Part I Synthesis Report

1. Long-term and mid-term targets

World leaders aspire to bold targets for emissions reductions.

At the G8 Hokkaido Toyako Summit in 2008, G8 leaders agreed to consider the achievement of at least a 50% reduction in global emissions by 2050. In 2009, at the L'Aquila Summit, G8 leaders recognised: 1) scientific evidence on the need to keep global temperature rises below two degrees Celsius above pre-industrial levels; 2) the need for a more ambitious emissions reduction goal for developed countries of 80% or more by 2050; and 3) the need for mid-term goals which would result in global emissions peaking as soon as possible. These issues were also discussed in the MEF that followed the G8 Summit. These goals are based on evidence presented by the IPCC and the wider scientific community. The new research task is to identify concrete and feasible measures that will allow us to achieve low carbon societies.

Co-benefits will arise from setting appropriate country- and region-specific targets.

As the consequences of climate change have become evident, emission reduction targets have come to play a more central role. However, profound differences among regions need to be considered when considering mitigation. For developed countries, traditional patterns of socio-economic development must be transformed into more robust and sustainable directions with implications for energy security, the re-engineering of existing processes and the transition from material-driven life-styles to value-driven ones. For developing countries, people's basic needs must be met and economic growth must be pursued to ensure a better quality of life. To achieve this, developing countries must seek to avoid the negative impacts, e.g. local air pollution, associated with traditional growth. "Leap-frogging" strategies are required that skip the material-driven industrial stage experienced by developed countries. Traditionally, economies have been driven by the abundant availability of fossil fuels and materials, giving rise to climate change, resource exhaustion and pollution. Low-carbon societies will have more balanced patterns of demand where the use of materials is no greater than is needed to achieve quality of life and permit required levels of economic growth. Research on new indices is needed to support the transition to LCS. These indices should cover: material-use efficiency; people's perceptions of quality-of-life; and the achievement of innovation targets. New indices such as these would underpin the setting of country- and region-specific targets for low-carbon societies reflecting local conditions.

Backcasting approaches can identify feasible and desirable pathways towards sustainable low-carbon societies.

Quantitative scenarios, using numerical simulation models, are needed to draw pictures of a future low-carbon society which integrate different targets. A participatory approach, building on dialogue with stakeholders in order to share visions of the LCS based on quantitative scenarios, is important. "Back-casting" can be used to identify the measures necessary to achieve shared visions of a LCS. A package of measures could include: targets for specific fields/sectors; the identification of barriers; technologies that address specific problems; and policies to support those technologies. Model-based back-casting approaches can demonstrate how such packages can achieve a LCS. Visualising the impact of packages of measures can motivate people by demonstrating the multiple benefits that they bring.

2. Economic aspects of Low Carbon Societies

Co-ordination is needed between environmental goals and innovation policies.

A low-carbon economy can be seen as a competitive, knowledge-driven economy. Technological innovation

Authors of the Synthesis Report Part I
Jim Skea (UKERC), Junichi Fujino (NIES, Japan), Giulia Galluccio(CMCC), Mikiko Kainuma (NIES, Japan), Stefan Lechtenböhmer (Wuppertal Insititute), Jean-Pierre Tabet (ADEME), and the LCS-RNet Secretariat: Shuzo Nishioka, Wataru Machida, Kyoko Miwa, and Takashi Otsuka (IGES).

will be a major driver for the achievement of consistency between economic growth, sustainable development and the stabilisation of GHG concentrations. Technological innovation at both the economic and political level is essential in order to achieve green goals.

Technological change can change profoundly the socio-economic system as a whole. It shapes not only the business environment, but also the cultural and the institutional context. This in turn can have important feedback effects on current and emerging technologies. Green growth is therefore the result of a coordinated, policy-driven process. The EU Climate and Energy Package has shown, for example, that economic growth and climate policy can go hand-in-hand.

To achieve coordination between innovation policies and environmental goals, policy instruments such as pricing and regulation need to be formulated flexibly taking into account the interaction between different policy instruments.

Sectoral and regional perspectives need to be taken into account.

While cost-effectiveness at the global level is essential, there must be awareness of factors that are specific to countries and regions. Local perspectives must be taken into account. The feasibility of specific actions will depend on financial and other factors that come into play in both the private and the public domains. The social transformation associated with the transition to a LCS in different sectoral and regional contexts needs further research.

New financing paradigms will be required if developing countries' mitigation and adaptation needs are to be met.

Investment flows will need to draw on both public and private contributions if a sustainable low-carbon society is to be achieved. Analytical tools are available to assess financial flows associated with the public sector as well as the institutional mechanisms through they could be delivered. There is a risk that international carbon markets as presently constituted will be neither adequate nor efficient in realising stated objectives. Internationally and nationally, a portfolio of mechanisms must be established. Developing countries need support in reducing poverty and improving financing and funding mechanisms. Particular attention has to be paid to: the development of social capital; institutional setting; and adaptation strategies which have major implications for the allocation of financial resources.

Issues to be considered

There is a need to improve the understanding of and integrate existing theoretical and empirical approaches to green growth, policy formulation and technological innovation.

It is also particularly necessary to take a comprehensive approach to the transition to LCS that takes into account the specificities of the situation of developing countries' relative to those of developed and newly-industrialised countries.

Market instruments are key in financing and supporting a new green growth development paradigm. An assessment of the implications of any new international climate agreement on the emerging carbon market will be required. The role of new financing instruments at the global and country levels needs to be identified.

3. The Role of Technology

Radical technological change is crucial in reaching a low-carbon society.

In order to reach a low-carbon society where GHG emissions are low and living standards are high, technology must play a key role in the near-, mid- and long-term. Each time frame needs a different R&D strategy. Near-term R&D needs to focus on improving existing technologies. It can also enhance the range of available technologies, lowering their cost and raising the effectiveness of investments. R&D investments focused on delivering radical technology innovation for the long term require investments in basic science to lay down the foundations for radical innovation.

Technological change is needed on the demand as well as the supply side. On the demand side, reducing GHG emissions will require an improvement in energy efficiency of more than a factor four in the long-term.

If global temperature increases are to be kept below $2^{O}C$, bio-energy could play a very important role. Negative emissions are possible in principle if carbon capture and storage (CCS) is combined with bio-energy use. This would however pose huge technical, economic and policy challenges. Alternatively, if bio-energy is used with high efficiency in the transportation sector, CCS/bio-energy might not be necessary. In both cases, policies to manage related land use changes effectively would be critical.

New "smart" electricity systems which actively match the demand and supply of electricity should be developed to encourage local production and consumption of renewable energy within each region. The most appropriate set of renewable technologies will differ from one region to another. "Supergrids" which can transmit large-scale renewable energy over long distances could also play a role, both domestically and internationally.

The development and diffusion of demand-side technologies such as LED lighting, hybrid cars and heat pumps are also essential in order to achieve a low-carbon society.

More investment in energy technology is needed.

The inherent inability to prevent the spill-over of knowledge gained through R&D is the root cause of sub-optimal levels of investment. Yet, the "positive externality of knowledge creation" is a key opportunity for the LCS transition. Externalities occur within and between sectors, nationally and internationally. International consortia may be necessary to facilitate knowledge exchange and reduce the financial risks associated with very costly projects.

Energy R&D accounts for only a small proportion of overall R&D investment. Addressing efficiency improvement and cost reduction is the most immediate challenge. Here, research and technology programmes need to be expanded very considerably, by as much as 5-fold. Encouraging the deployment and diffusion of technologies is crucial to realise the benefits of innovation.

Learning-by-doing effects can amplify the effect of R&D investment, accelerating the diffusion of advanced technologies as experience brings down costs and improves performance. With learning-by-doing, the cost of reducing CO_2 emissions will decline as technologies are deployed. If investment is delayed, the cost of achieving a low-carbon society will increase correspondingly.

The lack of a carbon price is one factor explaining low levels of energy R&D. We have under-invested in energy R&D partly because energy has been cheap for more than a century. Changing the relative prices of energy and other factors of production (e.g. labour), could help induce a radical long–term shift in R&D patterns.

Technology will not deliver a low-carbon society on its own.

Technology alone will not lead to the stabilisation of greenhouse gas concentrations at low levels. Ever more stringent limitations on emissions and ever higher carbon prices are essential if CO_2 concentrations are to be stabilised. It is essential that no sector should be exempted from emission limits. Exemptions not only raise the cost of meeting concentration targets, but may also render lower levels of emissions infeasible.

Technology measures need to be complemented by measures to transform industrial, transportation and social structures. Climate policy needs to include measures that induce investment in new infrastructures which will enhance quality of life and energy security.

Policy intervention will be needed to remove barriers to the diffusion of new technologies. These include: 1) the inadequacy of support infrastructures for delivery, technical support and maintenance; 2) the technical preparedness of users (both industries and end consumers); and 3) social values and preferences. Such barriers tend to be stronger in developing countries and in rural areas.

In order to achieve a low-carbon society, it is vital that people become aware of and actively choose new technologies. Studying the linkage between lifestyle and technology could enhance the deployment of energy-saving technologies.

Climate policies and R&D strategies must be synchronised.

If R&D policies are coupled with climate mitigation policy, investments in energy technology on both the supply and demand side could increase. Policies that align economic development and reduction of GHG emissions, often characterised as "green growth", could result in increased energy R&D investment.

The transformation of our economic structure should take into account not only climate change, but also other important issues such as health care, food security and energy security. Long-term policies with clear goals which accommodate a wide range of perspectives should be set. This is crucial for acceptance of climate policy by, different interest groups, policy makers and society at large.

Issues to be considered

The location of technology deployment is an issue. Investment in technology has a direct impact on a

region's economic development.

A substantial increase in energy R&D spending is necessary. Since R&D spending in the energy sector is only a small fraction of overall R&D spending, additional energy R&D investments induced by climate policy are not expected to cause a reduction in R&D investments in other sectors in the medium-long term.

We need to be cautious about using subsidies to encourage the take-up of energy end-use technologies. Even though the subsidy accelerates the deployment of advanced technologies, the funds available for subsidies are limited and might not flow back completely and there may be rebound effects which encourage increased use of energy services.

Given inherent uncertainties about technology development and diffusion, hedging strategies should be formulated. Broad portfolios of technologies are essential. For example, technologies such as CCS and nuclear, two important technologies, entail significant risks that could inhibit their deployment. A careful assessment of associated acceptability and safety issues is also necessary.

4. Public policy and lifestyle change

Public policy can lead the way to lifestyle change and a low-carbon society.

The shift towards LCS needs not only targets and technological change but also the promotion of behaviour change. New forms of governance which enable lower emissions will facilitate behavioural change. Conversely, an increased readiness on people' s part to adopt behavioural changes will permit a smoother process of societal change.

Many developed countries are facing critical decisions as to which pathways to follow in order to reduce emissions significantly. Some developing countries face a similar choice as to whether they can maintain low emission levels while realising economic growth.

Policy-makers need to take some risks in introducing effective measures that will lead societies towards LCS. To manage these risks, there is a need for a better understanding of public perceptions of LCS and people's capacity for action. To this end, there is a need for further behavioural research on LCS to demonstrate people's willingness and capacity to change and to quantify the possible impacts on emissions.

Facilitating behaviour change is not easy, but can be accomplished.

Facilitating behaviour change in order to reduce emissions is not an easy task. Research has shown a big discrepancy between what people say they are prepared to do and what they actually do in practice. This insight applies both at the individual and societal level. For example, a series of campaigns on environment and climate issues conducted in Canada have not achieved their goals.

On the other hand, there are successful stories associated with local initiatives. These include congestion charges introduced in London, UK, Singapore, Melbourne, Australia, Toronto, Canada and Oslo and Bergen in Norway. Other successful local initiatives relate to renewable energy, light rail track and bus rapid transit systems, and the introduction of bicycle-sharing in office areas.

The most effective measures will be tailored to individual countries and localities.

Both the perception of climate change actual and behaviour patterns vary from country to country. Behaviour patterns are influenced by socio-cultural context, the built environment and the range of options available in each society. Therefore, the policy mix should be carefully examined and customised for each country and for each locality,

One study found, for example, that Japanese people tend to be affected by information provided through the mass media, while people in Shanghai are more affected by information received through social networks, encompassing family members and neighbours.

Education and information provision are important and effective as part of a package. But there is also a need for direct approaches to induce behavioural change. These include regulatory and financial measures which provide direct positive and negative incentives.

There was a view expressed at the meeting that experimental or pilot projects conducted in a designated locality (e.g. a special LCS zone) have a role to play. If the impact of such projects on technology, the economy and people's behaviour are closely monitored, this could be an effective way to identify and customise the measures that might be undertaken more widely.

LCS lifestyles do not have to entail sacrifice.
Focussing on the upside of low-carbon strategies, in other words the co-benefits, could help to raise the level of public acceptance. Shifting towards LCS need not and should not imply that people must lower their quality of life. Attaining higher quality of life with lower carbon emissions is possible. For example, the introduction of low-carbon energy and transportation technologies is likely to reduce air pollution and congestion problems in urban areas. Pursuing a new lifestyle in line with LCS could help people to achieve a better work-life balance. Given that working towards LCS implies introducing new systems of environmental governance that must be acceptable to the public, further interaction between policy makers and social scientists is a high priority.

5. Cross-cutting issues

In addition to the areas discussed in the previous sections, the Meeting identified the following issues that have a cross-cutting nature or require coordinated efforts.

A persistent signal is needed to stimulate change across all sectors.
Innovation is needed in all LCS-related sectors. Environmental policies should not be considered as an "add-on" to economic policy. Environmental and economic policies need to be integrated as they are dependent, not in opposition to each other. Co-ordinated ("joined-up") policy making in the environmental and economic domains is essential.

There is no single technological innovation that can solve the climate change problem. No technology that could contribute to a potential solution should be ignored. Setting ambitious targets can stimulate technological innovation. Both industrial structure, and social capital, including social institutions, customs, urban infrastructure, and human capital, have to be transformed to achieve a LCS.

There is no option for human beings but to choose a low-carbon future. It can be attained only when everyone moves together with a shared determination. This strong message, reinforced by measures such as a carbon tax, has to be repeated to gain social consent and stimulate business innovation.

Planning for land use change is essential.
Even stringent emissions reductions will not be enough to stabilise atmospheric concentrations of CO_2. Therefore, alongside CCS, the capacity of terrestrial and ocean ecosystems to store increased amounts of carbon needs to be increased. The expectation of a large increase in bio-energy production implies that various types of land-use change will take place.

Land-use change which contributes to a LCS has to be well-designed so that energy does not compete with other land uses such as food production and settlement. Land-use change without careful planning could conflict with sustainable development. It is essential to design LCS in ways that bring co-benefits in terms of water resource and forest management. The historical example of ethanol production from corn conflicting with food security in less developed regions illustrates the undesirable result of unplanned land use change.

Cities provide an excellent opportunity to promote a Low Carbon Society.
To build a LCS, it is necessary to mobilise all the elements that make up society. Existing systems, which are already complicated and locked-in into an old "high-carbon" regime, need to be transformed to achieve the LCS. Cities contain all the elements needed to form a LCS. The administrative system generally falls under the control of a single local authority whose competence is wider than that of national authorities. As such, cities can form a test-bed for social experiments in LCS which can be replicated in other cities. The overall risk to society from conducting such experiments at the city level is smaller than the risk associated with experiments at the national level.

Research that would allow developing countries to set their own targets and pathways is essential.
Any delay in mitigation efforts in developing countries will place beyond reach any attempt to contain global temperature increases below $2^{O}C$. To enable developing countries to make progress toward a LCS, it is desirable for them to set their own targets and pathways, as developed countries are currently attempting. In some developing countries, efforts have already started. China, for example, has already conducted and published research which investigates bringing emissions, after an overshoot, back to current levels by 2050. Some developing countries are experimenting with LCS activities at the city level. Urbanisation and population growth in urban area in developing countries will continue. Therefore it is critical to apply LCS models to cities in developing

countries in order to avoid future lock-in to energy-dependent, high-emission systems.

For developing countries vulnerable to climate change, adaptation policies must be promoted in parallel with mitigations efforts. Policies for both mitigation and adaptation are at the core of sustainable development. Successful policies would bring co-benefits in areas such as water management and energy security.

Human resource development is needed as well as technology co-operation.

Funds must be secured to enable developing countries to undertake nationally appropriate mitigation actions (NAMA). The direct finance of investment in low-carbon technologies and social infrastructure in developing countries must be complemented by investment in human resource development. This should be undertaken from a long-term perspective and be long-lasting in character. Various types of funding are available: for example donations, loans, CDM investments or schemes entailing private investments. The appropriate mode of funding should be tailored to the specific investment.

We need to adapt to unavoidable climate change and remain alert to new scientific insights.

Working towards a low-carbon society requires us to adapt to climate change to which we are already committed and continue to improve climate predictions. Relevant insights may provide new information about elements of the earth system over which the human race exercises control (energy, land use, agriculture, etc.) and about the ambition of mitigation efforts required to avoid dangerous climate change. For example, it is necessary to further reduce uncertainties associated with the albedo effect of clouds.

A pre-requisite for improved adaptation and for the identification of the respective co-benefits from mitigation is the development of high resolution, short-term predictions of climate change. It is still not possible to translate regional impacts into monetary values. Short-term climate predictions can now be made on decadal scales and, in principle, grid spacings of as little as 1 km can be achieved. However, fine resolution predictions require exponentially increasing quantities of computational resources. Achieving fine resolutions will require the development of complex multi-institutional, transnational projects. Detailed multiyear planning covering the detailed definition of consortium targets and responsibilities and the phasing of experiment, analysis and archiving of results will be essential. It will also be necessary to assess the validity of results for use by the adaptation community. If numerical precision reflects “noise” rather than accuracy, model users may be misled.

Resources available for Earth systems research have been stationary or declining. To take climate prediction forwards, we need to identify the big scientific and technological questions that will make a real difference to policy and investment decisions in the coming decade. We need to mobilise new sources of funding and identify global institutional solutions, including public-private partnerships, to ensure that the private sector invests for the long term. We need to demonstrate that the benefits of improved climate prediction will be comparable to those from other advancements in knowledge and technology.