Stormy Energy Future (WEO2016)

Innovation for De-carbonization
Role of the Sustainable Nuclear Power

2016-11-30 the Canon Institute for Global Studies

Former Executive Director, IEA
President, the Sasakawa Peace Foundation
Nobuo TANAKA
Low Oil Price Scenario

Figure 4.1 Average IEA crude oil import price by scenario

What will happen if Oil Price of $50 per barrel continues well into 2020s?
Unprecedented wave of investment cuts in the upstream oil and gas industry

Cost deflation, efficiency improvements and reduced activity levels might lead for the first time to three consecutive years of investment decline
Instability in the Middle East a major risk to oil markets

The short-term picture of a well-supplied market should not obscure future risks as demand rises to 103 mb/d & reliance grows on Iraq & the rest of the Middle East
North American Energy Independence and Middle East Oil to Asia: a new Energy Geopolitics

Middle East oil export by destination

By 2035, almost 90% of Middle Eastern oil exports go to Asia; North America’s emergence as a net exporter accelerates the eastward shift in trade
A new ‘fuel’ in pole position

Change in total primary energy demand

Low-carbon fuels & technologies, mostly renewables, supply nearly half of the increase in energy demand to 2040
The energy transition provides instruments to address traditional energy security concerns, while shifting attention to electricity supply.
A wave of LNG spurs a second natural gas revolution

Share of LNG in global long-distance gas trade

- **2000**
  - 525 bcm
  - LNG: 26%
  - Pipeline: 74%

- **2014**
  - 685 bcm
  - LNG: 42%
  - Pipeline: 58%

- **2040**
  - 1,150 bcm
  - LNG: 53%
  - Pipeline: 47%

Contractual terms and pricing arrangements are all being tested as new LNG from Australia, the US & others collides into an already well-supplied market.
Geopolitics of the Shale Revolution: Strategic Positioning of Oil / Gas exporters and importers.

[Bar chart showing the strategic positioning of various countries as net gas importers, net oil exporters, net gas and oil importers, and net gas exporters, net oil importers, with data from IEA for 2013 and 2040.]
China’s Oil and Gas Import Transit Routes: One Belt and One Road (一带一路)

Figure 2. China’s Import Transit Routes.
Russian Gas Pipelines Will Extend to the East: Recent China Deal

Russian Gas Infrastructure

The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Source: IEA

Mid-Term Oil & Gas Market 2010, IEA
Blue Print for North East Asia Gas & Pipeline Infrastructure: Dr. Hirata’s Concept
Collective Energy Security and Sustainability by Diversity, Connectivity and Nuclear

Energy self-sufficiency* by fuel in 2013

Source: Energy Data Center, IEA.

* Self-sufficiency = domestic production / total primary energy supply

Note: Does not include fuels not in the fossil fuels, renewables and nuclear categories.
Power Grid Connection in Europe: Collective Energy Security and Sustainability

Physical energy flows between European countries, 2008 (GWh)

Source: ENTSO-E

Total: 334658 GWh
UCTE: 285182 GWh

Source: ENTSO-E
“Energy for Peace in Asia”  New Vision?

Demand Leveling (Time Zone & Climate Difference)
Stable Supply (through regional interdependence)
Fair Electricity Price

Phase 3
Asia Super Grid
Total 36,000km

Presentation by Mr. Masayoshi SON
Global Energy Interconnection

Transcontinental Grid Interconnection of Asia, Europe and Africa
Asia Super Ring

Masayoshi SON’s proposal
Lack of Grid connectivity in Japan

私見卓見

原子力事業、関西電力に集約を

2016−10−28
日経新聞
Japan’s power system: moving to a more diverse & sustainable mix

With nuclear plants expected to restart & increased use of renewables, Japan’s electricity mix becomes much more diversified by 2040 (Renewables 32%, Nuclear 21%, gas 23%, coal 22%)

Japan electricity generation by source and CO2 intensity

- Renewables
- Nuclear
- Oil
- Gas
- Coal
- CO2 electricity emissions intensity (right axis)

Historical vs. projected electricity generation by source in Japan, showing a shift towards renewables and away from coal as a percentage of total generation. The graph indicates a significant reduction in CO2 intensity of electricity generation over the projection period from 2020 to 2040.
The peak in Chinese demand is an inflexion point for coal; held back by concerns over air pollution & carbon emissions, global coal use is overtaken by gas in the 2030s.
The Shale Gas revolution in the US achieved Win-Win-Win. The US is the sole winner of the energy market.

From 2008-2013, United States CO₂ emissions went down by 7% due to coal-to-gas fuel switching, power generation efficiency gains & increased renewables output.
United States holds a strong position on energy costs

Weighted average cost of energy paid by consumers

Economies face higher costs, but the pace of change varies: China overtakes the US, costs double in India & remain high in the European Union & Japan
A 2 °C pathway is still some further efforts away

A peak in emissions by around 2020 is possible using existing policies & technologies; technology innovation and RD&D will be key to achieving the longer-term goal.
Global progress in clean energy needs to accelerate

Technology Status today against 2DS targets

<table>
<thead>
<tr>
<th>Electric vehicles</th>
<th>Solar PV and onshore wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other renewable power</td>
<td>Nuclear</td>
</tr>
<tr>
<td>More efficient coal-fired power</td>
<td>Carbon capture and storage</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Transport</td>
</tr>
<tr>
<td>Industry</td>
<td>Buildings</td>
</tr>
<tr>
<td>Appliances and lighting</td>
<td>Energy storage</td>
</tr>
</tbody>
</table>

- **Red**: Not on track
- **Orange**: Accelerated improvement needed
- **Green**: On track

Global clean energy deployment is still overall behind what is required to meet the 2°C goal, but recent progress on electric vehicles, solar PV and wind is promising.
Greater policy support boosts prospects for solar PV and wind

**Solar PV and wind generation, 2040**

Stronger policies on solar PV and wind help renewables make up 37% of electricity generation in 2040 in our main scenario – & nearly 60% in the 2 °C scenario.

**Increase in WEO-2016:**
- Rest of world
- United States
- China
- WEO-2015

**WEO2016**
The next frontiers for renewables are heat and transport

Renewable energy use by sector

Mtoe 1 200

Electricity
Heat
Transport

Today renewables in electricity and heat use are nearly at par; by 2040, the largest untapped potential lies in heat and transport
In the 2DS, by 2050 one billion cars are electric vehicles while public transport travel activity more than doubles.
No peak yet in sight, but a slowdown in growth for oil demand

The global car fleet doubles, but efficiency gains, biofuels & electric cars reduce oil demand for passenger cars; growth elsewhere pushes total demand higher
Impact of 450 ppm Scenario on Oil Market

Figure 2.5 ▶ World primary energy demand by fuel in the New Policies Scenario

Figure 8.5 ▶ Primary energy demand in the 450 Scenario by fuel

The Stone Age didn’t end because we ran out of stones.
Hydrogen as solution: Chiyoda’s Supply Chain Proposal

- Chiyoda established a complete system which enables economic H2 storage and transportation.
- MCH, an H2 carrier, stays in a liquid state under ambient conditions anywhere.

HGN: hydrogenation, DHG: dehydrogenation
TOL: toluene, MCH: Methylcyclohexane

- H2 Supply of a 0.1-0.2mmtpa LNG equivalent scale (M.E. to Japan) could be feasible.
Still a long way from a pathway to energy sector decarbonisation

Current pledges fall short of limiting the temperature increase to below 2 °C; raising ambition to 1.5 °C is uncharted territory
Sustainable Nuclear Power
Global electricity generation mix in the 2DS, 2013-50


Key point

Today fossil fuels dominate electricity generation with 68% of the generation mix; by 2050 in the 2DS, renewables reach a similar share of 67%.

- 2013 Generation share
  - Fossil fuels: 68%
  - Renewables: 22%
  - Nuclear: 11%

- 2DS 2050
  - Renewables: 67%
  - Fossil fuels: 17% (CCS12%)
  - Nuclear: 16%
Nuclear capacity grows by 60%, but no nuclear renaissance in sight

Net capacity change in key regions, 2013-2040

- China: +120 GW
- India: +40 GW
- Russia: +20 GW
- United States: +10 GW
- Japan: +5 GW
- European Union: +10 GW

Capacity grows by 60% to 624 GW 2040, led by China, India, Korea & Russia; yet the share of nuclear in the global power mix remains well-below its historic peak
Generations of Nuclear Energy

- **Generation I**
  - Early Prototypes
  - Shippingport
  - Dresden
  - Magnox

- **Generation II**
  - Commercial Power
  - PWRs
  - BWRs
  - CANDU

- **Generation III**
  - Advanced LWRs
  - CANDU 6
  - System 80+
  - AP600

- **Generation III+**
  - Evolutionary Designs
  - ABWR
  - ACR1000
  - AP1000
  - APWR
  - EPR
  - ESBWR

- **Generation IV**
  - Revolutionary Designs
  - Safe
  - Sustainable
  - Economical
  - Proliferation Resistant and Physically Secure

Timeline:
- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010
- 2020
- 2030

Source: [http://www.gen-4.org/Technology/evolution.htm](http://www.gen-4.org/Technology/evolution.htm)
“Pandora’s Promise”, a movie directed by Robert Stone, is a documentary of environmentalists who changed their views about Nuclear Power. IFR (EBR2) story comes up as missed opportunity.
Time for Safer, Proliferation resistant and Easier Waste Management Paradigm: Integral Fast Reactor and Pyroprocessing

Pyroprocessing was used to demonstrate the EBR-II fuel cycle closure during 1964-69

Dr. YOON IL CHANG
Argonne National Laboratory


High level waste reduces radioactivity in 300 years while LWR spent fuel takes 100,000 years.
Technical Rationale for the IFR

✓ Revolutionary improvements as a next generation nuclear concept:
  – Inexhaustible Energy Supply
  – Inherent Passive Safety
  – Long-term Waste Management Solution
  – Proliferation-Resistance
  – Economic Fuel Cycle Closure

✓ Metal fuel and pyroprocessing are key to achieving these revolutionary improvements.

✓ Implications on LWR spent fuel management
Passive Safety was proven by the 1986 Experiment very similar to the Fukushima event.

Loss-of-Flow without Scram Test in EBR-II

Dr. YOON IL CHANG
Argonne National Laboratory
Pyroprocessing equipment and facility are compact
More favorable capital cost and economics
Pyroprocessing costs much less than Aqueous Reprocessing

### Capital Cost Comparison ($million)

#### Fuel Cycle Facility for 1400 MWe Fast Reactor

<table>
<thead>
<tr>
<th></th>
<th>Pyroprocessing</th>
<th>Aqueous Reprocessing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size and Commodities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Volume, ft³</td>
<td>852,500</td>
<td>5,314,000</td>
</tr>
<tr>
<td>Volume of Process Cells, ft³</td>
<td>41,260</td>
<td>424,300</td>
</tr>
<tr>
<td>High Density Concrete, cy</td>
<td>133</td>
<td>3,000</td>
</tr>
<tr>
<td>Normal Density Concrete, cy</td>
<td>7,970</td>
<td>35-40,000</td>
</tr>
<tr>
<td><strong>Capital Cost, $million</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facility and Construction</td>
<td>65.2</td>
<td>186.0</td>
</tr>
<tr>
<td>Equipment Systems</td>
<td>31.0</td>
<td>311.0</td>
</tr>
<tr>
<td>Contingencies</td>
<td>24.0</td>
<td>124.2</td>
</tr>
<tr>
<td>Total</td>
<td>120.2</td>
<td>621.2</td>
</tr>
</tbody>
</table>
LWR Pyroprocessing
One-time processing of 700 tons of LWR spent fuel provides long-life fuel supply

35 tons Fission Products

Initial Inventory
80 tons Uranium
10 tons Actinides

Annual Budget

1000 MWe IFR

12.0 tons U
1.5 tons Actinides

1.0 tons Fission Products

On-site Pyroprocessing

0.5 tons excess actinides
For new IFR startup

Disposal (300-year lifetime)

575 tons Uranium

Used Uranium Reserve

10.5 tons Uranium
2.0 tons Actinides
1.0 tons Fission Products

Uranium Makeup

1.5 tons
Transuranic disposal issues

The 1% transuranic (TRU) content of nuclear fuel is responsible for 99.9% of the disposal time requirement and policy issues.

Removal of uranium, plutonium, and transuranics makes a 300,000 year problem a 300 year problem.
S-PRISM Nuclear Steam Supply System
Application of an IFR cycle to the existing Japanese nuclear fuel cycle

Figure 6: Fuel cycle concept using Pyroprocessing technology
Stepwise approach to SCNES (Dr. Yoichi Fujiie)

- **Fuel (U, Pu, MA) recycle (99.9%) + all radioactivity FP recovery (99.9%) / nuclear transmutation**
  - Waste material radioactivity is similar to natural uranium over a hundred years

**SCNES Step 1**
- U+Pu recycle light water reactor
- US IFR concept, etc.

**SCNES Step 2**
- U+Pu recycle Fast reactor
- Metal fuel Fast reactor cycle
- Once through Light water reactor

**SCNES Step 3**
- Ultimate SCNES Step 3

**Note:** Results of research carried out by Toshiba Corporation at the request of the Japan Atomic Power Company

**Current situation**

**5LLFP:** 5 long half-life fission products
(Tc99, I129, Cs135, Zr93, Sn126)

**All radioactive FP:** Fission products with a half-life of one year or longer

**MA:** Minor actinoid (Transuranium elements, except Pu, including Np, Am, Cm, and others)
Legend of Admiral Rickover: Success of LWR for nuclear submarine has crowded out Fast Reactors
Korea is eager to build fuel cycle by IFR by revising the 1-2-3 Agreement with US.

Long-term Plan for SFR and Pyroprocess

- **SFR**
  - Advanced Design Concept
  - System Performance Test
  - Specific Design
  - Detailed Design
  - Concept Design ('12)
  - Specific SAR ('17)
  - Specific Design Approval ('20)
  - Construction

- **Pyroprocess**
  - Korea-USA Joint Fuel Cycle Study
  - Korea-USA Joint Fuel Cycle Study
  - Pyro Feasibility Joint Determination ('20)
  - Prototype Facility ('25)
  - PRIDE Operation and Improvement
  - ACPF/DFDF Operation and Improvement
  - Pyro Equipment Development and mock-up Facility

- **PRIDE ('12)**

Timeline:
- '08
- '11
- '16
- '20
- '26
- '28
Radioactive High-level Waste Disposal or Storage

Finland Model: Olkiluoto Nuclear Power Plant and Onkalo nuclear spent fuel repository

HQ of Teollisuuden Voima Oyj Utility which own Olkiluoto Nuclear Power Plant exists in the Plant site.
Proposal: Japan-US Cooperation to Demonstrate IFR for the SF & Debris at Fukushima Daiichi

- Melt downed fuel debris and contaminated Spent fuels will likely stay in Fukushima, though nobody so admits.
- Pyroprocessing is the most appropriate method for treating spent fuels and debris.
- Pu and MA from Debris and Spent fuels be burned in IFR. Electricity is generated as by-product.
- High level waste of 300 years be stored rather than disposed geologically while decommissioning of units be cemented for years.
- Fukushima Daini (Second) Nuclear Plant of TEPCO is best located to demonstrate GE’s extended S-PRISM.
- International joint project of Japan-US-Korea will provide complementing regional safeguard for global non-proliferation regime.
- Provides ground for extension of Japan-US 1-2-3 Agreement in 2018 by demonstrating complemental fuel cycle options.
International Conference on “Sustainability of Nuclear Power and the Possibilities of New Technology” organized by the Sasakawa Peace Foundation (SPF) on November 18, 2016.

Technical Feasibility of an Integral Fast Reactor (IFR) as a Future Option for Fast Reactor Cycles
-Integrate a small Metal-Fueled Fast Reactor with Pyroprocessing Facilities -

November 18, 2016

Nuclear Salon
### 5. Research Results

**Amounts of fuel debris and nuclear materials from the TEPCO Fukushima Daiichi NPS (estimated)**

The distribution fraction of heavy metals (TRU+U+FP) is estimated to be as shown by the numbers to the right in red based on analyses using the SAMPSON code.*2

<table>
<thead>
<tr>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of core region debris (Approx. 120 tons):</td>
<td>0</td>
<td>Approx. 100 tons</td>
</tr>
<tr>
<td>Amount of MCCI debris (740 tons):</td>
<td>Approx. 260 tons</td>
<td>Approx. 170 tons</td>
</tr>
</tbody>
</table>

- Main composition of core region debris that fused/mixed with core structure material (SUS, Zry): (U,Zr)O₂, SUS-Zry alloy
- Main composition of MCCI debris that fused/mixed with concrete outside the pressure vessel: (Zr,U)SiO₄, CaAl₂Si₂O₈, etc.

Assumed states of the Unit 1~3 cores/containment vessels*1

<table>
<thead>
<tr>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost all of the molten fuel has fallen to the bottom of the RPV plenum and almost none of the fuel is left in the core.</td>
<td>Some of the molten fuel has fallen to the bottom of the RPV plenum or to the PCV pedestal, and some fuel still remains in the core.</td>
<td>It is estimated that more fuel than originally thought has fallen to the bottom of the PCV at Unit 3</td>
</tr>
</tbody>
</table>

- As the average fuel composition for debris in Units 1~3, we used the composition at the time when void reactivity is the most severe, a maximum minor actinide ((MA) neptunium, americium, etc.) content rate and the largest number of years since the disaster within the published data.

⇒**Transuranium element (TRU: Pu+MA) mass is 1.94 tons, and heavy metal (HM) mass is 251 tons**

---

The concept of an integral fast reactor (IFR) consists of reprocessing the fuel debris, fabricating TRU fuel, burning it in a small MF-SFR and recycling the spent fuel by reprocessing.

Amount of heavy metals (HM), such as uranium, present in fuel debris: Approx. 250 tons and TRU elements account for approximately 1.9 tons.

Configuration
  • A MF-SFR with inherent safety features (reactor output: 190 MWt)
  • Application of a metallic fuel pyro-processing method that makes debris processing possible.

Concept diagram of an IFR that combines a fast reactor with a fuel recycling facility
(Example: Argonne National Laboratory Experimental-Breeder Reactor EBR-II and fuel cycle facility (FCF))

Pyroprocessing Technology (for oxide and metallic fuels)

- Spent metallic fuel is dissolved in molten salt and metal U is deposited on solid cathodes using the difference in oxidation-reduction potential. After this, metal Pu, U and MA are deposited into molten Cd cathodes and the actinides are extracted all at once.

- If the electrolytic reduction process is used for preprocessing, the process can also be used for oxide fuels.
Debris Processing Scheme and TRU Reductions

- An assessment of TRU burn-up performances showed the originally estimated debris processing period of 15 years could be shortened to 10 years.
- The 1.9 tons of TRU present in the debris will be reduced to a total of 1.2 tons in 25 years after the launching the IFR including that remaining in the reactor and that existing in the spent fuel. Since the amount of TRU required to constantly fabricate fuel after this point will be insufficient, it will be necessary to procure TRU from external sources in order to continue continuous operation of the reactor.

Concept diagram of debris processing scheme

Debris Processing Scheme and TRU Reductions

- An assessment of TRU burn-up performances showed the originally estimated debris processing period of 15 years could be shortened to 10 years.
- The 1.9 tons of TRU present in the debris will be reduced to a total of 1.2 tons in 25 years after the launching the IFR including that remaining in the reactor and that existing in the spent fuel. Since the amount of TRU required to constantly fabricate fuel after this point will be insufficient, it will be necessary to procure TRU from external sources in order to continue continuous operation of the reactor.
Passive Safety of Small Metal-fueled Reactors

In case reactor temperature increases, reactor power will decrease by inserting negative reactivity feedback.

In addition, passive safety features are employed:

- In response to loss-of-flow events, large negative reactivity effect is generated by the GEM.
- In response to transient-over-power events, withdraw of the control rods is limited by the rod stop mechanism.
Reducing the Volume of Radioactive Waste and Decreasing Hazard Level (Radiotoxicity)

- By suitably processing fuel debris and recycling it in a fast reactor, TRU is either kept in the core or as part of spent fuel. (Surplus recovered uranium is separated/stored)

- A fast reactor cycle releases less long-lived isotopes outside the system by confining TRU in a cycle system as well as burning them, thus it has a beneficial effect on reducing the volume of waste and radiotoxicity.
  - Amount of high-level radioactive waste generated (when compared to direct disposal of spent fuel)
    - LWR cycle: Approx. 22%
    - Fast reactor cycle: Approx. 15%
  - Effect at reducing hazard level (Approx. 100,000 years to fall to levels equal to natural uranium required for equivalent power generation in the case of direct disposal of spent fuel)
    - LWR cycle: Approx. 8,000 years
    - Fast reactor cycle: Approx. 300 years

* A relative value assuming that the potential effect of spent fuel at the first year is 1.

Reduction in the volume of high-level radioactive waste

Reduction in duration of potential toxicity
Evaluation of Construction Costs for Reactor and Fuel Cycle Facilities

[Reactor]
- A small MF-SFR with the thermal output of 190MWt (electrical output: 70MWe) was estimated:
  - Decision on the major plant specifications, created general main-circuit system schematics, conceptual diagrams for reactor structures, and conceptual diagrams for the reactor building layout
  - Estimated plant commodity with referencing commodity data from past designs.
  - JAEA’s evaluation code for construction cost is adopted.
- Results: **Approx. 110 billion yen** (construction unit cost: Approx. **1.6 million yen/kWe**) (However, there is much uncertainty in these values since the system design has not yet been performed.)

[Fuel Cycle]
- A tentative assessment of the overall construction costs of pyroprocessing facilities capable of reprocessing **30tHM/y** and fuel fabricating **0.72tHM/y** was done as follows:
  - The number of pieces of primary equipment were estimated based upon the processing capacity of primary equipment after determining a general process flow and material balance.
  - A general assessment was made by referencing recycle plant cell volume and building volume from past researches.
- Assessment result: Whereas the construction cost of these facilities may be able to be kept at approximately **several tens of billions of yen**, there is much uncertainty in regards to reprocessing facilities and since design aspects have not been examined, it is necessary to refer to assessment values made during other design research into facilities with similar processing capabilities.
うつくしま、福島
（Fukushima, the Beautiful）

昨日はとても勉強になりましたし、何よりも明るい気持ちになりました。福島は日本の科学技術のために使っていた場所ですから。思いがけない傷を負ってしまった福島ですが、これからも技術者たちの挑戦を見届け、世界の技術発展と人類の未来のために使っていたく地になること、それこそが福島の前向きな選択であると感じました。

5年間悲観的な感情論を山ほど聞いて、どちらに向けて顔を上げていったらいいのか、福島の人間はずっと模索してきたのだと思います。
昨夜、田中様のお話しを聞いて、私は原発が街に初めてやってきた子供の頃のこと思い出しました。田中様のお話しは、私にその時と同じ気持ちを思い出させるものでした。そのような話を聞いたのは初めてです。ありがとうございます。
事故の前まで、福島県のキャッチコピーは、美しい島という意味で、「うつくしま、福島」だったのです。事故後に、そのポスターも言葉も消えました。私は科学技術に尽くすという意味で、「つくすしま、福島」でいいのではないか、これは決して後ろ向きの決意ではなく、福島の誇りだと思います。是非とも実現に向けて頑張っていただきたいし、ご協力できることがあればやらせていただければ嬉しく思います。私は身体障害者ですが、自由な時間はたくさんありますので、社会のお役に立てることがあるなら、身体が動く限り何でもやってみたいと思っています。
Statement by Dr. Takashi NAGAI after Nagasaki atomic bomb. "How to turn the devil to the fortune."

Dr. Takashi Nagai, a Professor at Nagasaki University in 1945 when the atomic bomb was dropped, exemplifies the resilience, courage and believe in science of the Japanese people. Despite having a severed temporal artery as a result of the bomb, he went to help the victims even before going home. Once he got home, he found his house destroyed and his wife dead. He spent weeks in the hospital where he nearly died from his injuries. But just months after the atom bomb dropped, he said:

“Everything was finished. Our mother land was defeated. Our university had collapsed and classrooms were reduced to ashes. We, one by one, were wounded and fell. The houses we lived in were burned down, the clothes we wore were blown up, and our families were either dead or injured. What are we going to say? We only wish to never repeat this tragedy with the human race. We should utilize the principle of the atomic bomb. Go forward in the research of atomic energy contributing to the progress of civilization. Devil will then be transformed to fortune. (Wazawai tenjite Fukutonasu) The world civilization will change with the utilization of atomic energy. If a new and fortunate world can be made, the souls of so many victims will rest in peace.”
Sustainable Nuclear Power

日本、米独と事情違う
原油安経いても原発必要

経済教室

持続可能な原子力を探る

日本、米独と事情違う
原油安経いても原発必要

ポイント

原油安続くと中東依存は一層高い懸念

日本原子力協定改定を見据え未来図描け

田中伸男
元国際エネルギー統制機構所長