Deep Decarbonization and Energy Security for Low-Carbon Societies

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Policy Report of the International Research Network for Low-Carbon Societies (LCS-RNet)

IGES

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About LCS-RNet

What is LCS-RNet?

The International Research network for Low Carbon Society (LCS-RNet) is an open community of researchers and research organisations contributing directly to policymaking and implementing processes, as well as like-minded relevant stakeholders, such as national and local policymakers, international organisations, business and financial entities and civil society, that together facilitate the formulation and implementation of science-based policies for low carbon development in the world.

Who has been participating?

Currently, 16 research institutes in Japan, Germany, France, Italy and UK, in cooperation with Brazil, China, India and Korea, play a core steering role in the network, promoting cooperation and activities with research communities in developed and developing countries.

How did it come about?

It began with a proposal from Japan at the Kobe G8 Environmental Ministers' Meeting (EMM) in 2008. The G7 EMM in Toyama, 2016 then reconfirmed the growing importance of the role of the science community and research network to support the Paris Agreement

Features & added value of LCS-RNet

As a platform linking science with policy towards decarbonised societies, LCS-RNet has distinguishing characteristics as shown below, and offers additional value.

- Comprehensive research ability to promote the transition to decarbonised societies: LCS-RNet is a network of research institutes promoting solution-oriented, multilateral, cross-cutting research.
- Close cooperation with policymaking and implementation: LCS-RNet member researchers and research institutes have worked in close collaboration with government agencies in charge of climate policies in each country, and have the connections to translate inputs into policies.
- Collaboration with international activities: Each research institute has worked with international organisations such as IPCC, UNFCCC and UNEP, and conducted much international joint research, including DDPP. They have strong ties with international society.
- Knowledge accumulation for the transition to decarbonised societies: While operating as a community of like-minded researchers, LCS-RNet also shares important research directions by promoting close cooperation, collaboration and knowledge exchange, leads researchers and experts, takes initiatives for joint research, and accumulates knowledge for joint policy recommendations.

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Executive Summary

Alexis R. Rocamora

While countries have committed to hold the increase in the global average temperature to well below 2°C above pre-industrial levels when signing the Paris Agreement in 2015, political changes in several parts of the world have since then lead to uncertainty regarding the direction of climate policy. National priorities seem to be shifting inwards, and as the global sense of unity in face of the common threat of climate change is being questioned, now is an opportune time to reaffirm the benefits of a decarbonized economy.

In response to this inward-looking trend, a good solution could be to show how the transition to a low-carbon society through the decarbonization of energy systems can bring social and economic benefits and foster countries' economic competitiveness. Indeed, while the national necessity to secure energy access and security is often used as an argument against climate action, research shows that decarbonization of energy systems is not only beneficial to both those issues, but it also impacts other Sustainable Development Goals (SDGs) through co-benefits and synergies (Chapter 1).

However, in order to realize the low-carbon transition of energy systems, governments need to take more proactive climate actions by adopting ambitious policies. The flows of climate finance notably need to be increased to match the levels pledged in the Paris Agreement and needed for supporting developing countries on their low-carbon development journey as well. To do this, governments can provide innovative policy support and radically change the way greenhouse gas (GHG) emissions are priced (Chapter 2).

As the economic performance of industries is tightly linked to energy systems and vulnerable to energy price fluctuation, governments also need to facilitate the transition of this sector by adopting industrial policies that take into account long-term decarbonization targets. This policy support is particularly relevant for carbon-intensive sectors such as basic material producing industries. Such policies can not only contribute to preserve the economic competitiveness of the industrial sector while undertaking this transition, but it can also foster innovation and resource productivity within the whole society (Chapter 3).

Finally, decarbonization of energy systems nowadays is no longer a theoretical matter. Many examples exist around the world of successful cases, from emerging economies to multinational companies. These cases provide solid evidence of the existence of effective solutions for a transition to a low-carbon society (Chapter 4).

Based on the analysis conducted in this report, the following policy recommendation can be made:

- In order to move forwards the implementation of the Paris Agreement, governments need to adopt long-term visions that integrate several policies, especially industrial policy, energy policy and trade policy.

- The transition to a low-carbon society needs to be paved by innovative financial mechanisms and ambitious carbon pricing. Further research is needed to quantify the social benefits of low-carbon investments.

- Energy access is one of the key challenges of this century, notably in developing regions such as Africa. It is crucial for related issues such as climate change mitigation and poverty reduction. The related financial, technological and social barriers should be addressed through innovative policies to facilitate energy access for a wide range of vulnerable populations and to raise awareness of the problem in developed countries.

- Green growth plans, industrial strategies, product regulations and standards should be further developed, taking into account long-term innovation and circular economy patterns.

This policy report was developed based on submissions from LCS-RNet research members, presented during the 9th Conference of the International Research Network For Low-Carbon Societies (LCS-RNet), which took place on 12 and 13 September 2017 at Warwick University, United Kingdom (detailed information available in the Appendix).

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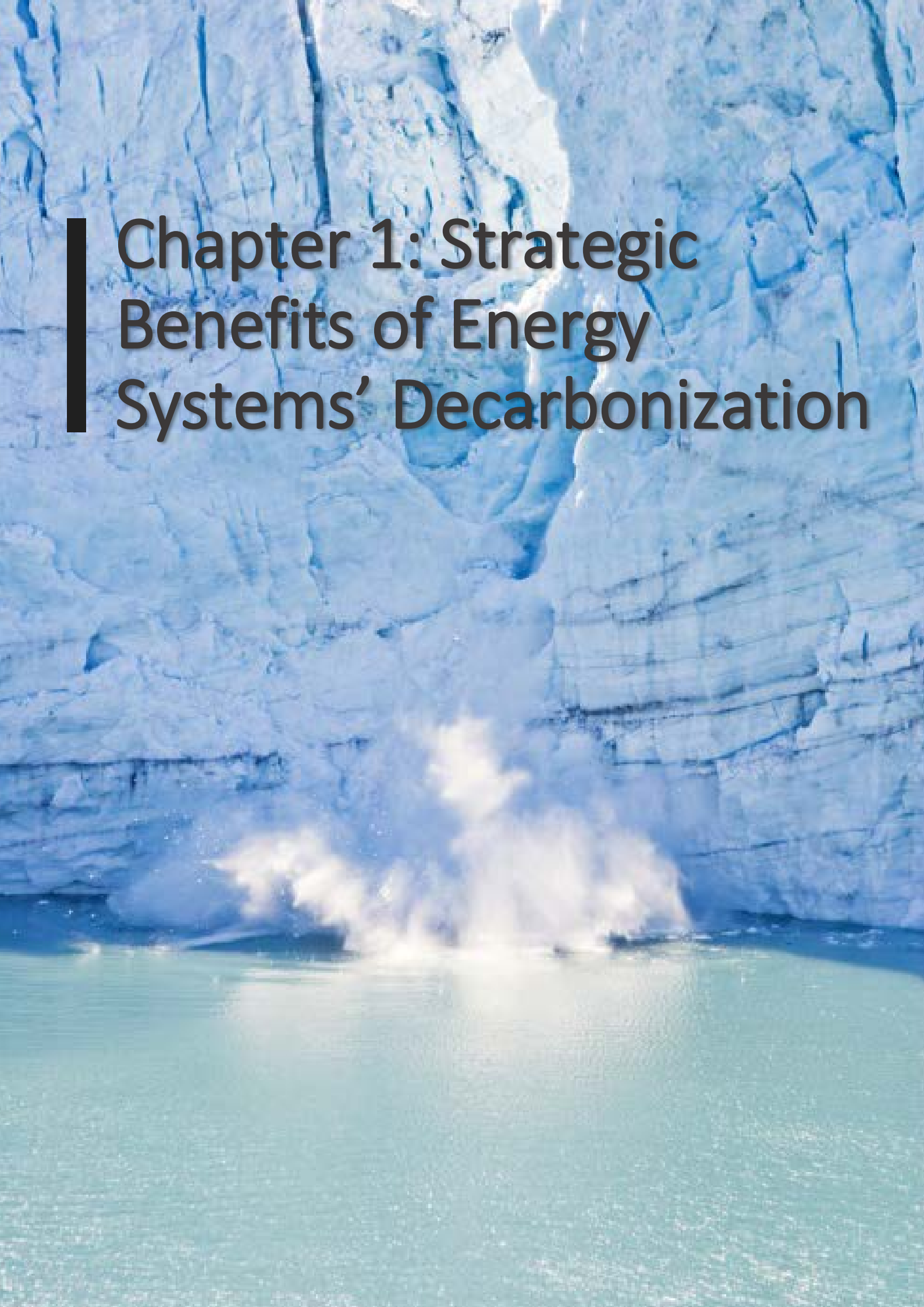


Chapter 1: Strategic Benefits of Energy Systems' Decarbonization

1.1 Co-benefits of Deep Decarbonization in Energy Systems for SDG Implementation

Mikiko Kainuma, Miho Kamei, Shuzo Nishioka, Tomoko Ishikawa, Rahul Pandey

World leaders agreed at COP21 to limit the average global temperature increase to well below 2°C compared to pre-industrial levels and to move forward to reduce greenhouse gas (GHG) emissions from human activities essentially to zero during the latter half of the 21st century (UNFCCC, 2015). In another historic UN summit in 2015 they adopted the 2030 Agenda for 17 Sustainable Development Goals (SDGs) (UN, 2015). Climate change is one of most important and urgent SDGs, as current actions will have a deep impact on the future environment and human activities. Moreover, many actions towards mitigating climate change can also help to achieve other SDGs such as ensuring access to affordable clean energy, promoting sustainable production and consumption activity patterns, and building resilient infrastructure.

Based on such movement, ten climate (or low carbon) actions are considered with the possibilities of their sub-actions being implemented (Figure 1). As these actions are closely related with the actions required to achieve the SDGs, synergies and trade-offs between climate and sustainable development actions and between different sectors are also examined (Kainuma et al., 2017).

In order to assure energy access, not only the supply side considerations such as increasing the power generation and distribution capacity, but also increasing the economic opportunities for the poor are important. Care needs to be taken so that the rural poor are not excluded from economic activities around local renewable energies and ICT. If that happens, it is likely that existing dominant communities who already own large land areas and other resources may exert control over low carbon systems, thereby implying that existing economic inequality and poverty conditions remain unchanged.

Actions for energy systems

Towards the realization of a Low Carbon Society (LCS), de-carbonization of energy demand as well as supply are vital. Energy-saving activities and the application of renewables such as solar photovoltaic (PV) and wind power are key to reduction of greenhouse gases (GHGs). The use of renewable energies will also improve energy access, eliminate energy poverty, and contribute to establishment of sustainable local energy systems.

Similarly, creation of a "smart" energy system that integrates the energy-demand side will be vital. To establish these systems, governments have to develop a medium to long-term energy policy that provides a clear direction at both domestic and global levels on the key goals and targets. Achieving these goals and targets would, in the short to medium term, need institutional interventions and policy incentives that enable introduction of renewable energy and energy efficient appliances and facilities.

In the long run, i.e. beyond 2030, the market pull in the wake of declining costs could deploy these technologies even without government incentives. In some countries, where the electricity access is limited due to short-supply of infrastructure, the governments would have to play an important role to enhance the infrastructure supply.

Synergies and trade-offs between actions for energy system and SDGs

There exist lots of synergies between energy systems and SDGs. For example, poor families in rural areas of developing countries can be involved in new business models centered around services based on local renewable energy systems. As part of this they can be provided access to microfinance and other basic services. Poor families can be engaged as part of cooperatives, micro-enterprises or as regular entrepreneurs, depending on what is effective to implement in a particular country. Training of youth in manufacturing, operation, maintenance and other service skills related to modern and sustainable energy systems can be included as part of skills development, employment, entrepreneurship programmes.

However, there are also trade-offs. For example, if the rural poor (landless and small farmers) are not involved as participants in the new economic activities based on local renewable energy systems, then existing dominant communities who already own large land areas and other resources may exert control over them, implying that the existing economic inequality and poverty conditions would remain unchanged. Such synergies and trade-offs are shown in Figure 13.

Discussions

It is a fundamental development need to provide access to efficient energy services for all sections of earth's population; however, it should be provided with low and/or zero carbon energy. Renewable energy is one of the prominent options which also addresses the concern of energy security. The share of renewable energy in global power generation was still only 11.3% in 2016, most of which was from hydro power.

However, renewable energy excluding large hydro accounted for 55.3% of the new electricity generating capacity added worldwide in 2016 (FS-UNEP Center, 2017). Some countries have higher share of renewables in installed electricity generating capacity, e.g., 33% in Philippines (Delos Santos, 2017) and 35% in Germany (Independent, 2017).

Many countermeasures have been considered and implemented, most of which are sector- and technology-specific. Naturally, such measures and efforts to develop innovative technologies are essential to meet the well below 2°C target. However, climate policies and their implementation require integrated efforts since each action is closely related to others and the combined impact differs from the sum of multiple isolated impacts.

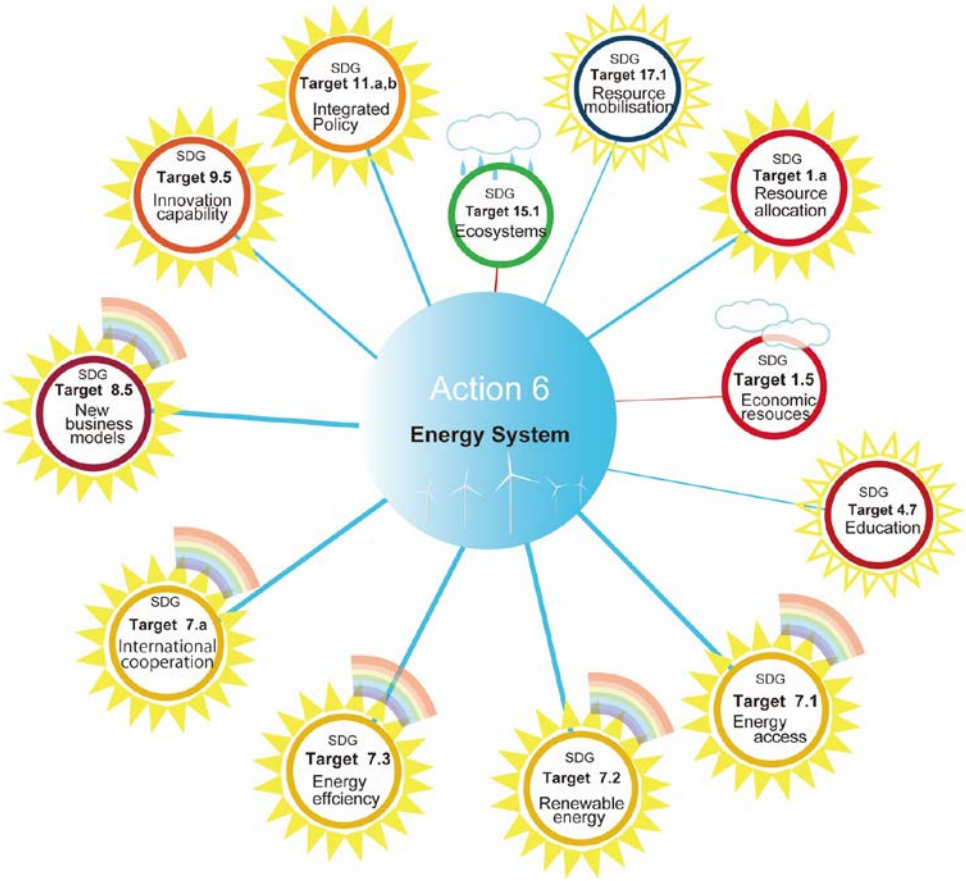
Most countries are making efforts to achieve their NDCs as well as SDGs, and implementing both will lead to mutual reinforcement. To achieve Goal 13 (climate action), it needs to be implemented in alignment with other SDGs as funds, human resources and other resources are shared among different actions and innovations.

It is also necessary to integrate climate actions with more fundamental efforts to develop infrastructure and economy. New trends of increasing investments in low carbon technologies are a good sign for innovation.

Figure 1: Ten actions for climate stabilisation

Source: Kainuma et al. (2017)

Figure 2: Synergies and conflicts between climate actions for energy system and SDGs



Source: Kainuma et al. (2017)

1.2 Deep Decarbonization and Energy Access for Low-Carbon Development

Jim Watson

According to the IEA World Energy Outlook 2017 (IEA, 2017a), around 1.1bn people do not have access to electricity whilst 2.8bn use traditional biomass fuels for cooking. Whilst there has been significant progress in improving electricity access, this has been much slower in sub-Saharan Africa and some areas of Asia than in other regions.

Ensuring access to affordable, reliable and sustainable energy is one of the Sustainable Development Goals (SDGs). By 2030, SDG7 states that there should be universal access to affordable, reliable and sustainable energy. It also includes specific targets for 2030, including a substantial increase in the use of renewable energy, a doubling of the rate of improvement of energy efficiency, greater international co-operation on energy innovation and an expansion of infrastructure. Against this background, it is necessary to explore how the urgent need to improve energy access and affordability for poverty alleviation can be aligned with the global imperative to reduce greenhouse gas emissions.

Whilst meeting SDG7 seems elusive, some progress is being made to improve levels of electricity access – and this applies to all global regions, including sub-Saharan Africa (IEA, 2017b). With respect to access to clean cooking, the challenge is greater due to the widespread use of traditional biomass fuels in many regions of the world – and a much slower rate of improvement. This causes major health problems due to air pollution.

Renewable energy will play an important role in making further progress between now and 2030, including roles for off-grid, mini-grid and grid-scale technologies. The precise mix will, of course, vary by country and region due to different resources, institutional and policy arrangements. The IEA's special report also shows that it is possible to meet the targets in SDG7 in a way that is compatible with the Paris Agreement – though this would require a substantial increase in the rate of connections to the grid and the adoption of cleaner technologies for cooking. It will also require significant improvements in reliability and affordability for many communities in developing countries that already have a physical connection to national or local electricity systems. This is because some of these systems only provide power on an intermittent basis (e.g. for a few hours per day). They can also have a limited capacity, so that they only provide a limited range of energy services.

The UK government's programmes to help meet SDG7 include programmes on energy efficiency, clean cooking and renewable energy (in households, mini-grids and larger scale grids). The UK Department for International Development (DFID) works with a range of other organisations including multi-lateral development banks and organisations, individual countries through bilateral programmes, businesses and NGOs. There is a need to provide financial support for renewable energy in a variety of ways, including via project financing (both debt and equity), supporting project and business development, and providing assistance to technical and policy development

within developing countries. Throughout these programmes, DFID seeks to use an evidence-based approach, including commissioned research programmes and in-depth evaluations.

There are a few case studies of specific research and innovation programmes funded by DFID. These include the Transforming Energy Access programme, which is designed to support early stage testing and scaling up of technologies and business models for energy access. They also include the Energy and Economic Growth programme, which is conducting applied research that explores links between energy, economic growth and poverty reduction.

Whilst there have been many previous initiatives designed to focus on the need to improve strategic energy planning in developing countries, they have not been successful enough in building capabilities for strategic planning within those countries. This DFID initiative is planning to bring together stakeholders to agree on priority problems and solutions. This includes a focus on access to data and models, capacity to use models and interpret their results, and the use of public funding to create private intellectual property.

1.3 Deep Decarbonization and Energy Security for Low-Carbon Societies

André Månsson

Energy security issues are frequently connected to fossil energy. Energy security can also be of relevance in low carbon energy systems but the character of the threats and capabilities to manage disturbances differ between these systems. Generally, improved energy efficiency reduces the vulnerability to high and volatile prices but can increase the sensitivity to physical disturbances. Renewable energy can reduce some political threats but short term variability and seasonal variations become more of a concern.

Energy security is one of the three goals of energy policies. The other two are economic competitiveness and the minimisation of environmental impact. The prioritisation between these goals differs among countries as well as over time. This proceeding discusses some of the synergies and conflicts that can arise between environmental and security objectives and highlight related research needs.

What is energy security?

Energy security has been described as "polysemic in nature" and "capable of holding multiple dimensions" (Chester, 2010). Johansson (2013) categorised the relationship between energy and security as: i) the functionality of the energy system should be secured from threats that it is exposed to, and ii) the energy system is generating or enhancing security. The former category is frequently referred to as security of supply.

Security of supply is sometimes divided into different dimensions that are evaluated separately, such as availability, accessibility and affordability (Kruyt et a., 2009). These dimensions are to some extent overlapping, since low prices are affordable in the short term but may result in

underinvestment that threaten the long term provision of energy. It should be noted that that the provision of energy requires a functioning supply chain that is no stronger than its weakest link. Energy security can be seen as the combination of threats and the capacity (or resilience) of the system to respond to the threats when it is impacted and how the outcome of the impact is valued. Actors may find some outcomes as acceptable while others are not.

Security of supply has also been evaluated using indexes that aim to compare the level of security for different jurisdictions and/or how it has evolved over time (see e.g. Ang et al., 2015). However, these indexes often add together the result of different indicators which reduce transparency and make it impossible to distinguish how different underlying trends evolve (Månsson et al., 2014). It is also unclear if the weighting of different indicators is in line with the values and preferences of policymakers.

Improving energy efficiency provide many security advantages

Several publications have identified how energy efficiency can improve energy security (Jonsson and Johansson, 2013; Jonsson et al., 2015). The main reason for this is lower vulnerability to high and volatile energy prices as a result of reduced variable cost. Another aspect is that a larger share of the total demand can be satisfied with the same pool of resources. Energy efficiency and renewable energy can therefore be seen as complimentary, since a more efficient use of energy enables a limited pool of (domestic) renewable resources to satisfy a larger share of demand. Efficiency is also a robust security enhancing strategy, since factors that are external to the decision maker have fairly little impact of the outcome of the strategy (see e.g. Jonsson et al., 2015; Månsson, 2016). This makes efficiency enhancing strategies preferable in situations that are perceived as uncertain.

However, there are some situations where efficiency can reduce security. This can for example be the case when efficiency results in optimisation and reduces redundancy. Such systems become less flexible and are therefore more sensitive if a physical disturbance should occur. This is an area that would benefit by more research as well as how it can be mitigated by e.g. increased end use flexibility.

Increasing the share of renewable energy can affect threat exposure

Renewable energy has more numerous production units, lower energy density, and it utilises flows rather than extracting finite stocks as is the case for fossil energy. A transition to renewable energy can therefore reduce some political threats (Månsson, 2015). However, other issues may become more prominent such as land use and the issues related to variability and seasonal variation.

It is more difficult to store renewable energy than fossil energy. Biomass feedstock is bulky, biofuels have a short shelf life and electricity needs to be converted which is expensive using currently available technologies. These issues can be managed technically but the governance approach needs to be developed, since the current one has to some extent relied upon centralised strategic stockpiling. This area has so far received little interest from researchers but is likely to become of increasing importance if the dominance of liquid fossil fuel in the transport sector is broken.

Renewable energy can sometimes increase the diversity of the energy system and hedge uncertainty. However, the extent to which diversity increase is sometimes exaggerated as a result

of dependencies between fossil and renewable energy systems. These dependencies should be recognised and analysed as they enable perturbations to spread between systems.

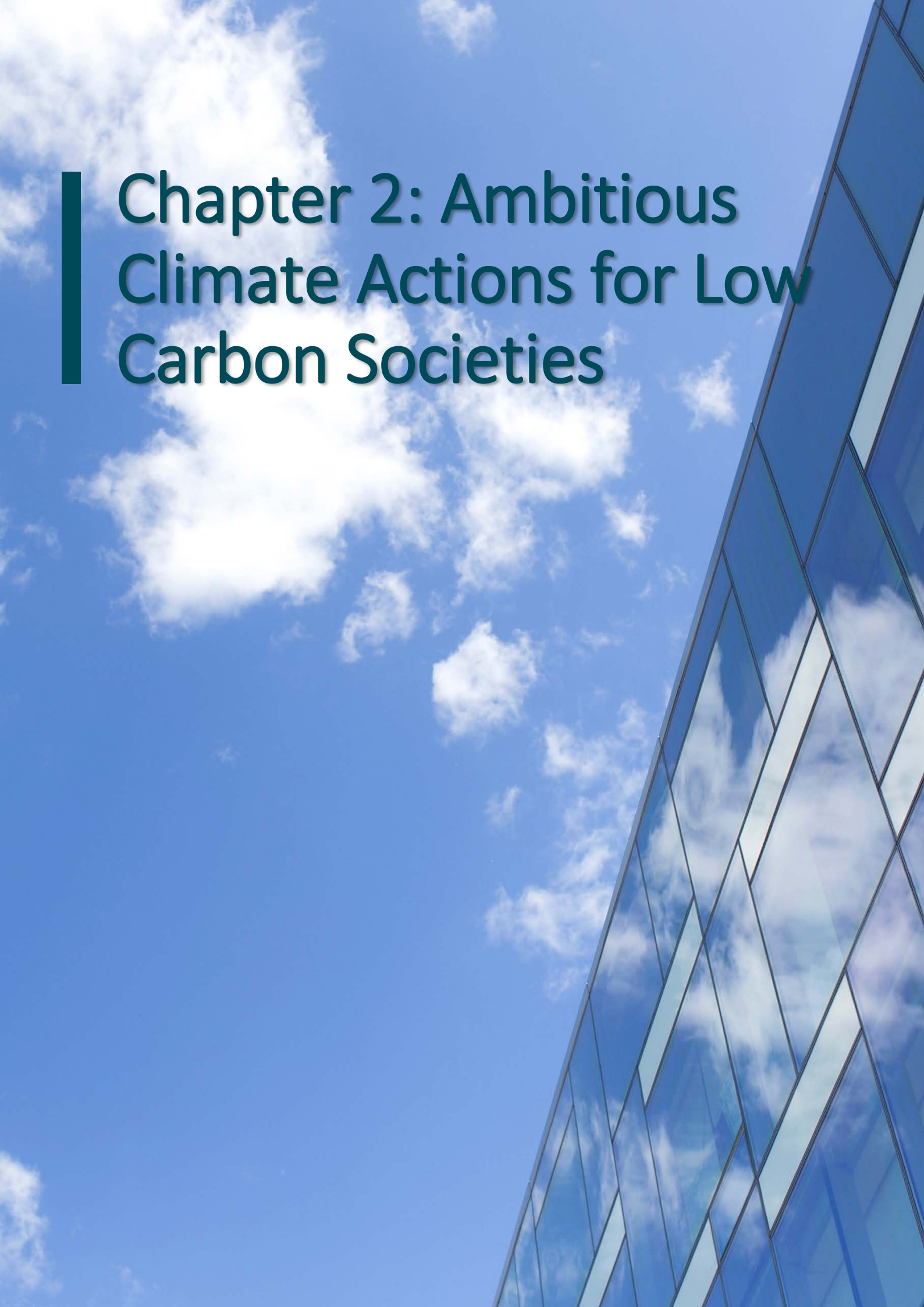
What to secure differ and affect the ability to achieve policy coherence

The framing of what to secure differs between actors, i.e. the referent object. Having a mind-set of stability and protection of status quo favours policies to supress threats. From this perspective, variable renewable energy introduces new threats. A more synergistic relationship between security and environmental objectives is achieved when security is framed as secure energy services. Security enhancing strategies can then encompass diversification of the provision of energy services and developing an infrastructure that enables a more diverse set of production technologies.

Conclusions

- Energy security and environmental protection are on policymakers agenda. The two goals can provide synergies but there are also trade-offs that should be acknowledged, dealt with or accepted.
- Generally, improved efficiency has many security advantages. On the other hand, renewable energy changes the character of threats from political to technical.
- Values affect the framing of what to secure and the ability to achieve policy coherence.

Chapter 2: Ambitious Climate Actions for Low Carbon Societies



2.1 Out of the $100 Billion Trap: A Paradigm Shift in Climate Finance

Jean-Charles Hourcade, Dipak Dasgupta, Christophe Cassen

The Copenhagen commitment of a $100 billion support per year by 2020 from developed to developing countries has become a stumbling block in climate negotiations. This section explores how to overcome it through an initiative of the willing (IW) that would bring together North and South countries in order to trigger a wave of investments in low-carbon and sustainable infrastructure. It shows the potential of coordinated issuance of public guarantees in order to (i) reduce the risk exposure of project developers and financial intermediaries and (ii) scale-up business engagement and initiatives by multilateral and national development banks, and institutional Investors in search of safe and sustainable investment opportunities.

The window of opportunity is closing fast for a world of under 2°C global warming (UNEP, 2017). The challenge of the Talanoa Dialogue at COP24 is to accelerate the low carbon transition by creating a circle of confidence between developed and developing countries, starting from fulfilling the '$100 billion a year and beyond commitment' of developed countries (para 53, UNFCCC,2015). However, the scaling-up of action at the required level implies the involvement of states to de-risk investments in low-carbon and sustainable infrastructures.

Given constraints impinging upon the public budgets of Northern countries, a main tool for this de-risking is sovereign guarantees for low-carbon investments because these guarantees are activated only in case of failure of the projects[1]. The aim of an alliance between Northern and Southern countries would be to coordinate their issuance, in a context where parallel initiatives to the UNFCCC process have flourished over past years (Hermville et al., 2015). It will do so according to "*social values of mitigation activities*" (SVMA) as provided for Article 108 of the Paris Agreement Decision, together with a common Monitoring, Reporting and Verification (MRV) processes, respecting the IPCC guidelines.

This would allow support a new form of 'where flexibility' (i.e. abating carbon emissions where it is cheapest to do so) that does not confront the same obstacles than an explicit carbon price. First, the guarantee would value the ton of avoided GHGs emission at a level that represents the willingness of high income countries to pay for mitigating climate change. This value is far higher than the capacity to pay of low income countries. Second, an *AAA guarantee* (the rating of developed countries reinforced by a *common guarantee mechanism* in the event of default by a partner) would allow for issuing *long-term low-rate bonds* for projects in countries that have access to capital only at high interest rates or that are non-rated.

Such a coordinated device would *reduce the risks* taken by project promoters and their financiers, which are aggravated for infrastructures with a long construction phase and high capital cost. It would provide a premium valuation to long maturity investments because they incorporate an upward trend of implicit carbon prices and would facilitate the emergence of low-carbon

[1] Public guarantees have always been important in underwriting global transformations in history (railways, electricity, telecommunications).

infrastructures as a new class of assets. These investments should at least be consistent with development aid, *adaptation and provision of basic needs*.

This initiative of the willing should not be conceived only through a climate lens but also as an instrument to provide the large 'co-benefits' of an equitable access to development and unleash a potential of reciprocal gains between 'North' and 'South'. This mechanism could catalyse global savings to finance sustainable low-carbon infrastructure and climate resilient development (UNFCCC, 2015, Art 2) and help developing countries implement their Nationally Determined Contributions (NDCs) by expanding their access to capital markets at lower cost and longer maturities. The increase in volume of financing, the de-risking of low-carbon investments will therefore enable bridging the large sustainable infrastructure funding gaps (Sirkis et al., 2015, Arezki et al., 2016).

The burden of public guarantees on public budgets for OECD countries will only be a fraction of the size of projects guaranteed and this system will not require compensating transfers towards developing countries. It will also open new markets and related benefits in terms of job creation and growth for its members.

If the demonstration effect of the benefits of these devices is convincing enough, it could be later expanded worldwide through the UNFCCC process as a practical way of implementing the common but differentiated responsibility principle (Hourcade et al., 2015). By doing so, it will enhance the chances that the UNFCCC process delivers in 2020 an agreement on the full implementation of the Paris Agreement.

2.2 Redesigning Emission Pricing with a New International Climate Agreement in the Emission Tax Club

Gjalt Huppes

Current climate policy uses the regulatory framework of environmental policy from half a century ago. Standards and permits, some made tradable for flexibility and efficiency, realize the desired emission reduction according to plan. This Planning & Control framework is also used internationally, as in Kyoto and Paris. Current CO_2 emission pricing follows this governance pattern, as also in tradable emission permit systems. Different political philosophies lead to a different set-ups of emission pricing.

An upstream administered system could be proposed, with a rising level of emission tax, as the prime instrument in Institutionalist governance, covering all fossil CO_2 emissions equally. An international agreement in the Emission Tax Club would specify the common tax system and level, and it would be open for all other countries to join. Each country would use the net proceeds as it sees fit. Each country might punish free riders for undue competitive advantage, under current WTO rules.

Global CO_2 concentrations are rising faster than ever, despite active climate policy since the 1980s, and international alignments since the 1997 Kyoto Protocol, see ESRL/NOAA (2017). There is broad agreement in economic-technical scenario models that emission pricing is essential for arriving at deep reductions. There are various approaches to emission pricing, including cap-and-trade

systems, and various ways to design emission taxes, related to various political philosophy and governance views. Most current reasoning starts from the Planning & Control instruments as developed for environmental pollution half a century ago, using standards and individual emission permits, with permits made tradeable for flexibility and efficiency. With the total of CO_2 emission permits capped, prices follow. Unstable and too low prices, free allocation with windfall profits, and only partial application with shifting boundaries hinder cap-and-trade based pricing as in the EU-ETS, quite unavoidably.

Improvements now can take this instrumentation as starting point again. There is a different strategic option, based on reasoning from a different line in political philosophy. This enables the redesign of institutions which have become inadequate.

Political philosophy: institutions guide long term development

Opposing views on central unity and efficiency versus decentral autonomy have been present in political philosophy since Plato versus Aristotle and are somewhat similar to Confucius (Kongfuzi) and Laozi. Modern highlights are the discussions following the Magna Carta (1215) on reducing the power of kings; the Dutch Republic with hardly any central government versus Hobbes' Leviathan; and the English Glorious Revolution with its Bill of Rights (1689) versus Louis XIV. The French Revolution has contradictions within. Democratic procedures limit the power of political leaders but increase the legitimacy of central state actions. Democratic welfare theory, as 'the greatest happiness for the greatest numbers' made operational, has built the basis for increasingly detailed central government action. Current climate policy instrumentation builds on that basis. Institutions work more indirectly, long term. Their design has a more general background in legal and ethical principles. They have formed the basis for the Industrial Revolution, over many centuries.

The post WW II explosion in global economic growth is based on innovations in institutions, linked to Keynes, repairing some deficiencies as led to the Great Depression and WW II. The role of central banks moved towards stabilizing currencies; new fiscal and monetary policy instruments prevented deep economic contractions and reduced balance of payments instability. Internationally, the IMF was set up to align global money supply with global economic growth. The GATT/WTO enabled open international trade. Later, open internet was provided publicly for free information exchange. Together institutions created unprecedented global economic growth in the last few decades, lifting billions out of poverty, see the *elephant curve* of Milanovic (2016).

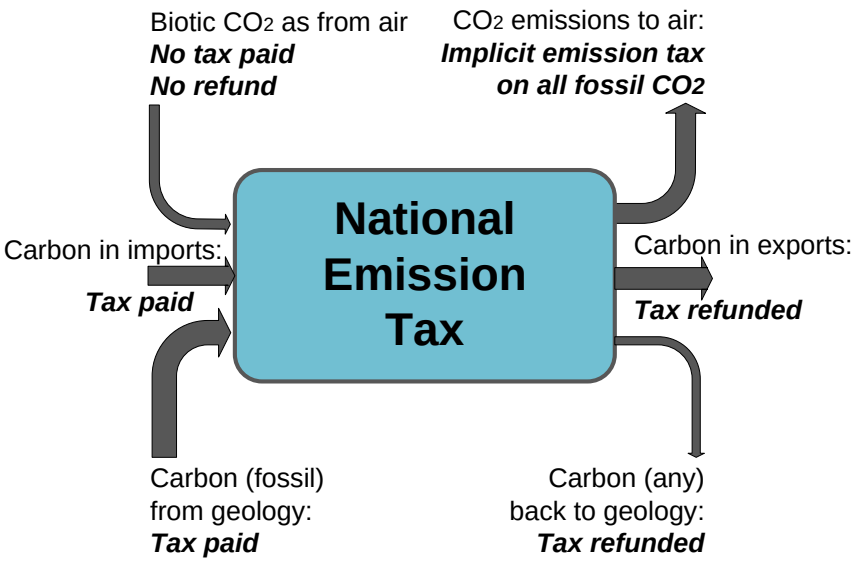
Induced global equality and national inequality are at levels beyond what any climate policy might ever induce. In the Institutionalist approach it is not just a technical issue to reduce the CO_2 emissions of main specific sources, like for the old environmental problems, but a basic feature of institutional design and redesign for industrializing global society. A deep redesign of market rules is due, consistent with overall concepts of responsibility and liability, with one specific set-up of a CO_2 emission tax as a key element, and with a redesign of electricity markets as a second main element. Reversing the neoliberal trend towards private ownership of natural monopolies is the third main issue to resolve for climate policy, and beyond.

Redefining market rules at national level

The institutional revision does not start from permits of specific emitters but from the general market deficiency as Pigou (1932 (1920)) first described from a still micro level economist point of

view. One main deficiency is non-applicability of tort law in holding persons liable for damages to third parties, for practical and philosophical reasons. Some rights must be inalienable (Calabresi and Melamed 1972). This holds for induced climate change, which is not just an economic issue (Weitzman 2011). Reasoning may then start from a broader systems approach, first nationally. Where do the emissions originate? Why are they rising, or not? In what directions may institutions be adapted to better deal with this issue? There is not one single answer for all emissions and not just one even for all climate changing emissions. For CO_2 there is one main source however: use of fossil fuels. One main answer is an encompassing emission tax, rising so as to reduce emissions to near zero.

Figure 3: A systems approach for taxing all national fossil CO_2 emissions, as a deposit



Source: Huppes (2017)

A systems analysis of CO_2 flows sees carbon flowing into the economy from geology and biotic sources and through imports, and flowing out through exports and geological carbon storage. The difference remaining covers all fossil CO_2 emitted (see figure 1). Putting a tax on fossil carbon at primary production and imports, refunded only in case of geological storage and exports, effectively creates an upstream administered tax on all fossil CO_2 emissions. Its level is determined by the overall goal of reducing climate change, not related to any specific emitter. Taxing and refunding in imports and exports is *not* border tax adjustment but part of national implementation of the emission tax. It does *not* cover upstream emissions abroad. Detailing is by lawyers and administrators, not economists and technicians.

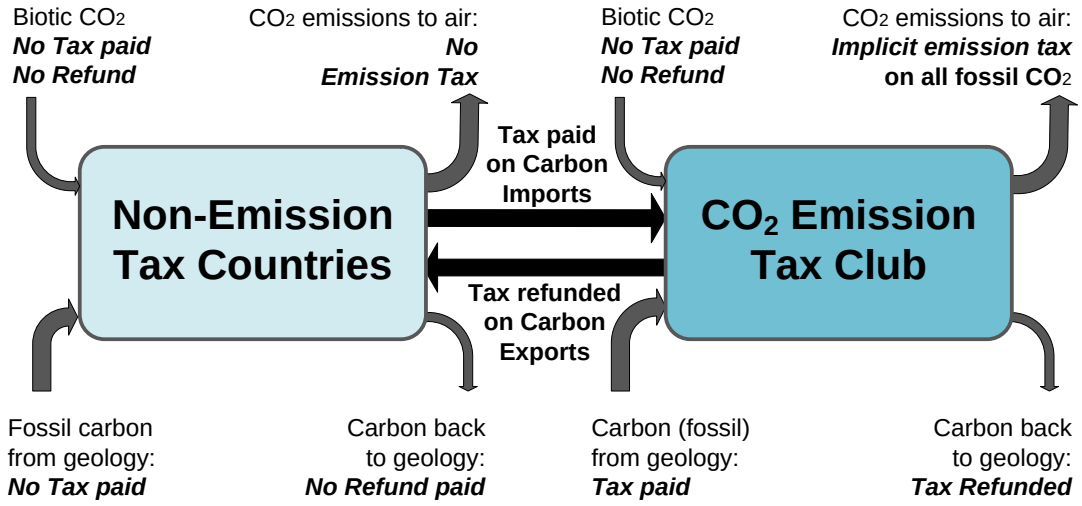
Redefining market rules at the international level: the ETC

All industrialized countries have institutions creating markets and adapting markets in changing situations. In a one-world country, not to be expected any time soon, the emission tax would be most simple, without imports and exports. But implementation would be partial. Countries having the same national emission tax would cooperate in the Emission Tax Club (ETC), after Nordhaus (2015), but not with his Club sanctions, with a specialized court for conflict resolution as in the WTO, similar to formerly in the Hanseatic League. Tax proceeds would be per country according to its

share in Club emissions. The tax on carbon imports in energy products from non-members is part of the Club Tax, as is the refund upon export to them. For some products such as iron, aluminium and cement, not-taxed upstream emissions may create a substantial competitive advantage.

A country may then apply a well-reasoned Border Tax Adjustment (BTA), fitting easily in the WTO framework. As the Emission Tax Club induces the most dynamic climate innovations, such border corrections may not be relevant long term. The Club Agreement is open for any country to join, then adhering to the same emission tax rules and level. Each country decides for itself on what to do with net proceeds.

Figure 4: A global system for taxing fossil CO_2 emissions: the Emission Tax Club (ETC)

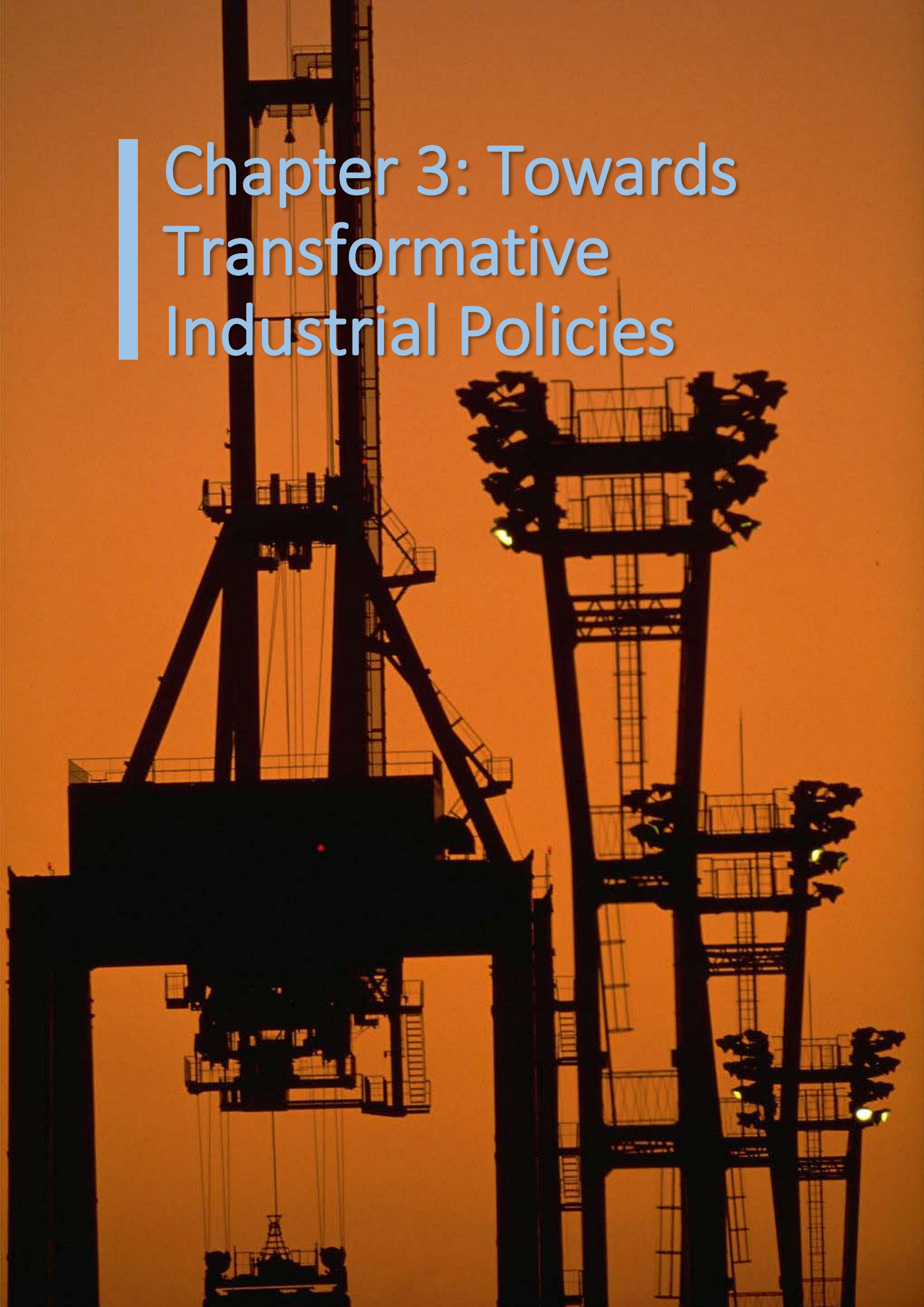


Source: Huppes (2017)

Prospects

There are developments towards national emission taxes going in the direction of the upstream administered rising emission tax. One is implemented in British Columbia with other Canadian provinces following, supported by conservatives and liberals. Extensive Scandinavian emission taxes have been implemented by social democrats. In the US there is a proposal from conservative Republicans covering this type of emission tax Baker III et al. (2017). The EU is in the process of transforming the EU-ETS and could stepwise transform the auctioned permit system to an encompassing emission tax. The Club Agreement doen not require near global agreement but can start with a few prime mover countries, incentivising other countries to join.

Chapter 3: Towards Transformative Industrial Policies



3.1 Industrial Policy for Innovation and Resource Productivity in a Low-carbon Society

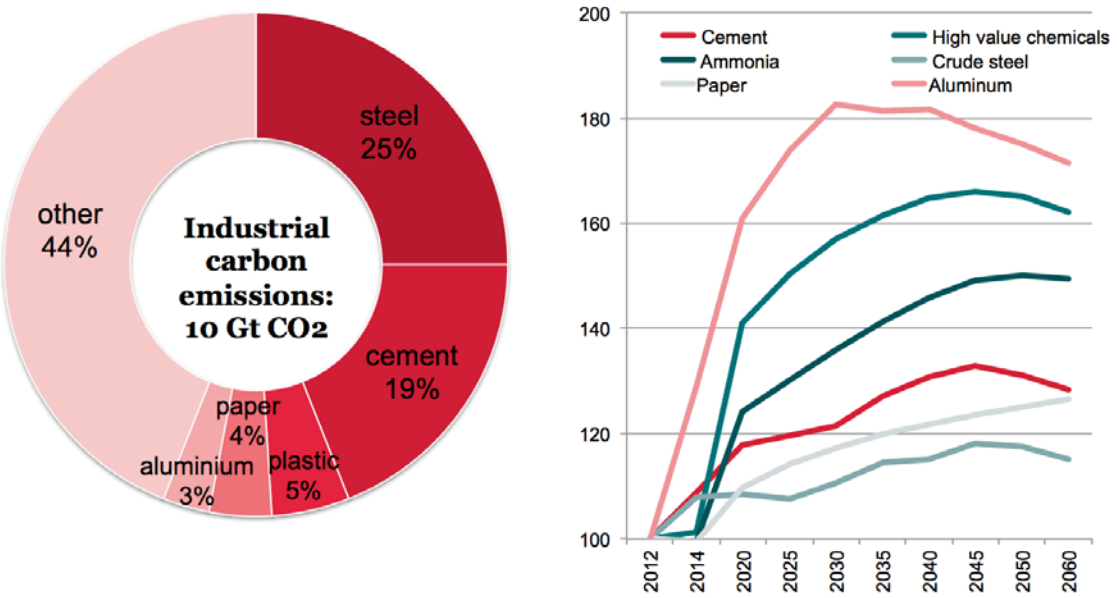
Stefan Lechtenböhmer

Low carbon societies need deep decarbonization of households and buildings, transport as well as all economic sectors, together with radical changes of the energy system towards low carbon energies. Energy-intensive process industries (EPIs) provide basic materials like steel, aluminium, pulp, paper, cement, plastics, chemicals, etc. These are needed for global infrastructures as well as consumer goods. Steel, insulation materials, silicon and other materials are essential for mitigation and energy transition across sectors.

Factors creating lock-in and barriers for deep decarbonization include strong international competition among basic materials, capital intensity, economies of scale and long-term investment cycles, high amounts of energy demand and the need for significant breakthrough technologies. Overcoming these barriers will require long-term innovation and transition strategies that go beyond incremental processes of change. It also requires international collaboration and a supportive climate policy framework. Deep decarbonization in these sectors requires changes in industrial, research, innovation, trade, energy and climate policies – changes that are still relatively unexplored.

Basic materials processing industries are responsible for over 20% of global GHG emissions and their production is rapidly growing (see Figure 1). The decarbonization of these industries is particularly challenging as many of the technologies needed (e.g. to electrify steel making or chemical feedstocks) are not yet available and the overall structures of these industries do not necessarily support fast decarbonization (cp. Wesseling et al. 2017).

Figure 5: Global industrial carbon emissions (2005) and expected growth rates by 2060



Source: own figure, data from Allwood et al. 2011 (left), IEA 2017 BY2DG (right)

Electrifying of basic materials and converting to biomass feedstock would need enormous amounts of biomass and RES-based electricity. For the EU, that could e.g. mean to increase electricity production by around 60% just for basic materials production (Lechtenböhmer et al 2016).

Therefore, it becomes obvious that on top of inventing and developing the technologies to decarbonize basic materials processing, it is important to curb basic material demand globally, by reducing material intensity of products and services. An example is the work on Business and resource efficiency presented in panel 1 by Nick Molho (Director, Aldersgate Group, UK).

To spur developments into this direction, industrial policies are needed that integrate climate and energy policies as well as innovation and resource productivity in an intelligent way.

A new paradigm for industrial policy to tackle the decarbonization challenge

These obvious challenges show that industrial policies are necessary which integrate climate and energy policies as well as innovation and resource productivity in an intelligent way. Industrial policy traditionally has a rather poor reputation as mainly trying to prevent structural changes. Therefore, until the recent past, industrial policy has rather been a barrier to climate mitigation than an asset. The high amount of environmentally harmful subsidies still paid is proof of this. A recent OECD study found out that OECD member states are still financing fossil energies with $US 70 bil. a year vs. only $US 20 bil. for renewables.

More recently there has been emerging a new concept: the green industrial policy or green growth idea. Policymakers in Korea and the EU, but also in many other countries, and also companies like Siemens found out that green markets were actually among the fastest growing sectors – a point that was particularly strong during the financial crisis – with also good prospects for further growth. This observation has led many policymakers, including in the EU, to put not only the challenges of climate policies but increasingly the chances of mitigation policies at the center stage of their "re-industrialization" strategies. The latest developmentz in the EU can be found in the most recent EC communication on "A renewed EU Industrial Policy Stratsgy" (EC 2017).

It is important but by far not enough that industrial policy discovers climate mitigation as a chance for innovation, growth and jobs and tries to harvest these options that are given by energy transition and climate leadership. Industrial policy needs to identify its crucial role in achieving the ultimate goals of sustainability and decarbonization. Without a targeted new industrial policy, economies will not be able to innovate fast enough to have the technologies in place to decarbonize materials processing industries, which is needed around mid of the century at the latest.

Governments will also not be able to provide the necessary infrastructure (e.g. green electricity and sustainable biomass) for such a development. Nor will companies and societies be able to harvest the potential benefits of dematerialization which are embedded along the value chain and therefore often out of the view of traditional players in industries

Important elements of such a policy, with a focus on the processing industries are described by Nilsson et al. (2017) point out that "an industrial policy for well below 2 degrees Celsius" requires profound changes in industrial processes as well as innovation, trade, circular economy, energy

and climate policies. They provide a brief overview of such a policy together with the innovation challenges for the processing industries and argue that a strong combination of technology push and market pull created by policy and regulation is needed in addition to the self-propelling voluntary markets. For this, governments need long term visions that can emerge from NDCs by looking beyond mid-term targets, and by including all stakeholder groups.

Industrial policy 3.0

All these points make it clear, we need a new industrial policy 3.0 which

- Puts sustainability and decarbonization at the center stage of its target system – not jobs and growth
- Integrates climate, energy innovation and resource efficiency
- And includes all societal stakeholders

Such an Industrial policy 3.0 would clearly mean a new paradigm for industrial policy which goes far beyond traditional views of industrial policy as well as green growth strategies, e.g. along the lines described by e.g. Aiginger (2014).

3.2 Industrial Policy for a Well-Below 2 Degrees Celsius World: The Role of Basic Material Industries

Lars J. Nilsson, Max Åhman, Valentin Vogl, Stefan Lechtenböhmer

The well below 2 degree Celsius target sets a clear limit to future greenhouse gas emissions and thus strict boundaries for the development of future industrial processes and sourcing of feedstock. This includes the primary production of steel, cement, plastics and other basic materials that currently account for more than 20 % of global greenhouse gas emissions. It requires decarbonised energy systems and more resource efficient and circular economies in material as well as molecular terms. For example, carbon used in plastics and chemicals can no longer be derived from fossil feedstock but should be sourced from biomass, carbonaceous waste streams, or the atmosphere.

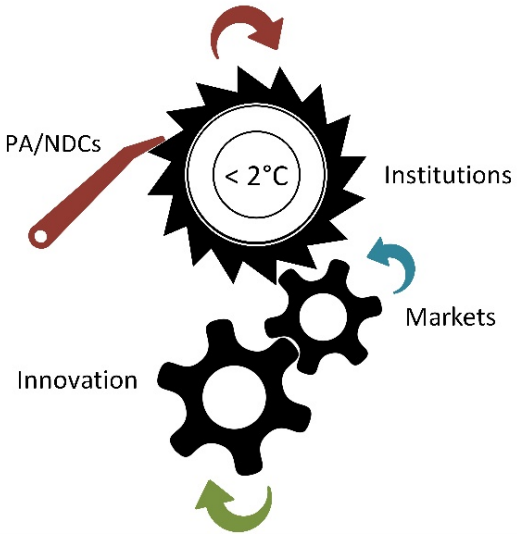
A new industrial policy is needed, one that respects *the necessity of zero emissions* and integrates this with the traditional goals of competitiveness, jobs, economic growth and industrial development. We argue that the recent turn in industrial policy towards green growth and resource efficiency does not fully recognise this necessity nor the policy implications of zero emissions in the basic materials industry. An industrial policy for well below 2 degrees Celsius requires an additional turn – a turn towards long-term target-oriented strategies with a focus on zero emissions in basic materials production.

Industrial policy can be any policy that aims at changing the industrial structure in the economy in a certain direction, or even at preserving it. Industrial policy is thus not one particular policy intervention but rather the combined effects of many policy instruments that are coordinated towards an industrial goal.

Industrial policies can be classified as being either vertical or horizontal depending on whether singular sectors or technologies are targeted (e.g. a national steel policy) or the whole economy

(e.g., general R&D or tax policies). Vertical industrial policies typically include more *direct* state interventions via state ownership of industries, public procurement, targeted subsidies and trade tariffs on specific products, demonstration projects, and infrastructure. Horizontal industrial policy relies more on *indirect* state intervention via exchange rates, emissions trading, general tax policies or R&D spending.

Figure 6: Ratchet mechanism for a well below 2 degrees Celsius industrial policy



Source: Nilsson and Åhman (2017)

In recent history, industrial policy has shifted from protecting incumbent industries. e.g., steel and shipyards in the structural crises of the 1970´s, to a greater focus in the 1990´s on promoting high-tech growth sectors and small and medium enterprises (SMEs) for job creation and economic development. Although most countries in principle embrace competition, free trade and globalisation, they still take precautions to support and protect their own industries in various ways. Examples of this abound and the basic materials industry is no exception. Motivated by concerns over reduced competitiveness and carbon leakage, it is typically sheltered from the potentially adverse effects of energy and climate policy, e.g., through free allocation of emission permits or energy tax exemptions (Wesseling et al., 2017).

The turn in industrial policy towards green growth has been championed by countries like South Korea and the European Union. Re-industrialisation is a core strategy for economic development in the EU since 2011, as part of a broad agenda that also includes a low-carbon and circular economy, digitalisation, and innovation (EC, 2017). The need for industrial policy and the turn towards green growth has also been advocated by scholars such as Rodrik (2014), Aiginger (2014) and Warwick (2013). They argue a strong case for systemic industrial policies that instead of being mainly growth oriented also support broader social and environmental goals.

Similar lines of thought in order to tackle societal problems that are systemic in nature are found in OECD reports on green growth (OECD, 2011) and system innovation (OECD, 2015). However, these approaches to industrial policy and innovation do not include, as of yet, explicit attention to

the necessity of zero emissions and the profound changes in production, use and recycling of basic materials that this entails.

The EU supports energy efficiency, renewable energy, resource efficiency and cleaner technologies through an array of policies and directives. However, the only policy so far that clearly targets greenhouse gas emissions from basic materials production is the EU Emissions Trading System (ETS). The ETS has not yet produced the carbon prices or long-term certainty that would motivate fundamental process and feedstock changes and investments for deep decarbonization in basic materials production.

The technical options for zero emission basic materials include materials and energy efficiency, carbon capture and storage or use (CCS and CCU) as well as carbon neutral electricity and biomass for process energy and feedstock (Wyns and Axelson, 2016, Lechtenböhmer et al., 2016). Fossil-free basic materials production will often lead to higher material costs but the share of material costs in final product prices is typically small, and it can be reduced through materials efficiency (see e.g., Rootzen, 2016).

The highest cost increases are likely to occur in plastics and organic chemicals production from hydrogen and carbon dioxide when compared to fossil feedstock (Palm et al., 2016). For example, the price of a 35 gram polyethylene bottle used for ketchup or shampoo may in this case increase from 10 cents to 20 cents. This is hard to implement in cost-cutting value chains, but it may be a necessary price to pay for zero emissions and closing the loop on anthropogenic carbon.

The transition to zero emission basic materials requires technology development, fossil-free energy and feedstock (or CCS), dematerialisation, markets for green and recycled materials, and large investments in production plants and infrastructure. The transition requires government engagement, facilitation, interventions and support in all these areas. Also, it should be governed so that it leads to a fair distribution of risks, costs and benefits. In short, it requires an industrial policy for well below 2 degrees Celsius.

Consider, for example, the Swedish steel maker SSAB who recently teamed up with the mining company LKAB and energy company Vattenfall. They will develop a process for fossil-free hydrogen reduction of iron ore through the joint venture company HYBRIT Development AB. The process for research, development, piloting, demonstrations and scaling up is expected to last up to 20 years. At commercial scale, it involves several billion EUR investments in hundreds of MWs installed electrolyser capacity and new hydrogen reduction shafts to replace today's blast furnaces. Government will be important in all steps of such a development and commercial scale-up, and not least in making it possible to get a return on such investments through a level playing field for fossil-free steel.

Innovation policy has traditionally focused on technology push, i.e., spending mainly on technology RD&D and less on creating market demand pull. This is a sensible strategy in the earlier stages of technology development and demonstration, but for full-scale demonstrations and commercial deployment, investors need certainty about the economic viability of projects. Experience from the EU NER300-programme, designed for innovative low-carbon energy demonstration projects, illustrates this point. Projects that will be implemented are typically those that demonstrate new renewable electricity technologies whereas projects in CCS and biofuels production have been put on hold or cancelled. High certainty about future demand for renewable electricity facilitates

investments. High uncertainty about future carbon prices, CCS regulations, and the demand for liquid biofuels deters investments (Åhman et al., 2017).

It is instructive to reflect on the experience from successful renewable energy policy for thinking about an industrial policy for well below 2 degrees Celsius. For renewables, technology push policies were complemented early on with strong demand-pull policies. Feed-in-tariffs, quota obligations and auctions for renewable electricity have played an important role in creating investor certainty and bankable projects. Another example is how, in Sweden, the highest carbon tax in the world (about 120 EUR per ton CO_2) effectively locks out fossil fuels from the district heating markets and created demand for fossil-free heating. This illustrates that carbon pricing can be very effective in a sector such as space heating where production cannot relocate geographically and there is no carbon leakage.

Governing decarbonization of basic materials is a much more complex task than decarbonising energy systems. This is due not least to international competition and trade, and the great diversity of materials, qualities and products. Furthermore, the energy sector is a sector with decades of institutional development and established governance structures. In contrast, for example, the "plastics system" is not thought of as a sector and nor is it governed as one. It is shaped by a mix of chemicals, waste, recycling, plastic bag regulations, energy and other policies. It is only very recently that a first attempt has been made to build a coherent approach through developing a European Plastics Strategy where the key challenges of fossil feedstock, low recycling rates, and littering and pollution are integrated.

An industrial policy is needed which respects *the necessity of zero emissions,* and in particular can deal with the technical and institutional challenges of deep decarbonization of the basic materials producing industries. This is a fundamental boundary condition within which to handle other demands on industrial policy, e.g., growth, jobs, globalisation, and digitalisation. The need for zero emissions is now increasingly recognised and accepted across these industries but there are still great uncertainties around technology options and potentially viable transition pathways.

A new industrial policy may evolve from the development of shared ideas and visions for zero emission materials. It would require systems for monitoring and verification so that green materials can be properly traced and their environmental attributes linked to the products. Initial voluntary approaches (e.g., niche markets and public procurement) may be followed by more binding policies if needed (e.g., feed-in-tariffs or quotas for green materials). It is important to find ways of sharing risks, responsibilities and benefits, as well as to create level playing fields for industry, companies and regions during the innovation and transition process.

Institutional capacity at the member state and EU levels is important to handle state-aid rules and many other challenges. The transition of industry to zero emissions must not degenerate to, or be wrongly perceived as, climate protectionism, but it should develop in a transparent way within the context of the UNFCCC and NDCs. Under the principle of common but differentiated responsibilities (CBDR) the EU can make the necessary investments in new technologies for basic materials that can later benefit other countries. This is similar to how some countries have invested in and spearheaded the development of solar and wind power technologies.

Chapter 4: Looking Ahead, Success Cases from a Changing World

4.1 Leapfrogging Challenge towards a Carbon-Neutral Society in Bhutan

Shuzo Nishioka, Miho Kamei, Tomoko Ishikawa, Kei Gomi, Yuki Ochi

The necessity of a huge transition to carbon neutral society within this century requires reconsidering of nations development bases, such as fossil fuel reservation into stranded asset. Historically, technological and development leapfrogging was realised by actors who regarded such big waves of change as an opportunity, a tailwind or trigger, and rode such waves through leveraging their inner strength. The transition to Carbon Neutral Society inevitably increases the value of natural resources such as forests, soil and hydro-power as carbon sinks and renewable energy.

Bhutan, already a carbon neutral nation, maintains plenty of forests and hydro-power and declared its wish to continue as a carbon neutral country in its INDC. Whether Bhutan can find a path to leapfrog onto a completely different track as that of developed countries is a challenge also experienced by other latecomer natural resource-rich nations.

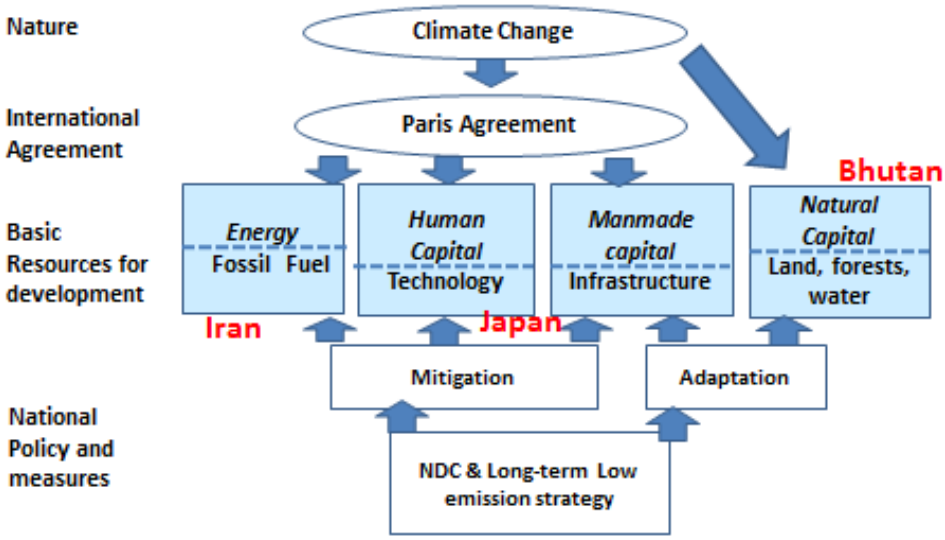
Many developing countries are already in a state of carbon-neutral society or are aiming at such, which is something the rest of world has to attain within the second half of this century. However, such state cannot be attained if they adopt the pathways of high energy intensity countries. This means they are expected to 'leapfrog' directly to a state of carbon-neutral society.

Bhutan, with its rich natural resources such as forests and hydro-power, has declared its intent to remain carbon neutral over the long term as one of the front-runners in the race to be carbon neutral. But there are many obstacles to overcome before it can achieve this, such as how to maintain natural resources under the influence of climate change impacts, depopulation in the countryside due to urbanisation as well as how its economy can develop in the face of globalisation pressures.

Although countries differ in terms of development stage, geographical environment and governance style, such issues are common in other natural resource-dependent countries. Further, these issues are also relevant for developed countries with degrading natural resources or populations decreasing due to low birth rates, as in Japan.

The Gross National Happiness concept is Bhutan's overall governing direction, and was in place domestically before the SDGs. Its position within the context of energy transition needs to be analysed in order to learn lessons to apply to the SDGs.

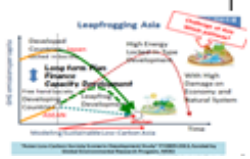
Figure 7: Climate Change Impacts on Values of National Development Resources



Source: Nishioka (2017)

Figure 8: Can Bhutan leapfrog? Some leading runners, leverage, tailwind

Can Bhutan leapfrog? Some leading runners, leverage, tailwind

Issue	*Country*	*Internal factors*	*External factors*
Industrial structure	India: '90s IT industry, Bangalore	Education/ human resources	Soft technology start Globalisation
Energy structure	Japan: '70s Low energy intensity	Technology Rapid growth/pollution	Oil crisis Energy security
Bioenergy	Brazil: '70s Bioethanol	Sugar cane Scarce oil	Oil crisis Energy security
Information technology	China: '00s- Mobile phones	Rapid economic growth, Poor telecoms network	IT technology Globalisation
Renewable energy / EV	China: '00s Wind/solar energy/EV	Large land area Technology/pollution	Decarbonisation trend Climate change
Develop-ment path?	Bhutan to 2050s High dependence on external funds High transportation cost Inadequate infrastructure	Political stability Natural and Pristine environment Competitively priced energy Nation of GNH Wide use of English language * 8	Carbon neutral world International cooperation climate finance capacity building 

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Source: Nishioka (2017)

Methodology and ongoing activities

This international joint research project aims to support Bhutan's carbon neutral policy with natural and social scientific bases, to develop academic capacity with its ownership and to explore the possibility of its transfer to other developing countries. Comprehensive and inter-disciplinary in nature, it consists of the following modeling and planning tools to evaluate Bhutan's carbon neutral development path.

Major research questions:

1) How are natural resource-dependent development countries facing the challenges of a carbon neutral world and energy access? 2) What problems do the impacts of climate changes and response strategies pose to sustainable development pathways? 3) Can an alternative development pathway be found, technologically, economically and socially, by leapfrogging beyond the high-energy intensity associated with modern society, using this transition as leverage? 4) Is the case of Bhutan transferable to other developing countries experiencing similar circumstances?

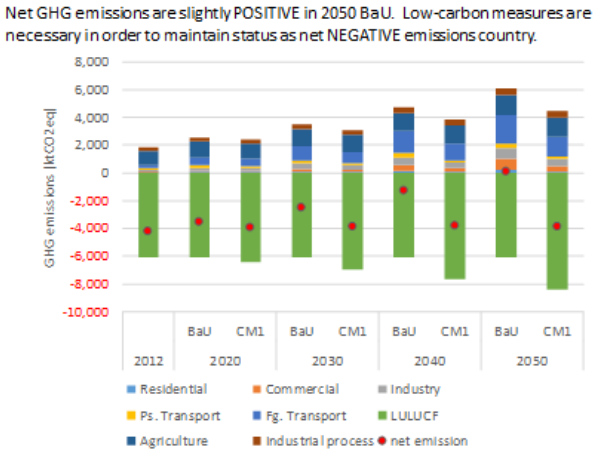
Several development paths are proposed and examined in terms of feasibility and relationship with policy. Two main models, i.e., a carbon neutral scenario and land-use plan, are being developed which interact with each other to harmonise energy policy (top down) with national land-use plan (bottom up).

The proposed quantitative models are:

- Climate change impact assessment for natural resources (forest, hydrology, agriculture, biodiversity)
- Carbon Neutral pathway (integrated assessment model)
- Absorption Scenario/GHG emission Scenario
- Multi-target (GNH) coordinated development scenario
- Dynamic national land-use planning

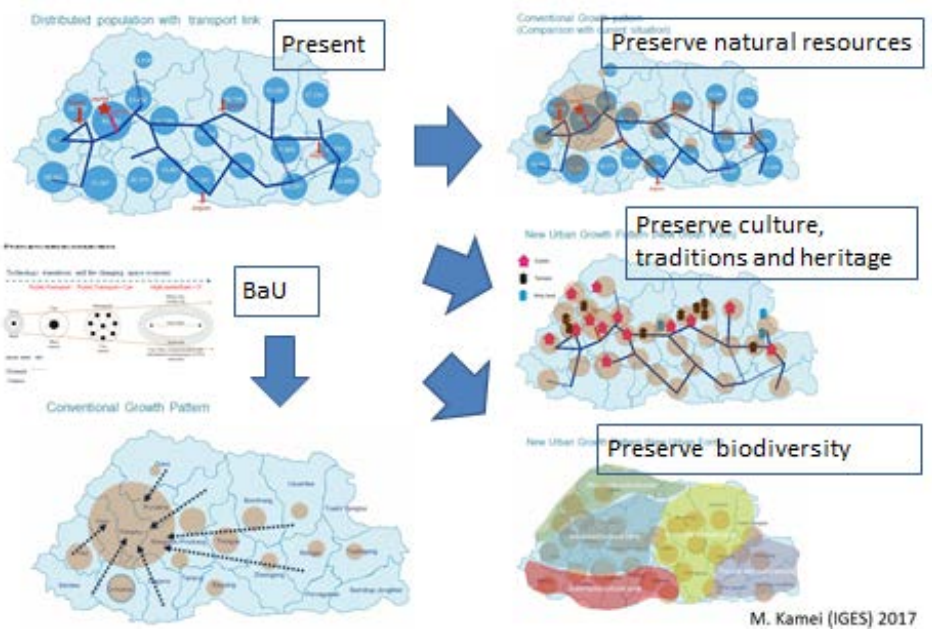
A Research Team consisting of IGES, NIES, Tokyo-Tech, National Environment Commission as well as two Research Institutes in Bhutan was put in pace in 2016. Whilst still in its initial stages, using pre-existing data, some preliminary results were obtained as follows.

Figure 9: Carbon neutral pathway of Bhutan (Preliminary result)



Source: Gomi and Ochi (2017)

Figure 10: Land use plan under carbon neutral & Gross National Happiness



Source: Kamei (2017)

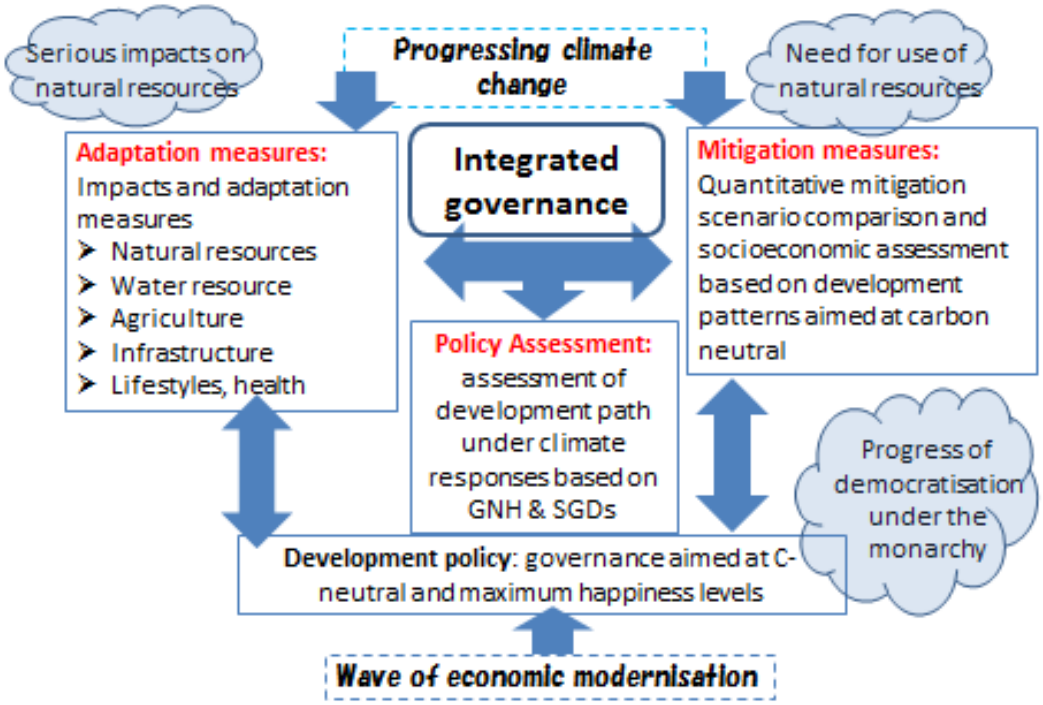
Results/Findings

- Bhutan has sufficient natural resources to realise a carbon neutral society today. Abundant biomass and hydro-electricity provide energy to each household, and exported electricity makes up about 1/5 of national revenue. Its forest area covers 70% of land and acts as both biomass provider and CO_2 absorption reservoir.
- Preliminary analysis using climate models suggests that substantial climate change in this mountain region may cause serious impacts to Bhutan's vulnerable natural resources.
- A full-scale nationwide forest and soil survey is underway to quantify the carbon stock.
- A more precise analytical study is required in order to assess possible future changes in absorption capacity.
- The scale of industry is currently small. The National Development Plan aims at self-resilience and full employment under the mantra of "High value, Low volume", which includes sectors such as high–tech, medical, tourism and education. To broaden the scope of its export industry, development under a banner "Brand Bhutan" is being considered, which is designed to embrace multiple aspects of the country such as vernacular culture and traditions of its different regions".
- Accordingly, Bhutan attaches the utmost importance to maintaining its local natural resources and cultural diversity in the fields of development and carbon neutrality. The key to this is harmonising the development plan with carbon neutral policy and decentralisation land-use plan.
- The higher-level concept of the development plan is GNH (Gross National Happiness), which is also considered in this study and forms part of the carbon neutral scenario.
- Whether Bhutan leapfrogs to a new carbon world or not is still under discussion. Its strong points are acknowledged as political stability, natural and pristine environment, competitively

priced energy, notion of GNH and wide use of English language. Barriers to be cleared are: high dependence on external funds, high transportation cost and inadequate infrastructure.

- Historical examples of leapfrogging show that big waves of transition on the outside, together with internal advantages that can capitalise on such transitions act as major push factors, as well as astute governance to utilise such opportunities and acting promptly (mainly in technology fields).

Figure 11: Factors of Carbon Neutral & Sustainable Bhutan under CC



Source: Nishioka (2017)

Conclusion

A preliminary analysis of the possibility of carbon neutral development of Bhutan, as a case study of natural resource dependent countries has come to the following conclusions:

- Bhutan has the capability to leapfrog development owing to its abundant natural and human resources and GNH based governance.
- It is important for Bhutan to set a long-term strategy that fully integrates development, carbon neutral and land-use plans.
- An international framework (e.g. GCF/REDD+) to re-evaluate carbon value for preserving natural (absorption and energy) resources is indispensable to enabling countries such as Bhutan to take off.
- Replicability of Bhutan's case needs to be discussed in consideration of broad range of individual historical and natural resource contexts of developing countries.

4.2 Universal Energy Access and Climate Change Mitigation in Sub-Saharan Africa

Anteneh G. Dagnachew, Paul L. Lucas, Andries F. Hof, Detlef P. van Vuuren

Access to electricity services is fundamental to development, as it enables improvements to the quality of human life. At the same time, increasing electricity access can have notable consequences for global climate change. This section analyzes trade-offs and synergies between achieving universal electricity access and climate change mitigation in Sub-Saharan Africa, using the IMAGE-TIMER integrated assessment model. The results show that, achieving universal electricity access requires an annual investment between now and 2030 of USD 27-33 billion on top of baseline investment. There is a strong synergy in emissions reduction and investment savings, particularly driven by the regions' efficiency improvements of household appliances. On the other hand, climate mitigation policies are projected to increase the cost of electricity per kWh, depending on fossil fuel share in the mix.

Ensuring access to affordable, reliable, sustainable and modern energy for all is one of the Sustainable Development Goals (SDG7) (UN, 2015) and is also acknowledged by the Paris Agreement as an important need [1]. However, over 1.2 billion people did not have access to electricity in 2013; more than half of which live in Sub-Saharan Africa (SSA) [2]. Achieving SDG7 thus requires countries in SSA to expand electricity access substantially, especially since population is projected to grow rapidly. However, the goal of increasing electricity access is coupled to other SDGs and societal goals, including mitigation of climate change [3]. This study addresses the impact of mitigation policies on electricity access in SSA, as well as the contribution that achieving universal electricity access in SSA has on global climate change.

Methodology

The IMAGE-TIMER model

For the purpose of this study, we have used the IMAGE model, which is an integrated assessment model looking at future global environmental change. TIMER forms the energy-system simulation model component of IMAGE, describing the demand and supply of 12 different energy carriers for 26 world regions [4]. Part of the TIMER model is the electrification sub model, discussed in detail in [5]. The model is designed to determine whether households have access to electricity; and if so, with which technology. The model determines the least-cost electrification technology (grid-based, off-grid or stand-alone) per grid-cell, based on the lifetime cost of generation, transmission and distribution of each technology and the consumption density (kWh per km^2 area) of the respective grid-cell.

Scenarios

Four scenarios are used in this section to assess the impact of climate mitigation policy on achieving the universal access target, and vice versa: a baseline scenario (BL), a universal electricity access scenario without climate policy (UA), a universal access scenario with global climate mitigation policy imposed in all regions (UA-CP), and a universal access scenario with global climate mitigation policy where Sub-Saharan Africa is exempted from carbon price (UA-NCP).

Results

The results of the UA-NCP scenario appear to be not-dissimilar to the UA scenario, so we haven't presented them in this conference proceedings.

Electricity demand

Based on the assumed continuation of the historic correlation between electricity access and GDP per capita, population density, and urbanization rate in the model [6], the BL scenario shows a considerable increase in the percentage of the population with access to electricity. In total, more than 550 million people are projected to have gained access in SSA by 2030, leaving about 515 million people without access to electricity. Total residential electricity demand in the BL scenario is projected to increase from 90 TWh in 2010 to almost 270 TWh in 2030. In the UA scenario, electricity demand increases further to 326 TWh. The electricity demand for the additional connections under UA-CP is projected to be 21 TWh less than what is projected under the UA scenario, while providing the same energy services.

Electricity production

Out of the 550 million people gaining access by 2030 in the BL scenario, close to 7% gain access through off-grid systems. In the UA scenario, off-grid electrification systems are projected to be the least-cost option for close to 3.5% of the additional connections, bringing the total number of people connected to off-grid systems to 110 million. Climate policy stimulates expansion of renewable energy-based off-grid systems with more people (10 million) being connected via off-grid systems in the UA-CP scenario than under UA scenario.

Total residential electricity-related CO_2 emissions in the BL scenario are projected to increase from 14 Mt in 2010, to 31 Mt in 2030. Universal electricity access results in an emissions increase of 8 Mt CO_2, i.e. 27% on top of the 2030 value in the BL scenario. Under the UA-CP scenario, the shift to low-carbon energy sources and efficiency improvements results in a total CO_2 emissions reduction of 65% in 2030, relative to the UA scenario, bringing total residential emissions from electricity to below 2010 levels.

Electricity prices and investments

Climate mitigation policies are projected to result in higher electricity prices in all regions (25% to 120%). Eastern Africa has the highest share of low-carbon electricity generation and, therefore, the carbon price leads to the lowest electricity cost increase of the four regions. The Republic of South Africa is most affected by the carbon price, due to the strong dominance of coal in its electricity mix.

Under the BL scenario, the average annual investment is projected to be around USD 16 billion. In the UA scenario, a cumulative investment of USD 660 billion, or USD 33 billion per year, is required on top of the projected investments in the BL scenario. In the UA-CP scenario, the additional investment requirement is projected to be 20% less than what is required under UA scenario.

Conclusions

- ***The increase in CO_2 emissions due to achieving universal electricity access is small compared to global CO_2 emissions.***

The increase in emissions from providing universal access to electricity in SSA is negligible relative to global emissions, and it barely influences global climate change. At the same time, climate

mitigation policy could offset the projected increase, due to efficiency improvements and a shift to low-carbon energy sources.

- ***Synergies between climate mitigation policy and universal access to electricity relate to efficiency improvements and declining renewable technology prices.***

SSA could benefits from a globally coordinated climate mitigation policy through efficiency improvements in household appliances and learning in renewable energy technologies, which seem mutually reinforcing.

- ***Achieving universal electricity access in SSA requires at least a tripling of the current annual electricity-system investments.***

Our model projections show that the annual cost of providing universal electricity access between now and 2030 in SSA ranges from USD 27 billion to USD 33 billion. This is a significant amount, but it probably understates the full costs of universal electricity access, due to large uncertainties resulting from lack of data and other challenges, such as political will and corruption that are difficult to model.

- ***A global carbon price results in increases in electricity prices.***

Climate mitigation policy, in our study imposed by a global uniform carbon price, is projected to increase the cost of electricity per kWh that will undoubtedly affect the poor. To facilitate access by the poor, climate mitigation policies can also be combined with complementary policies specifically designed to protect the poor from increasing electricity prices.

4.3 Renewable Energy Achievements and 2030 NDC Targets in Thailand

Bundit Limmeechokchai

Thailand had summited its Intended Nationally Determined Contributions (INDCs) in 2015 and ratified the Paris Agreement in September 2016. Its INDCs stated that by 2030 GHG emissions will be reduced by 20-25% when compared to the business-as-usual (BAU) scenario by using mainly domestic renewable energy resources and energy efficiency improvement. This section assesses the impacts of GHG emission reduction targets in Thailand's NDC by using the Asia-Pacific Integrated Model/Computable General Equilibrium (AIM/CGE). Mitigation scenarios are established by given the GHG emission constraints and the renewable power generation target. Energy efficiency improvement in the demand-side has been embedded in the power development plan (PDP2015).

Results show that under the PDP2015, INDC target of 20% is achievable by using domestic resources. Thus, it will improve resource productivity, and it reveals innovation in integrated energy-environment-economic planning. However, macroeconomic loss will be high in the reduction target of 25%. In addition, a push for more renewable energy is needed to realize a more stringent climate policy. Finally, the availability of land for deploying the renewable energy technologies such as solar, wind and biomass needs to be evaluated to meet high GHG emission reductions levels.

The IPCC Fifth Assessment Report (AR5) concluded that human activities are the main sources of GHG emissions inducing current levels of climate change. The AR5 also proposed the global carbon emission pathway to stabilize the global mean temperature should be less than 2°C compared to pre-industrial levels, and GHG emissions need to peak before 2030. GHG emissions should decrease to net-zero emissions by the end of the 21st century.

However, such targets will take a plenty of times for developing countries. In order to lessen the GHG emissions, the United Nations Framework Convention on Climate Change (UNFCCC) established an international climate agreement during the Conference of Parties (COP21) in December 2015. The Parties have agreed to diminish the effect of climate change toward the low-carbon development and climate-resilient development by preparing the post-2020 climate actions, so called Intended Nationally Determined Contributions (INDCs).

On 1st October 2015, Thailand communicated its INDC to UNFCCC, and on 21st September 2016 Thailand ratified the Paris Agreement. Thailand's INDCs aim at economy-wide GHG mitigation of 20-25% by 2030 when compared to the business-as-usual (BAU) scenario. This section analyzes the capability of GHG emission reduction by the role of renewable energy and energy efficiency improvement in Thailand's INDC.

Thailand's INDC Commitments under the Paris Agreement

The important messages in the pledged INDC are as follows: "Thailand intends to reduce its greenhouse gas emissions by 20 percent from the projected business-as-usual (BAU) level by 2030. The level of contribution could increase up to 25 percent, subject to adequate and enhanced access to technology development and transfer, financial resources and capacity building support through a balanced and ambitious global agreement under the United Nations Framework Convention on Climate Change (UNFCCC)." Table 1 shows the relevant information in the submitted Thailand's INDC.

Table 1: Information on the submitted Thailand's INDC.

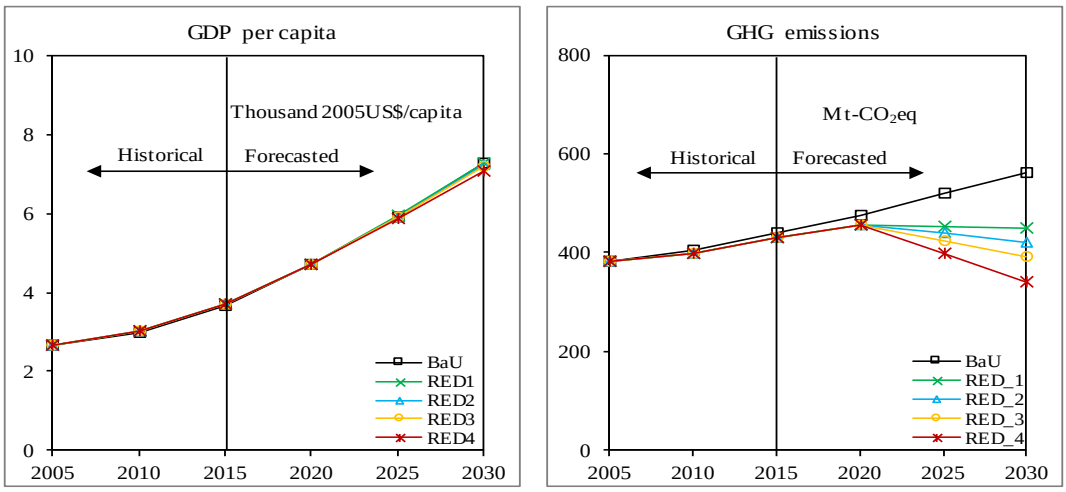
Baseline:	BAU projection from 2005 in the absence of major climate change policies. (BAU2030: approximately 555 $MtCO_2e$)
Time frame	2021-2030
Coverage:	Economy-wide (Inclusion of LULUCF will be decided later)
Gases	Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6)
Assumptions and methodological approaches:	Global warming potential on a 100-year timescale in accordance with the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report National statistics, including sector activity and socio-economic forecasts
Planning processes:	Thailand's INDC was developed through participatory process. Stakeholder consultations were conducted through the establishment of an inter-ministerial working group and steering committee comprising representatives from relevant sectoral agencies, academia and private sector. In addition, three national consultations were held during the technical analysis phase. Thailand's INDC was formulated based on the national plans approved by the Cabinet: - National Economic and Social Development Plans - Climate Change Master Plan B.E. 2558-2593 (2015-2050)

	- Power Development Plan B.E. 2558-2579 (2015-2036) - Thailand Smart Grid Development Master Plan B.E. 2558-2579 (2015-2036) - Energy Efficiency Plan B.E. 2558-2579 (2015-2036) - Alternative Energy Development Plan B.E. 2558-2579 (2015-2036) - Transport Infrastructure Master Plan B.E. 2556-2573 (2013-2030) - National Industrial Development Master Plan B.E. 2555-2574 (2012-2031) - Waste Management Roadmap
International market mechanism	Thailand recognizes the important role of market-based mechanisms to enhance the cost effectiveness of mitigation actions, and therefore will continue to explore the potentials of bilateral, regional and international market mechanisms as well as various approaches that can facilitate, expedite and enhance technology development and transfer, capacity building and access to financial resources that support Thailand's efforts towards achieving low-carbon and climate-resilient growth, as appropriate.

This section employed the AIM/CGE (Asia-pacific Integrated Model/ Computable General Equilibrium) model. The AIM/CGhas been widely used for global assessing climate change mitigation and adaptation policies. It is a recursive-dynamic general equilibrium model. Details of the model structure and mathematical formulas are described in Fujimori et al [5].

Effects of GHG mitigation targets on per capita GDP and GHG emissions are presented in Fig.1. Noted that RED_1, RED_2, RED_3 and RED_4 stand for mitigation targets of 20%, 25%, 30% and 40%, respectively.

Figure 12: Per capita GDP and GHG emissions of Thailand



Source: Limmeechokchai (2017)

Conclusions

Thailand's NDC will improve resource productivity and reveal innovation in integrated energy-environment-economic planning. Several implications of the modelling results, policy implications and limitations in this study are as follows:

- The renewable electricity generation in the PDP2015 is appropriated for achieving Thailand's INDC target. Due to the fact that renewable energy can lessen the GDP loss and welfare loss, an additional renewable energy and the availability of land for deploying the

renewable energy technologies such as solar, wind and biomass need to be evaluated to meet the GHG emission levels.

- Thailand has obviously switched from agriculture base to a major exporter in Southeast Asia. The people earn more income, thus, the capability of spending on high-quality goods with consumed less energy compared to the conventional one. Therefore, there is a shift from high-carbon intensive commodities to low-carbon intensive commodities.
- The renewable energy incentive policy should be aligned with the national climate policy. Nowadays, the government has already launched the incentive called "feed-in tariff" (FIT) mechanism. However, the present FIT should be revised.
- The smart grid and energy storage technologies are another mechanism to stimulate the penetration of renewable energy. Currently, the Thailand's smart grid policy plan and roadmap has been publicly disclosed. However, it will be effective after 2025.
- The effect of GHG emission reduction under the GHG emission reduction levels not only results in the sustainable development insight but also contributes co-benefits to human health.

4.4 Environmental Management Towards 2050 in the Private Sector – Toshiba case

Yoshinori Kobayashi

The Toshiba group has established its Environmental Vision 2050, which illustrates the ideal situation in 2050 and identifies the targets and contributions to be required towards 2050. To achieve this goal, an environmental action plan (EAP) has been formulated with several key performance indicators (KPIs) to be updated every 3-5 years, considering the progress and latest global trends. The combination of long-term vision and mid-term EAP is fundamental idea and furthermore, it is critical to set adequate KPIs, which link environmental aspects to business processes, for promoting effective environmental management. In order to reduce GHG emissions throughout corporate value chains, promotion of environmentally conscious products (ECPs) is one of the key countermeasures. The benchmark on environmental performances and expansion of ECPs especially on the emerging market are important factors and new eco-innovative product-service systems are required to be developed as well as commercialized in future.

Long-term environmental vision

For drafting the long term vision, it is essential to consider global mega-trends at first, which will have an impact on businesses, such as urbanization and income disparities, energy/environmental limitation and diversifying power sources, digital convergence and needs for secure information infrastructures etc. One of the objective of identifying mega-trends is to change risks into business opportunities, rather than only evaluating environmental aspects as restrictions. In Toshiba group Environmental Vision 2050, the ideal situation in 2050 has been decided as people lead rich lifestyles in harmony with the Earth. In order to achieve this goal, three challenges has been chosen, namely, to reduce environmental impacts due to population growth, to mitigate environmental impacts in a global perspective and to create rich value.

The target towards 2050 is based on the eco-efficiency concept, which is the performance divided by the environmental impacts and utilized to strike a balance between economic and environmental goals. In addition, the degree of the improvement of eco-efficiency can be defined as Factor index, which can identify how innovative business processes have been introduced.

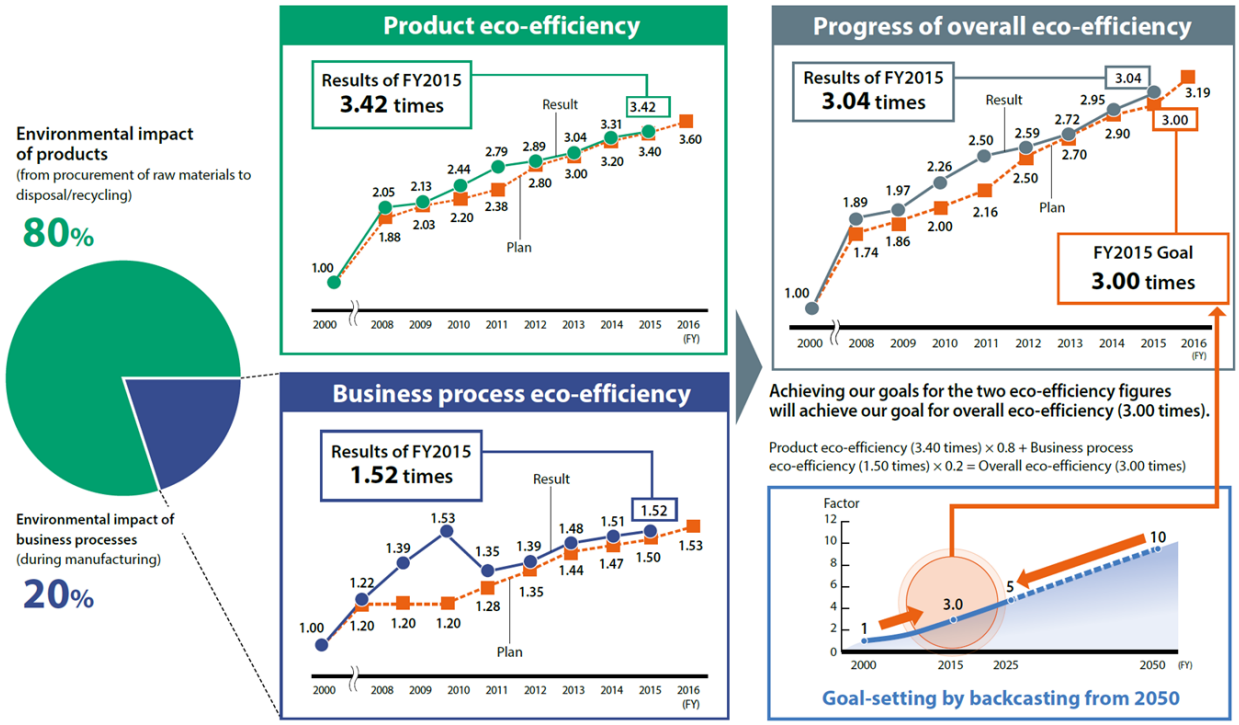
Factor target towards 2050 has been formulated in the vision by combining three metrics with future trends. First metric selected was global population growth and it will reach about 1.5 times the 2000 level. Second metric selected was GDP per capita. Second metric was GDP per capita, which is needed to increase to about 3.4 times the level of 2000 for increasing our wealth and eliminate poverty globally. Third metric was CO_2 emissions reduction. Multiplying the three metrics, the target for 2050 has been set as 10 times improvement, namely Factor10.

Mid-term environmental action plan

In order to achieve Factor10, EAP has been established by maintaining consistency with the Environmental Vision 2050 (Fig.1). In addition, EAP is in general formulated as combination of KPIs selected by considering activities to be strengthen, global trends, requests from stakeholders. By taking into account progress we made and the advancement of scientific knowledge, EAP have been updated every 3-5 years to set a stretch goal.

The progress towards Factor10 in the EAP is monitored based on overall eco-efficiency of Toshiba group. Therefore, improvements in every business process, every products and services can be summed up to improve overall eco-efficiency towards the realizing the vision. The eco-efficiency in FY2015 became 3.04 times than that in FY2000, namely Factor3.04, and the target for FY2015 was achieved.

Figure 13: Aiming to achieve a Factor 10



Source: Kobayashi (2017)

GHG emission reduction though ECPs

In FY2015, direct GHG emissions from electricity and other energy consumption in Toshiba processes (scope 1 and 2 emissions) was calculated about 3.0 million tons of CO_2. Indirect emissions from upstream and downstream (scope3 emissions) were estimated to be 7.5 million tons and 48.6 million tons, respectively. Several KPIs that can contribute to GHG emission reduction have been incorporated in the EAP. For example, improvement of total energy-derived CO_2 emissions per unit production and improvement of the industrial processes, replacement by new energy-efficient equipment and other options have been introduced to achieve the target. Since GHG emissions during the use of sold products account for more than 80% of Toshiba Group's GHG emissions, promotion of ECPs would be one of the main countermeasures to tackle climate change.

Development of ECPs

CO_2 emission reduction through Toshiba products was estimated to be 15.10 million tons globally by FY2015. It was calculated as accumulated annual CO_2 emission reduction in each product categories that were calculated if conventional products are replaced by ECPs. To maximize this value, both development of products that have large energy-saving effects and promotion of those in especially emerging markets would be required.

In order to expand competitive ECPs, it is important to set the eco-target in the product development process. Environmental performances are compared with competing products at the time that the product will be released on the market, and incorporated into product specifications as the eco-target. As a result, the product is certified as an Excellent ECP, when it outperforms other companies' products in terms of environmental performances at the time of its release on the market.

Excellent ECPs have been widely released in various business domains so that 95 products have been certified as Excellent ECPs in FY2015, for example industrial air conditioner with the highest energy-saving performance, LED with adjustable illumination that can reduce energy consumption by 85% and machine-roomless elevator that can reduce energy consumption by 50%.

The products with highest environmental performances can contribute to stimulating competition to make society better. Moreover, new "eco-innovative" product-service systems that can reduce environmental impact dramatically as well as strongly contribute the transition towards sustainable society are required in various business domains, such as paper reuse system, renewable energy and hydrogen system, rechargeable batteries system and ICT applications in Toshiba group.

Conclusion

Combination of long-term vision/targets and mid-term EAP will be fundamental and also universal. Breaking targets down to the individual product and business process design can make the system more effective, especially setting adequate KPIs, which link environmental aspects to business processes. From the viewpoint of GHG emission reduction throughout the value chain, development and promotion of ECPs would be essential.

In addition, there are strong needs for new product-service systems which can have a central role on the transition towards sustainable society. In general, there are various gates and barriers from

early R&D phase to commercialization, especially for eco-innovative product-service systems, which have a certain potential to change the social systems based on the unique technology.

The combination of several factors, such as top commitment and vision, roadmap, measurement and benchmark and collaborations with internal/external associations, are required to manage the business risks, and accelerate the development. Toshiba group will contribute to a sustainable society by focusing on business domains, centred on infrastructure, that sustains modern life and society and create new value with reliable technologies.

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Appendix: Agenda of the 9th LCS-RNet Annual Conference

International Research Network For Low Carbon Societies 9th Conference: Clean Growth And Innovation In A Changing World

12-13 September 2017, Warwick University, UK
Hosted by UK Energy Research Centre

Chair of the Conference

Jim Watson, UK Energy Research Centre (UKERC), and University of Sussex, UK

Conference objectives

The 9th Annual Meeting of LCS-RNet focused on three themes that reflect current debates in international climate change and energy policy, against the backdrop of recent political changes and uncertainties in Europe and the United States. The conference title was *Clean growth and innovation in a changing world,* and addressed specifically three topics:

1. Innovation: technology, resource productivity and industrial policy.
   - How could productivity in supply chains for products and services help to reduce emissions, energy use and demand for other resources?
   - How are low carbon technologies linked to/dependent on the development of low carbon infrastructures and particularly the supply of zero carbon energy?
   - What national policies and approaches are being used to develop and deploy low carbon technologies and infrastructures, including for (energy intensive) producing industries?
   - What is the role of international innovation collaborations such as Mission Innovation and the Breakthrough Energy Coalition?
   - To what extent do national emissions reduction plans (NDCs) incorporate innovation and resource productivity?

2. Global energy markets and forms of carbon pricing.
   - What do trends in global energy markets, including fossil fuel prices, mean for plans to deliver low carbon societies?
   - How important is explicit and implicit carbon pricing in different countries and regions, and what lessons can be learned from experience about its impact and future development?
   - How do other financial instruments and policy instruments complement or interact with explicit carbon pricing to shift investment toward the low carbon transition?

3. Energy access and low carbon development.
   - What progress is being made towards the Sustainable Development Goal of ensuring access to affordable, reliable, sustainable and modern energy for all?
   - How can developing countries make progress towards this goal whilst paying sufficient attention to other goals, especially the call for urgent action on climate change?

- What are the priorities for research and action at the intersection of low carbon societies , energy access and other basic needs?

The LCS-RNet conference was held in conjunction with the 2017 UKERC annual academic conference, which will overlap with day 2, and continued on the 14th September. It explored the implications of international trends within these themes for UK energy policy and research.

Conference agenda

DAY 1

09:30	Coffee and Registration	
10:00	**Introductory Session**	
	Welcome Introduction to the meeting	Chair: Jim Watson (UKERC, UK) Opening remarks from UKERC, Mikiko Kainuma (IGES Japan)
10:30	**Plenary Session 1: Innovation, Resource Productivity and Industrial Policy**	
	Chair: Stefan Lechtenböhmer (Wuppertal Institute, Germany) Speakers: • Lars Nilsson (Lund University, Sweden) • Nick Molho, (Aldersgate Group)	
11:30 -12:00	Break	
	Parallel session 1.1 Innovation and industrial policy: Chair: Sergio La Motta (ENEA, Italy) • Antonio Pflüger (Federal Ministry of Economic Affairs and Energy, Germany) • Yoshinori Kobayashi (Toshiba, Japan) • Flavio Tonelli (University of Genova)	**Parallel session 1.2** NDCs, resource productivity and innovation: panel of analysts from different countries Chair: Toshihiko Masui (NIES, Japan) • Bundit Limmeechokchai (SIIT-TU, Thailand) • Steve Pye (UCL and UKERC, UK)
13:15 – 14:15	Lunch	
14:15	**Plenary Session 2: Global energy markets and forms of carbon pricing**	
	Chair: Karsten Neuhoff (DIW Berlin) Speakers: • Jean-Charles Hourcade (CIRED, France) • Dipak Dasgupta (Distinguished Fellow at TERI)	
15:15 (75 min)	**Parallel Session 2.1** Fossil fuel markets and prices: implications for low carbon transition plans Chair: TBC • Mike Bradshaw (UKERC, UK) • Kentaro Tamura (IGES, Japan) • Andre Mansson (Lund University)	**Parallel Session 2.2** Carbon pricing and beyond: experience from different jurisdictions and future policy directions Chair: Jean-Charles Hourcade • Michael Grubb (UCL) • Gjalt Huppes (Leiden University) • Karsten Neuhoff (DIW)
16:30 – 17:00	Break	

	Panel: Global Co-operation on Innovation Chair: Paul Ekins (UKERC) Speakers: • Federico Villatico (CTCN-Climate Technology Centre and Network of UNFCCC) • David King (UK) • Antonio Pflüger (Federal Ministry of Economic Affairs and Energy, Germany).
18:00	Close of Day 1

DAY 2

10:00	**Plenary Session 3: Energy Access and Low Carbon Development**	
	Chair: Jim Watson (UKERC) Speakers: • Hannah Daly (IEA) • Will Blyth (UK Department for International Development: DFID)	
11:00 – 11:30	Break	
	Parallel session 3.1 Progress towards the energy access Sustainable Development Goal Chair: Shuichi Ashina (NIES, Japan) • Carmen Dienst (Wuppertal Institute, Germany) • Jiang Kejun (ERI, China) • Shuzo Nishioka and Miho Kamei (IGES, Japan)	**Parallel session 3.2** Interdependencies between energy access and other SDGs Chair: Sergio la Motta (ENEA, Italy) • Paul Ekins (UCL and UKERC, UK) • Anteneh Dagnachew (PBL Netherlands Environmental Assessment Agency, Netherlands) • Mikiko Kainuma (NIES)
12:45 – 13:45	Lunch	
13:45	**Plenary Session 4: From international context to national strategy**	
	Implementing Paris Chair: Christophe Cassen (CIRED, France) Speakers: • Henri Waisman (IDDRI, France) • Jiang Kejun (ERI) • Takeshi Abe (MOEJ)	
15:00-15:30	Break	
15:30	Panel: What are the implications of international trends for the UK? Chair: Jim Watson, UKERC 1. Innovation, Resource Productivity and Industrial Policy (Stefan Lechtenböhmer) 2. Global energy markets and forms of carbon pricing (Christophe Cassen) 3. Energy Access and Low Carbon Development (Jim Watson) Responses from a panel of UKERC academic conference delegates • Andy Kerr, Policy Director, ClimateXChange • Owen Bellamy, Committee on Climate Change	
16:30	Close of LCS-RNet conference	

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IGES

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