WORLD ECONOMIC FORUM

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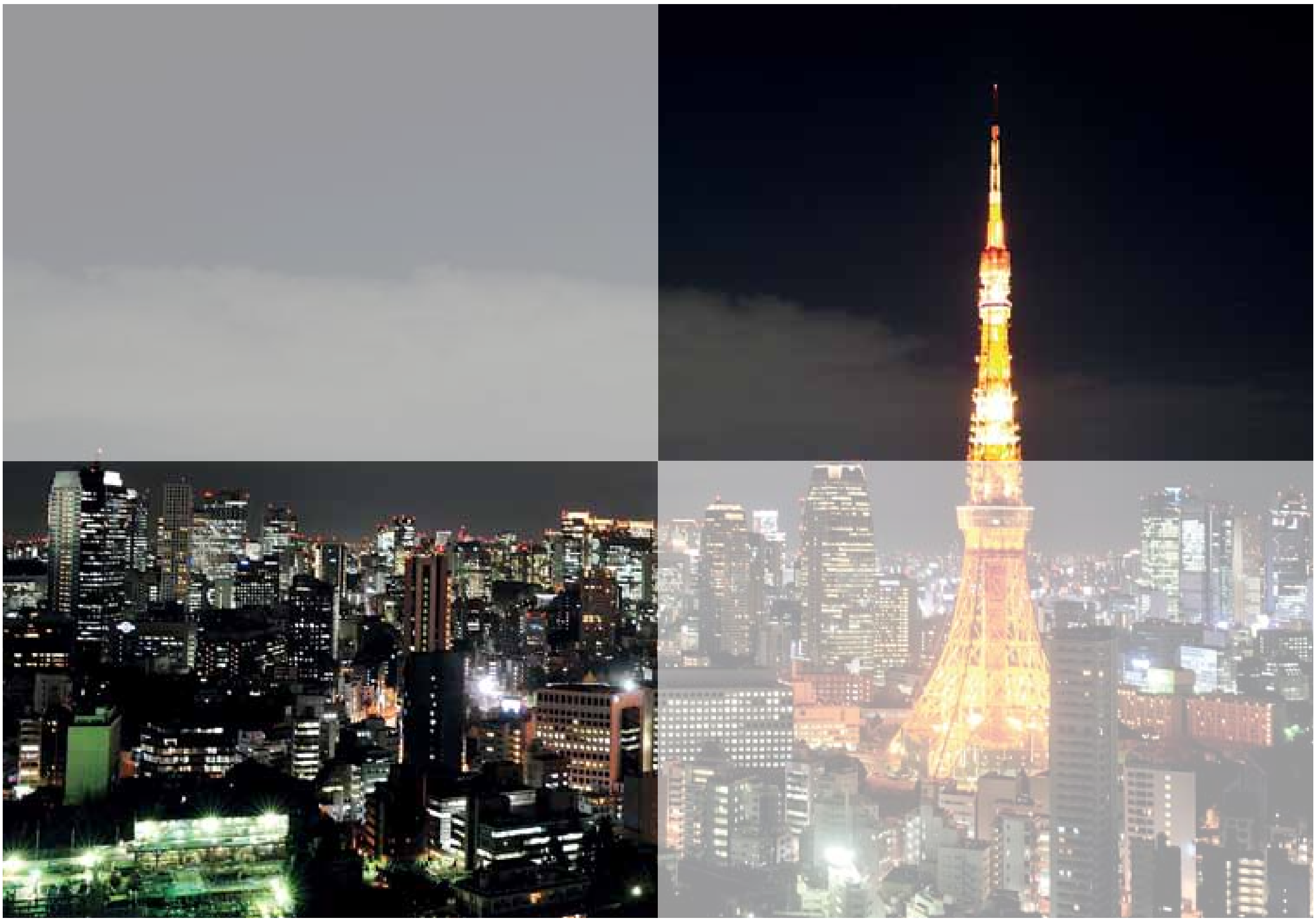
New Energy Architecture
Japan

World Economic Forum In partnership with Accenture



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A note on the creation of this study

This World Economic Forum report was developed by the Forum's Energy Industry Partnership in collaboration with Accenture.

A series of interviews with stakeholders from across the energy value chain and a workshop conducted in Tokyo in October 2011 (moderated by Professor Tatsuo Masuda, Nagoya University of Commerce and Business Graduate School, Japan, and Member of the World Economic Forum's Global Agenda Council on New Energy Architecture) form the basis of the sections on Japan's objectives for a New Energy Architecture and the enabling environments required to achieve them.

The views expressed in this publication do not necessarily reflect those of the World Economic Forum or Accenture.

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Executive Summary

On Friday 11 March 2011, Japan's north-east coast was hit by a magnitude 9 earthquake, followed by a large tsunami, devastating the region. There were four nuclear power sites with operating reactors in the area affected. The tsunami inundated the Fukushima-1 site where six boiling water reactors were located. As engineers struggled to get the reactors back under control, a series of explosions resulted in the release of radioactivity into the atmosphere.

The Fukushima incident has sparked a broad debate about the direction of Japan's energy architecture in which the general public and many other stakeholders have engaged on an unprecedented scale. It has been evident that the handling of the incident has led to a loss of faith in both the government and the power sector – there is a clear need to restore public confidence. In response, the government is conducting a wholesale review of energy policy that will result in the most significant changes to the sector since the response to oil shocks in the 1970s.

> **Japan does not have an energy crisis. It has a crisis of confidence.[1]**

Driving Innovation through the Creation of a New Energy Architecture

Before the Fukushima disaster, Japan had planned to generate up to 60% of its electricity from nuclear power by 2050. Worries over the sustainability of nuclear power, as well as increasing concerns about safety and security, have led the public and policy-makers alike to question Japan's energy policy. It has also made the issue of creating a New Energy Architecture much more prominent; the Japanese government has already responded to the concerns of civil society by committing to reduce dependency on nuclear power and promising to find alternatives to non-renewable sources. However, these transition objectives are not without costs. Decommissioning nuclear power plants is expensive and any rapid change would jeopardize Japan's energy security and increase its dependence on fossil fuel imports. Equally, a major shift towards renewables would require a transition on a scale never seen before and necessitate vast amounts of financial investment.

Japan's focus for the coming years will clearly be on restoring supply and ensuring energy security. In the longer term Japan has the opportunity to drive innovation in its energy architecture, creating a new model that other nations may learn from and adopt. To do so Japan should consider pursuing the following set of objectives:

- Objective 1 – Expand renewable deployment and support the development of "new" energy industries: Japan must look to develop and deploy renewable and "new" energy industries such as storage to decrease dependency on energy imports, diversify supply, reduce emissions, and to create a new export industry to drive economic growth.
- Objective 2 – Rethink approach to nuclear energy: Nuclear energy will continue to play an important role in Japan's energy mix for the foreseeable future; Japan should look to continue R&D in an effort to build a stronger nuclear industry. Fundamental changes to the running and regulation of the nuclear sector to ensure transparency and accountability are required to secure public acceptance.
- Objective 3 – Create new markets and infrastructure for energy transmission and distribution: Restructuring of the transmission and distribution industry is needed to drive increases in economic and technical efficiencies, increase transparency of the sector and enable the deployment of renewable generation capacity.
- Objective 4 – Create a new best practice model for energy efficiency: Demand side management has shown to be effective and responsive to supply shortages in the aftermath of the Fukushima incident. This potential to reduce demand while maintaining economic competitiveness should be leveraged through the introduction of energy efficiency measures.

[1] Interviewee, Tokyo, October 2011.

The Required Enabling Environment

To enable Japan to address its objectives, an enabling environment will be needed. The creation of an enabling environment will require support from across all four pillars:

Government policies must be created to facilitate the deployment of renewables and rebuild faith in nuclear. The government must create a policy framework to encourage the private sector to invest in renewables by providing further clarity on how the feed-in tariff will function. Planning regulations across local, regional and national bodies must be simplified and rationalized to facilitate deployment of renewables. An independent regulatory body for the nuclear industry must be created that regulates and fosters development in the nuclear industry.

Lack of infrastructure is preventing the deployment of renewable generation. Many of Japan's prime renewable generation sites are not covered by the power grid, thus preventing investment in the industry. In addition, a lack of interconnections between the 10 separate transmission networks is further preventing the deployment of renewables and reducing load levelling opportunities. Japan has one of the lowest Aggregate Technical and Commercial (AT&C) losses globally and a world-class reputation in scientific and engineering excellence; it must look to become the supplier of choice to the Asian markets through continued development and investment in "new" energy technologies.

New market structures can lower prices and increase security. The government should look to create Special Economic Zones in the tsunami affected areas to reinvigorate the economy and develop sustainable technologies. Japan has some of the highest industrial electricity prices in the world and the government needs to perform a cost-benefit analysis into more complete deregulation of the power market. A pan-Asian energy network would bring security of supply to the region and enable improved demand side management. Japan must leverage its technical, economic and political strengths to lead the way in the creation of a regional power market.

Highly skilled scientists and engineers will be required. Japan has been long renowned for its scientific and engineering excellence but a decline in new engineering graduates has been witnessed since the late 1990s. The availability of highly skilled engineers for innovative renewable energy research and other clean technologies such as electric vehicles is low. Opening up international science and engineering education programmes at universities will help to attract new talent.

The provision of information must be clear, transparent and honest. The population has already shown itself to be interested in the nuclear debate and capable of responding to information as seen with the need for energy efficiency in the aftermath of Fukushima. The establishment of clear communication channels will enhance the flow of information, increase trust of the energy sector and drive further change.

To create an enabling environment will require government, industry and civil society to work together. Government must become more transparent and responsive to change, instigating developments in policy and regulation in response to the demands of civil society. Industry must demonstrate that it can innovate and has the capacity and expertise to deliver change to Japan and the wider Asian market. Most importantly, civil society must utilize public sentiment and opinion in a post-Fukushima world to drive the creation of effective policy and fully engage debates over how the future energy architecture will be shaped.

The New Energy Architecture Project

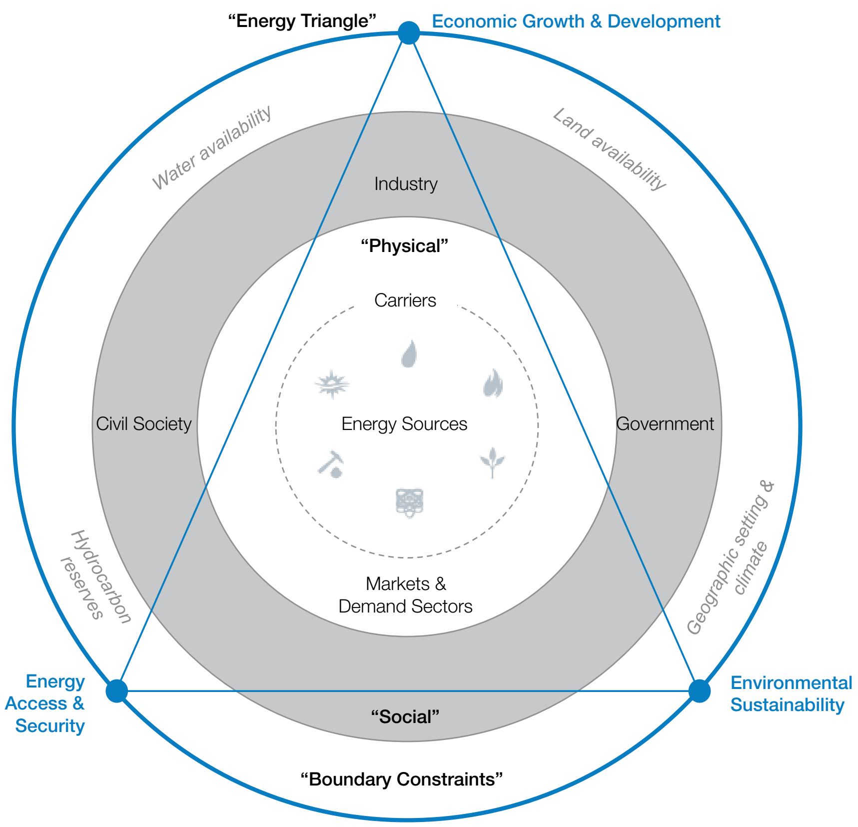
New Energy Architecture: Japan builds on the methodology and findings of the World Economic Forum's wider work, New Energy Architecture: Enabling an Effective Transition, which aims to better understand how countries can make the transition to a New Energy Architecture that more effectively underpins economic growth and development, environmental sustainability, and energy access and security.

Japan uses the same approach and methodology to provide more detailed considerations for policy-makers, industry and civil society seeking to discuss and identify current energy architecture changes for Japan. Following Fukushima there has been a broad debate about the direction of Japan's energy architecture, in which the public has engaged on an unprecedented scale. Japan has before it the opportunity to drive innovation in its energy architecture, creating a new model of international best practice that other nations may learn from and adopt. We hope this study will provide support to those considering how Japan can best achieve these goals.

A Methodology for Managing Transition Effectiveness[2]

It has been common for some time to characterize the concerns surrounding energy as a "triangle" of imperatives relating to the economy, the environment and energy security.[3] To be effective, energy architecture should be designed with these imperatives in mind, although it should be noted that delivery against each of them is limited by a set of "boundary constraints". We define energy architecture as the integrated physical system of energy sources, carriers and demand sectors shaped by government, industry and civil society. Our conceptualization of energy architecture can be seen in Figure 1. While this is a greatly simplified view, it provides an overview of the complex interactions involved, underlining that a systems-based approach should be taken to managing change.

Figure 1 – Energy Architecture Conceptual Framework



Definitions

Physical elements : Includes energy sources, their carriers and end markets.

Social elements : Includes political institutions, industry and civil society, which shape the physical elements.

The Energy Triangle : Ultimate objectives that the energy architecture is designed to support.

Boundary constraints : Factors limiting performance against the energy triangle, both physical and social.

[2] For a more detailed understanding of the New Energy Architecture methodology and conceptual framework, refer to World Economic Forum, New Energy Architecture: Enabling an Effective Transition, 2012.

[3] This concept is commonly referred to by the IEA, among others, whose mandate has been broadened to incorporate the "Three Es" of balanced energy policy-making: energy security, economic development and environmental protection.

This project was initiated to help decision-makers enable a more effective transition to a New Energy Architecture. To do so we have created a methodology to help them look to the long term and provide a stable policy environment, based upon a holistic and in-depth understanding of the consequences of decisions across the energy value chain. The end result will be a New Energy Architecture that is more responsive to balancing the imperatives of the energy triangle. This process comes in four steps (see Figure 2):

Step 1 – Assessing current energy architecture performance: This process begins with an assessment of current energy architecture performance using the Energy Architecture Performance Index (EAPI); a composite indicator that considers economic development, energy access and environmental sustainability. This is intended to help countries to monitor the progress of their transition, and guide policy and investment decisions with regard to energy accordingly.

Step 2 – Creating new energy architecture objectives: Based on strengths and weaknesses identified, a set of objectives for a New Energy Architecture that more effectively meets the imperatives of the energy triangle is created. These objectives are tested through in-country interviews with representatives from across the energy value chain.

Step 3 – Defining the enabling environment: An enabling environment that supports New Energy Architecture objectives is designed. Interviews are used to identify the enabling environments that should be put in place, with the suggestions further tested through a multistakeholder workshop.

Step 4 – Introducing areas of leadership: The ultimate output is the creation of an action plan that details the relative roles of government, industry, and civil society in creating an enabling environment for the transition.

Figure 2 – New Energy Architecture Methodology

	1. Assessing current energy architecture performance	2. Creating New Energy Architecture objectives	3. Defining the enabling environment	4. Defining areas of leadership
	The Energy Architecture Performance Index	An archetype approach	The four pillars of an enabling environment	Key considerations for stakeholders
Key question	• How is energy architecture currently performing?	• What are the objectives for a New Energy Architecture?	• What enabling environment will achieve transition objectives?	• Who is responsible for implementing enabling environments?
Activity	a) Understand current energy architecture b) Select KPIs to assess current and historic performance	a) Highlight energy architecture challenges b) Identify New Energy Architecture objectives	a) Create an enabler “toolkit” that highlights the potential actions that can be taken to accelerate the transition b) Map enablers to transition objectives	a) Develop high-level action plan for steps to be taken by government, industry, the finance community and civil society to shape the transition

In the following sections, we apply the methodology to Japan. This begins with an overview of Japan’s current energy architecture and the results of Energy Architecture Performance Index. We then identify Japan’s objectives for a New Energy Architecture based on where its current strengths and weaknesses lie. This is followed by an exploration of the enabling environments that need to be created to achieve objectives. The final section discusses the roles of government, industry and civil society in working collaboratively to create an enabling environment.

Step 1:
Assessing Current Energy Architecture Performance

[4] IEA, Energy Policies of IEA Countries: Japan, 2008.
[5] EIA Japan country analysis brief.
[6] IEA, World Energy Outlook 2011.
[7] The Federation of Electric Power Companies of Japan, Ten Electric Power Company Structure, 2010.
[8] Mergent Industry Reports, Oil and Gas – Asia Pacific, 2011.
[9] Datamonitor Market Research Profiles, Japan – Gas Utilities – Competitive Landscape, 2011.
[10] IEA, Energy Policies of IEA Countries: Japan, 2008.
[11] http://www.rice.edu/energy/publications/docs/JES_NuclearEnergyPolicyPublicOpinion.pdf
[12] http://ipsnews.net/news.asp?idnews=55342

1.1 Introduction to Japan's Energy Architecture

Japan has few domestic energy resources and is only 16% energy self-sufficient. It is the third largest oil consumer in the world behind the United States and China and the third largest net importer of crude oil. Japan is the world's largest importer of both liquefied natural gas (LNG) and coal.[4]

Japan is one of the major exporters of energy sector capital equipment and has a strong energy research and development (R&D) programme that is supported by the government. This support has ensured Japan's place as a world leader in domestic energy efficiency measures, helping to improve the country's energy security and reduce carbon dioxide emissions.[5]

Total primary energy consumption in Japan was 472 Mtoe in 2009.[6] Industrial consumption accounts for 40%, transport 26% and residential 14%, with the commercial sector consuming the remaining 20%. Oil is the most consumed energy resource in Japan, although its share of total energy consumption has declined from about 80% in the 1970s to 46% in 2009, following a concerted drive to reduce dependency on oil markets after the 1973 oil crisis. Hydroelectric power and renewable energy account for a relatively small percentage of total energy consumption in the country, with coal continuing to account for a significant share. Natural gas and nuclear power have increasingly become important sources in the past decade. Japan is the third largest consumer of nuclear power in the world after the United States and France. Japan's energy balance is shown graphically in Figure 2.

The main electricity sector players are Japan's 10 regional electricity companies, which generate, transmit and distribute electricity to the population and also import LNG.[7] The three largest integrated power companies are Tokyo, Kansai and Chubu Electric Companies. The main wholesale supplier is J-Power.

Within the oil sector, Japanese oil and natural gas companies are active in pursuing offshore upstream projects by providing engineering, construction, financial and programme management support as few domestic hydrocarbon resources exist. JX Holdings and Idemitsu Kosan are among Japan's leading refining and distribution companies[8] while INPEX and JAPEX are two of the largest upstream operators. Tokyo Gas, Osaka Gas and Toho Gas are the largest gas utilities.[9]

Several of the largest renewable energy equipment manufacturers globally are Japanese. Mitsubishi Heavy Industry produces mechanical parts for solar, geothermal and wind energy generation. Also active in the manufacture of renewable energy machinery are Toshiba, Fuji Electric and Sharp among others.

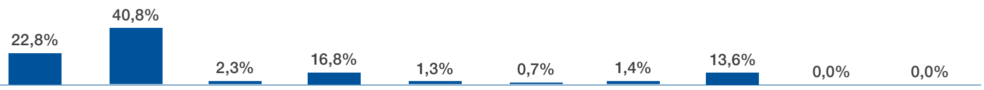
Managing the energy sector is the government's Agency for Natural Resources and Energy (ANRE) and the Nuclear and Industrial Safety Agency (NISA) arm. ANRE is a part of the Ministry of Economy, Trade and Industry (METI) and has been responsible for setting energy policies related to security, supply and environmental sustainability. NISA takes responsibility for safety and security regarding nuclear energy sources. Three organizations support the energy sector, the New Energy and Industrial Technology Development Organization (NEDO), Japan Oil, Gas and Metals National Corporation (JOGMEC) and the New Energy Foundation. NEDO is one of the largest R&D institutions for development and diffusion of new technologies, including energy technologies, while JOGMEC supports private sector companies with the exploration and development of oil, natural gas and metal resources.

While the involvement of civil society in determining the country's energy policy has traditionally been low, non-profit organizations and campaign groups are starting to exert greater influence. One example is the New Energy Foundation, which is a non-profit organization that seeks to raise public awareness about new energy and help develop new energy-related industries.[10] Since the Fukushima incident, the population has also sought a more direct role in determining their country's energy future, particularly regarding the use of nuclear power; between 30,000 and 60,000 people took part in anti-nuclear protests in Tokyo on Monday 19 September 2011[11] and organizations such as the Citizen's Nuclear Information Network (CNIN) are gaining in popularity.[12] It is clear that the government must communicate with the public to explain the role of nuclear energy in the national energy strategy and must increasingly involve civil society in the policy-making process.

Figure 4 – Change in Japan's EAPI Scores over Time and Relative Performance

Supply & consumption	Coal & Peat	Crude Oil	Oil Products	Gas	Hydro	Solar, wind etc.	Biomass & waste	Nuclear	Electricity	Heat	Total
Production	0	767	0	3,560	6,557	3,496	7,007	67,720	0	0	88,657
Imports	114,853	201,872	42,612	79,878	0	0	0	0	795	0	439,215
Exports	-665	0	-19,659	0	0	0	0	0	-33	0	-20,324
International marine bunkers	0	0	-5,305	0	0	0	0	0	0	0	-5,305
International aviation bunkers	0	0	-5,920	0	0	0	0	0	0	0	-5,920
Stock changes	-683	260	-340	277	0	0	3	0	0	0	-484
TPES (Total primary energy supply)	113,505	202,899	11,387	83,715	6,557	3,496	7,010	67,720	0	0	496,838

% Share



Source: IEA; Accenture analysis

1.2 Japan's Current Energy Architecture Performance

The Energy Architecture Performance Index (EAPI) assesses nations' past and current performance in balancing the imperatives of the energy triangle and is intended to be a transparent and effective insight into current challenges, providing a solid basis from which to develop future objectives based on strengths and weaknesses. The index covers 124 nations, enabling countries to benchmark performance in comparison to their peers. Furthermore, the collection of historic data from 1990, and 1999 to 2008, also enables countries to see how they have progressed over time. Countries receive an overall score between 0 and 3 for the index, with a score between 0 and 1 for each of the sub-indices. It should be noted that the EAPI is in the first year of its development. As with any nascent area of research further work needs to be done to expand the robustness and coverage of the index. This will be completed over the coming year.

Japan receives a score of 2.34 on the EAPI, up from 2.07 in 1990 and 2.30 in 2000, placing it 14th on the global list just behind the United States of America. Figure 4 provides an overview of Japan's scores on the index in 2008, 2000 and 1990, the actual data for each indicator, as well as the cumulative change in its score between 1990 and 2008. Figure 5 provides further detail of how Japan's performance has changed over time on each of the indicators. This analysis shows that Japan's relative strength is in relation to economic growth and development, where it now scores in the top quartile on all indicators. The environmental sustainability of the sector has also improved over time, particularly in relation to outdoor air pollution. Improving energy intensity is now one of Japan's most pressing concerns, while the government must also look to reduce the dependency on imports to meet the countries primary energy demands.

In the below sections, a further breakdown of the results with regard to each imperative of the energy triangle is provided:

Economic Growth and Development

Japan's score on the economic growth and development sub-index has remained strong for the past decade and can be attributed to the country's strong economy. Economic growth has however resulted in an increase in energy imports, particularly natural gas, with Japan's energy import bill as a share of GDP more than doubling from 1990 to 2008 (1.37% to 2.97%).

Since the oil shocks of the 1970s the economy has achieved an energy intensity improvement of around 30%. Since the mid-1980s, this improvement has leveled off somewhat, but declines continue with a reduction from 0.19 to 0.14 toe/thousand 2000 US$ from 1990 to 2008, meaning that Japan remains more efficient than many of its peers such as the US. Much of this decrease has been driven by the industrial sector, and, in particular the Top Runner Program. The 1998 amendment of the Act on the Rational Use of Energy sets energy efficiency performance targets for categories of machinery and equipment, including vehicles both domestically manufactured and imported. These targets are baselined on the performance of the most energy-efficient equipment on the market at the time of the value-setting process. Final energy consumption in the commercial and residential sectors has experienced steady increases, due to increasing demand for heating and cooling and rising penetration of electrical appliances.

Retail electricity prices in Japan had been among the highest of IEA countries. During recent years they have fallen due to increased efficiency and the effects of market reform.[13] Prices for large commercial users fell by 16% between 1999 and 2005 as a result of initial deregulation.[14]

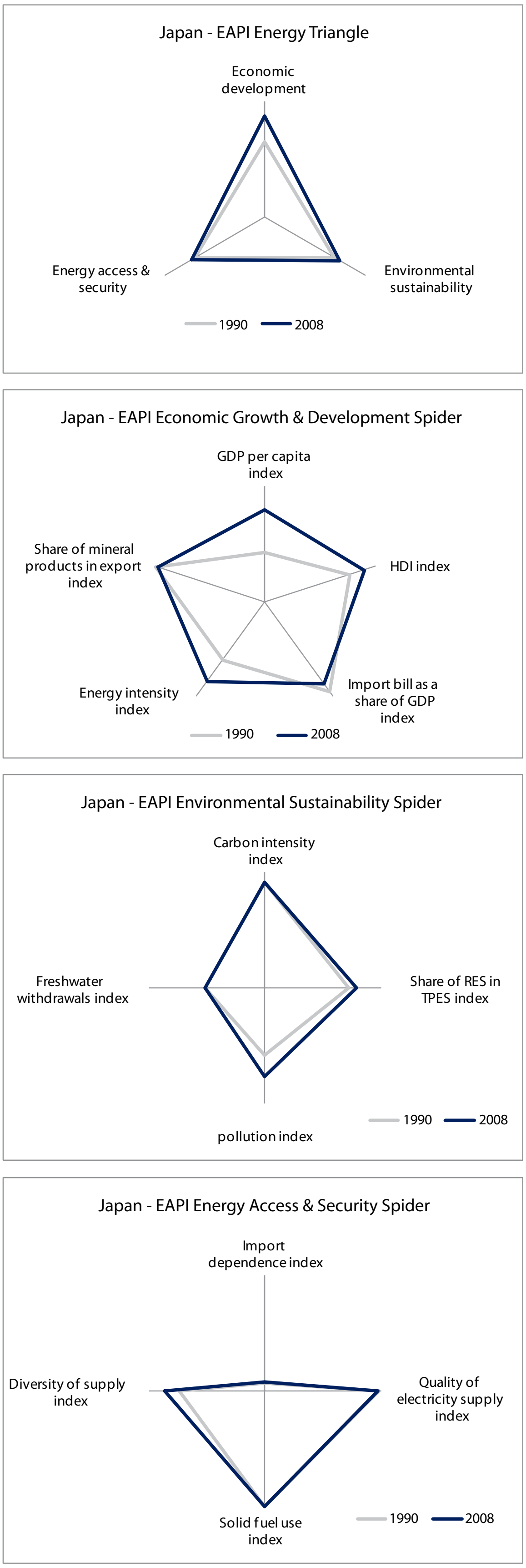
Figure 4 – Change in Japan's EAPI Scores over Time and Relative Performance

KPI	2008 Index	2008 Actual	2000 Index	2000 Actual	1990 Index	1990 Actual	Cumulative index change 1990-2008
EAPI	**2.34**		**2.30**		**2.07**		0,30
Economic Growth & Development	**0.87**		**0.81**		**0.66**		0,21
GDP (PPP) (current US$)/capita	0.79	29,026	0.64	23,538	0.43	15,899	0,36
HDI	0.90	0.88	0.85	0.86	0.77	0.81	0,12
Import bill as a share of GDP (%)	0.87	2.97%	0.93	1.66%	0.95	1.37%	-0,08
Energy intensity (toe/thousand 2000 US$)	0.84	0.14	0.70	0.16	0.61	0.19	0,23
Share of mineral products in export (%)*	0.97	3.21%	0.99	1.44%	0.99	1.44%	-0,02
Environmental Sustainability	**0.74**		**0.76**		**0.68**		0,06
Carbon intensity of energy use	0.91	0.26	0.90	0.28	0.91	0.27	0,01
Share of RES in TPES (%)	0.79	15.56%	0.93	18.37%	0.73	14.37%	0,06
Outdoor air pollution (PM10 [mg/m3] p.a.)	0.76	27.14	0.69	32.93	0.58	42.18	0,18
Freshwater withdrawals (% int. resources)*	0.51	20.56%	0.51	20.56%	0.51	20.56%	0,00
Energy Access & Security	**0.73**		**0.72**		**0.70**		0,03
Net imports/TPES (%)	0.08	82.12%	0.09	79.61%	0.07	82.88%	0,00
Quality of electricity supply (0-7)*	0.97	6.75	0.98	6.79	0.98	6.79	-0,01
Population using solid fuels (%)*	1.00	<5.00 %	1.00	<5.00%	1.00	<5.00%	0,00
Diversity of supply (1-0)	0.86	0.71	0.82	0.69	0.74	0.64	0,12

*In a number of instances historic data was not available. In these instances data was kept constant from the last available year in which it was available. This applies to the following indicators: Share of mineral products in export – Data was only available for 2005-2008. In calculations of the index for the years 1999-2004 and 1980 the data from 2005 was kept constant; Water scarcity – Data was only available for 2000. This was kept constant across the time periods covered; Quality of electricity supply – Data was only available for 2005-2008. In calculations of the index for the years 1999-2004 and 1980 the data from 2005 was kept constant; Access to modern forms of energy – Data was only available for 2003. This was kept constant across the time periods covered.

[13, 14] IEA, Energy Policies of IEA Countries: Japan, 2008.

Figure 5 – Comparison of Japan's EAPI Scores in 1990 and 2008



Environmental Sustainability

Japan's environmental sustainability index has remained above the median for the past 20 years (0.68 in 1990 and 0.74 in 2008). However, Japan's CO2 emissions increased by 13% from 1990 to 2006, due to the expansion of coal-fired generation in the 1990s.

In terms of non-carbon energy sources, Japan responded proactively to the threat posed by last century's oil shocks, making the use of nuclear power an official national strategic priority in 1973 and investing heavily in the development of new energy technologies. As a result, by 1990 it was the world leader in several key clean energy technologies, including batteries, heat pumps, fuel cells, mass transportation and solar power. However, since 2000 Japan's leadership has been overtaken by Germany, Denmark, Spain and China, although Japan is still among the global leaders in some clean energy industries. Japan has the 3rd largest installed solar PV capacity (capacity has doubled since 2009 to reach generation levels of 3.6 GW) and the 4th largest solar water heating capacity.[15] Japan's renewable energy strategy is focused on residential projects instead of developing projects with the electric utilities, as reflected by the small share of renewables in primary energy supply.

Outdoor air pollution in Japan has continually improved as the amount of particulates in the air has been decreasing (42.18 µg/m3 in 1990 to 27.14 µg/m3 in 2008). Japan has one of the strictest legal and regulatory systems globally with regards to emissions of sulphur dioxide and other oxides such as nitrogen oxide. This was a result of the high post-war period pollution levels, which caused respiratory diseases in industry intense cities.[16] A nationwide monitoring network now exists to continually monitor the concentrations of various air pollutants, allowing prefectures to take actions to ensure levels are below environmental standards. Further improvements were mandated as of 1993 when new environmental legislation ("Basic Environment Law") was instituted, placing tighter restrictions on emissions and placing more emphasis on energy conservation. The impact of this legislation is evident in the improvement of this KPI.

Energy Access and Security

The electrification rate of Japan is listed as 100%, meaning universal access to electricity. Generation capacity has steadily increased to cover the growth in peak load demands with a comfortable level of reserve capacity (averaging between 50-60% from 2000 to 2005) if peak load is surpassed. Transmission and distribution losses have stabilized around 5.2% and system reliability is very high with few transmission and distribution interruptions. These characteristics have led Japan to have a consistently high quality of electricity supply (0.97 in 2008 from 0.98 in 1990). Additionally, the diversity of Japan's supply has continually maintained high levels. Japan's energy balance is well diversified with four different sources making significant contributions to the TPES: oil (40.3%), coal (22.8%), gas (16.8%) and nuclear (13.6%). The diversity of supply has improved considerably since the 1970s where 70% of the TPES was from oil, which has been replaced primarily by natural gas and nuclear.[17]

Japan's energy security is challenged by high levels of import dependence: 82% as of 2008. In 2008, Japan imported almost 99% of its oil, 98% of its coal and 96% of its gas. Most of the oil originates in the Middle East, particularly the United Arab Emirates (UAE), Saudi Arabia, Iran, Qatar and Kuwait. For coal, Japan relies on Australia, China, Indonesia, Russia, the United States, South Africa and Canada. Almost all natural gas is imported, primarily from Indonesia, Malaysia, Australia, Qatar, Brunei and the UAE. Japan's high reliance on imports places the country at risk to potential physical interruptions to its energy supply as well as negatively affecting its trade balance.

1.3 Comparing Japan's Current Energy Architecture Performance with the Rationalize Archetype

The results of the Energy Architecture Performance Index (EAPI) must be read in context, paying particular heed to the structure of a nation's economy. Contextual differences mean that energy architectures will look very different in different countries, affecting performance on the EAPI. For example, an economy that is dominated by primary extraction and processing will struggle to improve energy intensity without a radical restructuring of its industry sectors.

To account for such differences, studies on energy transitions often take a regional perspective. However, there is considerable heterogeneity between countries within single regions. In recognition of this the EAPI has been used to create a series of archetypes, grouping countries that face similar challenges in their current energy architecture and therefore have a similar objective for the transition to a New Energy Architecture. This process has resulted in the identification of four archetypes: Rationalize, Capitalize, Grow and Access.

Japan falls within the Rationalize archetype. This consists of nations that are leaders across the three imperatives of the energy triangle. Their focus is increasingly on rationalizing and reorganizing energy architecture to balance the energy triangle. Key opportunities for these countries are in advancing existing infrastructure, identifying and integrating new sources of supply, and driving greater efficiency across the value chain.

Figure 6 reports the scores and actual data for Japan and a select group of Rationalize nations. Figure 7 is a heat map that complements the raw scores, which allows for a reading of Japan's performance in the EAPI in relative terms. It also provides a sense of the distance in scores that separates Japan from other members of the Rationalize archetype. Blue-shaded cells and grey-shaded cells indicate that Japan scores or ranks respectively higher or lower than the comparator, while no shading means that there is no significant divergence; the darker the shading, the greater the difference in performance.

The heat map mirrors Japan's performance pattern described above. Relative weak points include dependence on imports, underlining that Japan has significant challenges in relation to energy access in comparison to its peers. Relative strengths include energy intensity and share of non-carbon sources in the energy mix, indicating the efficiency of Japan's energy use. Figures 6 and 7 show that the country currently lags comparators within most indicators under the environmental sustainability imperative.

Figure 6 – EAPI Results for Japan and Selected Comparators from the Rationalize Archetype

Economic Growth and Development	GDP per capita		HDI index		Import bill as a share of GDP		Energy intensity		Share of mineral products in export	
Country	KPI	Raw	KPI	Raw	KPI	Raw	KPI	Raw	KPI	Raw
Canada	0.90	32790	0.91	0.89	0.84	0.03	0.54	0.21	0.64	31.74
Denmark	0.88	32312	0.87	0.86	0.86	0.03	0.92	0.09	0.88	10.72
France	0.77	28176	0.87	0.87	0.77	0.05	0.81	0.13	0.93	6.33
Germany	0.82	29895	0.90	0.88	0.75	0.05	0.85	0.11	0.96	3.54
Italy	0.75	27416	0.84	0.85	0.70	0.06	0.92	0.09	0.95	5.12
Japan	0.79	29027	0.90	0.88	0.87	0.03	0.84	0.12	0.97	3.21
New Zealand	0.67	24573	0.94	0.90	0.72	0.06	0.77	0.14	0.91	8.02
Sweden	0.89	32513	0.91	0.89	0.78	0.05	0.76	0.14	0.89	9.52
Switzerland	0.95	34838	0.88	0.87	0.82	0.04	0.95	0.08	0.95	5.08
United Kingdom	0.87	31773	0.83	0.85	0.87	0.03	0.91	0.10	0.81	16.99
United States	1.00	40309	0.93	0.90	0.90	0.02	0.69	0.16	0.89	9.56

[15] REN21, Renewables 2011 Global Status Report, 2011.
[16] American University, Japan Air Pollution, 1997.
[17] IEA, Energy Policies of IEA Countries: Japan, 2008.

Environmental Sustainability	Carbon intensity		Share of non-carbon energy		Outdoor air pollution		Freshwater withdrawals	
Country	**KPI**	**Raw**	**KPI**	**Raw**	**KPI**	**Raw**	**KPI**	**Raw**
Canada	0.77	0.50	1.00	21.63	0.91	15.00	0.96	1.61
Denmark	0.95	0.20	0.17	3.32	0.89	16.26	0.59	17.40
France	0.95	0.19	1.00	45.29	0.93	12.94	0.63	15.88
Germany	0.90	0.28	0.67	13.30	0.89	16.21		
Italy	0.92	0.25	0.26	5.13	0.81	23.33	0.41	24.83
Japan	0.91	0.26	0.79	15.56	0.76	27.14	0.51	20.56
New Zealand	0.87	0.34	1.00	27.03	0.95	11.93	0.99	0.65
Sweden	0.98	0.14	1.00	45.92	0.96	10.52	0.96	1.64
Switzerland	1.00	0.11	1.00	39.60	0.82	22.36	0.85	6.47
United Kingdom	0.93	0.23	0.36	7.09	0.94	12.67		
United States	0.81	0.44	0.57	11.20	0.86	19.40	0.60	16.78

Energy Access and Security	Import dependence		Quality of electricity supply		Solid fuel use		Diversity of supply	
Country	**KPI**	**Raw**	**KPI**	**Raw**	**KPI**	**Raw**	**KPI**	**Raw**
Canada	0.64	-52.71	0.93	6.56	1.00	5.00	0.93	0.76
Denmark	0.59	-39.88	1.00	6.89	1.00	5.00	0.90	0.74
France	0.22	48.73	0.98	6.79	1.00	5.00	0.84	0.70
Germany	0.17	60.00	0.97	6.75	1.00	5.00	0.94	0.76
Italy	0.06	84.70	0.69	5.34	1.00	5.00	0.76	0.65
Japan	0.08	82.12	0.97	6.75	1.00	5.00	0.86	0.71
New Zealand	0.37	12.11	0.66	5.19	1.00	5.00	0.96	0.77
Sweden	0.28	32.97	0.97	6.74	1.00	5.00	0.93	0.75
Switzerland	0.20	52.32	0.98	6.80	1.00	5.00	0.88	0.72
United Kingdom	0.34	20.03	0.89	6.37	1.00	5.00	0.83	0.69
United States	0.31	25.29	0.91	6.47	1.00	5.00	0.90	0.74

Figure 7 – Heat Map Indicating Differences between Japan and Selected Archetype Comparators*

Country	**Economic growth & development**	GDP per capita	HDI	Import bill as a share of GDP	Energy intensity	Share of mineral products in export	**Environmental sustainability**	Carbon intensity	Share of non-carbon energy	Outdoor air pollution	Freshwater withdrawals	**Energy access & security**	Import dependence	Quality of electricity supply	Solid fuel use	Diversity of supply
Japan	**0.87**	**0.79**	**0.90**	**0.87**	**0.84**	**0.97**	**0.74**	**0.91**	**0.79**	**0.76**	**0.51**	**0.73**	**0.08**	**0.97**	**1.00**	**0.86**
Canada	0.13	-0.10	-0.01	0.03	0.31	0.33	-0.17	0.14	-0.21	-0.15	0.4	-0.15	-0.57	0.04	0.00	-0.07
Denmark	-0.02	-0.09	0.03	0.00	-0.07	0.09	0.10	-0.03	0.62	-0.13	-0.07	-0.15	-0.51	-0.03	0.00	-0.04
France	0.04	0.02	0.03	0.09	0.03	0.04	-0.13	-0.04	-0.21	-0.17	-0.11	-0.03	-0.14	-0.01	0.00	0.02
Germany	0.01	-0.02	-0.01	0.11	0.00	0.00	-0.08	0.01	0.11	-0.13		-0.04	-0.09	0.00	0.00	-0.08
Italy	0.03	0.04	0.06	0.17	-0.07	0.02	0.14	-0.01	0.53	-0.05	0.10	0.10	0.01	0.28	0.00	0.10
New Zealand	0.07	0.12	-0.04	0.14	0.08	0.06	-0.21	0.05	-0.21	-0.18	-0.47	-0.02	-0.29	0.31	0.00	-0.10
Sweden	0.03	-0.10	-0.01	0.08	0.08	0.07	-0.23	-0.07	-0.21	-0.20	-0.45	-0.07	-0.21	0.00	0.00	-0.07
Switzerland	-0.05	-0.16	0.02	0.04	-0.11	0.02	-0.17	-0.09	-0.21	-0.06	-0.33	-0.04	-0.13	-0.01	0.00	-0.02
United Kingdom	0.01	-0.08	0.06	-0.01	-0.06	0.16	0.00	-0.01	0.43	-0.17		-0.04	-0.26	0.08	0.00	0.03
United States	0.01	-0.21	-0.03	-0.03	0.15	0.07	0.04	0.11	0.22	-0.09	-0.09	-0.05	-0.24	0.06	0.00	-0.04

*This heat map allows for a reading of Japan's performance in the EAPI in relative terms. It provides a sense of the distance in scores that separates Japan from other members of the Rationalize archetype. Blue-shaded cells and grey-shaded cells indicate that Japan scores or ranks respectively higher or lower than the comparator, while no shading means that there is no significant divergence. The darker the shading, the greater the difference in performance.

Score Difference -0.7 -0.4 -0.1 0.1 0.4 0.7

1.4 The Japanese Earthquake and Tsunami – Implications for the Energy Sector[18]

The Fukushima-1 Incident and Near-term Response

On Friday 11 March 2011 Japan's east coast was hit by a magnitude 9 earthquake, followed by a large tsunami. There were four nuclear power sites with operating reactors in the area affected by the tsunami: Fukushima-1, Fukushima-2, Onagawa and Tokai. The tsunami inundated the Fukushima-1 site, where six boiling water reactors (BWRs) are located. At the time of the earthquake three reactors were operating, with Reactor Unit 4 on refueling outage and Reactor Units 5 and 6 shut down for maintenance. When the earthquake struck, all three operating reactors shut down automatically and shutdown cooling commenced. When the tsunami hit the site all alternating current electrical power to the cooling systems for the reactor and reactor fuel ponds was lost. Over the next few days, the fuel heated up and its cladding reacted with steam releasing hydrogen, which ignited, causing several explosions. For over a week the site struggled to provide cooling water to the reactors and the reactor fuel ponds. Electrical supplies were gradually reconnected and a degree of control returned. Heavily contaminated water, used to cool the reactors and spent fuel ponds, collected in uncontained areas onsite and leaked out to sea.

Before the accident at Fukushima-1 there were 54 nuclear power reactor units operating on 17 sites around the coast of Japan. Twenty-four of these units are pressurized water reactors (PWR) and 30 are BWRs. A further two advanced BWRs are under construction at the Shimane and Ohma sites. Nine of the regional utilities operate nuclear plants of which Tokyo Electric Power Company (TEPCO), which owns Fukushima-1, is the largest with 17 reactor units. Since the earthquake, all 10 reactor units at Fukushima-1 and Fukushima-2 remain shut down, as do the three BWR reactor units at the Onagawa site and the reactor unit at the Tokai site. Three reactor units at the Hamaoka site have been closed indefinitely following government concerns over long-standing seismic safety issues. Nineteen reactors continued to operate beyond Friday 11 March 2011.

The government decided in late June 2011 that 38 of the 54 units were safe enough to operate, pending implementation of enhanced longer term severe accident management measures. However, in the face of rising public safety concerns, the government announced on Wednesday 6 July 2011 that all reactors must complete a stress testing programme to demonstrate adequate safety levels. As a consequence of the stress testing process, all 54 nuclear plants in Japan will be shut down as of May 2012. Before they come back on line, plants must successfully pass the stress test and gain sign-off from the local government and the Ministry of Economy, Trade and Industry (METI).

Looking to the future, the Minister for National Policy announced in July 2011 that the national energy policy will now consider how to reduce future dependency on nuclear power. Later that year the Japanese prime minister reasserted Japan's desire to reduce reliance on nuclear power, stating that the new national energy strategy would "thoroughly review the country's nuclear policy and seek new solutions".[19]

Under the terms of the Basic Energy Plan 2010, nine new nuclear plants were due to have been constructed by 2020, with a further 14 by 2030. These plans are now on hold.

Long-term Policy Formulation Timeline

In response to the Fukushima incident, the government is conducting a wholesale review of the energy sector. This consists of three work streams to be completed by the summer of 2012:

1. Basic Energy Plan (BEP): METI has been asked to review the BEP to cover scenarios out to 2030
2. Nuclear Committee: METI has formed a working group to review the nuclear sector
3. National Energy Strategy: Review of energy strategy being conducted by the Prime Minister's Office

At the time of writing the government was due to release a short-term response plan to tackle the potential for energy shortages during the winter of 2011 and summer of 2012.

Implications for the Energy Triangle

- Economic growth and development: Japan's response to Fukushima-1 has underlined the potential for further improvements in energy intensity. Measures currently underway in Japan include reducing the temperature of heating and air conditioning and having large employers stagger their working week. LED lighting has been very successful, as growth in demand enabled sufficient scale to bring down prices. In some instances these measures have been very painful to adopt and may have a negative impact on the competitiveness of Japan's manufacturing sector, which will have to work at 75% power availability, requiring new shift patterns.[20]
- Environmental sustainability: In response to government targets, the Japan Atomic Energy Agency (JAEA) had modelled a 54% reduction in CO2 emissions (from 2003 levels) by 2050; by 2100 they hoped to achieve a reduction of 90%. To achieve this Japan planned that 60% of the national primary energy mix would be met by nuclear power. As discussed above, national policy has changed dramatically in response to the Fukushima incident and there is now a strong belief among policy-makers that Japan must seek alternatives to nuclear power.
- Energy access and security: Japan's 54 nuclear reactors meet 27% of electricity demand. With the load factor for nuclear power plants reported to be at 26.4% in August 2011, the country has increased the quantity of LNG and thermal coal imports (18.2% and 7.1% year-on-year).[21] A full sh ut down of nuclear plants in 2012 would require a further 10% reduction in energy use, on top of the 20% achieved this summer.

[18] This section is based on input received during a series of interviews conducted in Japan in October 2011, with supporting detail from HM Chief Inspector of Nuclear Installations, Japanese earthquake and tsunami: Implications for the UK nuclear industry, September 2011.
[19] http://www.world-nuclear.org/info/inf79.html.
[20] http://www.reuters.com/article/2011/03/28/us-japan-quake-ports-idUSTRE72R0ZY20110328.
[21] Bloomberg, Japan LNG, Thermal Coal Imports Rise to Record in August; Oil Imports Gain, 2011.

Summary: Key Challenges for Japan's Current Energy Architecture

- **High import dependence:** Net imports account for over 80% of Japan's TPES, with close to complete import dependence for hydrocarbons. Absolute import levels may rise as the country recovers from the Fukushima disaster and reassesses its nuclear energy plans.
- **Supply/demand balance:** The low load factor of nuclear plants, and the prospect of a full shutdown in spring of 2012, raises significant challenges for meeting demand in the electricity sector in the short term.
- **Air quality:** CO2 emission levels have continued to be high and are contributing to poor air quality. In addition, the country is far from meeting its Kyoto Protocol targets.
- **Increased integration of Renewable Energy Sources (RES) in the energy mix:** Further integration of RES in the national energy architecture is an imperative for all Rationalize countries to diversify supply, provide energy security and reduce greenhouse gas emissions.

Step 2:
Creating New Energy Architecture Objectives

2.1 Defining Japan's Objectives for a New Energy Architecture

A consideration of Japan's performance on the EAPI helps highlight the challenges that its energy architecture faces. It helps provide a foundation for identifying a set of objectives for the creation of a New Energy Architecture in Japan that is more responsive to the imperatives of the energy triangle.[22] These objectives were further shaped and tested during a series of interviews with a range of representatives from across the energy value chain, as well as through a multistakeholder workshop conducted in Tokyo. The objectives below therefore represent participants' suggestions of the issues that Japan should focus on.

It was clear throughout this process that there are a number of different, and often opposing, opinions with regard to how Japan should change its energy architecture to tackle both near and long-term challenges. In the remainder of this report we have tried to present a balanced overview of these perspectives. Ultimately, the different camps will have to find common ground, conceding ground by making difficult trade-offs. It is only through this universal approach that an appropriate solution will be found.

Objective 1 – Expand renewable deployment and support the development of "new" energy industries

Japanese firms are among the global leaders in green technologies such as wind, solar and geothermal. For example, 70% of steam turbines and power gear used in the geothermal industry is produced in Japan. Yet these sources account for only 1% of domestic power generation. There is significant potential for expanding renewable deployment. Japan possess the world's third largest geothermal resources, is an attractive site for tidal power due to the Kuroshio surface ocean current, and has high potential for both onshore and offshore wind, particularly on the east coast.[23] Increasing the share of these energy sources will increase energy diversity, reduce Japan's dependence on imports, and lower emissions.

Key implications: Private investors need to be attracted to realize the large potential of renewables and power feed-in tariffs coordinated with utilities. Regulations and bureaucracy around utility-scale renewable deployments need to be simplified to reduce obstacles for suitable projects. Innovation in energy storage and renewable technologies will support deployment and create a new export industry.

Objective 2 – Rethink approach to nuclear energy

Nuclear energy will continue to play an important role in Japan's diversified energy mix. This is the perspective not only of advocates of nuclear power, but of the consensus of industry experts interviewed as part of this study. A large rally held in Tokyo on Monday 19 September 2011 called for the end of the construction of new plants and an agreed schedule for phasing out nuclear power as existing plants come to the end of their natural life. Such protests and widespread calls for an end to nuclear power highlight the intensity of opposition that the Fukushima crisis has triggered. The government must make fundamental changes to how the nuclear sector is run and regulated in order to rebuild public confidence in the Japanese government and the nuclear energy sector.

Key implications: Ensuring public buy-in is central to re-establishing nuclear energy's role in Japan.

Objective 3 – Create new markets and infrastructure for energy transmission and distribution

Japan currently has partially unbundled the downstream retail component of the electricity supply chain. However, further benefits can be imparted through complete state utility vertical de-integration.[24] Such a move could help further improve electricity market efficiency and increase transparency in the sector, as shown by similar moves in the United Kingdom, the Nordic countries and Australia.[25] However, it would need to be accompanied by strong regulatory change.

Liberalization could also help facilitate the creation of a regional energy infrastructure in Asia, based upon an expanded natural gas pipeline network and a cross-border power network. Such a move would help bolster regional energy security, but would require an effort on the part of the Japanese government to build stronger relationships with East Asian nations.

Key implications: Large-scale coordination and capital will be required to install new transmission lines and integration equipment. A restructuring of the energy industry requires Japan to undergo a turbulent period where the government must attract private investors, ensure an adequate level of market competition and learn how to regulate the liberalized market.

Objective 4 – Create a new best practice model for energy efficiency

The response to Fukushima has shown that when the population recognizes a challenge and agrees on a solution, they can act quickly and in unison. Actions included reducing air conditioning use, having large employers stagger their working week and public broadcasts during peak hours advising citizens to reduce demand. Peak electricity use fell by nearly a fifth from 60 GW to 49 GW in the Tokyo region compared with last year. These were temporary measures and in many cases are not practical beyond the short term. However, they provide a clear indication of the potential for energy efficiency initiatives to manage demand while remaining economically competitive with the appropriate technology and market support.

Key implications: Creation of new schemes to promote energy efficiency. Investment in technology to allow better management of energy demand.

[22] These transition objectives are intended to indicate the focus that Japan will have over the course of the next 15-20 years and are not intended to be exhaustive.
[23] IPCC, Working Group III – Mitigation of Climate Change, Special report on renewable energy sources and climate change mitigation, 2011.
[24] Global Energy Network Institute, National Energy Grid Japan, 2007.
[25] IEA, Lessons learned from liberalised electricity markets, December 2005; IEA, Learning from the blackouts: Transmission system security in competitive markets, December 2005.

Step 3:
Defining the Enabling Environment

3.1 Achieving Japan's New Energy Architecture Objectives: Creating the Right Enabling Environment

Achieving each of Japan's New Energy Architecture objectives is contingent on the creation of an appropriate enabling environment. The research conducted as part of the wider New Energy Architecture project has shown that enabling environments consist of four pillars:

1. Policy initiatives: Frameworks and incentives should be created to put in place the rules, price signals and risk-return incentives that attract investors and facilitate development. Regulations should be consistent, transparent, evidence based and include strict standards of governance. A strong policy platform will unlock the potential of business to do what it does best; to profitably invest and innovate.
2. Technology and infrastructure: Technological innovations should be deployed to fix specific challenges in a country or stage of the value chain, as was the case in the past in Japan. Government and industry must look to create and align standards to reduce production costs and facilitate integration.
3. Market structures: Market structures should be created to allow producers to meet consumer's needs efficiently. The government must take an active role in creating market links between different players along the value chain and should guarantee private investment in renewable energy projects to reduce the risk involved in such ventures.
4. Human capacity: Human capacity should be developed to drive change and develop solutions. To drive change will require increased citizen access to information (e.g. smart metering). To develop solutions will require increased focus on education, training and accreditation by professional bodies to overcome the scarcity of technical knowledge, ability and experience.

Sitting across these four pillars is information. Making changes to energy architecture requires building support from all stakeholders in civil society, including the public at large. The establishment of communication channels with all stakeholders is a necessary step towards promoting better understanding of the risks and benefits associated with energy architecture change. The provision of information is therefore central to driving a bottom-up acceptance of, and even pull for, change.

In the following section we provide an overview of the options that Japan should consider pursuing to create enabling environments that support its transition to a New Energy Architecture, applying the above framework. The options highlighted are based on interviews and a multistakeholder workshop conducted in Japan.

Figure 8 – The Four Pillars of an Enabling Environment

3.2 Defining Enabling Environments for Japan's New Energy Architecture

1. Expand renewable deployment and support development of "new" energy industries

1.1 Create a detailed policy framework to support growth of the renewable energy sector

Japan turned to renewable energy in search of energy security and supply stability after the first oil shock seriously weakened the nation's economy. Starting in 1974, MITI (Japan's Ministry of International Trade and Industry, now METI) launched the "Sunshine Project", which aimed to achieve technological progress with new energy technologies, and significant funds were directed to solar PV R&D. In 1993, the programme was expanded to encompass sustainable development objectives, including CO2 reductions. Targets were established for solar PV deployment and a gradually declining subsidy for residential rooftop solar PV systems was initiated. The result was a dramatic increase in installed capacity and accompanying reduction in solar PV costs. Japan rose from a minor player to become the world's largest solar PV producer in less than a decade. Over the 1994 to 2004 period, system costs declined by two-thirds and annual installations increased more than 1,000-fold.[26]

While the programme successfully promoted the growth of residential systems, large-scale utility level systems have not been developed, resulting in a lack of penetration of solar and other renewables in Japan's total primary energy supply. To support the development of large-scale projects, the government has approved a new law implementing a feed-in tariff policy starting July 2012, with the goal of reaching 30 GW of power generation from renewable energy sources. This represents the most significant policy initiative within the renewables sector in the past 10 years, marking a turning point in the policy environment. However, there remains a lack of clarity over how new producers of solar power can sell power to the grid. The special parliamentary committee created to manage the programme needs to create more detailed specifications on how the feed-in tariff will work.

[26] IPCC, Working Group III – Mitigation of Climate Change, Special report on renewable energy sources and climate change mitigation, 2011.
[27] These principles were highlighted by participants during the course of the working group discussion conducted on New Energy Architecture in Tokyo in October 2011.
[28] IEA, Energy Policies of IEA Countries: Austria, 2007.
[29] IEA, Deploying Renewables; Principles for Effective Policies, 2008.

The framework, which dictates future renewable energy policy, should pay recognition to the five principles explained below.[27] While these principles are applicable to all countries, a number of examples from within the Rationalize archetype have been provided. The aim is to illustrate how countries with similar objectives and levels of economic development have succeeded or failed by adhering to or ignoring these principals.

i. As transparent as possible: The introduction of renewables in Austria was hindered by a lack of transparency, particularly with regards to price formation in the gas and electricity sectors. High levels of vertical integration and government intervention resulted in poor information flows and a lack of choice among consumers. A 2006 government report, intended to reinvigorate the electricity market, declared improving transparency as one of their main objectives. As a result, major electricity providers agreed to stop utilizing fixed price conditions and an information leaflet was delivered to all electricity customers explaining their options in a liberalized market. As a result, new companies have been encouraged to enter the market and Austria now has some of the world's most ambitious targets for the uptake of renewables.[28]

ii. As stable as possible: In 2005, the United States led the world in annual onshore wind power capacity additions, supported by state and federal policies, including generous tax incentives. However, the lack of stability in the provision of the tax credits has led to substantial boom and bust cycles in US wind power installations over recent years. Without consistency in government policy, private companies were increasingly unwilling to cover the high capital costs of building wind farms leading to a decrease in their construction.[29]

iii. Tailored according to the level of maturity of the technology: Scotland has excellent potential for generating electricity by capturing wave energy. It has ambitious targets to deliver 1600 MW of power by 2020 through wave power; a figure unrivalled anywhere in the world. The Scottish government has put in place very generous financial incentives. However, by placing so much emphasis on wave power the government is tailoring their energy policy to an immature technology. The scarcity of many real success stories has led the major utilities companies, which are the key backers of wave projects, to start losing faith. As recently as July 2011, German firm RWE withdrew its support for the Siadar Bay wave energy project in Scotland, planned to be the world's largest.[30]

iv. Feed-in tariffs should be gradually phased out based on the maturity of technologies: In Germany, decade-old feed-in tariffs have long supported the growth of renewable sources with solar power becoming particularly widespread. These feed-in tariffs compel the country's utilities companies to buy all the power generated by Germany's solar PV plants. In 2010, however, the government decided to double the rate at which the solar subsidies decrease to 10% each year, responding to criticisms that the subsidy was leading to an unaffordable proliferation in solar energy production. In this case, subsidies that were designed to support a nascent industry had actually started to increase costs, illustrating that government policy must change in response to the maturity of renewable energy technologies.[31]

v. Tailored according to a country's strengths: The United Kingdom has only modest natural resources for hydropower, biomass and solar energy but has an excellent wind profile. Therefore, the British government has pursued policies to encourage the construction of both onshore and offshore wind facilities; 166 onshore wind farms are in the planning stage and the government offered grants of around 10 million British pounds to each successful offshore wind farm project.[32]

1.2 Build out supporting infrastructure

Geographic areas that are optimal for renewable energy sources are not necessarily connected to the main power grid. For example, high potential areas for wind exist in Tohoku and Hokkaido in the north and in Kyushu in the south but there is limited access to the grid from those areas.

Japan's complex planning laws heighten the challenges of integrating large-scale renewables into the transmission network. Planning decisions are taken at a local, regional and national level. For the complicated type of infrastructure construction that an increase in renewables would require, many different stakeholders would need to be consulted. Local and city planning authorities, prefecture governors and the Minister of Construction must all be convinced before a public draft is prepared. Only once public consultation has occurred and the Minister of Construction has coordinated with all other involved ministries will any plan gain approval.[33]

The unique way in which Japan's power grid is designed poses further problems for the integration of non-dispatchable renewables, such as wind and solar. Most developed countries' grids resemble a spider web of unified production and distribution channels, helping to generate uniformity across the system. Japan's grid more resembles a fishbone with 10 vertically integrated utilities controlling both production and distribution in each region. Interconnections between the regions could be strengthened. The south-western and north-eastern electricity grids operate at different frequencies (60Hz and 50 Hz). Transmitting electricity across these different cycles requires conversion facilities of which only three currently exist.

Improvements in infrastructure will go some way to tackling these challenges. Potential solutions include: expanding ultra high-voltage transmission lines to connect coastal areas to the network; updating the grid to "smart" technology for better management of intermittent sources; investing in transformers to bring greater uniformity across regional production and distribution channels; and developing storage systems to provide back-up supply.

Such improvements will of course come at some considerable cost. The government has already introduced a 2.1 billion-yen programme to attempt to solve some of these issues, but academics and industry experts wonder whether it will be enough to create the improvements necessary. It will also require strong political will and a streamlining of planning laws to prevent the additional costs that come with project delays.

1.3 Build on success at the city level

Japan has achieved success in improving environmental sustainability by pursuing initiatives at the city and prefecture level. Several groupings of cities are working together to tackle emissions. An example is the voluntary cap-and-trade scheme; the Metrocap Project in which five cities are involved.

Japan should look to similar initiatives to support the deployment of large-scale renewable projects. It has been suggested, for example, that Special Economic Zones be created in areas impacted by the tsunami to bring in investment, new jobs and to speed up infrastructure development. These areas could be used as hubs for the development of new sustainable technologies and provide an opportunity for experimentation unique among Rationalize nations.

1.4 Increase engineering graduates for sustainable growth of clean-tech research and development

The country has been experiencing a decline in new engineering graduates (approximately 1.1% are foreign students) since the late 1990s, and manufacturing firms are experiencing a war for talent.[34] This challenge is further exasperated by a declining population growth rate.[35] The availability of highly skilled engineers for innovative renewable energy research and other clean technologies, such as electric vehicles, is low. Opening up international science and engineering programmes at universities will help attract new talent. Additionally, foreign workers can be hired and brought into the country or R&D activities can operate in other countries, such as China, to access local talent.

1.5 Build on lessons learned from clean technology initiatives to help emerging countries

Mobilizing technical resources from the developed world to promote change in the developing world will play a central role in reducing emissions.[36] If Japan can provide the technology and policy models to boost efficiency in newly industrializing countries such as China and India, it can have a significant impact on carbon emissions: Japan's CO2 emissions make up only 4% of the world's total; China by comparison already contributes 23%.[37] Working with emerging economies to export and develop clean energy technologies can therefore help Japan contribute towards the global sustainability agenda while providing an international market place for Japanese firms. Japan should therefore look to export best practice initiatives and technologies, such as the Top Runner programme.

[30] Herald Scotland, World's Biggest 'Wave Farm' In Crisis, 2011.
[31] The Economist, Germany's Solar Subsidies: Fed Up, 2010.
[32] IEA, Energy Policy of IEA Countries: The United Kingdom, 2006.
[33] Japan Urban Observatory, Japan: An Overview of Planning, http://www.gdrc.org/uem/observatory/jp-overview.html.
[34] The New York Times, High-Tech Japan Running out of Engineers, 2008.
[35] National Institute of Population and Social Security Research, Summary of the Japanese Population Projection, 2011.
[36] Keidanren, Policy proposal: Towards a new international framework for the post-Kyoto protocol era, September 2011.
[37] United Nations Statistics Division, Millennium Development Goals indicators: Carbon dioxide emissions (CO2), thousand metric tonnes of CO2.

2. Rethink approach to nuclear energy

2.1 Establish a fully independent regulatory agency that will appraise new and existing facilities for quality and safety compliance

Following the Fukushima incident, three-fifths of the public stated that they have little confidence in nuclear power.[38] This is symptomatic of a wider loss of faith in the government. Politicians should focus on tackling the causes of the disquiet by telling the truth. Otherwise, there is a risk that legitimate criticisms of the handling of the Fukushima incident will turn into an unwarranted assault on the whole political system. To bring nuclear plants back online, the government must begin by restoring public confidence. To do so, it must be transparent in releasing the details of nuclear stress tests to the public. The government should also consider rationalizing the activities of the Japanese Nuclear Safety Commission, Japanese Atomic Energy Commission and Nuclear and Industrial Safety Agency to establish a fully independent regulatory agency that will appraise new and existing nuclear facilities for quality and safety compliance.

Fukushima also represents an important turning point for the International Atomic Energy Agency (IAEA). Sign off from the IAEA is seen in some quarters as a formality, and many see it as a promoter of nuclear energy as opposed to a regulator. In response to this, the IAEA should look to strengthen its technical functions. A potential means by which to achieve this is by combining the Nuclear Energy Agency (NEA) and IAEA to build stronger capabilities. Stronger global oversight will help assure the public more broadly.

2.2 Build technical capabilities across the nuclear value chain

The Fukushima incident has revealed a number of weaknesses within Japan's capabilities in the nuclear value chain, particularly in relation to managing cooling shutdown, unbundling spent fuel storage and contaminated water disposal, and decommissioning.

Japan should look to invest in R&D to overcome these challenges, bringing in international expertise to assist. This should include an exploration of fourth-generation nuclear technology, including the thorium cycle. Japan is already part of the Generation IV International Program, which focuses on collaborative research and development, and plays a prominent role in the IAEA-organized International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), which promotes international actions to support innovations in nuclear systems. Japan should look to build on this work over the coming years.

The safe running of nuclear plants involves not only technical aspects but also managerial aspects. Almost all past nuclear accidents were partially caused by human error. There is therefore a need to review organizational systems and oversight, as well as cultural behaviour.

2.3 Communicate lessons learned from Fukushima to the international community

In many parts of the world the appetite for nuclear generation remains unchanged: China is still predicted to grow from less than 3% of global nuclear capacity to 27% in 2050.[39] India is also pushing on with expanding its capacity and is expected to contribute up to 11% of global production in the same time period. It is therefore important that Japan clearly communicates the lessons learned from the disaster to the international community. The Global Nuclear Energy Partnership (GNEP) provides a framework for countries seeking to expand the use of nuclear energy while promoting non-proliferation and secure supplies of fuel. The IAEA also promotes a global safety regime, including the Convention on Nuclear Safety. Japan must seek to use these international bodies to share the knowledge gained post-Fukushima so that its experiences can be used to prevent similar incidents elsewhere. It should also look to export best practice in nuclear infrastructure design to help meet emerging countries' needs for nuclear power station development.

3. Create new markets and infrastructure for energy transmission and distribution

3.1 Compete a full cost benefit analysis of the benefits of market liberalization in the electricity sector

The Fukushima incident has prompted discussions of whether Japan should pursue greater market liberalization. Japan's utilities sector is partially deregulated downstream, but it is the only country within the OECD that does not have an independently operated transmission system.[40] Options for further liberalization include unbundling, allowing new players, such as gas companies, to compete in the electricity market. Value chain efficiencies and consumer gains can be achieved from a highly competitive market, encouraging firms to improve their operations to lower costs and produce innovative services and product offerings to downstream buyers.

Technical options for improving regional supply should also be considered. These include the addition of further conversion facilities to allow unconstrained transmission of electricity between regions, and an increased focus on regional decentralized distribution and generation hubs connected by long distance ultra-high voltage lines.

The government should conduct a full cost benefit analysis of market liberalization and the technical options highlighted, taking into account the cost of implementation, the regulatory framework required and the potential impact on consumers.

[38] The Economist, Energy in Japan: Bright Ideas Needed, 2010.
[39] IEA, Technology Road Map: Nuclear Energy, 2010.
[40] IEA, Energy Policies of IEA Countries - Japan 2008 Review.

3.2 Encourage the development of a liberalized regional gas market

Japan and Asian countries more broadly pay a premium for LNG supplies. In the current price environment greater market liberalization, with a move away from dependence on long-term take-or-pay oil linked contracts in favour of hub based pricing, could help reduce this premium. This could form part of a policy to build a diversified portfolio consisting of partly oil-indexed long-term gas contracts and partly hub-linked long-term gas contracts, while remaining open to the spot market and to gas storage.[41] In Japan, it has long been argued that such a move would reduce energy security. However, the experience of the United Kingdom in establishing the National Balancing Point has shown that market liberalization can provide energy security.

3.3 Support the development of pan-Asian energy infrastructure to boost regional energy security

The move towards a hub-based regional gas market could be supported by greater physical integration in the region, such as through the construction of a pipeline from the Russia to Japan. Such a move would need to be supported by the expansion of the pipeline network in Japan itself, since pipeline networks are centred near LNG import terminals, with the trunk pipeline networks not fully interconnected across the country. It would also require an effort on the part of the Japanese government to build stronger relationships with East Asian nations.

This could form part of a broader attempt to build regional energy architecture for Asia. Both the Japan Productivity Center and the Japan Renewable Energy Foundation have proposed the creation of a cross-border power grid to create an international trade area for electricity. Such a move would promote energy security since the larger a regional grid, the greater the options for managing system load by relying on this larger suite of resources. Within an adequately regulated framework and with independent system operations, the right incentives would be in place to ensure efficient sharing of resources across jurisdictions. Such a network would provide considerable business opportunities for expansion among Japanese utilities, as has been seen in Europe.

4. Create a new best practice model for energy efficiency

4.1 Promote behavioural change in energy use to reduce peak demand

Demand side management is both about behavioural and educational elements, as well as technology. The response to Fukushima has shown that when the population recognizes a challenge and agrees on a solution, they can act quickly and in unison. Actions included reducing air conditioning, having large employers stagger their working week, and public broadcasts during peak hours advising citizens to reduce demand. Peak electricity use fell by nearly a fifth from 60 GW to 49 GW in the Tokyo region compared with last year. Japan should look to pursue policies that further embed these behavioural changes.

4.2 Expand smart grid programme to institutionalize behavioural changes

Many of the behavioural changes seen during the summer of 2011 were uncomfortable and impractical. Technology can be leveraged to promote long-term change. The introduction of smart technology is one such example. Steps have already been made in this regard. Recently, METI has begun an initiative called the Next Generation Energy and Social System Pilot in Yokohama City, Toyota City, Kyoto Prefecture and Kitakyshu City from 2011 to 2014. The aims are to investigate issues related to the implementation of a Home Energy Management System, a Renewable Energy System, and Electric Vehicles and Electric Condensers.[42] As part of this programme, ENNET – Japan's largest primary power provider – started a trial providing Demand Response Services to 3,000 households in Yokohama. The scheme allows ENNET to compare energy use among users and adopt a new pricing strategy accordingly. Information from the scheme has also allowed ENNET to reward users who cooperate with the Demand Response Programme.

Japan should build on the success of the smart city programme in Yokohama and smaller residential demand side pilots in other cities to develop a next phase of regional smart grid deployments. Such deployments are vital for retaining Japan's position among the world leaders in energy efficiency innovation, supporting electric vehicle deployment and encouraging diversification of the energy supply mix to include renewables and distributed generation (such as rooftop solar PV).

New business models can also be leveraged to promote behavioural change. Sliding tariffs that vary according to demand provide consumers with an incentive to change their consumption patterns more permanently. Such tariffs have already been introduced, offering discounted rates during the evening, with higher rates during the day. Such tariffs are further enabled through the use of smart meters.

[41] Accenture, Global gas markets: Separate paths or a shared future?, 2012.
[42] Ida, After a Disaster: The Future of Japanese Energy and Smart Grid Policy, 2011.

Step 4:
Defining Areas of Leadership

4.1 A Multistakeholder Action Plan for Japan

The creation of an enabling environment that is resilient to risk and responsive to the imperatives of the energy triangle goes beyond an individual corporation or government's scope. Three key groups of stakeholders have a role to play: policy-makers, industry and civil society.

The Fukushima disaster has bought Japan's national energy policy into sharp focus. Before the incident, Japan had planned to generate the majority of its electricity from nuclear power by 2050. Now concerns about safety and environmental sustainability have lead people to reappraise the role nuclear power should play in Japan's future. The government is already responding to the concerns of civil society by committing to reduce dependency on nuclear power and finding alternative renewable sources. However, these options are not without costs. The rapid decommissioning of nuclear power plants would lead to a massive increase in fossil fuel imports and raise serious questions about energy security. Equally, any major shift towards renewable energy would require massive financial investment, as well as huge amounts of faith in immature technologies. The scale of the challenge facing Japan is therefore massive and will require stakeholders to work together.

Considerations for industry

The electricity and nuclear supply industries will be largely responsible for the investment required to upgrade Japan's energy infrastructure. To ensure government backing, industry must show that new technology can be reliably built on time and within expected costs, making continuous effects to reduce construction and control costs by strengthening supply chains and making the construction process more efficient. Industry should tailor future activities to achieving Japan's New Energy Architecture objectives, considering the following options:

- Expand renewable deployment and support the development of "new" energy industries by being at the forefront of clean technology development: Industry must be at the forefront of efforts to develop cheaper and more efficient means of renewable energy generation. This would not only enable Japan's transition to a New Energy Architecture, but would also provide a business opportunity to export and develop clean energy technologies in emerging economies, helping Japan contribute towards the global sustainability agenda.
- Rethink approach to nuclear energy by building technical capabilities across the nuclear value chain: The investment needed to update Japan's ageing nuclear infrastructure will inevitably come from the private sector and the energy industry must work with the government to determine the role of nuclear power in Japan's future energy policy.
- Create new markets and infrastructure for energy transmission and distribution by investing in a national and regional transmission and distribution network for electricity and gas: The insular nature of Japan's energy infrastructure, reinforced through the dominance of regional power companies, creates inefficiency; the difficulty of conversion between regions presents a particularly significant issue. Not only must industry help extend and expand the transmission grid in areas with renewable energy potential, but it must do so in a nationally coordinated way. Furthermore, the connection of Japan's energy network to its regional neighbours will provide utilities with significant new business opportunities.
- Create a new best practice model for energy efficiency by adopting new business models to embed behavioural change: New business models can be leveraged to promote behavioural change with regard to energy consumption. Utilities should expand the use of sliding tariffs that vary according to demand, providing consumers with an incentive to change their consumption patterns more permanently – a process that would be further enabled through the introduction of smart meters.

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Considerations for civil society

Beyond the provision of information, civil society must be look to fully engage in the decision-making process to support the creation of a New Energy Architecture in Japan. Individual objectives must be set against the context of national strategy to aid the government and industry in achieving the country's energy and environmental policy goals.[44] Civil society should tailor future activities to achieving Japan's New Energy Architecture objectives, considering the following options:

- Expand renewable deployment and support the development of "new" energy industries by playing a direct role in the expansion of decentralized generation projects: In the future, civil society could play a direct role in the expansion of small-scale decentralized renewable generation projects by channeling investment to such initiatives. This will help ensure that civil society and consumers have a tangible stake in Japan's New Energy Architecture.
- Rethink approach to nuclear energy by helping shape the debate on the future direction of the industry: Civil society must look to participate in discussions about the future of Japan's nuclear power industry and ensure that the voice of the public is heard. This will go some way to rebuilding the public's faith in the energy sector.
- Create a new best practice model for energy efficiency by promoting the adoption of behavioural changes: Non-profit organizations, campaign groups and other non-government bodies must seek to raise public awareness about how changing consumption patterns can contribute towards a more efficient energy system, as well as promoting the adoption of new technologies (such as smart meters and LEDs) that can help promote change.

[43] IEA, Technology Road Map: Nuclear Energy, 2010.

Appendices:
The Creation of the Energy Architecture Performance Index

Appendix A: Computation and Structure of the Energy Architecture Performance Index

This appendix presents the structure of the Energy Architecture Performance Index (EAPI). The index is designed to understand how countries are performing in relation to each of the imperatives of the energy triangle: economic growth and development; environmental sustainability; and energy access and security. A sub-index was created for each of these imperatives. For each sub-index a set of key performance indicators (KPIs) were chosen based on an understanding of the objectives of the imperative:

- Economic growth and development: This sub-index aims to measure the extent to which energy architecture supports, rather than detracts from, economic growth and development. The following KPIs were chosen:
  - Energy intensity
  - Cost of energy imports as a share of GDP
  - Share of mineral products in export
  - GDP per capita
  - HDI
- Environmental sustainability: This sub-index aims to measure the extent to which energy architecture has been constructed in a manner that reduces negative environmental externalities. The following KPIs were chosen:
  - Carbon intensity of energy use
  - Share of non-carbon energy sources
  - Outdoor air pollution
  - Water scarcity
- Energy access and security: This sub-index aims to measure the extent to which energy architecture is at risk to an energy security impact, and whether adequate access to energy is provided to all parts of the population. The following KPIs were chosen:
  - Import dependence
  - Diversity of supply
  - Quality of electricity supply
  - Access to modern forms of energy

To create comparative data that could be aggregated into an overarching index, the data has been normalized. An individual index was created for each KPI. Performance for each KPI is expressed as a value between 0 and 1, calculated as per the below expression:

$$\text{Score} = \begin{cases} 0, & x > \text{BASE} \\ \dfrac{x - \text{BASE}}{\text{TOP} - \text{BASE}}, & \text{TOP} > x > \text{BASE} \\ 1, & x < \text{TOP} \end{cases}$$

Instead of using the maximum and minimum values of each data set, anomalies were first removed by establishing TOP and BASE levels. TOP is the point of the raw data that is mapped to 1 and is calculated based from the mean +/- two standard deviations (dependent on whether a high or low value for the original metric is “good” or “bad”). BASE is the point of the raw data that is mapped to 0 and is calculated from the mean +/- two standard deviations (dependent on whether a high or low value for the original metrics is “good” or “bad”). All other values then follow a linear distribution from the BASE to the TOP.

In the case of diversity of supply, the raw data was first converted into a Simpson’s Diversity Index to measure the distribution of energy supply across seven supply sources: coal and peat; crude oil and oil products; gas; nuclear; hydro; other renewables such as geothermal and solar; and combustible renewable and waste. The Simpson’s Diversity Index is expressed using the below function, where n is the relative abundance of each energy source:

$$D = 1 - \left(\frac{\Sigma\, n(n-1)}{N(N-1)} \right)$$

To create the sub-indices for environmental sustainability, as well as energy access and security, the individual indices for each KPI were aggregated by expressing each as a share of 1, with all KPIs evenly weighted (i.e. each indicator could contribute up to 0.25 to the sub-index). In the case of economic growth and development, energy intensity was given a higher weighting. This was in response to feedback received from the project steering board, which emphasized the importance of demand side management measures. Energy intensity therefore accounts for 30% of the index, with the remaining four indicators accounting for 70% of the index. The scores for GDP per capita and HDI were combined to provide a base level indication for economic growth and development, and together account for 17.5% of the index.

To create the overall score for each country the scores on each sub-index were added together, with the maximum score on the EAPI therefore being 3.

Historic data

To understand how countries have progressed over time, historic data was collected for the years 1999 to 2008, and also for 1990. To complete the normalization process for historic data the TOP and BASE values used were those from today's index. The historic indicators thus show how countries are performing in comparison to today.

In a number of instances historic data was not available. In these instances, data was kept constant from the last available year in which it was available. This applies to the following indicators:

- Economic growth and development
  - Share of mineral products in export: Data was only available for 2005-2008. In calculations of the index for the years 1999-2004 and 1980, the data from 2005 was kept constant.
- Environmental sustainability
  - - Water scarcity: Data was only available for 2000. This was kept constant across the time periods covered.
- Energy access and security
  - Quality of electricity supply: Data was only available for 2005-2008. In calculations of the index for the years 1999-2004 and 1980, the data from 2005 was kept constant.
  - Access to modern forms of energy: Data was only available for 2003. This was kept constant across the time periods covered.

Creating archetypes

Archetypes were created by grouping those nations that displayed common features during the KPI analysis, and are defined as follows:

- Rationalize: Those nations that scored in the top quartile for economic growth and development
- Capitalize: Those nations that scored outside the top quartile for economic growth and development, and in the top quartile for energy access and security
- Grow: Those nations that scored below the top quartile for economic growth and development, and energy access and security, but above the bottom quartile for energy access and security
- Access: Those nations that scored in the bottom quartile for energy access and security

A review of countries that fell towards the boundaries of the above criteria was completed. This was in recognition of the fact that many countries display features of more than one archetype. In these instances, countries have been allocated to the archetype that represents their most pressing need.

Appendix B: Technical Notes and Sources for the Energy Architecture Performance Index

This appendix presents the technical descriptions and sources for the 13 KPIs of the Energy Architecture Performance Index. The most complete data set available for the indicators was from 2008. Data from this year was therefore used, unless otherwise unavailable.

Economic Growth and Development

Energy intensity

GDP per unit of energy use (PPP $ per kg of oil equivalent) | 2008

Provides an indication of the efficiency of energy use, and whether there is an opportunity to improve energy availability by reducing energy intensity. Total primary energy supply is calculated as indigenous production plus imports, removing exports, international marine bunkers, international aviation bunkers, and then adding or taking away stock changes. (Source: The World Bank)

Cost of energy imports as a share of GDP

Value of import of fuels/GDP | 2008

Provides an indication of the extent to which the energy sector has a negative impact on growth. Import bill is calculated based on the import of fuels (mineral fuels, lubricants and related materials) as classified under the Standard International Trade Classification, Revision 3, Eurostat. (Source: WTO Statistical Database)

Share of mineral products in export

Mineral products in export/national exports | 2008

Provides an indication of the efficiency of energy use, and whether there is an opportunity to improve energy availability by reducing energy intensity. The share of mineral products includes minerals fuels as classified under the Harmonized System Codes of Chapter 27, which covers mineral fuels, mineral oils and products of their distillation; bituminous substances and mineral waxes. (Source: ITC)

GDP per capita

GDP (PPP) (current $) per capita | 2008

GDP per capita is gross domestic product divided by mid-year population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products, using purchasing power parity rates. (Source: The World Bank)

HDI

Human Development Index | 2008

The Human Development Index is used to assess comparative levels of development in countries and includes PPP adjusted income, literacy and life expectancy as its three main matrices. The HDI is only one of many possible measures of the well-being of a society, but it can serve as a proxy indicator of development. HDI has been shown to correlate well with per capita energy use. A certain minimum amount of energy is required to guarantee an acceptable standard of living (e.g. 42 GJ per capita), after which raising energy consumption yields only marginal improvements in the quality of life. (Source: The World Bank)

Environmental Sustainability

Carbon intensity of energy use

Carbon intensity (total carbon dioxide emissions from the consumption of energy per dollar of GDP using market exchange rates (metric tons of carbon dioxide per thousand year 2005 US dollars) | 2008

Estimate carbon dioxide emissions from the consumption and flaring of fossil fuels, per thousand dollars of GDP, using market exchange rates. When there are several fuels, as in this case, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption levels. (Source: EIA)

Share of non-carbon energy sources

Alternative and nuclear energy/TPES | 2008

Clean energy is non-carbon energy that does not produce carbon dioxide when generated. It includes hydropower, nuclear, geothermal and solar power among others. This is taken as a share of total primary energy use. (Source: The World Bank)

Outdoor air pollution

PM10 [mg/m3] per annum | 2008

Particulate matter concentrations refer to fine suspended particulates less than 10 microns in diameter (PM10) that are capable of penetrating deep into the respiratory tract and causing significant health damage. Data for countries and aggregates for regions and income groups are urban-population weighted PM10 levels in residential areas of cities with more than 100,000 residents. The estimates represent the average annual exposure level of the average urban resident to outdoor particulate matter. (Source: The World Bank)

Water scarcity

Freshwater withdrawals as a share of internal resources | 2000

Annual freshwater withdrawals refer to total water withdrawals, not counting evaporation losses from storage basins, and are a proxy measure for water scarcity. Withdrawals also include water from desalination plants in countries where they are a significant source. Withdrawals can exceed 100% of total renewable resources where extraction from non-renewable aquifers or desalination plants is considerable or where there is significant water reuse. Withdrawals for agriculture and industry include withdrawals for irrigation and livestock production and for direct industrial use (including withdrawals for cooling thermoelectric plants). Withdrawals for domestic uses include drinking water, municipal use or supply, and use for public services, commercial establishments, and homes. Data are for the most recent year available for 1987-2002. (Source: AQUASTAT)

Energy Access and Security

Import dependence

Net imports/TPES | 2008

Provides an indication of the extent to which a nation is dependent on sourcing imports to meet energy demand. Net imports are calculated across all energy sources, as well as carriers including electricity and heat. This is taken as a share of total primary energy supply. Dependence on energy imports exposes affected economies to potential price risk fluctuations. (Source: World Bank)

Diversity of supply

Simpson's Diversity Index | 2008

Greater diversity in sources of supply will reduce dependence on any one fuel, and therefore increase energy security. Given the interdependence of economic growth and energy consumption, access to a stable energy supply is a major political concern and a technical and economic challenge. All else being equal, the more reliant an energy system is on a single energy source, the more susceptible the energy system is to serious disruptions. Examples include disruptions to oil supply, unexpectedly large and widespread periods of low wind or solar insulation (e.g. due to weather), or the emergence of unintended consequences of any supply source. (Source: IEA; Author's calculations)

Quality of electricity supply

Rating from 0 to 7 | 2008

Assesses the quality of the electricity supply within a country based on lack of interruptions and lack of voltage fluctuations. This has been used in favour of measures of the percentage of the population supplied with electricity, as we believe that it is a nuanced measure more suited to the purposes of a global comparison. This is taken from the World Economic Forum's Executive Opinion Survey, in which respondents were asked: How would you assess the quality of the electricity supply (lack of interruptions and lack of voltage fluctuations) of your country? [1 = insufficient and suffers frequent interruptions; 7 = sufficient and reliable]. (Source: World Economic Forum, Global Competitiveness Index)

Access to modern forms of energy

Percentage of the population using solid fuels | 2008

Provides an indication of whether the population has access to modern sources of energy. Solid fuels include biomass, such as wood, charcoal, crops or other agricultural waste, as well as dung, shrubs and straw, and coal.

Although solid fuels are used for heating purposes, the World Health Statistics database is a compilation of information on the main fuel used for cooking purposes only. (Source: World Health Organization)

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