Setting the Scene surrounding Nanotechnology in Japan

International Symposium on Assessing the Economic Impact of Nanotechnology

March 27, 2012

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1. Evolution of Nanotechnology

1980 1990 2000 2010 2020

ERATO(1981) JRCAT(1992) | *NNI and national nanotech projects*

Progress Nano (1st generation)

Progress of Nano-world (1-100nm) in each independent discipline via top-down, bottom-up or combination process

TEM,STM,ALE,lithography, CNT, computer science, omics

Fusion Nano (2nd generation)

Interdisciplinary fusion of nano-worlds of different disciplines, producing new function of material, process or device

low-k material via block-copolymer process, chemical biology

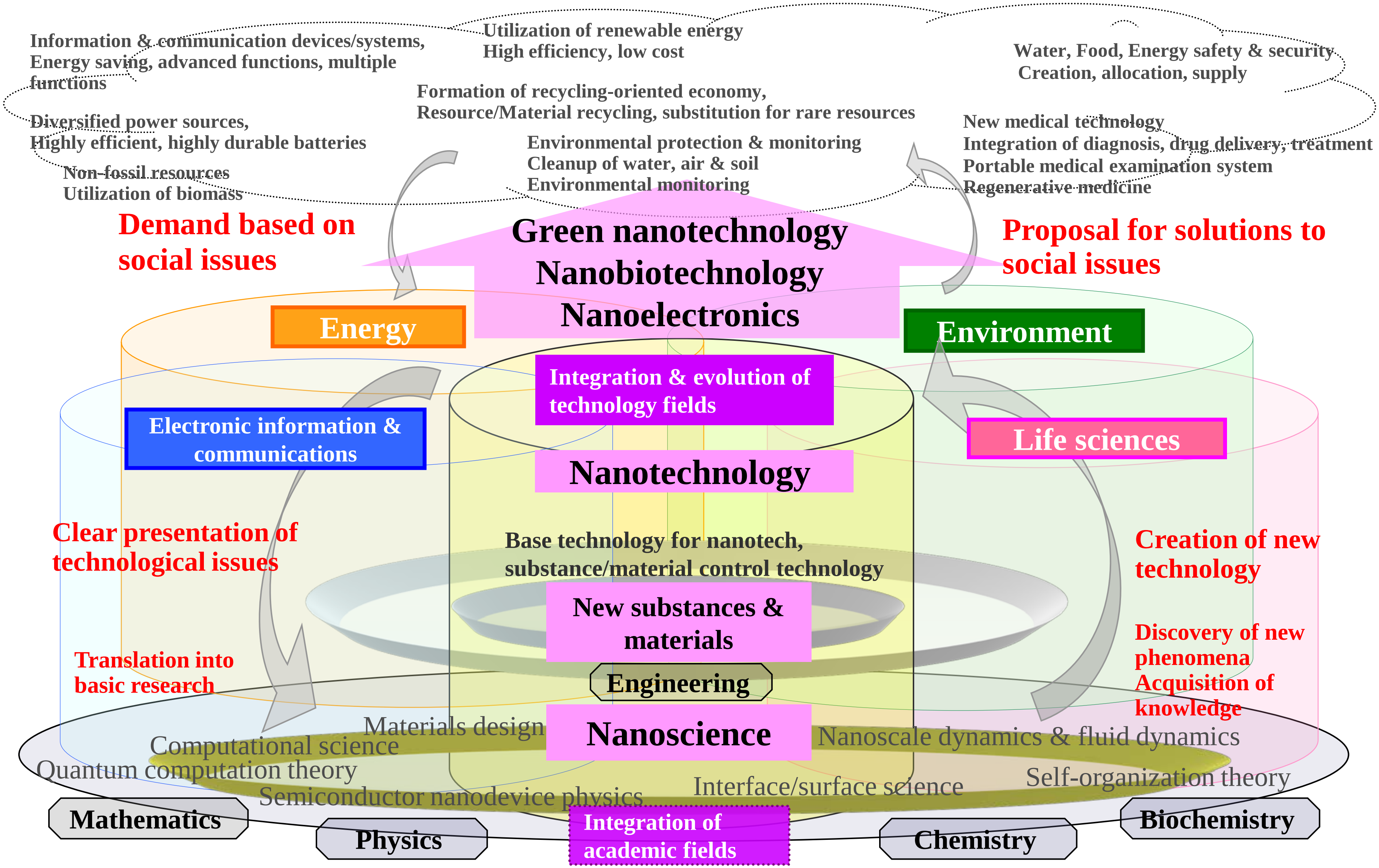
Systems Nano

Integration of various nano-worlds into functional systems

materials design, molecular electronics, ceranostic medicine, hierarchical self-assembly of systems (→innovative products)

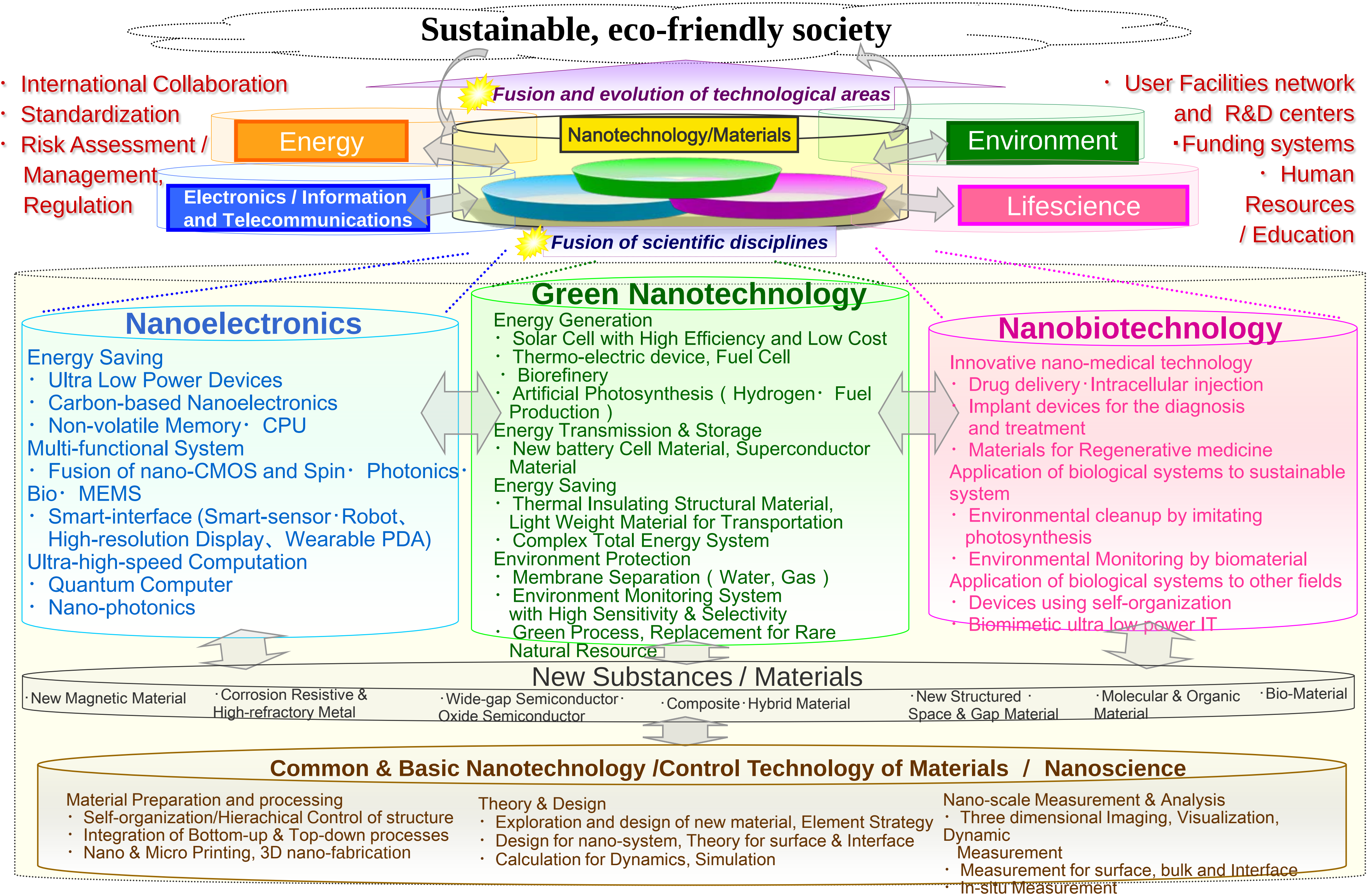
Engine for Innovation

2. Role of Nanotechnology toward Sustainable and Eco-friendly Society



(Source) Center for Research and Development Strategy, Japan Science and Technology Agency, "CRDS-FY2010-SP-02 Nanotechnology – Grand Design in Japan", March 2010

3-1. Major Issues of Nanotechnology toward Sustainable and Eco-friendly Society



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3-2. Major Issues of Nanotechnology toward Sustainable and Eco-friendly Society

Field

Green nanotechnology

- High-efficiency thin-film solar cells (20%)
- Fuel cells: SOFC/PEFC
- Search for & design of new rechargeable battery materials
- New thermal insulating structural materials (Construction materials, Transportation)
- Search for new superconductors
- Materials for light transportation
- Low-pressure, high-strength separation membranes for environmental cleanup (Water, Gas)
- Ultra-low-friction materials (Nanotribology)
- Substitutes for rare natural resources
- Room-temperature fabrication process (Energy saving, Resource saving)
- Thin-film organic solar cells (20%)
- High-efficiency thermoelectric elements (ZT＞3@Room temperature)
- Low-cost, long-life rechargeable batteries
- Superconducting power transmission
- Radiation-resistant self-repairing materials (Nuclear power generation)
- Low-cost, high-efficiency solar cells (7 yen/kwh,30%)
- Ultra-high-efficiency solar cells (Concentrator, multiple-junction, ≥60%)
- Platinum-free fuel cells (PEFC)
- Hybrid smart energy systems
- Biorefineries (Same cost as petroleum)
- Artificial photosynthesis (Hydrogen & fuel production)

Nanobiotechnology

- Materials for regenerative medicine
- DNA chips
- Protein chips
- Nanoscale drug delivery systems
- Molecular imaging
- Environmental monitoring with biomaterials
- Advanced regenerative medicine
- Cell chips
- Integrated system of drug delivery, diagnosis & treatment
- Information devices utilizing self-organization
- Implanted diagnostic/treatment devices
- Metabolic chips
- Environmental cleanup imitating photosynthesis
- Intracellular nanosurgery
- Intracellular 3D imaging
- Ultra-low-power biomimetic IT

Nanoelectronics

- Flexible electronics
- Carbon-based nanoelectronics
- Novel nonvolatile memory
- Integration of nano-CMOS & MEMS
- Smart grids
- High-resolution displays
- Smart sensor networks
- Integration of nano-CMOS & photonics
- Silicone nanophotonics
- Wearable PDAs
- Integration of nano-CMOS & spin
- Super-smart grids
- Integration of nano-CMOS & bio
- Spin-wave electronics

2015 2020 2030

(Source) Center for Research and Development Strategy, Japan Science and Technology Agency, "CRDS-FY2010-SP-02 Nanotechnology – Grand Design in Japan", March 2010

4. Impact of Nanotechnology on Industry and Economy; How to measure it

"Nanotech Inside"– difficult to recognize nanotech used in commercial products / T.Kawai (Osaka univ)

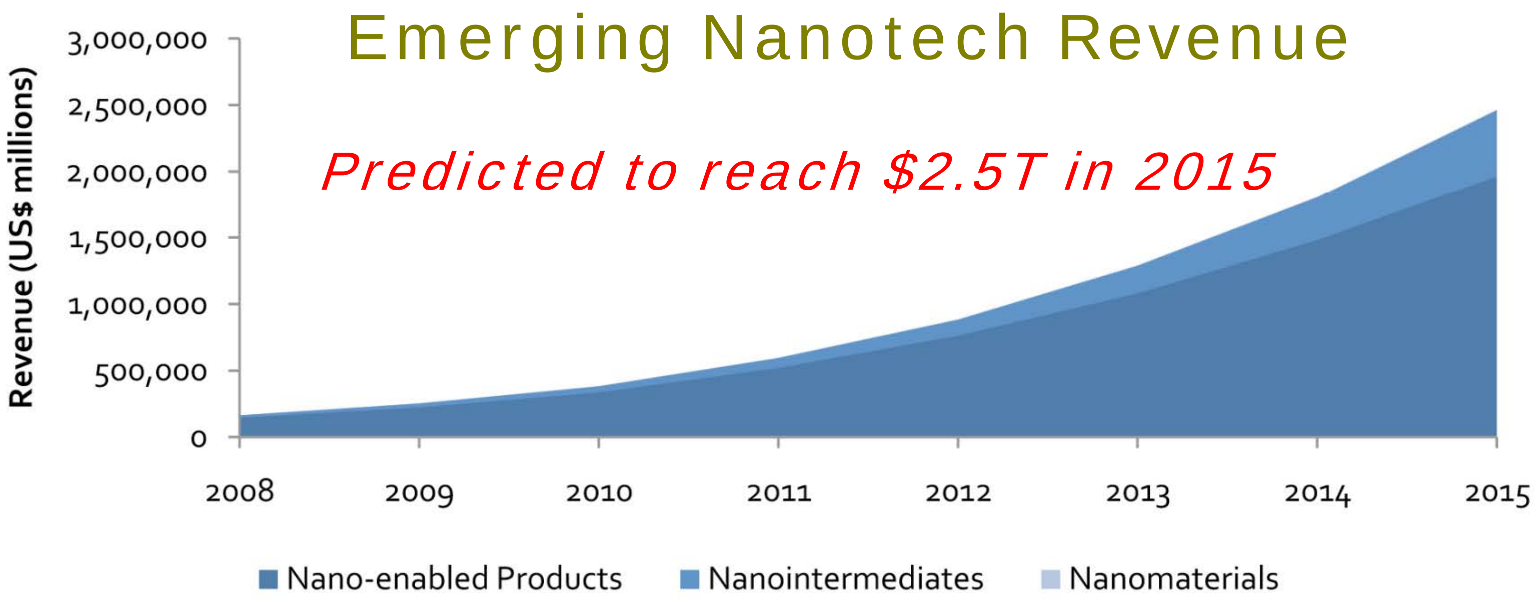
- Prediction of market size for the nanotech industry (Lux Research, Inc.)

  nanotechnology-based goods (2007) US$88B

  nanotechnology-enabled goods (2015) US$2.5T

- PEN project taking statistics of the number of catalogued nanotech products in the world (US)
- "NanoMark" system for promoting commerciallization of nanotech products (Taiwan)
- KoNTRS statistics on nanotech researchers, companies, and nanotech courses in univs (Korea)

5. A Challenge to measure; Nanotech-enabled Consumer Products



Value chain stage	2008	2009	2010	2011	2012	2013	2014	2015
Nano-enabled products	$145,291	$223,785	$336,062	$519,425	$762,204	$1,081,025	$1,480,928	$1,962,950
Nanointermediates	$18,353	$28,839	$45,592	$75,712	$120,206	$206,823	$322,691	$498,023
Nanomaterials	$812	$1,074	$1,309	$1,540	$1,798	$2,098	$2,462	$2,916
Total	$164,457	$253,699	$382,963	$596,677	$884,208	$1,289,947	$1,806,081	$2,463,890

Lux Research report, 2009
“The Recession’s Ripple Effect on Nanotech”

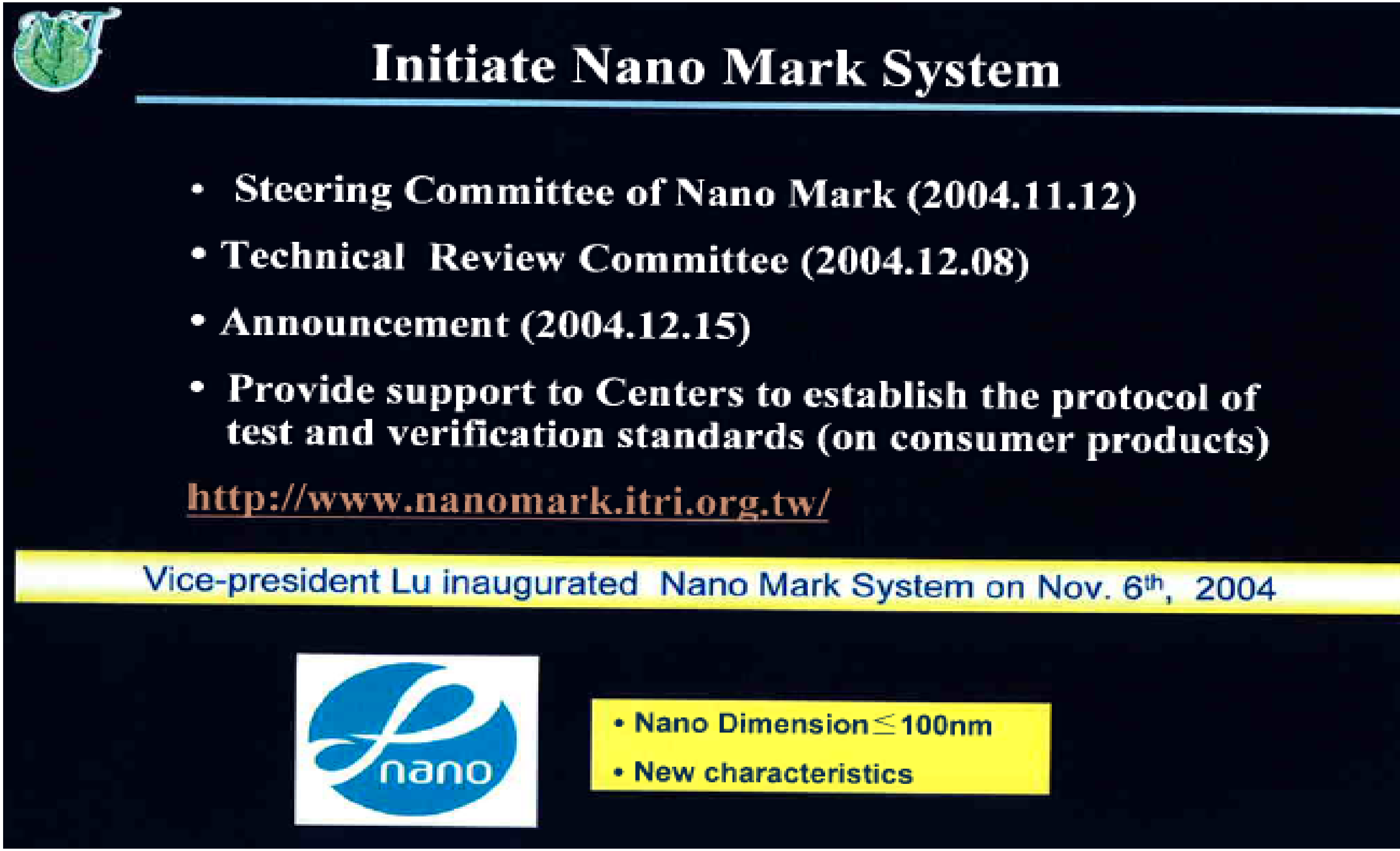
6. A Challenge to measure; Nanotech-enabled Consumer Products

Nanotechnology-based consumer products

As of March 2011, the inventory has grown by nearly 521% (from 212 to 1317 products) since it was released in March 2006

PEN, Woodrow Wilson International Center for Scholars
http://www.nanotechproject.org/news/archive/9231/

7. A Challenge to measure; Nano Mark System



Nano Mark products exceeds 300 (Taiwan / 2009)

Courtesy ; M-K Wu (May 2006)

8. A Challenge to measure; Nanotech Companies

KoNTRS

Review of the 10 years NT Initiative (Korea, 2001-2008)

	2001	2008
Investment	105.2B Won	242.9B Won (2.3 Times)
No. of NT Researcher	1,015	>4,000 (>4 Times)
No. of NT Company	78 (Venture:33)	274 (Venture: 145)
No. of NT Department	3	59 (19.6 Times)
No. of Paper (SCI)	408 (8^{th} in the World)	2,639 (4^{th},in the World)
No. of Patent	548	2,357 (4.3 Times)
Level of Competitiveness	-	4th

Number of NT companies increases from 78 (2001) to 274 (2008)

Courtesy ; H.M. Kim

9-1. A Challenge to measure; Relative Patent Applications

Investment effect on 8 promotion areas in the 3rd S&T Basic Plan (2006-2010)

- 4 focused promotion areas + 4 promotion areas

Life Science (19.2%) *Energy (26.6%)*

IT (9.3%) *Manufacturing (2.0%)*

Environment (7.1%) *Social Infrastructure (16.7%)*

Nanotech & Mat (5.0%) *Frontier (14.1%)*

*Resource Allocation (%) to 8 areas (FY2008)

- *Economic impact of strategic investment on the 8 promotion areas was estimated* in terms of relative number of patent applications of each area, weighted using the concordance table between patents of 8 areas and the sales of 22 different manufacturing industries of Japan

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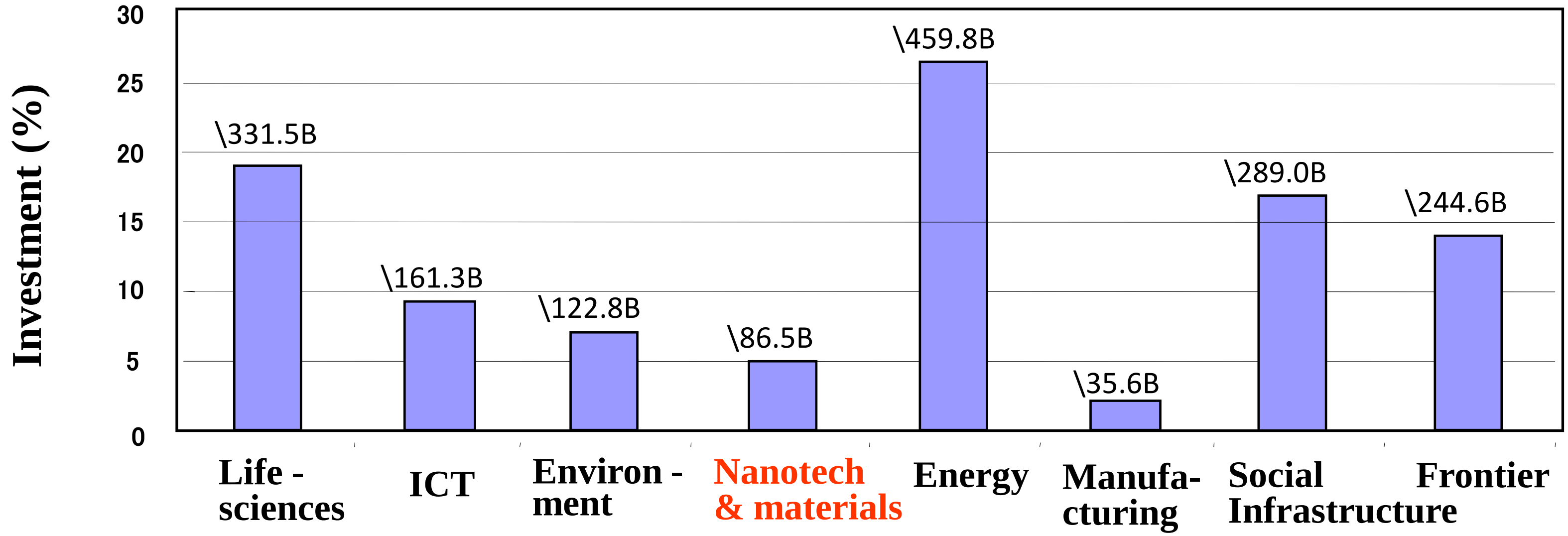
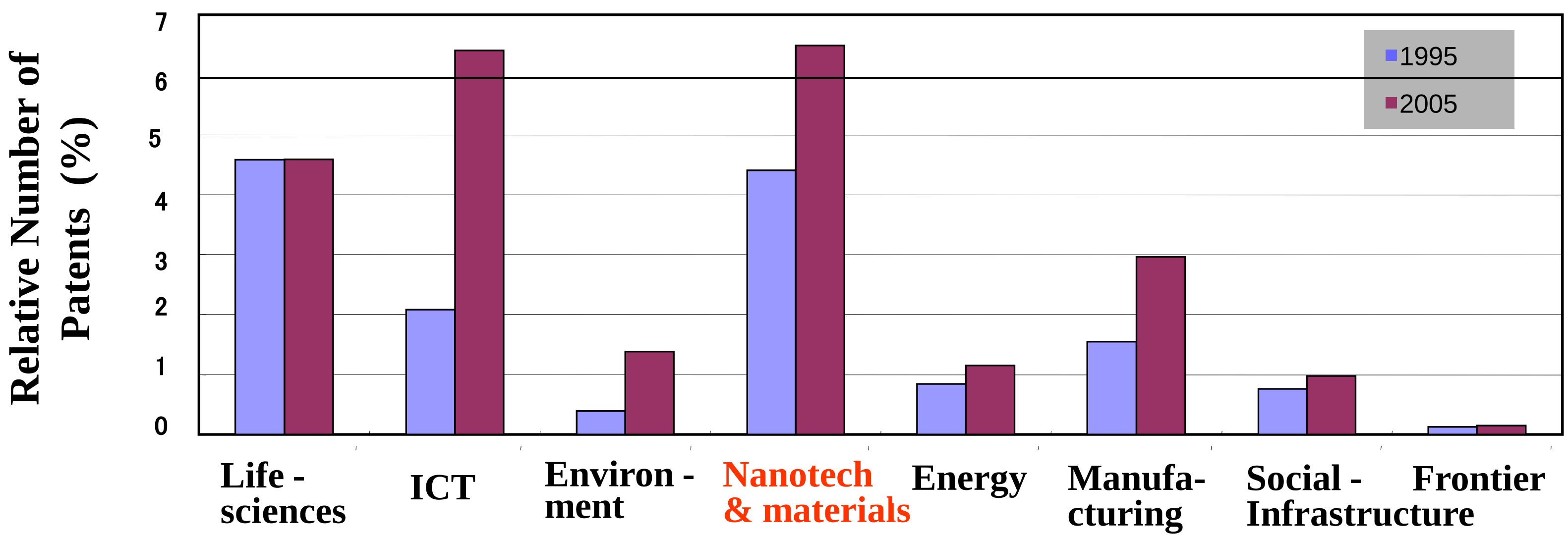
9-2. A Challenge to measure; Relative Patent Applications



Nanotechnology - the highest impact among 8 areas



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10. The 4th S&T Basic Plan in Japan (2011-2015)

- *2011-2015 / the 4th S&T Basic Plan*

  Final approval on the 11th August, 2011
  (delayed due to the Disaster, March 11, 2011)

- Shift from *"R&D-priorotization"* policy to *"problem-solving"* one in order to meet with urgent social needs / *CO2 reduction by 25% by 2020 (2009)*

- *(1)"Safety. Recovery & Reconstruction Initiative"*

  from the Great East Japan Disaster, March 11, 2011

- *(2)"Green Innovation"* and *(3)"Life Innovation"*

  as a New Growth Initiative

- *(4)"Promotion of Basic R&D activities and Strengthening of Human Capability Development"*

Evolution to systems via Innovation
How to drive and accelerate?

11. Post 2011 S&T Policy in Japan

- Shift from *"R&D-promotion-based"* policies to *"problem-solving-oriented"* ones in order to meet with urgent social needs / *CO_2 reduction by 25% by 2020 (2009)*

- 2011-2015 / the 4th S&T Basic Plan

  Final approval delayed due to the Great East Japan Disaster, March 11, 2011

- *New Growth Initiative* including *Green Innovation* and *Life Innovation*

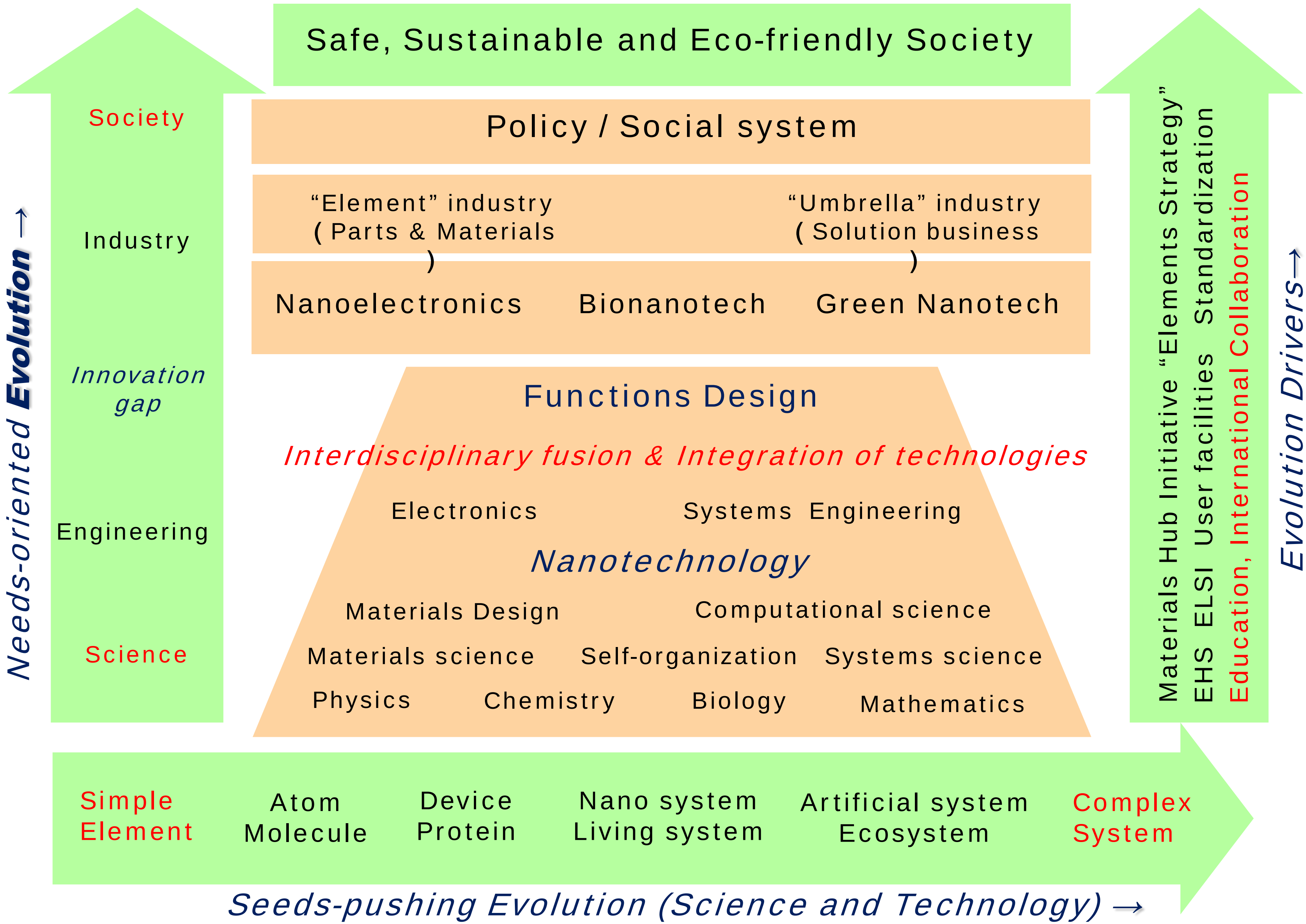
- *Nanotechnology* as a common S&T basis →

  Green Nanotech, Bionanotech, Nanoelectronics

- *Safety and Security* issue will be explicitly described in a main scenario of the Basic Plan

In addition to "Progress Nano" and "Fusion Nano", "Systems Nano" should be strongly encouraged

12. Evolution to System and Society



13. Systems Nano and Commercialization; Evolution to System and New Product

Seeds pushing evolution

Scientific and technological *evolution from simple element to complex system* via interdisciplinary fusion of physics, chemistry, biology, mathematics, materials science, and systems science

materials design, self-organization, quantum computer

Needs oriented evolution

“Functions Design” which provides powerful engine for *evolution from science to society* via integration of novel and existing technologies and disciplines

Non-CMOS computer, High-efficiency solar cell made by low-cost and energy-saving process

Evolution drivers

Promotion & acceleration of evolution, user facilities, EHS & ELSI, standardization, human capability, International collaboration

Interdisciplinary fusion, Integration and Design, and Drivers → Innovation