Exploration of a New Future with the
"Synergy of Nuclear and Renewable"

A Course JAEA Will Take

～How to utilize nuclear energy to build a decarbonized society～

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Japan Atomic Energy Agency

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The Great Wave of Change Surrounding our Country

How will Japan Survive?

These great challenges must be solved by our generation for the future generations.

political

The postwar international order, led by the United Nations, is becoming dysfunctional in the wake of Russia's invasion of Ukraine.

economical

The free trade system that is the premise of Japan's industrialism is collapsing, and the trend of splitting into trade blocs is becoming more pronounced.

social

The rapid transition from a conventional carbon-consuming society to a decarbonized, or sustainable society has become a realistic issue.

Concurrency / Urgency

These, we'd like to solve using nuclear technology.

Current Situation in Japan

Declining national strength, aging national assets, declining nation's tax-bearing due to population decline and aging, and excessive dependence on other countries for various resources.

The Current State of Japan (Weak National Foundations)

Strong sense of impending crisis

- **Food Self-Sufficiency Rate**
  Our country **cannot produce enough food to feed a population of 120 million people**. In addition, there is **concern that the** situation will worsen **further in the future** due to a decrease in the number of people engaged in primary industries.

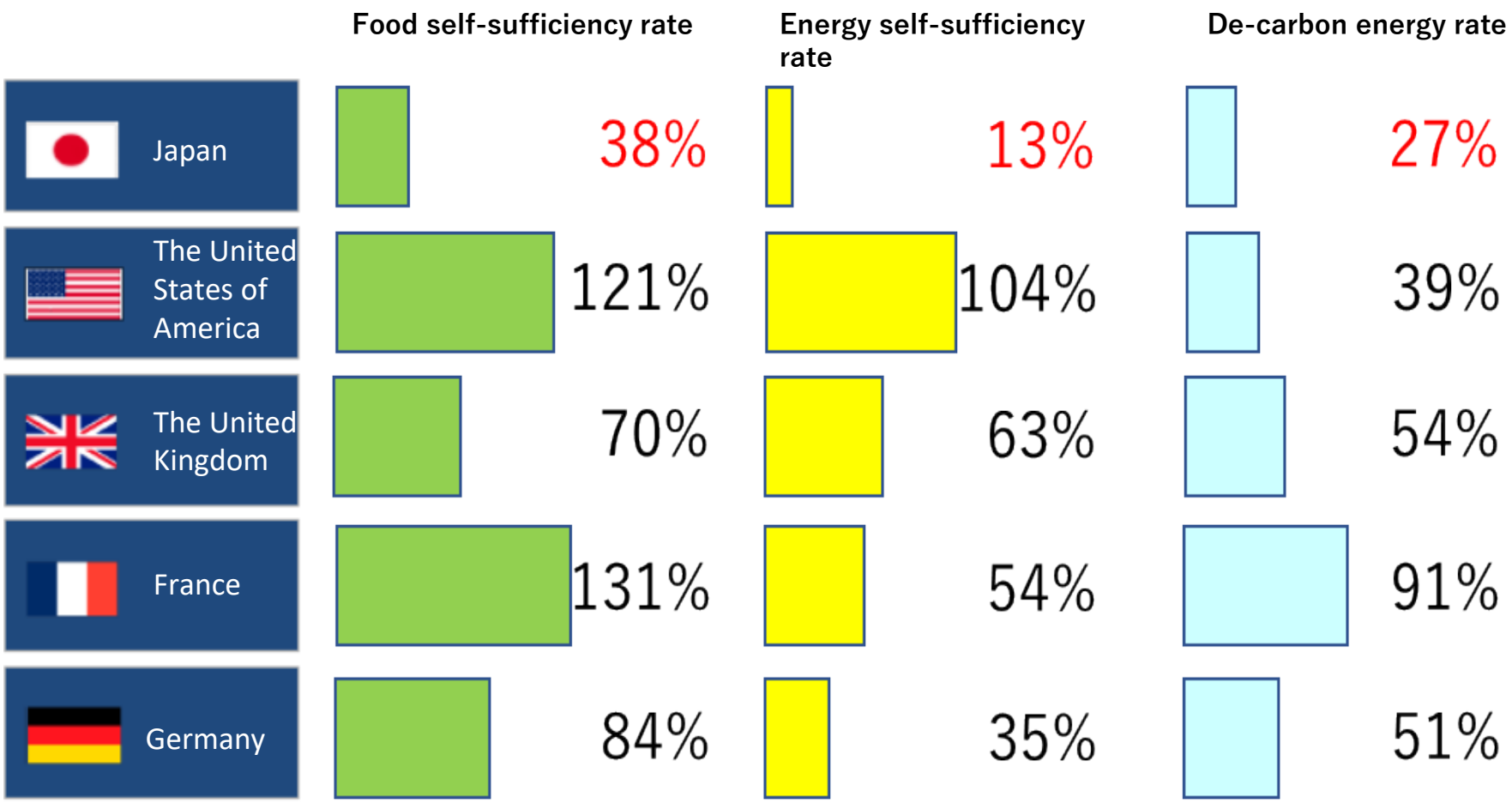
- **Energy Self-Sufficiency**
  Our land **does not provide enough energy sources to support industrialism**. In particular, as the electrification of various fields, including EVs, progresses further, **it will become more difficult to secure green energy.**

- **Decline in National Strength**
  Our country's **basic BS (population, social infrastructure, social institutions, etc.) is deteriorating**. In addition, the country is devoting most of its resources to preserving the legacy of the past and **has no capacity for new investment**. Furthermore,the population will continue to age and decline, and **the tax-bearing capacity of the people will decline.**

- **Complications in the International Situation**
  The international order led by the United Nations and the **stable free trade system** built around the U.S. dollar, which were the basic premise (Yoshida Doctrine) for Japan's postwar breakthrough, **are collapsing.**

- **National Consciousness**
  During the lost 30 years, the nation has **become more inward-looking in terms of policies and national consciousness, and the spirit of active involvement in the international community is fading** (mental isolation).
  Bashing => Passing => Nothing (the image of a declining old power)

The Current State of Japan (Resource Self-Sufficiency)



Food self-sufficiency rate (2019): Compiled by METI based on data published by MAFF (Food self-sufficiency rates of other countries and regions, etc.)

Energy self-sufficiency rate (2021): Compiled by METI from IEA database (data available as of June 22, 2023); Japan: Compiled by METI from "Comprehensive Energy Statistics (FY2021 preliminary figures)
Japan: on a fiscal year basis

Source: the Ministry of Economy, Trade and Industry, Energy and Resources Investigation Committee, Basic Policy Subcommittee (held on June 28, 2023)
The decarbonized energy ratio is the ratio of nuclear power, hydroelectric power, and renewable energy in the power source composition.

The Current State of Japan (Declining Economic Strength, Severe Public Finances)

GDP transition of each country

	2005	2010	2015	2020	2023
Japan	4,830	5,760	4,440	5,050	4,230
United States of America	13,040	15,050	18,210	21,060	26,950
Chinese	2,290	6,030	11,110	14,860	17,700
France	2,200	2,650	2,440	2,650	3,050
Germany	2,850	3,400	3,360	3,880	4,430

(Billion US $)

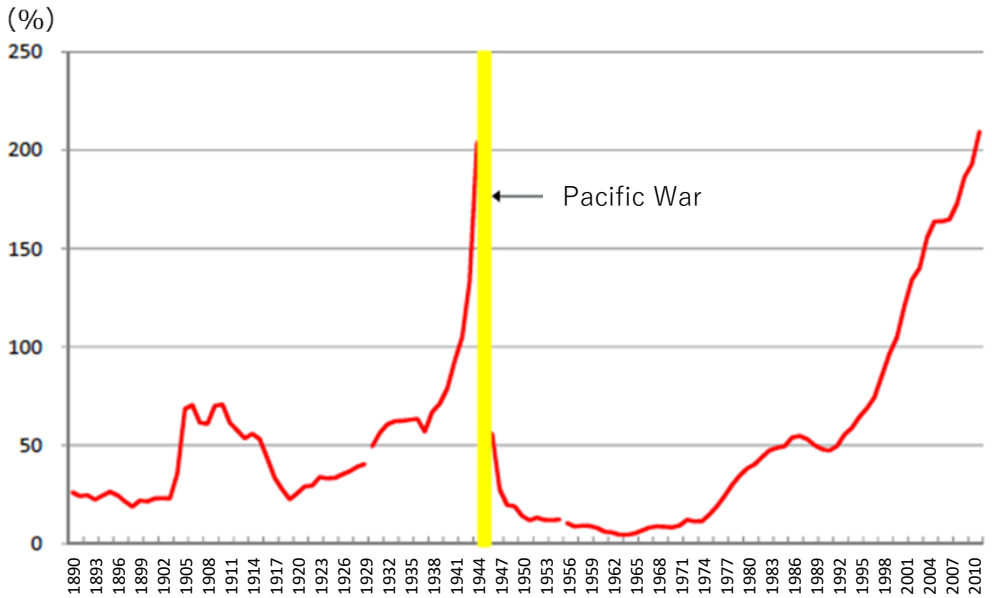
Exchange rates

	2005	2010	2015	2020	2023 Sep
Against the U.S. dollar	110.2	87.8	121.0	106.8	149.4
Against the Euro	137.1	116.3	134.3	121.9	157.9

(Japanese Yen)

Source:

<GDP trends for each country>
Calculated based on 2005-2020 world statistics (Statistics Bureau, Ministry of Internal Affairs and Communications) (annual average)
<Exchange rate>
2023.9 Bank of Mitsubishi UFJ foreign exchange rate chart table



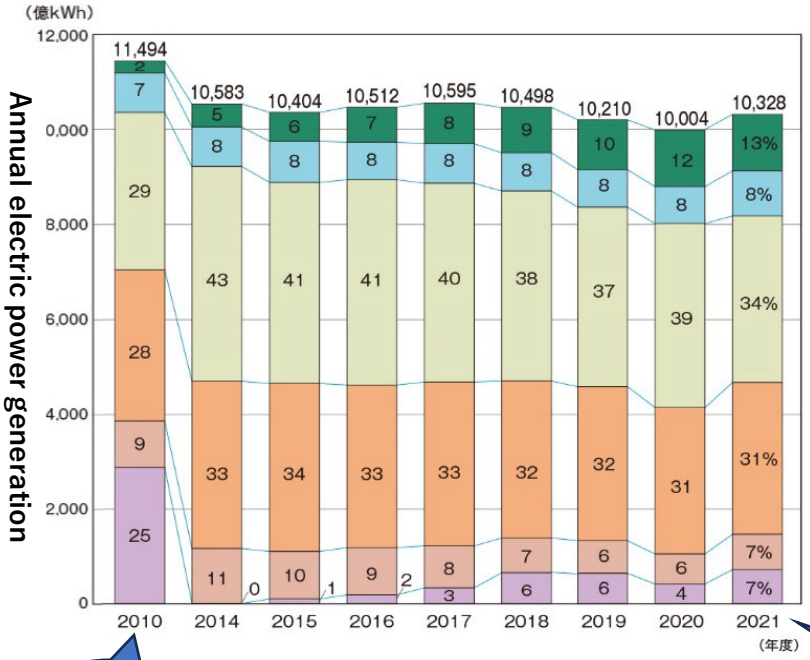
(Source: "Integrated Reform of Social Security and Tax", Ministry of Finance

Ratio of Japan's outstanding government debt to nominal GDP

The Current State of Japan (Energy Mix)

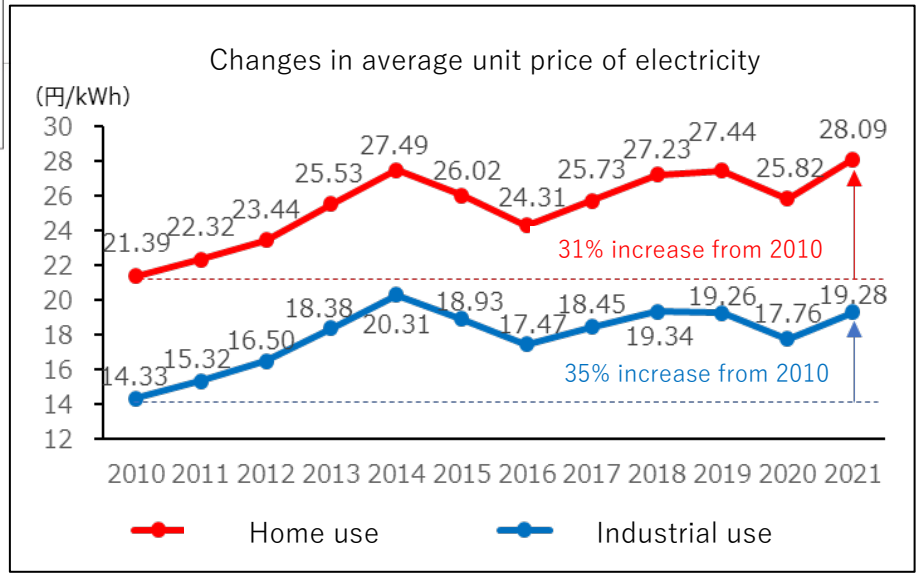
Energy is essential for us to live healthy and convenient lives. Food is manageable in a sense (probably). However, **unless Japan increases its energy self-sufficiency (specifically by decarbonization), it will not be able to establish its presence in the international community.**

The conventional energy mix approach is outdated; instead of doing something like 1 + 1 + 1 = 3, we should pursue synergies like 1 + 1 + 1 = 5.



non-carbon 34%.

Source: Based on a collection of energy drawings.



non-carbon 28%.

Source: Based on Japan's Energy 2022 (Agency for Natural Resources and Energy)

The Nature of GX Policy

- Resolving our country's deep-seated problem (excessive dependence on other countries for food and energy resources)
- Break away from past inferiority and make a fresh start under the new value system of achieving a decarbonized society. (If we continue as we are, we will lose not only to other developed countries but also to developing countries. We must win international competition with a new dimension.)

- Create a **low-resource, high-efficiency** society
  (Creating a compact society that does not require huge national finances)

- In terms of energy supply, **we must change** the current system that requires energy resource development, reforming, transportation, and power generation facilities that are pushed to the limit as machines, **to a compact, sustainable, low-resource, high-efficiency system.**
- **We must build an industrial system with high productivity and added value** in a small population and land area (e.g., factory production of agricultural products, extreme reduction of transportation costs by constructing a decentralized, self-reliant society, etc.)
  We will achieve all of these **through decarbonization.**

The Nature of GX Policy
(Why Japan's Electricity Rates Are So High)

It is commonly said that
they are due to soaring energy prices (oil, gas, coal, etc.) caused by international competition and a weak yen.

But is that really the case?　(Is that all there is to it?)

In fact, there is another problem behind it: the decline in facility utilization rates.

- Renewables are inherently (by their basic nature) **low in utilization.**
- Gas generation, the backup power source for renewables, has been affected by this and **is operating at low capacity.**
- Most nuclear power plants are either shut down or decommissioned, and **only a few are** actually **in operation.**
- Coal-fired power plants **are kept at low operating rates** due to "CO_2 emission limits

As a result, the public and industry bear high power costs
=> Isn't this a policy issue?

The Role of Nuclear Energy in Building a Decarbonized Society (1/2)

Not 1 + 1 = 2
We'll make it 3 or 4

Direction for Solution

[Direction #1.

Pursue not only the combination (mix) of various power sources but also their **synergistic effects**

- Utilize unutilized assets (decommissioned nuclear power plants or depleted uranium) to develop huge uranium batteries to collectively store renewable energy, whose electricity will be distributed to the grid under the control of a power company.
- Decarbonize the whole industrial zone by setting HTGRs as an energy center for industrial complexes for supplying sources of hydrogen, heat, and electricity using renewable energy to make up for shortfalls.

[Direction #2

Aim for becoming a long-term stable energy source while meeting the new demands of building a decarbonized society

- Life prolongation of uranium fuel, volume reduction of high-level waste, reduction of toxicity, and recycling
- Social implementation of means to convert radiation and heat emitted by high-level radioactive waste directly into electricity (radiation power generation, thermal power generation)

The Role of Nuclear Energy in Building a Decarbonized Society (2/2)

[Direction #3]

Search for the **use of nuclear energy in various fields** (medical, materials, agriculture, and other industrial fields) by taking advantage of its characteristics

Achieve these goals with high efficiency and low resources

- Development of Cancer Drugs
- Utilization as a power source (e.g., ultra-compact nuclear batteries)
- Practical application of technology to generate electricity directly from radiation and heat (spin-tronics)

Pursuit of energy synergies → Synergy

Aiming for a long-term stable energy source → Sustainable

Utilization in various fields → Ubiquitous

JAEA's Research Direction

In order to solve the above-mentioned issues of nuclear energy, R&D to be conducted by JAEA is organized as follows. This will help **realize the mission and vision of JAEA.**

I R&D for Nuclear x Renewable **synergy**

R&D aimed at optimizing energy production in Japan through the pursuit of thorough safety and efficiency of nuclear reactors themselves, and in cooperaton with renewable energy sources.

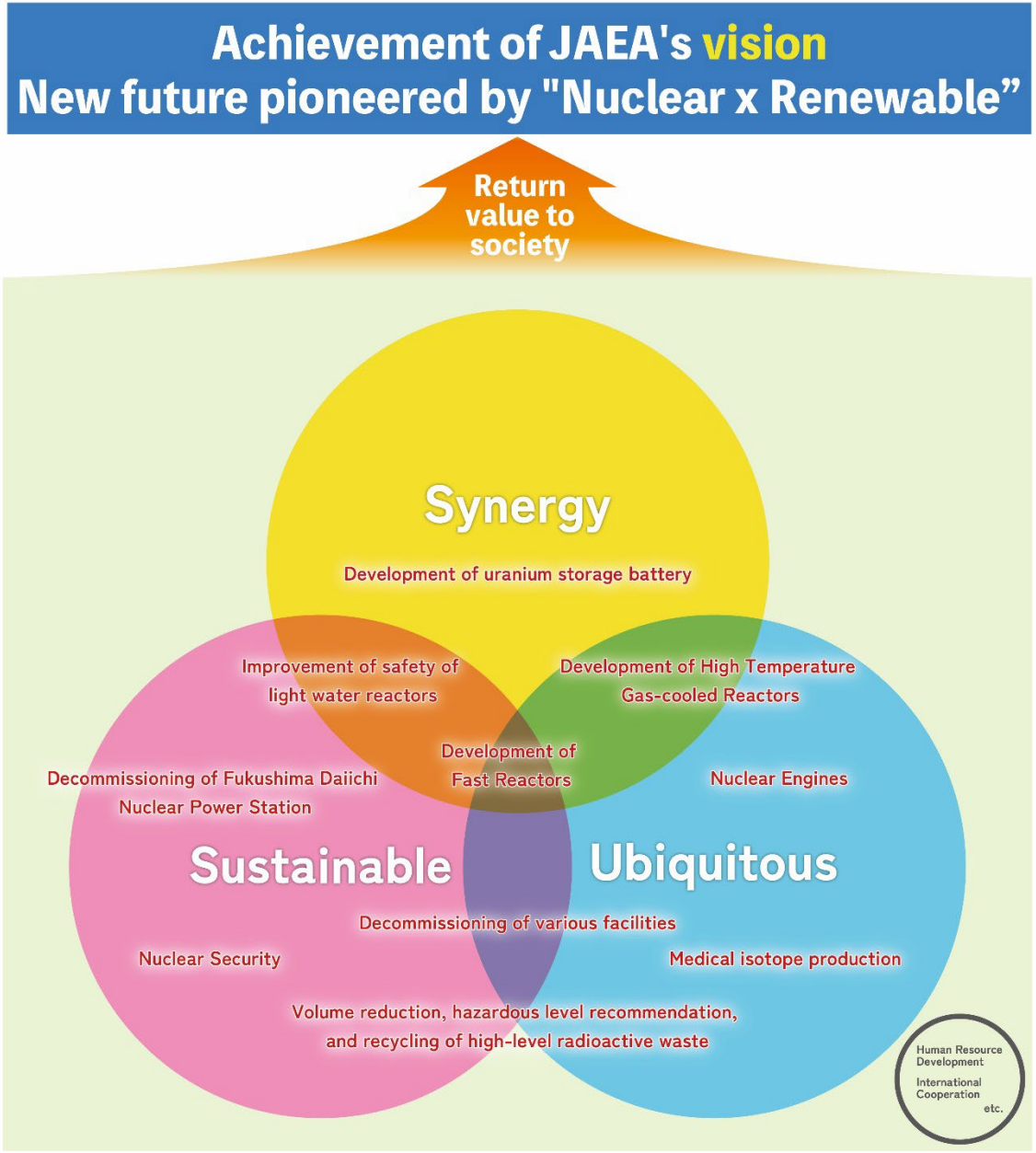
II R&D to make nuclear energy itself **sustainable**

R&D that provides reassurance to the public by resolving the back-end problem, which is one of the major concerns about nuclear energy among the public, and by demonstrating the safety of nuclear energy in general.

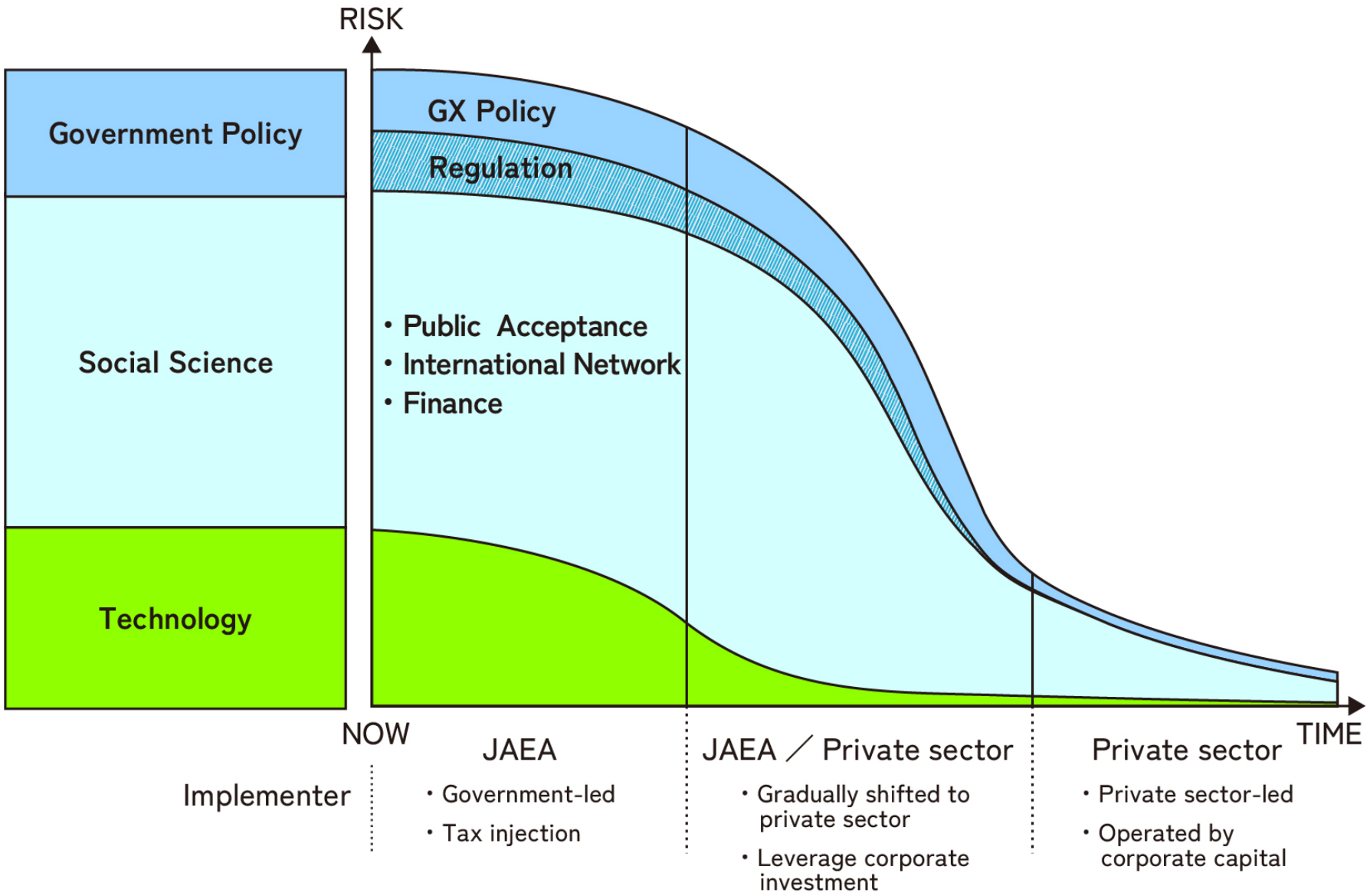
III R&D for diversification of nuclear energy use (**Ubiquitous**)

R&D aimed at maximizing the inherent potential of nuclear energy so that it can be applied in a variety of fields and used safely in everyday life as if the utilization of nuclear energy were a matter of course.

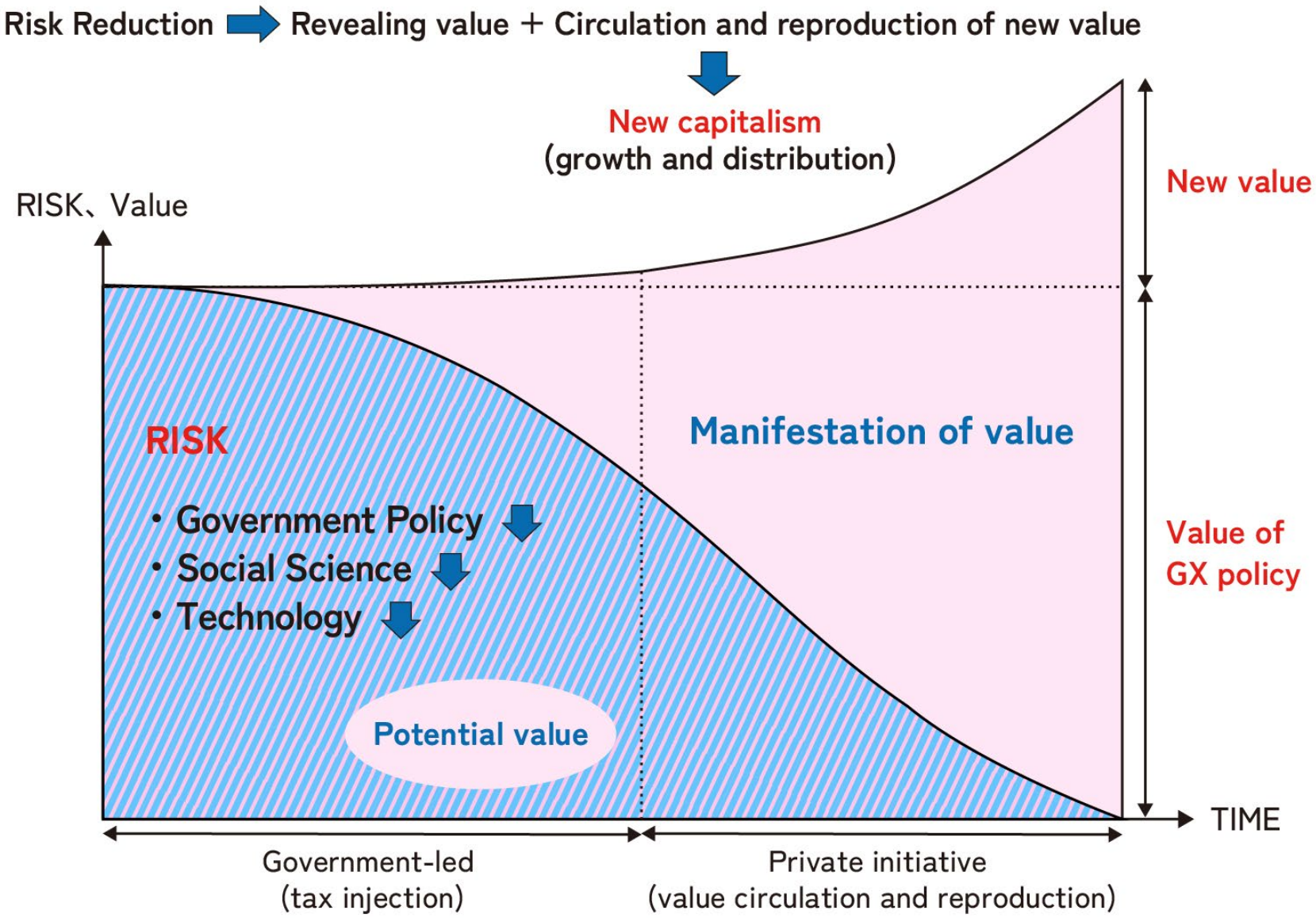
JAEA's Research Direction (Image)



JAEA's Research Direction (Risk and Social Implementation)



JAEA's Research Direction
(Revealing latent value and creating new value)



Problems Nuclear Energy Has and Directions for Solution(1/3)

Problems nuclear energy has

☐ Safety concerns

- If the reactor control system does not work properly due to natural disasters or human error, extremely enormous damage (direct and indirect) will be caused over a wide area: Fukushima Daiichi Nuclear Power Station.
- No process has been established for decommissioning (accident termination) of plants that have experienced accidents, such as the Fukushima Daiichi Nuclear Power Station
- The degree of radiation exposure to the human body (especially internal exposure through food intake) is not well communicated to the public.
- Insufficient protection against attacks on nuclear facilities (power plants, fuel fabrication facilities, etc.) caused by terrorism, war, etc.

☐ Concerns about radioactive waste

- High-energy, long half-life materials (high-level radioactive waste) are generated as fission products from power generation by light water reactors, but their disposal has not yet been determined (liquid waste extracted from spent fuel is being managed and stored as vitrified waste): the reprocessing plant has not been operated for a long time.
- In addition, the treatment and disposal of intermediate-level and some low-level radioactive waste generated from the use of nuclear facilities and experiments has not yet been determined (stored in drums after volume reduction).
- Concerns have been raised about the environmental impact of low-concentration radioactive materials (e.g., tritium) released into the atmosphere and ocean.

Problems Nuclear Energy Has and Directions for Solution(2/3)

Direction for solution

◻ Safety of nuclear facilities

- **Promote R&D to enhance accident resilience of new types of high-safety reactors and nuclear facilities**, and establish a system to minimize damage in the event of an accident.
  - ✓ **Development of a new type of reactor (fast reactor, high-temperature gas-cooled reactor) with inherent safety features [Oarai Research Institute].**
  - ✓ **Development of Nuclear Fuel with Enhanced Accident Tolerance [Nuclear Science Research Institute].**
  - ✓ Reinforcement of facilities that can cope with natural disasters, etc. (reinforcement of protection of safety-critical facilities) **[Nuclear Fuel Cycle Engineering Laboratories (NFCEL), etc.]**
- Safe and efficient decommissioning efforts with knowledge accumulated from decommissioning operations
  - ✓ Safe decommissioning of existing nuclear facilities **[Tsuruga Sector, NFCEL, Ningyo-Toge, Aomori, etc.]**
  - ✓ Development of remote handling technology under high radiation environment **[Tsuruga Sector, Fukushima Sector].**
  - ✓ **Clarifcation of decommissioning procedures for plants that experienced accidents by developing technologies for analyzing the properties and characteristics of fuel debris and other materials and for processing radioactive debris [Fukushima Sector, Oarai Research Institute, NFCEL, Nuclear Science Research Institute].**
- Although knowledge on the effects of radiation exposure on the human body is being gathered, it **will be necessary to provide appropriate information to the public for their understanding. [Public Relations Department, Nuclear Science Research Institute].**
- How to defend nuclear facilities from attacks by terrorism and war is an issue to be addressed. It is necessary, not only domestically but internationally, to reestablish an international framework for nuclear nonproliferation activities led by IAEA and for the prevention of attacks on nuclear facilities for peaceful use. Russia's invasion of Ukraine has made the previous efforts come to naught **[ISCN, Safety Research and Disaster Prevention Sector].**

Problems Nuclear Energy Has and Directions for Solution(3/3)

◻ Handling of radioactive waste

- When a nuclear reaction occurs in a nuclear reactor, fission products are produced. Among these are high-energy elements with extremely long half-lives called plutonium and minor actinides (high-level radioactive waste). These elements are **modified using neutrons to reduce their toxicity and shorten their half-lives**. At the same time, **rare metals (platinum, iridium, vanadium, etc.)** contained in high-level radioactive waste are **extracted and recycled**. **[Oarai Research Institute, Nuclear Science Research Institute, NFCEL, J-PARC]**
  - ✓ Of the fission products, plutonium is extracted and reused as fuel, while other actinides are **converted to other materials by neutron irradiation (burning) in a fast reactor to** reduce toxicity and shorten half-lives (from 100,000 years to 300 years) **[Oarai Research Institute, NFCEL]**.
  - ✓ R&D of extraction technology for rare metals is also underway **[Nuclear Science Research Institute]**.
  - ✓ Furthermore, R&D is underway to recycle the heat and radiation generated from high-level radioactive waste as an energy source **[Nuclear Science Research Institute]**.

Shift from the idea of burying garbage in the ground to the direction of burning, sorting and recycling.
(The final residue that will inevitably remain will be disposed of in geological formations and/or buried as low-level radioactive waste.) **[Horonobe, Tono]**

- Radioactive materials (e.g. tritium) released into the atmosphere and ocean will be **sufficiently diluted** (to well below regulatory standards) **and handled in a manner that eliminates any significant impact on human health and the environment** **[Fukushima Sector]**.

Summary

- Professor Claudia Goldin of Harvard University, the winner of this year‘s Nobel Prize in Economics, cited that radio, automobiles, and computers as technologies that have revolutionized society, analyzing that it took more than 70 years from their invention to their practical application or diffusion.

- It has been 120 years since the discovery of nuclear energy (Marie Curie's discovery of radium at the beginning of the 20th century) and more than 70 years since the atomic bomb was specifically utilized (tragically: this has also become the Japanese original landscape of nuclear energy).

- In this time frame, we **have yet to fully comprehend the potential of nuclear energy, and we are still inexperienced in the means to control it**. However, the **energy produced by nuclear reactions is the very foundation of the universe, and the radiation produced by nuclear reactions is very common in the universe**.

- Humanity is trying to break away from a carbon-consuming society and to achieve a decarbonized society (a sustainable society). Amid these shifting trends, **JAEA is further committed to R&D for the construction of a new society using nuclear energy.**