A REVIEW STUDY ON MID AND LONG-TERM SCENARIOS TOWARDS A CLIMATE-NEUTRAL SOCIETY

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It is required to reduce greenhouse gas emissions drastically by the middle of 21st century in order to stabilize climate at a safe level. Recently several European countries and international organizations have developed scenarios that would realize such a goal. The authors reviewed and organized them in terms of their types and steps to develop, and then deduced implications for a Japanese scenario development.

As a result of this review, some critical points for formulating these scenarios were found out: setting goals such as a stabilizing level of greenhouse gas concentrations, formulating baseline scenarios such as business-as-usual, societal renovation such as lifestyle change, and technological innovation such as carbon sequestration technology.

Key Words: *climate-neutral society, scenario, explorative, normative, societal renovation, technological innovation*

1. BACKGROUD AND PURPOSE OF THIS STUDY

Article 2 of the United Nations Framework Convention on Climate Change refers to the ultimate objective of the Convention and relevant legal instruments as follows: "the objective is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The Article also stipulates a required time-frame as: "Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" [1].

A climate-neutral society can be conceptually defined as a society that minimize human-induced impacts on the climate system[2] and realize a sustainable development although there is no scientific consensus on, at which levels and by when global mean temperature and/or greenhouse gas concentrations should be stabilized and is no uniform consensus on what a sustainable society is. What is regarded as a climate-neutral society depends on the outcome of societal and political decision-making processes.

Europe is a leading region in terms of such a decision-making process. The European Union and some of its member countries have stated that the concentrations of GHGs should be stabilized before the end of the 21st century at a level well below twice the pre-industrial level. They have recently formulated several mid and long-term scenarios towards a climate-neutral society, aiming at reaching the above safe level.

The purpose of this study is to extract essential features and methodologies of such a scenario development in view of formulating a Japanese climate-stabilization scenario. The authors collected relevant literatures relating to mid and long-term scenarios towards a climate-neutral society, organized them in terms of their types and steps to develop, and then deduced implications for a Japanese scenario development as follows.

2. SCENARIOS – THEIR TYPES AND STEPS TO DEVELOP

Scenarios, in general, describe hypothetical processes and sequences of events that could develop over a long period of time and cannot be predicted with high certainty. It is clearly different from a mere prediction or forecasting of the short-term future that will be an extension of the past trend and can be estimated with a high probability.

(1) Category of scenarios

a) "Exploratory" or "Normative"

There are two types of scenarios: exploratory one and normative one. Exploratory scenarios are designed to explore several plausible configurations of the future. The purpose is to identify the most robust strategies in view of the subject for which the exploration is undertaken. In case of energy and/or climate change scenarios, identifying factors that affect GHG emissions trajectories over mid and long-term would contribute to make policy options such as new technology development and investment to social infrastructure. Thus Explorative scenarios are able to help scientists and policy-analysts to identify the main dimensions and drivers that shape those future worlds, and are particularly useful in the proximity of crossroads, when a sign of changes takes shape in current phenomena[3].

On the other hand, normative scenarios can be formulated based on a set of desirable goals or norms that the future world has to achieve. This type of scenario is naturally action-oriented and prescriptive. Such scenarios are usually designed on the assumption that policy and measures can shape a future in the desired image. In case of energy/climate change scenarios, normative scenarios may be characterized by setting a goal of stabilization of GHG concentrations, for example, at 450ppmv by the end of this century. These goals are usually starting points where backward-trajectories would depart in order to identify the societal conditions that must be fulfilled or mitigation measures to be taken along the backward-path.

To sum up, while exploratory scenarios created a basis to describe what could happen, normative scenarios contribute a decision-making on what we should do.

b) "Qualitative" or "Quantitative"

Another category of scenarios is qualitative one or quantitative one. Qualitative scenarios are narrative stories describing how future might unfold without numerical analysis. This type of scenarios can easily accommodate an interdisciplinary perspective and the complex interrelationship of a system.

However, policymakers are usually more interested in scenarios providing quantified credible representations of policy and measures and their impacts. Since a minimum level of quantification is useful to verify the consistency of the scenario, mathematical models are often utilized as a simulation tool.

(2) Steps for formulating scenarios

A basic requirement of scenarios is that they be internally consistent, logical and plausible constructs of how the future might unfold. Additionally scenario development is an inherently interdisciplinary process since it requires compiling many dimensions of the issue concerned.

The process of scenario formulation is a complex exercise that consists of following steps: define the issue and its horizon; gather information, expert views and past data on the system under investigation and build a coherent system; identify the key factors and separate predetermined or unavoidable factors and trends; rank these factors by importance or by uncertainty and identify the two or three critical factors [3].

In order to quantify an exploratory scenario, the storyline and its main drivers must be transposed into a set of exogenous variables and corresponding values in the chosen model, which is then run until it adequately represents the underlying story. On the other hand, formulating a normative scenario requires to: define desirable visions or norms; express them in measurable terms; back-cast from them to current situations; identify bottlenecks and priority areas for policy action.

3. FEATURE OF SUSTAINABILITY SCENARIOS

(1) Overview of the scenarios

Table 1 shows an overview of recently-developed scenarios according to their main characteristics: explorative or normative, time-frame (short, mid or long), geographical scale (global or country), issued targeted (global issues or energy/climate). Short –term scenarios explore issues until the year of 2020-2030, mid-term scenarios cover the paths until 2050, and long-term scenarios range to 2100. Narrative or qualitative scenarios are shown in the table with the annotation while others are quantitative scenarios.

The World Business Council for Sustainable Development (WBCSD) and the Global Scenario Group (GSG) of Stockholm Environment Institute (SEI) built global issue scenarios that deal with global issues in general such as disparity between the rich and the poor

Table 1 Taxonomy of sustainability scenarios

		Global Issue Scenarios		Energy/Climate Scenarios	
		Global	Country	Global	Country
Explorative	short	WBCSD(1999)[4] *"narrative"*		IEA/World Energy Outlook(2002)[7]	UK/DTI/Energy Futures (2000)[14] Japan/METI/Japan's energy Outlook(2004)[15] USA/DOE Lab./Scenario for a Clean Energy Future (2000)[16]
	mid	SEI/GSG(2002)[5] Millennium Project(1999)[6]		IEA/Energy to 2050(2003)[3] Shell(2001)[8] *"mostly narrative"*	Canada/NRCan/Energy Future Technology (2000)[17] Netherlands/MEA/Long-term Outlook for Energy Supply (2000)[18] *"mostly narrative"*
	long			IPCC/SRES(2000)[9]	
Normative	short			EU/6th Environmental. Action Program(2001)[10]	Japan/WWF Japan/Power Switch (2003)[19] Japan/MOE/Committee on Climate Change Mitigation Technology(2004)[20]
	mid	SEI/GSG(2002)[5]/Policy Reform Scenario Millennium Project(1999)[6]/ Normative World		IEA/Energy to 2050(2003)/ SD Vision Germany/WBGU/Kyoto and beyond (2003)[11] U.K./Royal Commission on Environmental Pollution (2000)[12]	Netherlands/RIVM/COOL (2001)[2] UK/DTI/Energy White Paper (2003)[21] France/ MIES /Reducing CO_2 fourfold (2004)[22] Sweden/the Climate Committee/ Climate Strategy(2001)[23]
	long			IPCC/Post-SRES (2001)[13]	

(Note) short-term: 2020~2030 / mid-term: ~2050 / long-term: ~2100

Table 2 Types of sustainability scenarios in view of societal and technological change

		Scenario Types	Global Scenarios	Country Scenarios
Heavy Env. Burden	Without Societal Renovation	High growth/Existing technologies	IPCC/SRES(2000)/A1FI IEA/World Energy Outlook(WEO) (2002) / Reference Scenario SEI/Global Scenario Group(GSG) (2002) / Conventional-World (Market-Forces) Shell(2001)/Dynamic-as-usual WBCSD(1999)/First-Raise-Our-Growth(FROG)	Canada/ Energy Technology Future (ETF)(2000)/Life Goes On Netherlands/ Long-term Outlook for Energy Supply (LTVE) (2000) /Free-Trade USA/Scenario for a Clean Energy Future(CEF)(2000)/ Business as usual UK/Energy White Paper(2003)/World Market France/Reducing CO_2 fourfold (2004)/Business as usual Japan/Japan Energy Outlook(2004)/Reference case WWF Japan/Power Switch (2003)/Reference case
		Mid growth/ Little technological progress	IPCC/SRES(2001)/A2 IEA/Energy to 2050 (2003) / Clean-but-not-sparkling SEI/GSG(2002)/Barbarization	Canada/ETF(2000)/Grasping at Straw Netherlands/LTVE(2000)/Isolation
		High growth/ Technological innovation	IPCC/SRES(2001)/A1T IEA/WEO(2002)/Alternative Policy Scenario IEA/Energy to 2050(2003)/Dynamic-but-careless SEI/GSG(2002)/Conventional-World(Policy-Reform) Shell(2001)/Spirit-of-Coming-Age	Canada/ETF(2000)/Taking care of business USA/CEF(2000)/Advanced scenario Netherlands/the Climate OptiOns for the Long-term (COOL) (2001)/Vision A UK/Energy White Paper(2003)/Global Sustainability France/Reducing CO_2 fourfold(2004)/Factor4
Light Env. Burden	Societal Renovation	High Growth/ Technological Innovation	IEA/Energy to 2050(2003)/Bright-skies WBCSD(1999)/Jazz	Canada/ETF(2000)/Come-Together Netherlands/LTVE(2000)/Great Solidarity WWF Japan/Power Switch (2003)/WWF scenario
		Mid growth/Deep penetration of exiting technologies	IPCC/SRES(2001)/B1 SEI/GSG(2002)/Great- transition WBCSD(1999)/GEO policy	Netherlands/LTVE(2000)/Ecology on a small scale Netherlands/COOL(2001)/Vision B

and global environmental issues. The SEI/GSG and the Millennium Project developed not only explorative scenarios but also normative type of scenarios. There is no global issues scenario at a country level.

Most of sustainability scenarios have been formulated for the purpose of responding energy and/or climate change issues both at global level and a country level. International organizations and firms such as the IPCC, the International Energy Agency (IEA), and the Shell have created energy/climate scenarios at global level while governments have developed their own countries' scenarios for decision-making.

(2) Types of the scenarios in view of societal and technological change

Table 2 offers a synoptic view of the scenarios categorizing from the aspect of societal and technological change. The scenarios are classified in terms of the assumption of economic growth as well as societal renovation and technological innovation that would lead to less environmental burden.

Most of scenario works have a scenario with high economic growth utilizing existing technologies (usually dominated by fossil-fuel technologies) as a reference case or business as usual although the Special Report on Emission Scenarios (SRES) of the IPCC created several scenarios including environmentally-sound one as reference scenarios. Conventionally a reference scenario is a starting point of formulating a mitigation scenario whose innovative technologies would countervail the increase of environmental burden owing to high economic growth.

The feature of recent scenario works is the inclusion of a scenario with drastic societal change which would enable us to realize an environmentally-sound society whether it is a reference case or a mitigation case. The scenarios with societal renovation are not necessarily accompanied by technological innovation such as carbon sequestration.

(3) Features of country scenarios on energy and/or climate change

Table 3-1 and **Table 3-2** summarize several country scenarios which estimate energy demand and/or GHG emissions quantitatively based on assumed driving forces such as GDP growth and population increase. The assumption of GDP growth in baseline scenarios is around 2% per year.

Most of the scenario projects belong to a normative type which has clear future goals such as stabilizing levels of CO_2 and/or GHG concentrations in the atmosphere (ex. 450ppm for CO_2; 550ppm for GHGs) and emission levels of them (ex. 50-80% reduction compared to the 2000 level by 2050). Some scenarios have no explicit goal, which can be categorized to explorative one.

When looking into mitigation scenarios, they include a variety of policy and measures supported by technological innovation such as renewable technologies and societal change such as service-oriented economy. Some sensitivity studies suggest that potentiality of nuclear energy and carbon storage technology in future is critical for reducing GHG emissions drastically while renewable energy and hydrogen energy play an important role in most of the scenarios reviewed.

4. CONCLUSION AND CHALLENGES

This review shows following implication for developing scenarios towards a climate-neutral society:

- Recently the number of country level scenarios has been increasing, especially in Europe;
- As norms, they set several goals such as GHG stabilizing concentrations, GHG emission constraints in total and/or per capita and reduction rate compared to the target stipulated in the Kyoto Protocol;
- There is a variety of baseline scenarios, which determine the extent of mitigation measures required, raging from business as usual to environmentally conscious societies that do not originally aim at a climate-neutral society;
- Most of baseline scenarios at a country level assume continuous economic growth, approximately 2% per annum;
- In case of high economic growth with technological innovation, a hydrogen energy system supported by nuclear energy and carbon sequestration has a critical role in achieving a climate-neutral society.

In terms of a Japanese scenario which has not been developed yet, some issues and challenges can be derived from this review as follows:

- How to reckon Japanese trends in a baseline scenario, such as a low-birthrate and aging society, personal lifestyle and preference change, structural change of industry including service economy, and structural change of land-use including multi-polarization and a compact city?
- What kind of technologies can be counted on, considering the potentiality and acceptability of nuclear energy and carbon sequestration in Japan?
- What kind of other constraints should be taken into

Table 3-1 Summary of several countries' GHGs emission/reduction scenarios

Country/Organization Project <Model/approach>	target years	GHG stabilizing and/or emission goals	Baseline scenarios (GDP, population, transport, etc.)	Mitigation scenarios (social/economic reform, technological innovation, etc.)	Economic Effects
France/MIES "Reducing CO_2 emission fourfold in France" (2004)[22]	2050	CO_2: 450ppm -75%(CO_2)=32MtC 1.8tC/capita(2000) 0.5tC/capita(2050)	GDP growth: 1.7%/year Private transport demand: 2%/year Electricity demand: 2%/year Business as usual: 140MtC(2050)	Energy efficiency/Low-carbon fuel: 111MtC Nuclear: 34MtC (150% increase of nuclear) Without nuclear: 60MtC Without nuclear with CO_2 removal: 32MtC	-
UK/Department of Trade and Industry Energy White Paper "Our Energy Future" (2003)[21] <MARKAL>	2050	CO_2: 550ppm +2℃ -58%(CO_2)=64MtC	GDP growth Baseline: 2.25%/year World market: 3%/year Global sustainability: 2.25%/y	Primary energy intensity: 2.5%/y decrease Natural gas: 70% , shift to H_2 Renewable in electricity: 25-40% Nuclear: little effects Without CO_2 removal: cost increase highly, shifting to H_2 from biomass.	Costs to GDP 0.5-2%/y Reduction -0.01~0.0 2%/year
Netherlands/RIVM *et al.* The Climate OptiOns for the Long-term(COOL) (1999-2001)[2] <Participatory Integrated Assessment>	2050	CO_2: 450ppm GHGs: 550ppm -15~-25% globally -50~-80% in DCs -80%(GHGs)	Internationally-oriented(A) Regionally-oriented(B) Population growth: (A)10% ,(B)25% GDP growth: (A) over 5 times (B)4 times Transport demand increase: (A) private 80%, freight 8 times (B) kilometers-cars 80%	(A): a large-scale hydrogen infrastructure based on coal and biomass, CO_2 removal and storage, nuclear still remains (B): a large-scale imported biomass, wind, solar, coal bed methane, natural gas	-
Germany/ "Enquete Commission on Sustainable Energy Supply "(2002)[24]	2020 2030 2050	-40% -50% -80%	Primary Energy Consumption(PEC): Reference: 12,000PJ (2050)	Conversion efficiency: no nuclear, carbon storage, PEC=9,000~11,000PJ (2050) RES/EEU: no nuclear, 50% renewable energy in total, PEC=8,000~10,000PJ (2050) Fossil-Nuclear Energy Mix: 50% nuclear in total PEC=12,000~13,000PJ (2050)	-

Table 3-2 Summary of several countries' GHGs emission/reduction scenarios (continued)

Country/Organization Project <Model/approach>	Target years	GHG stabilizing and/or emission goals	Baseline scenarios (GDP, population, transport, etc.)	Mitigation scenarios (social/economic reform, technological innovation, etc.)	Economic Effects
Sweden/the Climate Committee "Swedish Climate Strategy"(2000)[23]	2050	CO_2: 550ppm 4.0~4.5tCO_2/cap -50%(GHGs)	-	-	-
Finland/National Technology Agency "Climtech programme" (1999-2002)[25] <EFOM>	2030	-20% compared to the Kyoto target	1990 level: 77Tg CO_2eq	Kyoto: 77 Tg CO_2eq Conventional technology: 67 Tg Optimistic: 60Tg	Direct Annual Cost (ME2000) Kyoto: 200 Conventional: 570 Optimistic: 100
USA/5 DOE national laboratories "Scenarios for a Clean Energy Future"(2000) <NEMS>[16]	2020 2050	-	GDP: billion 1997 US$ 8,171(1997) 13,128(2020) 1990 level: 1,346MtC Business as usual: 1,922MtC(2020)	Moderate: 1,743MtC(2020) 29.5% more than 1990 level Advanced: 1,357MtC(2020) same level as 1990	Billion1997US$(2020) Moderate: Costs: 38.6 Savings:100.3 Advanced: Costs:81.7 Savings:121.9
Canada/Natural Resources Canada "Energy Technology Future" (2000)[17]	2050	Kyoto trend line: 2%/year reduction →248Mt(GHGs) (approx. -60%)	Population: 44 millions (2050) GDP growth: 2%/year until 2025 Business as usual: 1,135Mt Life goes on: 1,125Mt (GHGs)	Grasping at straw: 810Mt(GHGs) Taking care of business: 586Mt Come together: 324Mt	-
Japan/WWF Japan "Power Switch"(2003)[19] <AIM-enduse(Japan)>	2020	-	GDP growth: 1.4%/year(2020) CO_2: 305MtC(1998) Reference case: +5%	Mitigation case: -13% WWF scenario (efficiency, service-economy, lifestyle change) : -24% (217MtC(2020))	-

account, such as limitation of waste disposal sites?

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気候中立社会に向けた中長期シナリオに関するレビュー研究

島田幸司・河瀬玲奈・松岡譲

気候を安全なレベルで安定化させるためには，21 世紀半ばまでに温室効果ガスの排出量を大幅に削減する必要がある．近年，欧州諸国や国際機関がそのような目標実現に向けたシナリオを開発してきており，著者らはこれらの類型や開発ステップの観点からシナリオ群をレビュー・整理するとともに，日本シナリオの開発に際しての含意を導き出した．

レビューの結果，気候中立社会に向けたシナリオ形成のための重要なポイントとして，①温室効果ガス濃度の安定化レベルなど目標の設定，②成り行きケースなど基準シナリオの作成，③ライフスタイルの変化など社会的な変革，④炭素隔離技術など技術革新，といった点を見出した．