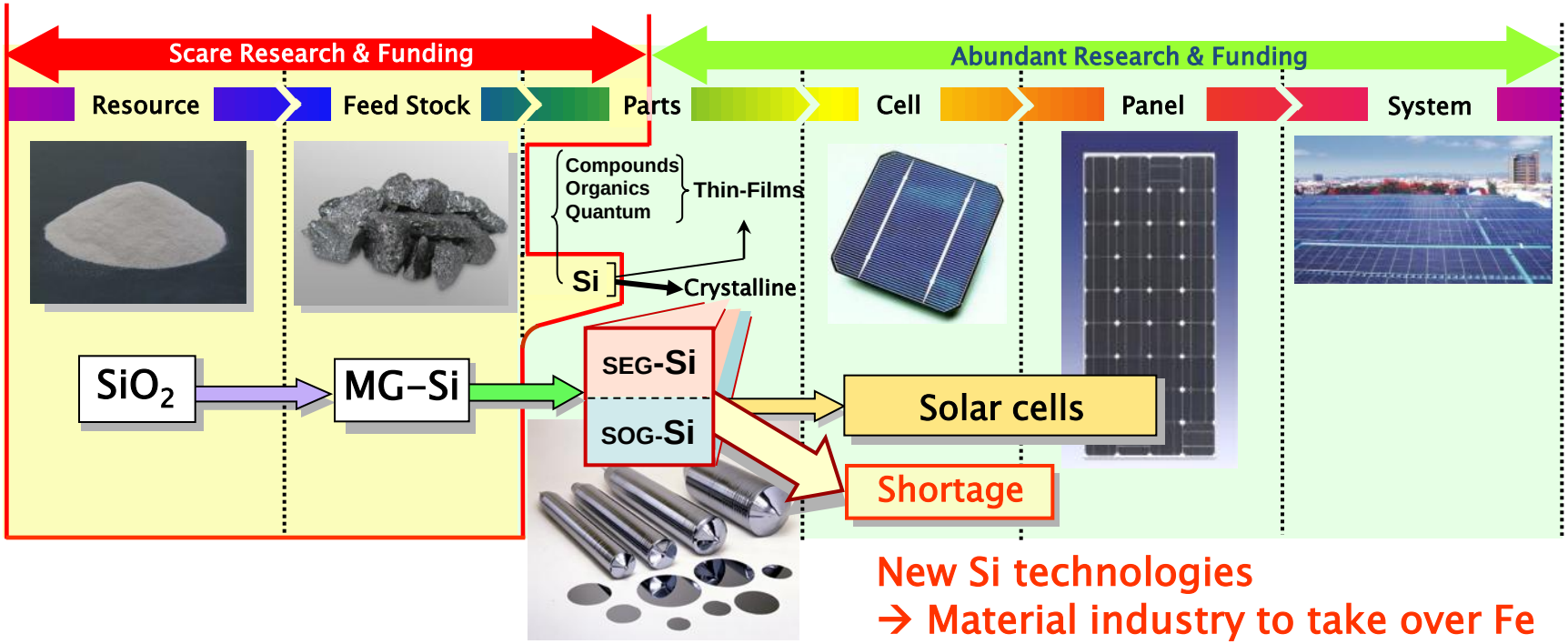


PV panel in USTO campus (2009.5)

<Innovative technologies for PV>

Solar Si materials and focused research targets

Flow chart from natural resources through Si-PV system



New Si technologies
→ Material industry to take over Fe

Defects in current Si process

I. Batch process
II. Low rate
III. Low yield
IV. Need of precursors

Innovation

Innovation

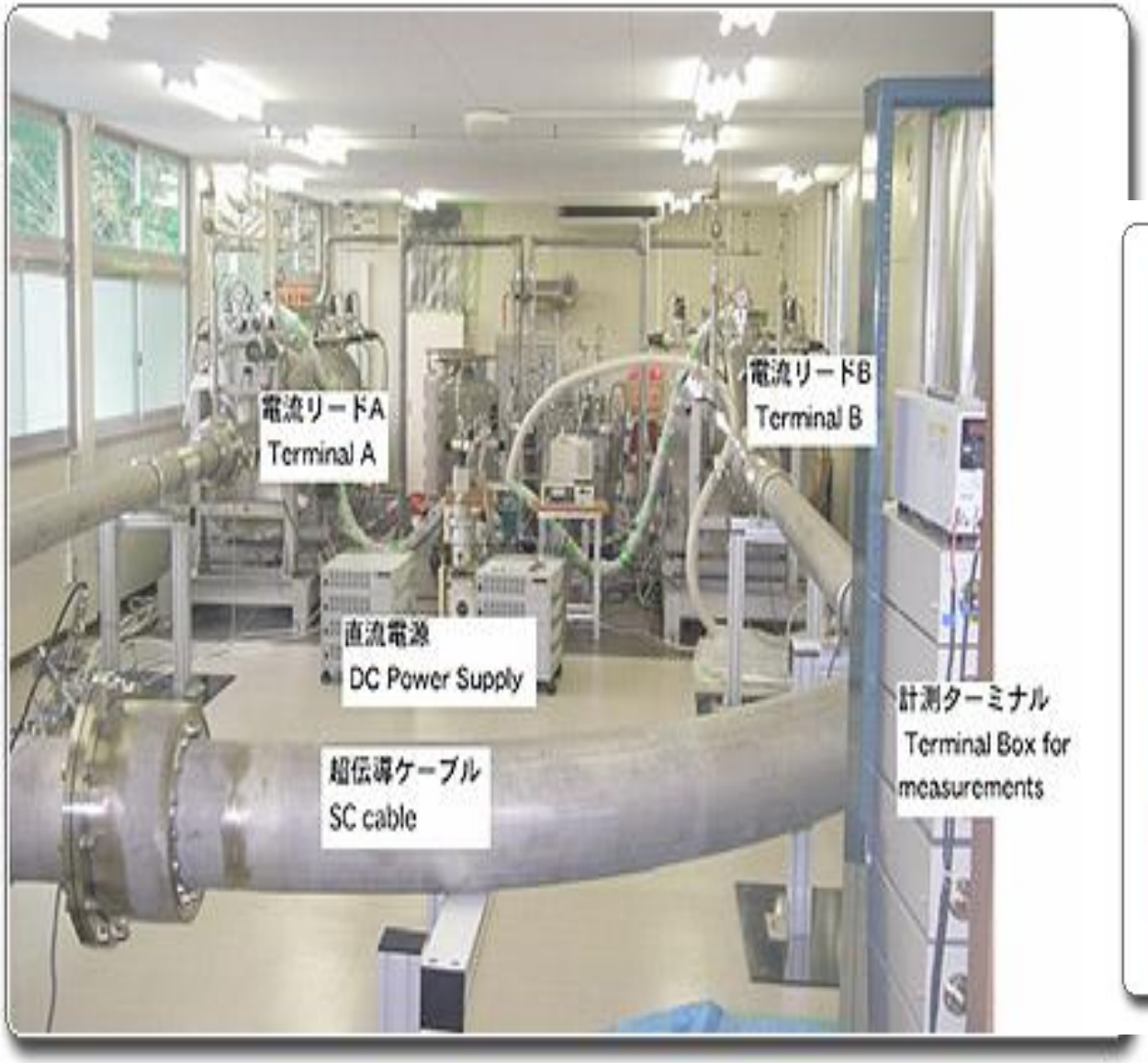
To jump up reaction rate and yield of current process
(1) New CVD: SiHCl3 + H → Si
To change SiO2 feed into sand and improve purity
(2) Direct reduction :
SiO2 (Silica sand) + C → SOG-Si
To improve substrate fabrication
(3) New Si Sheet technology

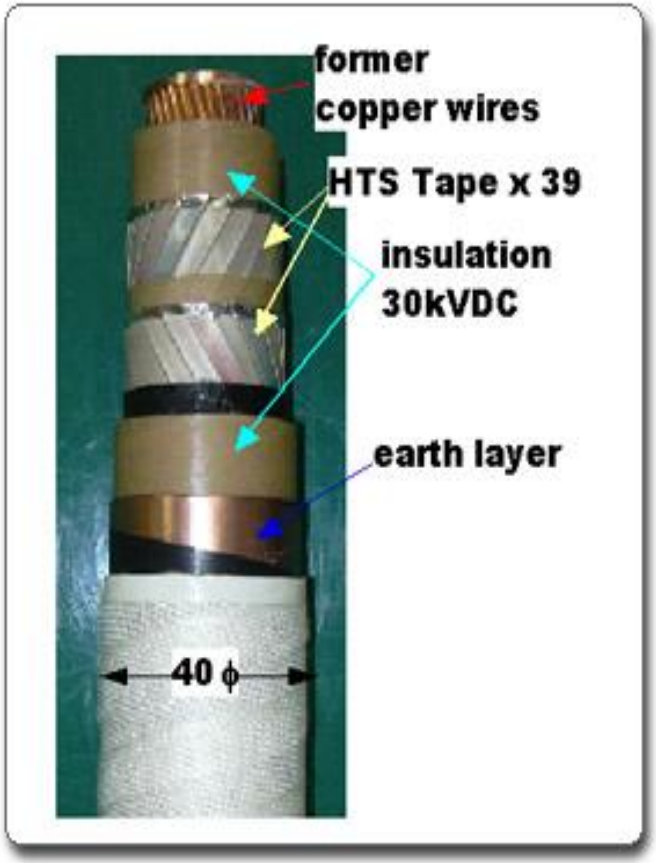
Now we have ~350 Nuclear Stations in the World,
we will make ~2000 Nuclear Stations in 21st Century

Europe (mid night) ⟶ Japan (day time)
Europe (day time) ⟵ Japan (mid night)

DC superconducting power transmission system connecting Europe with Japan through China and Russia.

The cheap electricity in early morning and mid night area will be sent to the daytime area each other. This business model will enhance and contribute to the global peace because we must be connected deeply. (Yamaguchi@Chubu Univ.)





DC power transmission test line @Chubu Univ., Japan

SSB Plan: Coupling of PV from the desert and HTSC

- **Shift of global energy system：**

  Fossil fuel / pipe line, tanker → PV ＋ HTSC Hwy.

  （High-C, Energy wasting society ）（Low-C, sustainable society）

- **Shift of industrial structure**

  Stem Material: **Steel → Silicon , Super oxides**

  Core Product: Car → Solar cell, HTSC application

- **Key word: Back to Nature !**

	Apollo project （For the dream to space and US)	**Super Apollo Project** (For the future of space ship 'earth')
When	1961-1969	2010（Inauguration of SSB age)－?
Why	Space exploration、Military	Future of earth、Clean energy
What	Rocket, IT for control and measurement, Moon landing	PV, HTSC cable technology, New energy network
How	Concentration of human resources、Money (22 B$ up)	Si chemistry, PV@ deserts, DC grid, Fund, Global consortium
Where	From earth to moon	From Japan-Africa to the world
Who	NASA, USA	**SCJ→ SSEC → SSBF ?**