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National Institute of Transforming India

Joint Project between NITI Aayog and Institute of Energy Economics Japan (IEEJ)

On

Overall Energy Scenario of Japan

A Research Report

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The Institute of Energy Economics, Japan (IEEJ) was established in June 1966 and certified as an incorporated foundation by the Ministry of International Trade and Industry in September that year. The aim of its establishment is to carry on research activities specialized in the area of energy from the viewpoint of the national economy as a whole in a bid to contribute to sound development of the Japanese energy-supplying and energy-consuming industries and to the improvement of people's life in the country by objectively analysing energy problems and providing basic data, information and reports necessary for the formulation of policies. With the diversification of social needs during the three and a half decades of its operation, IEEJ has expanded its scope of research activities to include such topics as environmental problems and international cooperation closely related to energy. In October 1984, the Energy Data and Modelling Centre (EDMC) was established as an IEEJ-affiliated organization to carry out such tasks as the development of energy data bases, building of various energy models and econometric analyses of energy. In July 1999, EDMC was merged into IEEJ and began operating as an IEEJ division under the same name, i.e., the Energy Data and Modelling Centre. More information about the IEEJ can be found at: https://eneken.ieej.or.jp/en/

Objectives of the Report

The objective of the study was to analyse the overall Energy Scenario of Japan. While creating scenario for overall Energy Scenario of Japan, the objective was also to analyse Primary Energy Consumption, Final Energy Consumption, Fossil Fuel Consumption, Power Generation Mix, Energy Self Sufficiency, Overall Emission reduction and Energy Import of Japan.

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List of Abbreviations

IEEJ – Institute of Energy Economics Japan

GHG - Greenhouse Gas

LNG - Liquefied Natural Gas

IEA - International Energy Agency

SEP - Strategic Energy Plan

METI - Ministry of Economy, Trade and Industry

INDC - Intended Nationally Determined Contribution

OCCTO - Organization for Cross-regional Coordination of Transmission Operators

TPES - Total Primary Energy Supply

PV – Photovoltaic

ARIMA - Auto-Regressive Integrated Moving Average

PEC - Primary Energy Consumption

RS - Reference Scenario

ATS - Advance Technology Scenario

FEC - Final Energy Consumption

TWh – Terawatt hour

Mtoe – Million Ton of Oil Equivalent

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Abstract

Japan's energy policy has been dominated by efforts to overcome the impact from the 2011 Great East Japan earthquake and the subsequent nuclear accident. At the 15th Conference of the Parties (COP15) in 2009, Japan had pledged to reduce its greenhouse gas (GHG) emissions by 25% from 1990 to 2020. This ambitious pledge largely relied on plans to increase nuclear power's share in electricity supply from 30% to 50%. After March 2011, however, the country's entire nuclear power capacity was gradually shut down in the aftermath of the Fukushima Daiichi nuclear accident and came to a complete halt in 2013.

The nuclear shutdown left a gap of around 30% in electricity supply. This gap was closed mostly by at the time expensive fossil fuels, primarily by liquefied natural gas (LNG), but also by oil and, from 2013 on, by coal. Electricity savings and, since 2012, additional renewable electricity capacity also helped to close the gap. Yet by the end of 2013, import dependence had risen to 94% from 80% in 2010. Annual CO2 emissions from power generation had grown by more than 110 million tonnes, or by one-quarter. Electricity prices had increased by 16% for households and 25% for industry, according to IEA data, and were set to continue to rise fast. The situation was unsustainable for the long term. Thus, the government decided to fundamentally rethink its energy policy.

1. Introduction

In April 2014, the government adopted the fourth Strategic Energy Plan (SEP) and based on that plan, the Ministry of Economy, Trade and Industry (METI) prepared the 2015 "Long-Term Energy Supply and Demand Outlook" to 2030 which was adopted in July 2015. The SEP introduces safety among the key objectives of energy policy, alongside the three "Es" of energy security, economic efficiency and environmental protection. These objectives are intertwined and the government has been careful to balance them in the subsequent outlooks and strategies to 2030 and beyond.

After the adoption of the 2015 Outlook, Japan announced its intended nationally determined contribution (INDC) for COP21 (held in Paris from 30 November to 12 December 2015) to reduce GHG emissions by 26% from 2013 to 2030. In May 2016, it adopted the Plan for Global Warming Countermeasures. The plan is based on the INDC and the Paris Agreement by which Japan pledges to head towards cutting emissions by 80% by 2050 under the condition that this is compatible with economic growth.

Further, the 2011 Great East Japan earthquake and the Fukushima Daiichi nuclear accident highlighted several weaknesses in the electricity system and prompted the government to begin an overdue reform of the electricity market. The reform has three objectives: to secure a stable supply of electricity, to suppress electricity rates to the maximum extent possible, and to expand consumer choice and business opportunities.

The reform is being implemented in three stages. First, in April 2015, the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) began to operate. It is tasked with assessing generation adequacy and ensuring that adequate transmission capacity is available. It also has the power to order the construction of new transmission lines. Second, full liberalisation of the retail market took effect in April 2016. Third, in April 2020, the transmission and distribution segment of the electric power companies will be legally unbundled from the generation and retail segments.

However, Japan's gas industry remains dominated by a few vertically integrated companies that are based in large urban regions. They control the importation and regasification of LNG and the supply, marketing and transport of gas to larger individual customers and smaller gas distributors and retailers. They are regionally based with limited pipeline interconnectivity which makes effective competition in the sector challenging. The sector also needs wholesale trading markets and visibility of price drivers. Consumers (both large and small) would also benefit from access to better information on cost structures, for example.

Following the electricity market reform, the government has also embarked on a gas market reform, with the same three objectives: securing supply, decreasing prices as much as possible, and expanding consumer choice and business opportunities. The gas market reform consists of introducing full retail competition in 2017, improving access to pipelines and improving third-party access conditions and tariffs related to LNG terminals.

Moreover, oil continues to account for more than two-fifths of Japan's Total Primary Energy Supply (TPES). Securing oil supplies has traditionally been a key part of the government's energy policy as reflected in its active resource diplomacy and upstream investments abroad by Japanese companies, often with government support. Oil stocking policy was revised after

the Great East Japan Earthquake to allow for stock release also when a supply shortage arises as a result of a natural disaster.

Japan introduced a feed-in tariff system in July 2012 for renewable energy to increase generation as quickly as possible. However, the results of this approach have been mixed. While renewable energy experienced a significant and unexpectedly rapid boost, growth was concentrated in solar photovoltaic (PV) the total capacity of which has exceeded 32 gigawatts. The rapid scale-up of solar PV has translated into an urgent need to increase the flexibility of the overall power system, to significantly reduce generating costs and to increase the capacity of other renewables, such as wind and geothermal energy.

In view of above, Grid integration of variable renewable electricity is challenging in Japan, owing to both the country's geography and the historical evolution of the electricity sector. To reap the full benefits from the electricity market reform, it will be critical to designate an independent body to advice on the technical issues of grid integration in a neutral way. Combining this with Japan's excellent research and development (R&D) infrastructure will create a positive environment to make further progress.

2. Methodology of Projection

Methodology:

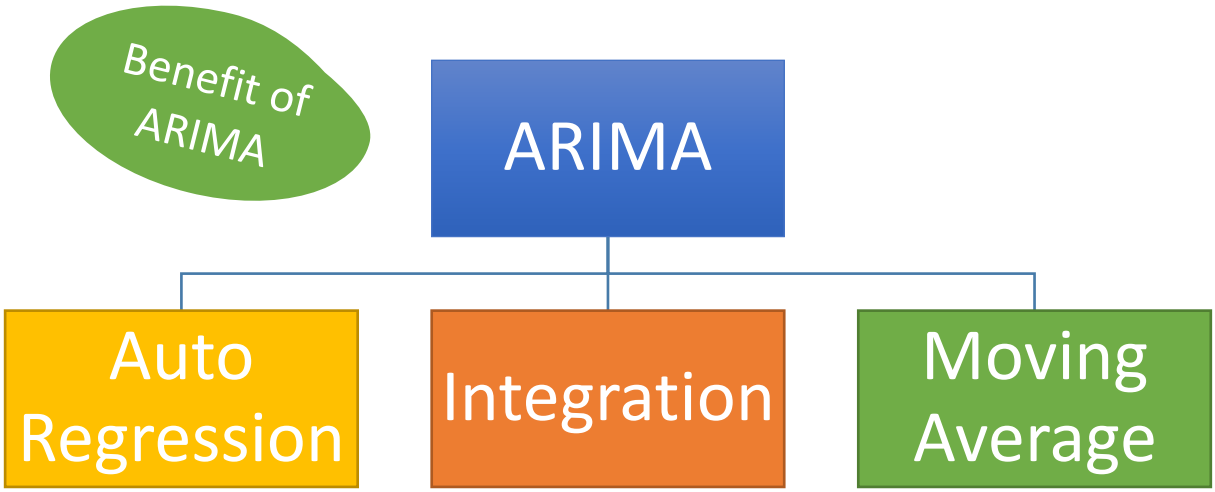
Uni-variate & Multivariate modelling of Auto-Regressive Integrated Moving Average (ARIMA) Model and Macroeconomic model structure have been used for projecting overall energy scenario of Japan. The reference scenario (policy as usual) and advanced technology scenario (energy efficient technology policy) has been considered for the projections. These scenario has been created by assuming following macro-economic indicator of the Japan.

- GDP: 1.4% (CAGR) Growth 2012-2047,
- Population: 1.2 Billion (2012) - 1.05 Billion (2047),
- Urbanization: 92% (2012) - 97% (2047)
- Share of Manufacturing: 18% (2012) – 20% (2047).

Auto-Regressive Integrated Moving Average (ARIMA) Model

An ARIMA model can be used as a "filter" that tries to separate the signal from the noise, and the signal is then extrapolated into the future to obtain forecasts.

Figure No.1: ARIMA Model



The ARIMA forecasting equation for a stationary time series is a linear (i.e., regression) equation in which the predictors consist of lags of the dependent variable and/or lags of the forecast errors. i.e., Predicted value of Y = a constant and/or a weighted sum of one or more recent values of Y and/or a weighted sum of one or more recent values of the errors. If the predictors consist only of lagged values of Y, it is a pure autoregressive ("self-regressed") model, which is just a special case of a regression model and which could be fitted. Lags of the stationarized series in the forecasting equation are called "autoregressive" terms, lags of

the forecast errors are called "moving average" terms, and a time series which needs to be differenced to be made stationary is said to be an "integrated" version of a stationary series.
A non-seasonal ARIMA model is classified as an "ARIMA (p, d, q)" model, where:

P is the number of autoregressive terms,
d is the number of non-seasonal differences needed for stationarity, and
q is the number of lagged forecast errors in the prediction equation.
The forecasting equation is constructed as follows. First, let y denote the dth difference of Y, which means:

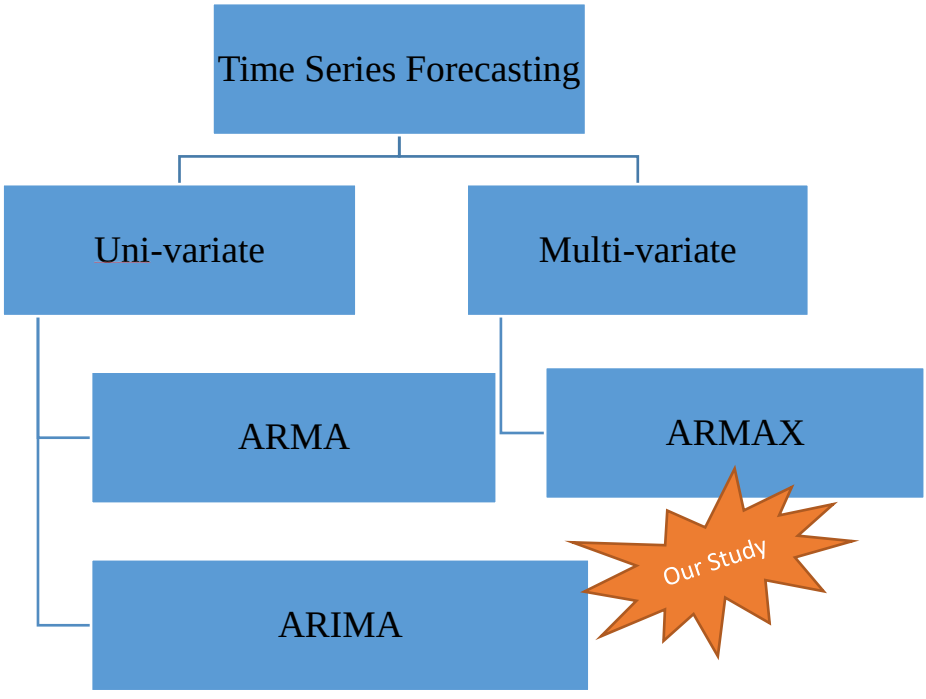
If d=0: $yt = Yt$
If d=1: $yt = Yt - Yt\text{-}1$
If d=2: $yt = (Yt - Yt\text{-}1) - (Yt\text{-}1 - Yt\text{-}2) = Yt - 2Yt\text{-}1 + Yt\text{-}2$

The second difference of Y (the d=2 case) is not the difference from 2 periods ago. Rather, it is the first-difference-of-the-first difference, which is the discrete analogue of a second derivative, i.e., the local acceleration of the series rather than its local trend. Since the all the data series found non stationary, we have used the first and 2nd differences for the prediction. In terms of y, the general forecasting equation is:

$\hat{y}t = \mu + \phi 1\ yt\text{-}1 + \ldots + \phi p\ yt\text{-}p - \theta 1 et\text{-}1 - \ldots - \theta q et\text{-}q$

Here the moving average parameters (θ's) are defined so that their signs are negative in the equation, following the convention introduced by Box and Jenkins. To identify the appropriate ARIMA model for Y, we begin by determining the order of differencing (d) needing to stationaries the series and remove the gross features of seasonality, perhaps in conjunction with a variance-stabilizing transformation such as logging or deflating.

Figure-2: Modelling Based on ARIMA Model



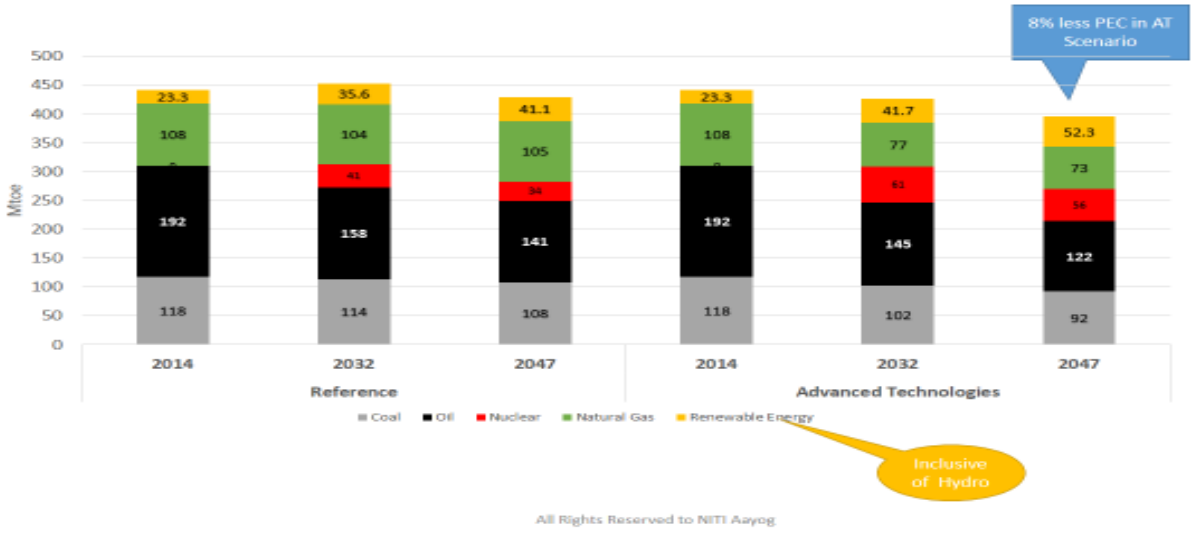
3. Outcomes of the Scenario

3.1 Primary Energy Consumption:

In Japan Primary Energy Consumption (PEC) will decrease from 442 Mtoe to 429 Mtoe during 2014-2047 in reference scenario (RS), while PEC will be 395 Mtoe in 2047 in advance technology scenario (ATS). Therefore, there will be 8% less consumption of primary energy in Japan in ATS as compare to reference scenario from 2014-2047.

Further, oil & coal will be major contributor in primary energy scenario till 2047, as there share will be 31% to 33% and 23% to 25% in PEC of Japan in advance & reference scenario in 2047. Share of natural gas will be 18% to 25% in PEC of Japan in 2047. Meanwhile, nuclear energy share will increase from 0% to 8-14% in PEC of Japan from 2014-2047 in ATS. The renewable energy contribution will be 8% to 11% till 2047.

Graph-1: Primary Energy Consumption (Mtoe)

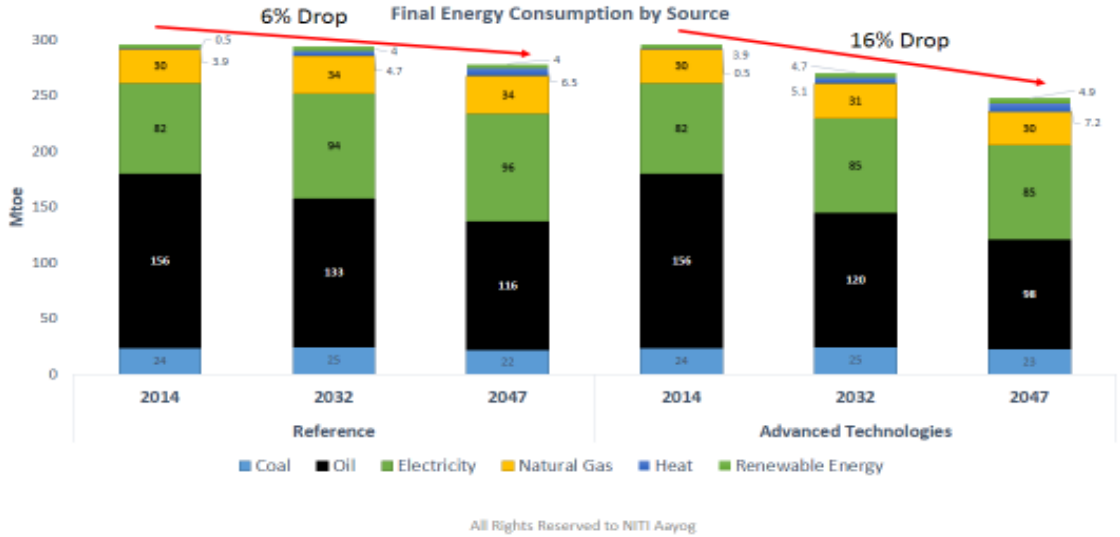


3.2 Final Energy Consumption (Sources)

Final Energy Consumption (FEC) by sources (i.e. coal, oil, natural gas, electricity and renewable energy) will decrease from 296 Mtoe to 279 Mtoe during 2014-2047 in reference scenario (RS), while FEC by sources will be 248 Mtoe in 2047 in advance technology scenario (ATS). Therefore, there will be 16% less consumption of final energy in ATS and 8% less consumption in reference scenario from 2014-2047.

Further, oil & electricity sources will be major contributor in FES till 2047, as there share will be 40% to 42% and 34% in FEC of Japan in advance & reference scenario in 2047. Share of natural gas will remain i.e. 12% in FEC in 2047 under both scenario. Meanwhile, share of coal will be 9% & renewable energy will be 2% in 2047 in FEC under ATS.

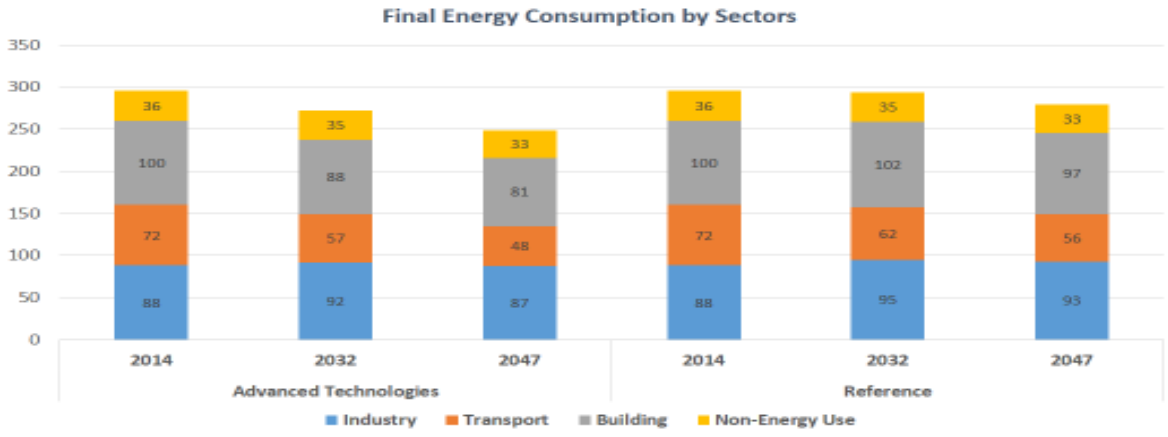
Graph-2: Final Energy Consumption by Sources



3.3 Final Energy Consumption by Sectors

Industry and Buildings will consume 33% to 35% energy from 2014-2047 under ATS & RS. Meanwhile, the share of transport sector in energy consumption will be 19% to 24% during same period in same scenario.

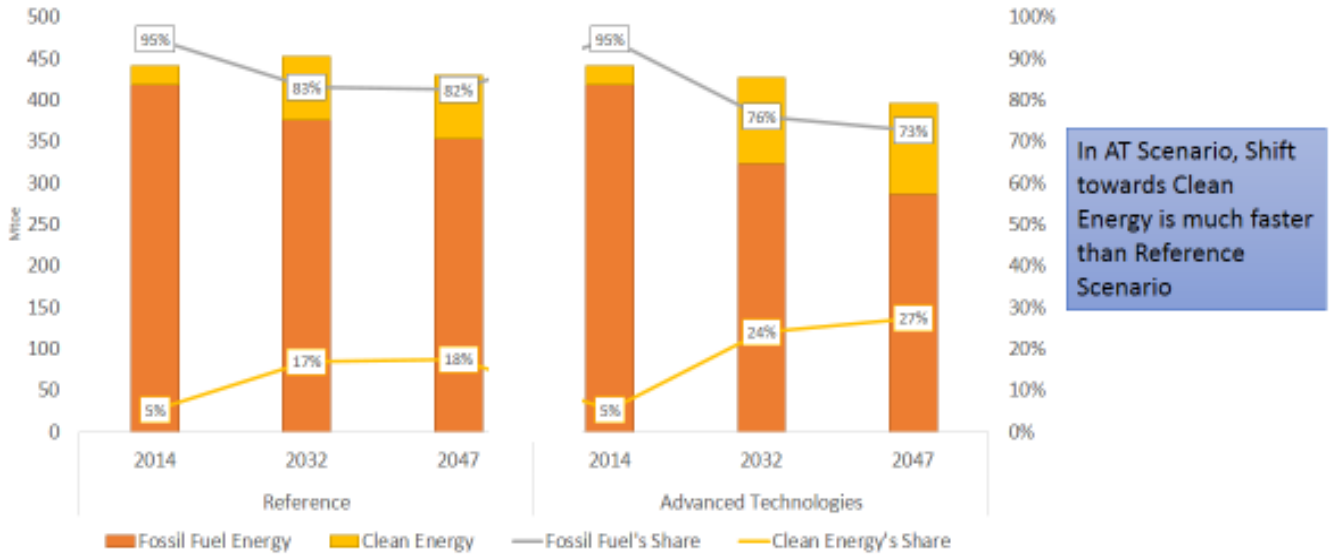
Graph-3: Final Energy Consumption by Sectors



3.4 Fossil Fuel Energy Vs Clean Energy

The share of fossil fuel energy will be decreased 95% to 82% from 2014-2047 under reference scenario, while it will be 73% in 2047 under ATS. Moreover, clean energy share will increase from 5% to 18% from 2014-2047 under reference scenario and 27% in 2047 under ATS. However, under INDC commitment, Japan Government has given target of 48% share of clean energy (22% to 24% nuclear energy & 22% to 24% renewable energy) by 2030.

Graph-4: Fossil Fuel Energy Vs Clean Energy



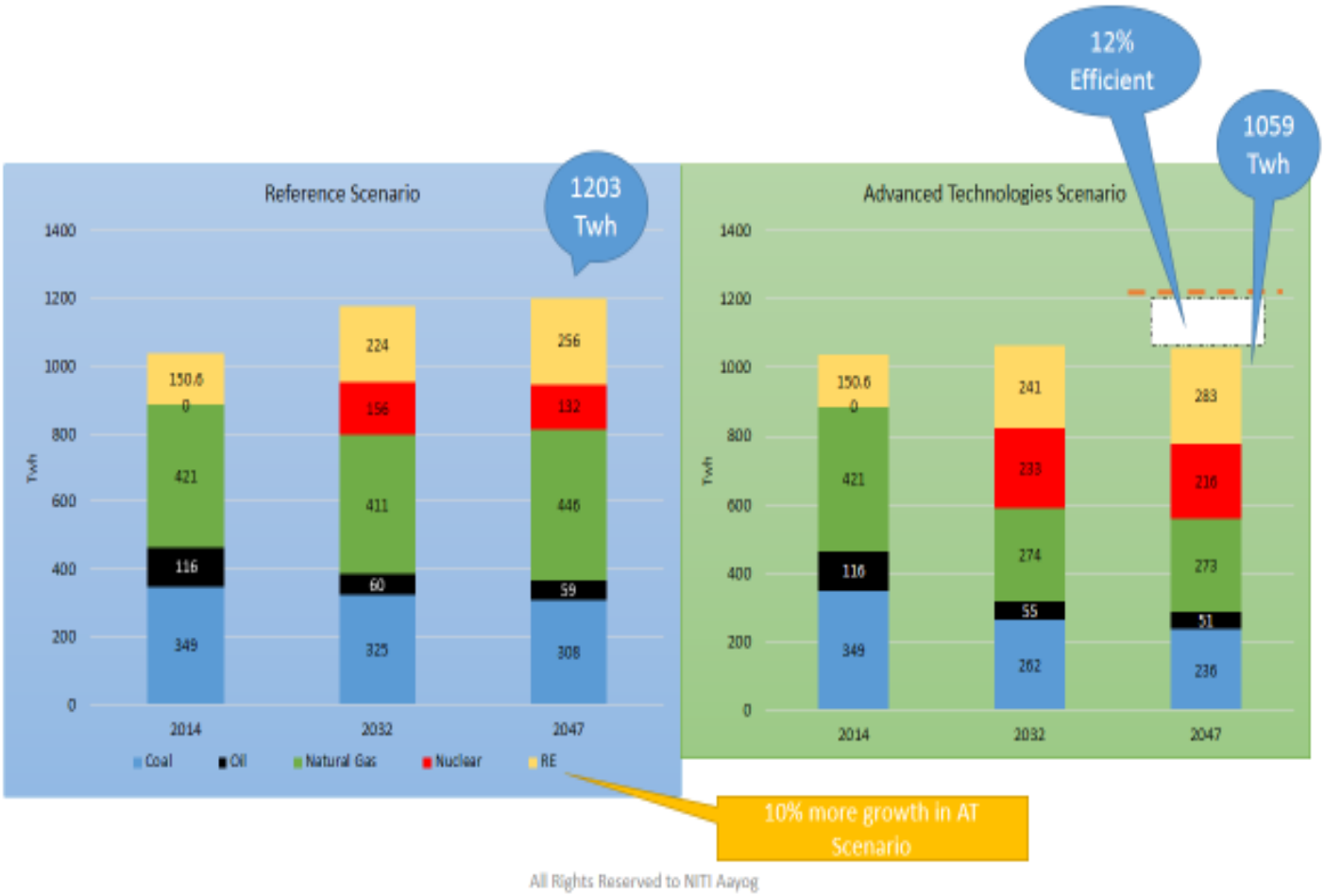
3.5 Power Generation Mix

The natural gas based power generation will decrease from 41% to 37% during 2014-2047 under reference scenario and 26% in 2047 under ATS, while coal based generation will decreased from 34% to 26% under reference scenario and 22% under ATS during same period. Meanwhile, oil based generation will drastically reduce from 11% to 5% under both scenario during 2014-2047.

The nuclear based generation will increase from 0% to 20% and renewable based generation will increase from 7% to 18% under ATS. The nuclear based generation will however depend on local residence response and nuclear safety issues which are challenged in different courts of the Japan.

Meanwhile, Japan will save 1203 Twh energy during 2014-2047 in reference scenario and 1059 Twh energy during same period in ATS due to energy efficiency and demand side measurements.

Graph-5: Power Generation Mix



3.6 Power Generation Mix Scenario

Since, the future of nuclear energy is uncertain due to great earthquake in Japan in 2011 and Japan has recently started renewable energy installation. Under new feed in tariff policy for renewable energy in Japan, Japan has started picking up renewable energy realization path. Therefore to observe the nuclear energy and renewable energy response in total power generation mix scenario of Japan, three power generation mix scenario has been created.

Scenario-1: High Renewable, Low Nuclear Energy Scenario: Under this scenario renewable energy has taken increased 15% to 21% during 2014-2047 and nuclear energy 0% to 11% under reference scenario, while under ATS, renewable energy has been increased to 30% and nuclear energy 20% in 2047.

Scenario-2: High Nuclear, Low Renewable Energy Scenario: Under this scenario nuclear energy has been taken has been increased to 0% to 21% and renewable energy has been decreased to 15% to 11% during 2014-2047 under reference scenario, while under ATS,

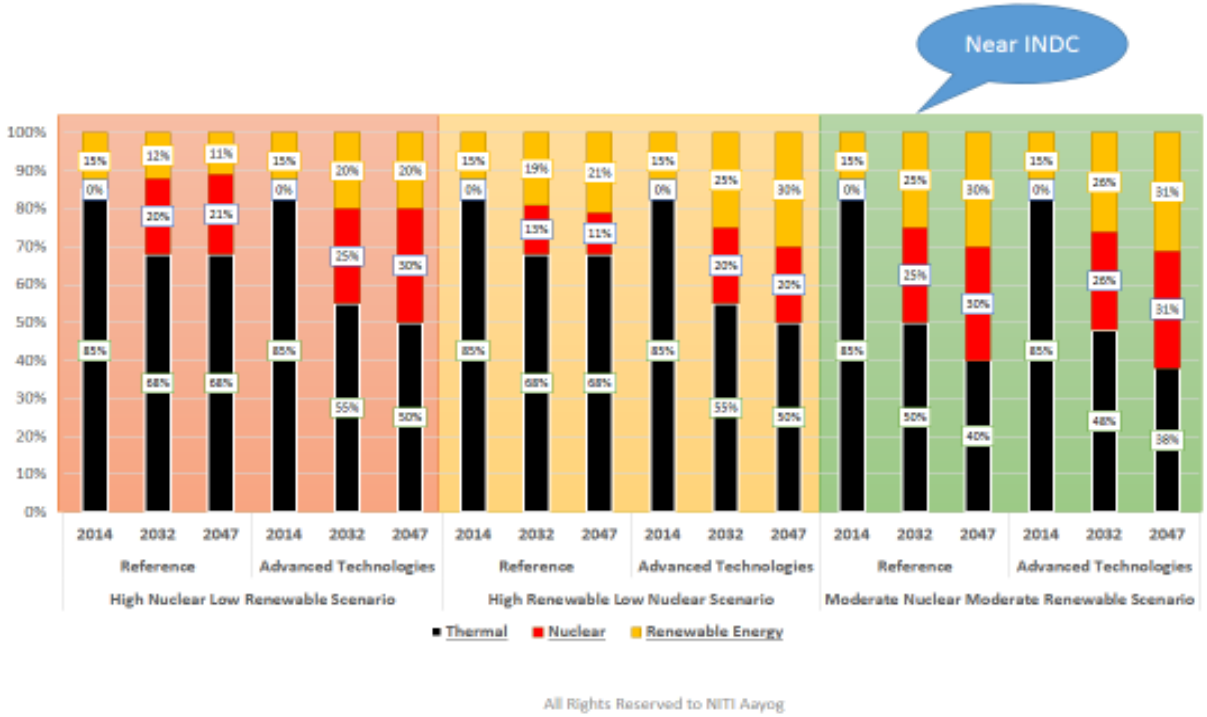
renewable energy has been decreased to 20% and nuclear energy has been increased to 30% in 2047.

In both scenario 1 & 2, thermal energy contribution has been reduce from 85% to 68% during 2014-2047 under reference scenario and thermal energy contribution has been reduce to 50% in 2047 under ATS.

Scenario-3: Moderate Nuclear and Moderate Renewable: Under this scenario equal share of renewable energy and nuclear energy has been increased i.e. 0% to 30% nuclear energy and 15% to 30% (renewable energy) during 2014-2047 under reference scenario and 0% to 31% nuclear energy and 15% to 31% renewable energy during same period under ATS. Therefore, thermal energy contribution has been reduce from 85% to 40% during 2014-2047 under reference scenario. Meanwhile, thermal energy contribution has been reduce to 38% in 2047 under ATS.

Scenario 3 is closed to INDC target of power generation mix scenario of Japan.

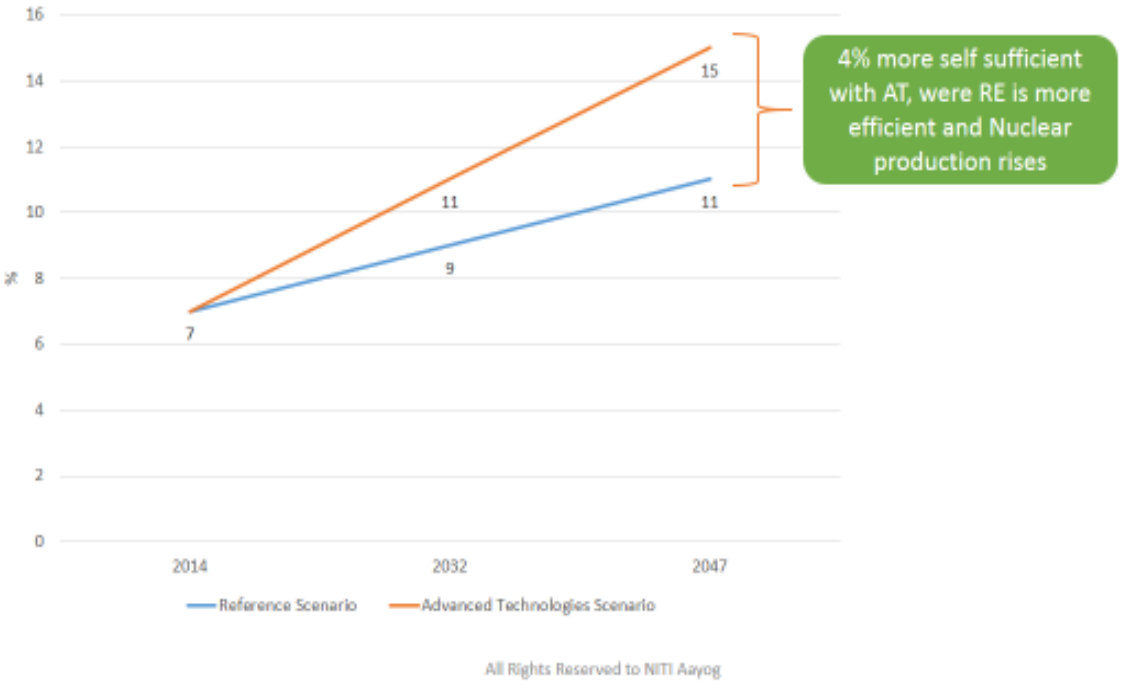
Graph-6: Power Generation Mix Scenario



3.7 Energy Self Sufficiency

The energy self sufficiency of Japan will increased from 7% to 11% in reference scenario during 2014-2047 and 15% in ATS. However, Japan will not be even 25% energy self-sufficient by 2047. Japan has given a lot of focus on renewable energy and energy efficiency in its energy policy 2014 and it is aiming to achieve 25% energy sufficiency by 2030. Japan is also exploring next generation fuels to become more energy self-sufficient in future.

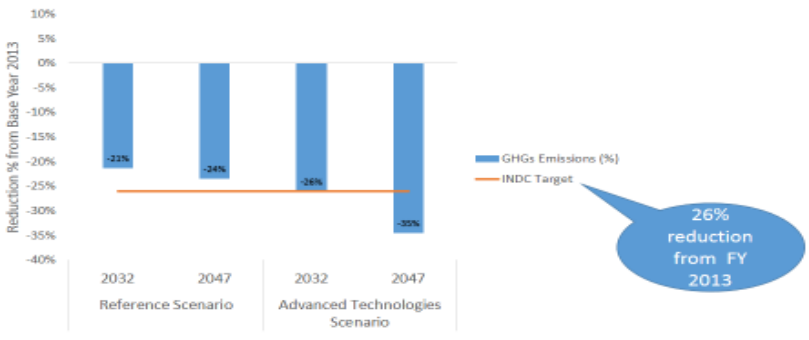
Graph-7: Energy Self Sufficiency



3.8 Emission

There will be 26% GHG emission reduction in 2047 from 2013 base level in reference scenario and 35% GHG emission reduction in 2047 from 2013 base level under ATS. However, under INDC commitment, Japan has given 26% GHG emission reduction target and 25% energy related CO2 reduction target in 2030 from 2013 base level. Due to energy efficiency and demand side management, it is possible that Japan may not only achieve 26% GHG emission reduction target but even surpass it.

Graph-8: Emission



4. Conclusion

The main conclusions from this report can now be summarised below:

1. Japan will have 8% less consumption of primary energy under ATS as compare to reference scenario from 2014-2047. Further, it has 16% less consumption of final energy under ATS and 8% less consumption in reference scenario from 2014-2047. However, the highest fall will be in oil consumption which will be 145 Mtoe to 122 Mtoe during 2014-2047.

2. The share of different sectors in final energy consumption will decline from 296 Mtoe to 249 Mtoe i.e. by 15% in ATS while in reference scenario it has declined from 296 Mtoe to 279 Mtoe. The highest decline in energy consumption in terms of sectors is in the case of transport sector from 72 Mtoe to 48 Mtoe in ATS and from 72 Mtoe to 56 Mtoe in reference scenario i.e. by 33% and 22% respectively.

3. In terms of sector wise percentage mix of final energy consumption, industry's share is gaining from building's energy consumption under ATS while transport is reducing by same quantum in both the scenario.

4. Japan's oil dependency is reducing in ATS and shifting towards natural gas.

5. In Japan, clean energy share will increase from 5% to 18% from 2014-2047 under reference scenario and 27% in 2047 under ATS. In AT Scenario, Shift towards Clean Energy is much faster than Reference Scenario

6. Japan will save 1203 Twh energy during 2014-2047 in reference scenario and 1059 Twh energy under ATS due to energy efficiency and demand side management. It may also be mentioned that in AT Scenario, there is more diversification in energy mix.

7. Comparing the three scenarios viz (i) High nuclear low renewables (ii) Low nuclear high renewables and (iii) Moderate nuclear and moderate renewables, it is found that the third scenario is very nearer to INDC.

8. In terms of self-sufficiency, if we compare the Reference scenario and advanced technologies scenario, the later is able to achieve 4% more self-sufficiency where RE is more efficient and nuclear production rises.

9. Japan will not be able to achieve 25% energy self-sufficient by 2047. Japan has given a lot of focus on renewable energy and energy efficiency in its energy policy 2014 and it is aiming to achieve 25% energy sufficiency by 2030. Japan is also exploring next generation fuels to become more energy self-sufficient in future.

10. Japan will be able to reduce 26% GHG emissions compared to 2013 figures which enable to achieve INDC target.

11. The predicted LNG import of Japan increases from worth $75 billion in 2014 to $312 billion in 2047 whereas oil import increases from $152 billion to $292 billion during the same period.

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