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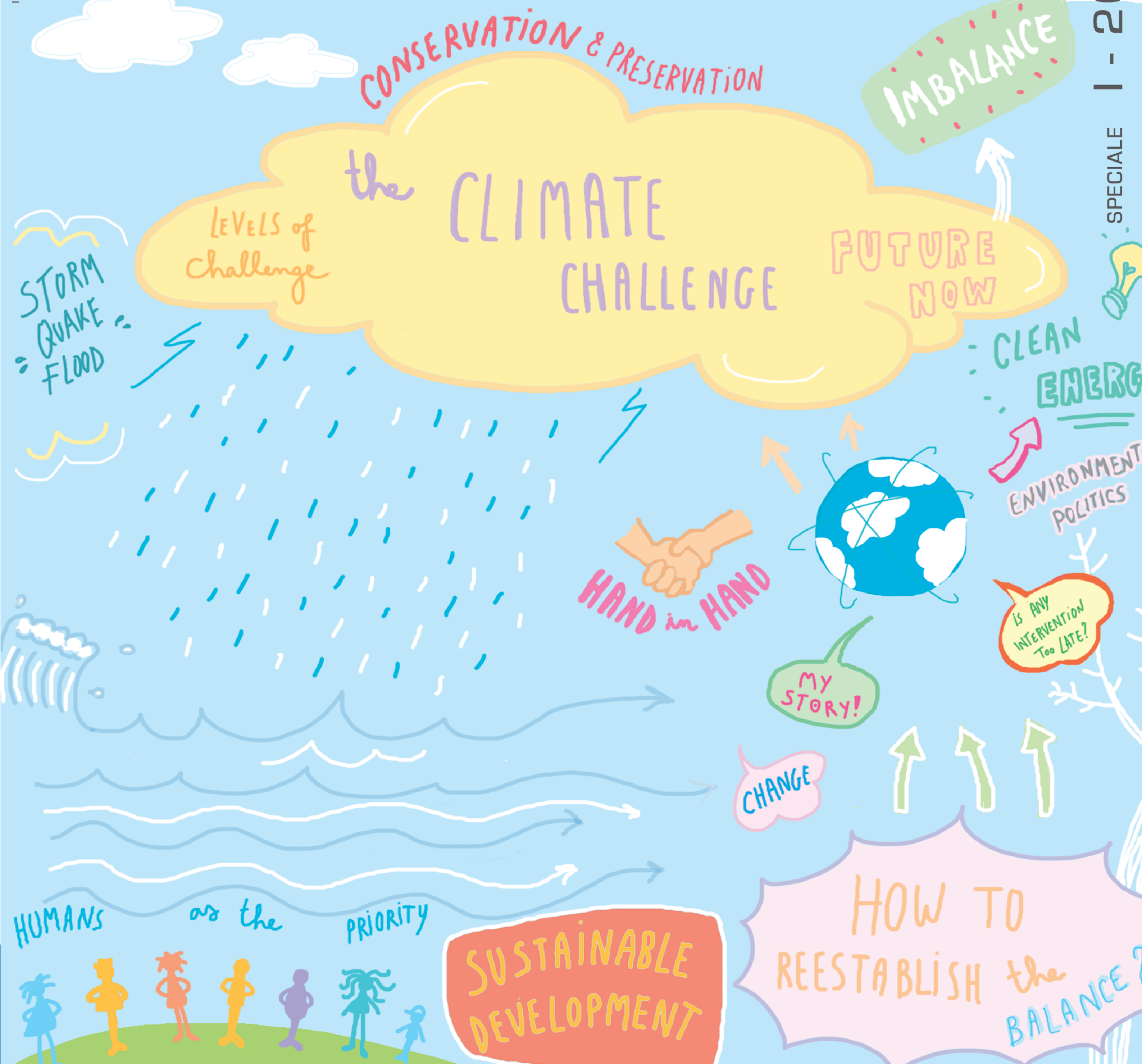

Energia, Ambiente e Innovazione

Speciale

Transition and global challenges towards low carbon societies

A cura di S. La Motta, J.C. Hourcade, S. Lechtenböhmer, T. Masui, J. Watson

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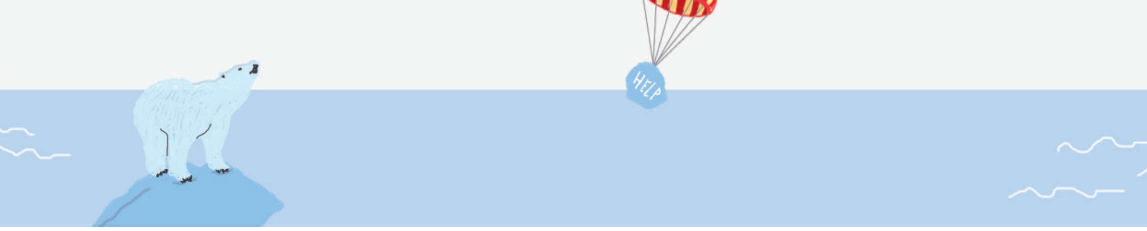
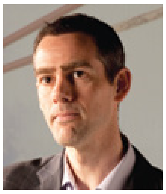


Foreword

Sergio La Motta, Jean-Charles Hourcade, Stefan Lechtenböhmer, Toshihiko Masui, Jim Watson







The International Research Network for Low Carbon Societies (LCS-RNet) was established in 2009 on the initiative of the G8 Environment Ministers' Meeting (G8 EMM). At their 2008 meeting in Kobe the G8 Environment Ministers recognised the need for each country to develop its own vision of a low carbon society (LCS) and how such transition might be achieved. This vision would aim to cut global greenhouse gas emissions by more than 50 per cent by 2050, in order to prevent average global temperatures rising above 2 degrees Celsius and avoid dangerous impacts on Earth's major eco-systems. The G8 Ministers initiated RNet as a strong endorsement of this pathway towards LCS.

The sixth Annual Meeting of LCS-RNet was held over 1-2 October 2014 in Rome, Italy, and was co-hosted by Italy's National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), The Ministry of the Environment and Protection of Land and Sea (MATTM), and The Municipality of Rome, Italy.

The meeting presented a wide range of discussion on four key issues that are at the forefront of the climate change debate. These issues included: integration of climate policies with the more traditional policies in the energy sector, i.e. security of supply and cost reduction; climate mitigation and resource efficiency improvement nexus; securing adequate financing for mitigation and adaptation activities, as well as strengthening international collaboration.

Each of these themes was tackled to offer an in depth analysis from different perspectives. In the energy sector, the status of the technologies was offered together with an investigation of the impact of the behavioral change on GHG emissions; resource efficiency improvement was analysed from industrial and territorial management perspective; finance was tackled analysing barriers and opportunities of financing/investing in mitigation and adaptation together with the issue of building consensus to support climate policies; international cooperation focused on the challenges in developing countries and on the use of pathway modeling to raise ambition level of nationally determined contributions (NDCs) and raise awareness of the existence of serious opportunities for alternative development paths and leapfrogging to avoid carbon lock-in.

It also considered future plans and expectations of the LCS-RNet in the run-up to 21st meeting of the United Nations Framework Convention for Climate Change (COP 21) in Paris. The authors hope that an international agreement on climate change will be agreed in 2015, national policy frameworks will then be developed over the next five years and implemented from 2020. However, we acknowledge the challenges this will involve and will use this network to inform discussions under the UNFCCC.

The articles in this special issue of the ENEA journal

are organized in four groups representing each theme tackled; each group of articles is preceded by an introductory article that can help the reader to realize the background of the theme, guide him through the storyline the articles are presenting and let him know about the next steps and gaps to be filled.
This publication is intended to be a basis for the next LCS-RNet annual meeting in Paris in spring 2015. The goal of the meeting in Rome and the next meeting in Paris is to elaborate a "policy brief" that will be a contribution of LCS-RNet to the COP 21 in Paris.

Acknowledgements

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We would also like to express our special appreciation to Italy's Ministry of Environment and Protection of Land and Sea for its generous support of LCS-RNet activities. We greatly value the support and recommendations provided by governments and LCS-RNet contact points. Particular thanks are due to all the Italian research institutes involved – Fondazione Eni Enrico Mattei (FEEM), Euro Mediterranean Center on Climate Change (CMCC) and ENEA, and Municipality of Rome – for their strong leadership in planning the meeting and for their hospitality in Rome.

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Theme 1: Can low carbon societies deliver on energy policy goals, including security and affordability?

Transitions to low carbon societies will have far reaching implications for national and international energy policies. Whilst climate change mitigation remains an important driver of these policies, other policy objectives, such as energy security and affordability, are also high on the agenda in many countries. Understanding the potential and trade-offs that could result from specific policies, strategies and technologies is therefore necessary, as is identifying opportunities to maximise synergies and co-benefits.

J. Watson

Background

Making transitions to low carbon societies will have far reaching implications for national and international energy policies. Whilst there is a need for urgent action to reduce greenhouse emissions, climate change mitigation is not the only goal of these policies. Other important goals include the need to ensure that energy systems are secure and reliable, and the desire to provide affordable energy services for household and business consumers.

It is therefore important to pay sufficient attention to synergies and trade-offs between these different policy goals, and to consider what technologies, policies and institutional frameworks might be required to maximise synergies and to manage trade-offs.

Key findings

- Some trade-offs between climate mitigation and energy security goals are inevitable, but many can be addressed if a 'systems' perspective is adopted. For example, there are potential security and affordability benefits from shifting to low carbon energy

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systems by reducing the use of fossil fuels; though these benefits are partly dependent on future trends in fossil fuel prices. However, low carbon societies could mean new energy security risks, such as resource availability (e.g. of bioenergy or scarce materials) or electricity system reliability. New strategies to mitigate these risks and strengthen energy system resilience will be required.

- Energy efficiency policies should be a priority since they are likely to address all three policy goals. A 'package' of energy efficiency policies is often required to address the multiple barriers identified by research, and to address the needs of different consumers. This package could include a combination of price incentives, standards and targeted investment programmes (e.g. to upgrade the housing stock). Whilst measures to increase energy prices could help, they are unlikely to be sufficient on their own – and they will have distributional impacts on low-income consumers and energy intensive industries that need to be mitigated. Policy evaluations and assessments should focus on the impact of policy packages rather than on single policies in isolation.
- Recent advances in low carbon technologies, coupled with reforms to electricity markets, have led to an expectation that electricity will play a major role in low carbon transitions. Significant up-front investment in low carbon power technologies will be required to enable this, as will further national and international support for technology development and deployment. But there would also be co-benefits, for example from reduced expenditures on fossil fuels and reduced pollution.

In this section the focus is on the extent to which low carbon societies can meet other energy policy goals, including energy security and affordability. There are different definitions of energy security, and that tensions or synergies with other policy goals will depend on what dimensions of security are seen as important, what risks to security are being considered, and which actors are the focus of the analysis. As a result, the implications for security of policies to reduce carbon emissions are likely to be mixed, and will vary according to timescale and geography. A discussion is also included of ways in which energy policies could be more integrated so that they not only deliver lower emissions, but also lead to 'co-benefits'. Immediate co-benefits in many cases include improved air quality for example. The importance of energy efficiency is also highlighted since, if effective, it could help to meet a range of policy goals – including affordability, security, and emissions reduction.

With regard to low carbon transitions in the power sector, important features of low carbon power systems are discussed in addition to the need to support the development and deployment of low carbon generation technologies. These include significant improvements in energy efficiency, the importance of flexibility of generation and demand, the potential for using low carbon electricity to decarbonise heat and transport, and the crucial role of storage. Realising such power systems in practice is not only a technical challenge, but is also likely to require changes to incentives for investment, policy frameworks and market arrangements.

With respect to energy efficiency and the role of consumers of energy, the section focuses on the multiple barriers to implementing energy efficiency, even in the large number of cases where there would be clear economic benefits to energy users. Policies to close the 'efficiency gap' between the potential for energy efficiency and implementation in practice are also discussed. Finally, a discussion is included on the related area of energy storage. If commercialized successfully, electricity storage could make a significant impact on the feasibility of low carbon electricity (and energy) systems – especially where they include large shares of intermittent renewables.

Way forward

An extensive analysis of the potential co-benefits of climate change mitigation policies is highlighted, and the extent to which these policies can help meet (or conflict with) other policy goals. However, there remains significant scope for further analysis to inform the development and implementation of energy policies.
With respect to the specific interactions between climate change and energy security agendas, analysis understandably tends to focus on impacts on fossil fuel imports. However, there are a range of other energy security risks such as the vulnerability national energy infrastructures to technical failures or deliberate attack. Energy security risks will also change over time. For example, the transition to low carbon electricity systems that include smarter technologies and greater contributions from intermittent renewable sources will require new strategies to ensure that they continue to meet consumer demand for reliable and affordable energy services.
It is also important to consider energy security impacts on specific energy system actors, such as consumers or utilities, as well as understanding impacts at a national level.
Turning to specific technologies and measures, further action is needed to improve energy efficiency since it can help to meet several policy goals simultaneously. Whilst there is already a lot of emphasis on energy efficiency in international assessments and national policies, a number of gaps were suggested. These include the need for more incentives for the renovation of existing buildings, the need for more action on transport, and the potential for integrating energy efficiency initiatives with broader programmes to improve resource efficiency and energy demand reduction.
A number of areas are identified, where further technological innovation (including demonstration and deployment) is required in tandem with the implementation of policies to support such innovation. These include carbon capture and storage (CCS), which remains at the demonstration stage (especially for power sector applications), and has not yet made the transition to commercial availability. Yet, many climate change mitigation assessments see CCS as an essential component of low carbon energy systems.
Electricity storage is also discussed in some detail. Storage technologies could help to facilitate electricity systems with high shares of intermittent renewables – especially if electricity systems expand to meet demand for heating and transport that has traditionally been met by fossil fuels. Further support for research, coupled with demonstration and deployment incentives, is needed if the costs of storage are to be reduced - and the potential of storage is to be realized over the medium term.
Finally, storage is one of a range of strategies that could help to deliver reliable, low carbon electricity (and energy) systems. Further assessments and, where appropriate, incentives are required to support flexible demand, the flexibility of low carbon generation technologies such as CCS and nuclear power, and investment in international interconnectors.

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Benefits for whom? Energy efficiency within the efficient market

How should the lack of an efficient energy market affect the design of energy efficiency policies and their implementation? What the consequences of an inefficient energy market on end users' behaviour? This article tries to give an answer to such questions, by considering the decision making of domestic users following a few fundamental concepts of behavioural economics. The mechanism of price formation in the market, with particular reference to the internal energy market in Europe, will be examined and we will show that price remains the inflexible attribute in making an energy choice. Then, some conclusions will be addressed to policy makers on how to overcome the barriers illustrated.

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D. Chello

Introduction

The forty-year history of energy efficiency policies and measures began with the "oil shocks" of the 1970s.
Despite appropriate efforts deployed both in terms of innovative technologies and legislative and regulatory frameworks enabling it, some analysts recognise that the untapped potential for energy efficiency remains huge (World Energy Outlook 2013).
In other words, while energy-efficient technologies offer considerable promise for reducing the costs and environmental damage associated with energy use, these technologies appear not to be used by consumers and businesses to the degree that one would expect based on their private financial net benefits.

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The energy efficiency gap

For some thirty years, there have been discussions and debates among researchers and others in academia, government, non-profits, and private industry regarding the so-called "energy efficiency gap" or "energy paradox". Explanations for this "energy efficiency gap", as Prof. Robert N. Stavins says, tend to fall into three broad categories: (1) market failures, such as lack of information or misplaced incentives; (2) behavioural effects, such as disregard for future energy savings when purchasing energy-consuming products; and (3) modelling flaws, such as assumptions that understate the costs or overstate the benefits of energy efficiency.
Behavioural economics offers different explanations and states that there are several biases in the decision-making of the user and that marketing and offers have to be designed to overcome these biases. For our discussion here, it is enough to consider Kahneman and Tversky's (1979) concept of reference points, which can be summarized as follows:

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"Goods are evaluated by comparison with other goods the decision maker is thinking about";
"The salience of each good's attributes relative to the reference good, such as its quality and price, determines the attention the decision maker pays to these attributes as well as their weight in his decision";
"Consumer's attention is drawn to salient attributes of goods, such as quality or price. An attribute is salient for a good when it stands out among the good's attributes, relative to that attribute's average level in the choice set".
For electricity, and natural gas too, attributes come down to one only: the price. As a matter of fact, so far, it is impossible for the end-user to evaluate the primary source of his commodity and attach high weight to renewable electricity rather than nuclear electricity or vice versa. Similarly, distinguishing between Russian gas and Algerian gas evaluating the respective lower calorific value (Kcal/nm^3) is very hard for the standard end-user. Other attributes which could made the offer more attractive are not yet given enough consideration, as for instance, offering package solutions like comfort, energy security, health and safety, collective services, instead of selling electricity or natural gas as a stand-alone item.
Therefore, price remains the inflexible attribute in making an energy choice. But, what margin of freedom do suppliers (and retailers) have to set affordable and competitive prices?

A well-functioning energy market

To answer this question we need to consider the mechanism of price formation in the market. We're going to do this, with particular reference to the internal energy market in Europe.
The European Commission clearly recognises that the internal energy market is not an end in itself, but its implementation is absolutely essential to achieve the objectives of EU energy policy, in particular the objectives of energy efficiency.
A well-functioning single internal energy market must deliver tangible benefits to European energy consumers, in terms of greater choice and better prices.

The Post-Tax Total Price (POTP) is defined as the sum of the commodity price (Pc), regulated transmission and distribution charges (Ptr and Pdis), and retail components (Rc = billing + metering + customer services + a fair margin on such services) plus VAT, levies and any surcharges (as applicable):

$$POTP = Pc + Ptr + Pdis + Rc + VAT + Levies + Surcharges$$

In this sum, some additions are not negotiable in terms of competitiveness, while others (Pc and Rc) are.
In most Member States, household energy prices are greatly influenced by taxation and network charges, which usually make up more than half the total energy bill. Over the last few years, these non-negotiable charges have significantly increased in many Member States, particularly as a result of costs related to support schemes for renewable energy sources. As a consequence, retail price competition is weakened by the decreasing negotiability of end-user prices. Other consequences of this reduced ability of retailers to compare prices fairly can be summarised as follow:

- lack of switching,
- lew entry into retail energy markets, and finally,
- no means of rewarding the best supplier for their efficiency in producing energy.

Nevertheless, the domestic end-user could continue to invest in energy efficiency whatever the price of the energy supply. It is worth adding here that the capital for investment in energy efficiency is negotiable. Therefore also other types of spending must be considered and a decision between them must be made: at home maybe you could choose to invest in culture or entertainment instead of LED lamps. You then invest in energy efficiency only if it promises a payback time lower than alternative investments, and this does not always happen.
When the result in terms of energy savings is modest, the consumer is inclined to reject the option, albeit economically advantageous.
In other words, in the case of small gains, there is a built-in tendency to put off making the effort, which is considered an inconvenience compared to the expected gain.

Conclusions

Energy-efficient technologies offer considerable promise for reducing the costs and environmental damage associated with energy use. However, these technologies appear not to be used by consumers and businesses to the degree one would expect based on their private financial net benefits (Awareness).

Communication to increase the attractiveness and social acceptance of energy efficiency remains the best tool for tackling climate change, for competitiveness and security of supply in order to enhance no-costs actions (Change bad habits).

Nevertheless, to increase investment in energy efficiency by domestic end-users, and to allow end-users to choose the best supply in terms of price, saving their money and indirectly rewarding the most virtuous producer (retailer) in terms of efficiency (Ability of consumers to switch), a well-functioning single internal energy market needs to deliver tangible benefits to European energy consumers, in terms of greater choice and better prices. In particular, it is suitable:

1. integrating renewable energy into the power exchange;
2. reducing the incentives for renewable energy;
3. moving the surcharges from the energy bill to general taxation.

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Enabling the decarbonisation of fossil fuel based power sector through CCS

The application of CCS to industrial sectors is expected to deliver an overall 14% of the required emission reduction by 2050. Two key challenges in the short term are geological storage and the application of CCS to industrial sectors other than power. Apart from the overview of the state of the art of CCS R&D in Europe, it is worth stressing the economic potential, options and challenges for this technology to contribute to the decarbonisation of the energy system.

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P. Deiana

Introduction

Since CCS can achieve significant CO_2 emission reductions, it is considered a key option within the portfolio of approaches required to reduce greenhouse gas emissions. CCS technology involves three major steps [1].

Capture: separation of CO_2 from other gases produced at large industrial process facilities, such as coal and natural gas power plants, oil and gas plants, steel mills, cement plants, etc. Transport: once separated, CO_2 is compressed and transported via pipelines, trucks, ships or other methods to a site suitable for geological storage.

Storage: CO_2 is injected into deep underground rock formations, often one kilometer deep or more.

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Enabling CCS means providing governments, regulators, policymakers, communicators and others interested in CCS with resources to help different entities and stakeholders to act into the deploying. The

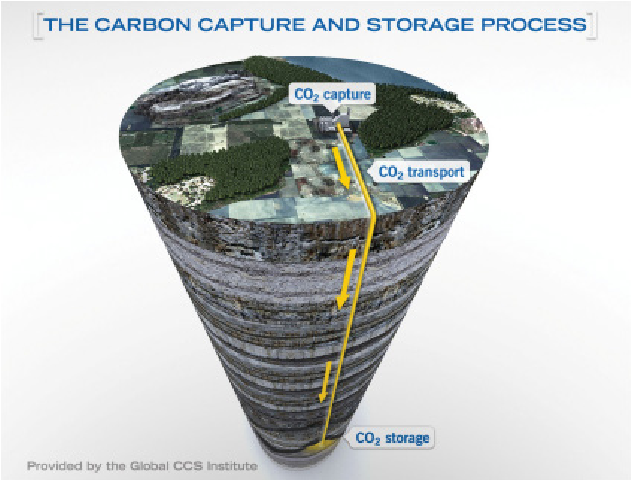

FIGURE 1 The CCS technology chain
Source: GCCSI

International Energy Agency showed that in scenarios that do not consider this option the total cost to halve CO_2 emissions levels would increase by 70%. Therefore CCS can play its part, ensuring an affordable energy supply at reduced costs.

The state of ongoing activities

Despite considerable efforts to take the lead on CCS development, apart from Sleipner and Snohvit projects that deal with natural gas sweetening, in the EU none of full-size demonstration projects are still running, and even the most promising EU projects are facing major delays. When the planning of CCS demonstration projects started in 2008, companies and, actually, legislators and regulators were expecting a further rise in certificate prices in the near future, being soundly optimistic on the assumption that the savings in CO_2 certificates will be able to compensate for the additional costs of CCS after the demonstration phase, thus opening a business perspective for this technology. Certificate prices of 25 €/t-CO_2 had been a common assumption, and went into the economic calculations of the project proponents. Since then, certificate prices have dramatically fallen, and now languish at a price of around 5 €/t-CO_2, thus making the operational costs of the CCS chain more expensive than the potential savings. Without additional European or national support, the demanding CCS demo program of the EU, having at least 5-6 demo projects running, will fail [2].

Challenges and opportunities

The recession in Europe, along with a significant increase in renewable electricity production triggered by subsidies, has undermined the EU Emission Trading System (ETS). Cleaning up power plants or industrial installations by CCS will require additional investments for equipment and will increase the operational costs of the plants. Support schemes such as the European EEPR program and the NER-300 support for CCS demonstration projects are not sufficient to make the project work. Additional national support by capital grants and/or feed-in tariffs will most likely be necessary to bring demo projects to a positive investment decision. The cost for adding CCS at demonstration plant scale of 250 MWel will typically be in the range of 500-1000 million euro.

The EU CCS Directive provided the legal framework for the storage of CO_2 in the EU. However, to be applicable in the different Member States (MS), the EU directive needs to be transposed. Fortunately most MS, with demonstration projects under way, had transposed it into national law but with some delays. In addition, project developers are facing the challenge that there remain significant uncertainties regarding the liabilities and the handover processes and requirements once the CO_2 storage phase has been completed.

Renewable energy has the highest support rate in general even if all large scale infrastructure projects are heavily debated. A key challenge with all infrastructure projects is that advantages and disadvantages for any individual need be balanced with the advantages and disadvantages for society. Carbon capture and storage, as a new technology, has still to explain and prove its merits to the public, requiring the testing and application of the technology at demo scale. All this has caused severe delays for demo projects planning to store CO_2 onshore. There is still a strong belief in the general public that the electricity supply can be completely shifted to fluctuating renewable energy and therefore CCS might not be necessary. However people tend to ignore that electricity from renewables together with the necessary reinforced grids and energy storage will be more costly than allowing CCS in the electricity mix.

The European industry has to compete internationally, and significantly higher electricity prices will reduce the competitiveness of industry, which is the key driver for economic growth and jobs in Europe.

In the CCS technology development significant progress has already been made, bringing down the energy penalty from 17% point to values of around 8% points. It is expected that significant further learning effects can be realized, based on the experience from demo projects and further R&D. Conventional natural-gas-fired power plants are likely to be a serious competitor to coal CCS in the short to medium term, providing large emission reduction opportunities by shifting fuel from existing coal power plants to new highly efficient gas-fired combined cycles. Such development can be a barrier for early deployment of CCS and could result in the delay CCS commercialization [3].

The introduction of carbon sequestration technologies will result in the increase in a number of costs. Specifically: increased capital costs for each plant to be equipped with carbon separation/capture; additional capital costs for CO_2 transport and storage; increased fixed operational costs and increased variable costs; additional operating costs for CO_2 transport and storage. There is currently no clear difference between any of the three CO_2 capture technologies (post, pre-combustion or oxy-fuel), that could be competitive once successfully demonstrated.

Several analyses show that investment costs are the main factor influencing total costs. The associated European Unit Allowances (EUA) break-even cost corresponds to a price of 34 €/t-CO_2, and 90 €/t-CO_2 for gas. At an EUA price of 35 €/t-CO_2, coal-fired CCS power plants are therefore close to becoming commercially viable.

Conclusions

Enabling policies are required in the intermediate period – once the technology is commercially proven, but before the EUA price increases sufficiently to allow full commercial operation. The goal is to make new-built power plants with CCS more attractive to investors than those without, and with a secure environment for long-term investment.

All recent studies and roadmaps have proven the importance of CCS, even if not fully recognized by the public at large. It is therefore important to ensure that CCS can keep its momentum to deliver from 2020 onwards. Therefore, at least 2 or 3 demonstration projects have to be realized in Europe during this very decade.

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Can low-carbon societies deliver on energy security?

The impact of low-carbon policies on energy security depends on both the timing and intensity of these policies, and the definition of energy security: security of what?; security for whom?; and security from which threats? The priorities of the EU's 2030 climate/energy package and energy security show little if any alignment. Global climate stabilization policies benefit the energy security of India, China, and the EU, but may have negative impacts on export revenues of the U.S. and other energy exporters.

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J. Jewell

Introduction

With rising energy demand in Asia and the crisis in Ukraine threatening gas supplies to Europe, energy security is on top of the political agenda. Can low-carbon societies deliver on this political priority? Answering this question is crucial to understand the political implications and drivers of low-carbon policies.

In this article, I argue that to answer this question both "low-carbon societies" and "energy security" need to be defined. After providing such definitions, I explore the tension between energy security and two examples of low-carbon policies: (1) Europe's 2030 climate/energy package and (2) global long-term climate stabilization policies. I show that the relationship between energy security and decarbonization depends on the time horizon and on the way energy security is defined.

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Defining "low-carbon"

Low-carbon transitions may imply different extents and speeds of decarbonization. On one end of the spectrum there are near-term policies to introduce renewables and improve efficiency. It is important to know how such concrete policies will affect existing energy security concerns. At the same time, stabilizing the global climate requires much more radical and comprehensive de-carbonization over a longer time scale. The analysis of energy security under such scenarios is less focused on today's energy security problems, but can at the same time lend insight into longer-term political drivers of deep decarbonization.

In this article I pose two questions: one about shorter-term climate policies and the other about longer-term decarbonization:

- What impact would the EU2030 climate/energy package have on energy security?
- What impact would climate stabilization have on energy security?

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Defining energy security

Conceptualizing and measuring energy security is more difficult than defining low-carbon transitions. Energy security is a political, not a scientific concept, and as a result means different things to different people. This does not mean that energy security cannot be conceptualized, on the contrary, such conceptualization is necessary and it should explain rather than ignore different views.

Effective measurement of energy security should start with answering three basic questions: "security of what?", "security for whom?" and "security from which threats?" [1]. These three questions are captured in the definition of energy security as "low-vulnerability of vital energy systems". A vital energy system is an energy system which supports critical social functions. Identifying a vital energy system and its boundaries clarifies the questions: "security of what?" and "security for whom?".

In the case of the EU's 2030 climate/energy package, I evaluate the energy security of oil and gas in the EU as a whole and in individual member countries, and their vulnerabilities to import disruptions (Table 1).

Exploring the energy security implications of longer-term energy scenarios requires a broader definition of vital energy systems and their vulnerabilities since both can fundamentally change under a radical energy transformation. Thus, I build on three historically persistent perspectives on vulnerability which link it to: (1) hostile actions by foreign actors (the sovereignty perspective), (2) natural and technological risks and trends which can be predicted and managed (the robustness perspective), or (3) from uncertain and unpredictable risks (the resilience perspective) [2]. For each perspective and each vital energy system I use simple indicators: energy trade for sovereignty, resource depletion for robustness, and diversity of energy options for resilience [3].

Short-term interaction between climate policies and energy security in Europe

The EU's 2030 climate/energy package sets the following targets for 2030: decrease GHG emissions by 40% below 1990 levels, increase the share of renewable energy to 27%, and increase energy efficiency by 30% [8]. What impact would these energy system changes have on EU's energy security?

Gas is clearly at the top of the EU's energy security agenda. Europe imports 65% of its natural gas and relies on it for over 40% of heating which makes natural gas a vital energy system. However, strictly speaking, oil is a bigger energy security challenge. Not only is the oil import bill five times higher than that for natural gas, but the oil share in the vital transport sector is almost 90% (Table 2).

For the Union as a whole, modeling results suggest that the EU's climate energy package would lead to a modest decrease in Europe's oil imports but may either decrease or increase natural gas imports depending on the assumptions [4].

However, one of the reasons why natural gas ranks so high on Europe's agenda in is that certain countries are much more vulnerable to natural gas disruptions than the Union as a whole. In fact, natural gas vulnerabilities vary widely across Europe – from Sweden, where natural gas imported from Denmark is used in one municipality, to former Eastern bloc countries such as

	What impact would the EU2030 energy goals have on energy security?	What impact would climate stabilization have on energy security?
Security of what?	oil and gas	imports, resources, energy options
Security for whom?	EU + European countries	major economies
Security from which threats?	import disruptions	import disruptions, price volatility, resource scarcity and unknown threats

TABLE 1 Exploring the energy security implications of low-carbon societies requires answering three fundamental security questions

Gas	Oil	Data source and year
40% heating & 20% electricity	90% transport	IEA for 2010
65% imported	>85% imported	Eurostat for 2012
50 €billion/year import bill	350 €billion/year import bill	Bloomberg for 2012

TABLE 2 Oil is a universal European energy security challenge even though gas dominates the policy discourse

Lithuania and Latvia, both importing all of their natural gas from Russia and whose district heating systems are almost entirely dependent on it.

The heterogeneity of natural gas vulnerability is well-recognized in EU policies. In the latest communication from the Commission on energy security, all but 5 of the Commission's 27 key security-of-supply projects for natural gas are located in the former Eastern bloc countries [5]. These projects are crucial to ensuring security of natural gas in the new member states but will have little to no climate impact other than pulling away resources from developing low-carbon energy sources [6].

Thus, over the short-term, the priorities for energy security and low-carbon policies are different. For energy security, the priority is to protect the most vulnerable European member countries, which are often the smallest and lowest emitters. But for climate, the priorities are decarbonizing the biggest countries, which account for a greater proportion of GHG emissions.

Long-term interaction between climate policies and energy security in major economies

Evaluating long-term energy security under radical energy transformations is conceptually challenging, since energy security is fundamentally a short-term issue focused on the stability of energy systems. Nevertheless, understanding how energy security might develop under radical energy system changes is necessary to anticipate and mitigate any risks which might emerge during de-carbonization. Using six long-term energy system models, I look at how energy trade, resource depletion and diversity of energy options evolve under both a business-as-usual (BAU) scenario without any climate policies and a climate stabilization case[4].

In the BAU scenario, global trade rises with coal trade overtaking oil trade by the end of the century in most models. Additionally, global oil reserves become completely depleted in several models [4]. Under the climate stabilization case, global energy trade is up to ten times lower and oil extraction stays within existing reserve and resource estimates.

In addition to analyzing global energy security, we examine how major economies – China, India, the EU and the US – fare in deep de-carbonization scenarios [4]. Energy security impacts differ from one region to another. China and India are the biggest winners of climate policies. Under the BAU scenario, they experience rising imports, resource depletion and low or declining diversity of energy options. Under climate stabilization their energy imports are up to 10 times lower and the diversity of energy options for electricity rapidly rises as they shift to domestically-produced renewables and increase energy efficiency. In the EU, energy imports also drop under climate policies. However, for the EU, the difference in energy imports between the BAU scenario and climate stabilization one is not as pronounced as for China and India, since the EU has already high diversity of electricity production and already manages high energy imports.

The results for the U.S. are in stark contrast to the other three major economies because it will likely become energy independent in the next three decades and, hence, should not have to worry about rising energy imports under a BAU development. Quite the contrary, it will probably be interested in maximizing its exports. Long-term climate policies are likely to reduce these potential energy export revenues in the US as they will for the traditional energy exporters (the Middle East and Russia). In fact, some have suggested that the development of cheap non-conventional resources in the US has led to a shift in policy discourses about climate policy in the Republican Party [7].

Conclusions

In this article, I examine the interaction between low-carbon policies and energy security. I define energy security as low vulnerability of vital energy systems which is both specific enough to explain today's policy concerns and, at the same time, generic enough to be applicable in low-carbon societies. Evaluating energy security requires answering three key questions – "security of what?", "security for whom?" and "security from which threats?".

To examine the energy security impact of low-carbon policies over the short term, I evaluate the impact of the the EU's 2030 climate/energy package on oil and gas imports. The EU's 2030 climate/energy package would slightly reduce oil imports, but may either increase or decrease natural gas imports. At the member state level, the priorities for energy security and climate change mitigation diverge. For climate mitigation the priorities are to reduce emissions of the biggest emitters – which are the biggest countries. However, for energy security, the priorities are to reduce the vulnerability of the most vulnerable countries – which are generally the small former Soviet Bloc countries and are not significant from a climate mitigation point of view.

Over the long term, climate stabilization policies globally lead to lower trade, lower resource scarcity and higher diversity of energy options. But this impacts major economies differently. China and India experience up to ten times lower imports and higher diversity of energy options under the climate stabilization scenario. Climate policies have similarly beneficial though more modest impacts on the EU's energy security. The US in contrast becomes energy independent under the business-as-usual scenario and may lose energy export revenues under climate stabilization.

In sum, the impact of low-carbon policies and measures on energy security depends on the definition of low-carbon, the time horizon, and the answers to the key security questions. Over the short term, the priorities for energy security and low-carbon transitions may diverge: the highest priority for climate are the biggest emitters but the highest priority to improve energy security are the smallest and most vulnerable countries. Increasing use of domestic coal may benefit energy security but harm climate. However, over the long term these two energy objectives are more in line with each other in most economies – with climate policies curbing imports (including coal), resource depletion, and increasing diversity of energy options. However, even in such a climate-friendly world there would be regional losers – most notably energy exporters, who would lose their export revenues.

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Electric energy storage as an element of low-carbon energy supply

Energy storage is one option to provide the electricity grid with flexibility. Short-term storage can provide system services for power quality, whereas medium-term storage allows to shift significant amounts of energy over some hours up to days. Seasonal or long-term storage can, for example, be provided by the power-to-gas technology. Significant amounts of storage will be necessary, especially when a fully renewable supply is approached. New mechanisms are needed to ensure anticipatorily that sufficient flexibility is in the system at any time.

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C. Krüger

Introduction

Energy demand and supply have to be in balance at all times. That is crucial especially for the electricity system: A mismatch endangers the stability of the supply grid. In a conventional energy system, the balance is ensured by the in-time production of energy from fossil fuels. When moving towards a low-carbon energy supply, the energy from those fossil power plants needs to be replaced by feed-in from renewable energy sources. However, renewable feed-in is less flexible than fossil generation, since electricity is generated when the wind blows or when the sun shines, not when it is needed. This means a loss of flexibility in electricity generation. To compensate for that loss, new forms of flexibility are needed. There are several options to achieve that: apart from energy storage, grid extension, demand side management or over-installation of renewables can also contribute. None of this options is going to be the only solution, but a concerted use of all of these will most probably turn out to be the best answer to the challenge of balancing renewable energy supply. It is therefore important to keep in mind that storage is one among several balancing options.

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Storage technologies

There are several electric storage technologies that differ in size, response time, capacity, power and in the kind of energy used to store electricity. Figure 1 gives an overview over those technologies.
Short-term storage does not allow to shift larger amounts of energy, but can respond within milliseconds and has a high output power. That qualifies it to provide system services, such as inertia control or reactive power, which are important for voltage quality in transmission grids.
The term ***medium-term storage*** identifies storage

technologies that are able to store and provide energy for minutes up to some days, such as pumped hydro-storage or large batteries.

Long-term storage is also referred to as "seasonal storage". It is a kind of storage that provides energy over long periods, ranging from several days up to months. It is an alternative to having fossil backup capacities and becomes important in systems with high shares of renewables. Technologies suited to those tasks are either pumped hydro-storage with very large reservoirs or the use of the so called power-to-gas technology, i.e. the conversion of electricity to hydrogen via electrolysis and the optional further processing with carbon-dioxide, which results in methane. Both forms of gas can be used in different gas-appliances.

Cross-sectoral storage is another kind of storage that uses links between the electricity and other sectors. For example, heat pumps and combined heat and power plants (CHP) are links between electricity and heating. When these are equipped with thermal storage, they give extra flexibility on the electrical side: their electricity consumption or production can be shifted to proper times, thereby providing a "virtual electricity storage". In the transport sector, electric vehicles are likely to be a widely spread technology in the future. Their batteries can be charged in suited times, providing a virtual storage compared to uncontrolled charging.

Also, there is a huge potential in electrifying appliances that have so far been fuelled by other forms of energy. In a renewable energy system, this has a double use: on the one hand, decarbonising electricity is easier than other forms of energy. On the other hand, if the consumption of those appliances can be timed, this gives additional flexibility to the electricity system.

When will storage be needed?

This is not a question aiming at a certain point in time, but at the share of renewables. Figure 2 gives an overview over different phases of storage demand. In a system with low to medium renewable shares, storage rather promotes fossil base-load power plants: By providing an additional load in times of high renewable feed-in (going along with low energy prices), storage raises energy prices to a level suited to conventional power generation.

Above a share of about 40%, physical excess feed-in from renewables will occur. At that point, storage becomes necessary to promote the integration of renewables into the electricity system by shifting energy from times of excess to times of demand.

Without storage, a fully renewable electricity supply, based on fluctuating renewables such as wind and solar, can't be achieved as there will always be times without sufficient feed-in, which needs to be covered either by storage or by conventional power plants.

The higher the share of

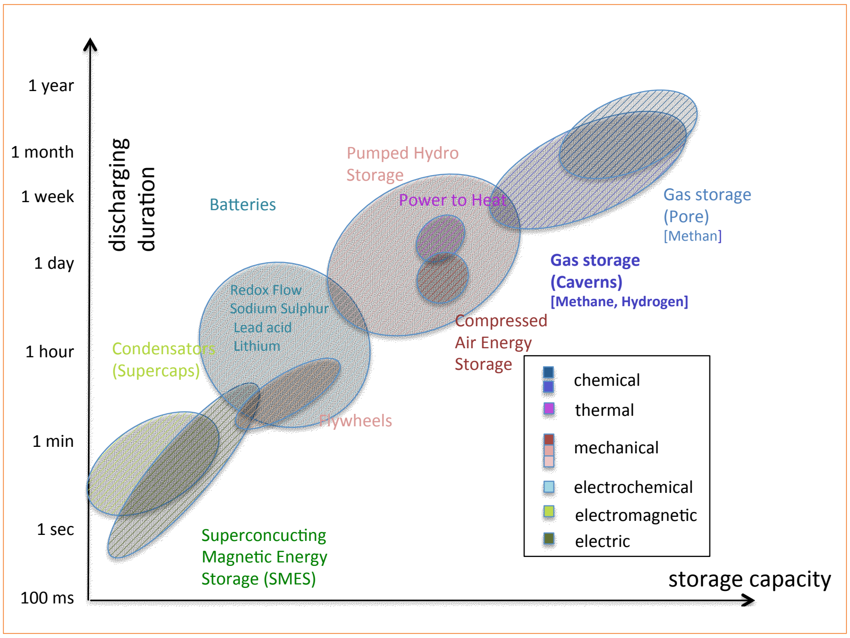

FIGURE 1 Overview over electric storage technologies
Source: own figure based on [1]

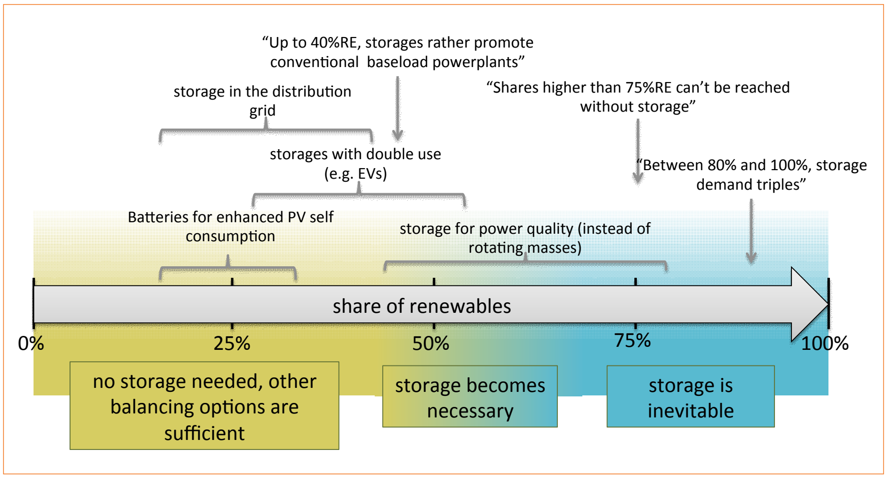

FIGURE 2 Development of flexibility demand over share of renewables
Source: own figure based on [2, 3, 4]

renewables, the larger the storage needed. Storage demand rises particularly fast when approaching 100%, as large amounts of energy need to be stored to ensure sufficient energy supply at all times.
Locally, short-term storage can already be necessary at an earlier stage. Conventional power plants do not only provide energy, but also system services such as reactive power control. Short-term storage is one option to compensate the loss of conventional plants' system services.
Apart from the task of balancing energy, storage also comes into the grid for other purposes. For example, the batteries for electric vehicles' or for solar home systems have different primary functions, but can also be used for grid balancing.

Recommendations regarding energy storage

Along with the rising share of renewables, new forms of flexibility are needed in the electricity grid. In the short to medium term, measures such as flexible power generation, demand side management and grid extension might be sufficient but, in the long-term, storage will be necessary to balance the electricity supply.
Therefore, new mechanisms are required, which ensure that sufficient flexibility already exists when it is needed. Such mechanisms can be, e.g., capacity markets or regulatory instruments. These mechanisms have to be designed in a way that they escort the transformation of the energy system towards renewable supply. This means anticipating the needs of different stages of transformation and thereby providing a framework for storage when it becomes necessary.
To determine the future demand for storage technologies, additional research is necessary. Studies have been conducted and have given first ideas, but deeper insights are necessary since the energy supply is a highly complex system.
Even though the amount of future storage demand is uncertain, conceivably rather large storage capacities will be needed. Therefore it is important to prepare storage for the future: research is needed to decrease storage costs across technologies. New business models for storage have to be developed and demonstrational projects need to be funded in order to gain experience, especially regarding new promising technologies.
Since the installation of large storage units has a high impact on nature and landscape, public acceptance is likely to become crucial to storage. Therefore concepts are needed to involve stakeholders in participatory processes from early planning stages.

Conclusions

With rising share of renewables, new flexibilities are needed to match energy demand and supply. Energy storage is one among other balancing options which are able to provide this flexibility. In a near system near 100% renewable share, storage will be indispensable. By now, there is only a low demand for electricity storage from the electricity grid perspective, but there are other reasons for implementing storage systems, such as PV self supply or electric vehicles. A significant demand for storage will presumably not occur before the next two to three decades. But to enable a purposeful and system compliant integration of storage, in-depth, multidisciplinary research needs to be conducted to provide a profound base for creating suited regulatory frameworks.

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Governance and communication for energy efficiency

Energy efficiency has multiple benefits. It usually is a win-win option for all aspects of sustainability – environment, social objectives, and economy. We need to evaluate and communicate these multiple benefits – to citizens, companies, and policy-makers. Due to strong market barriers, effective governance and policy packages for energy efficiency are needed. Evaluation shows effective policy can achieve around 2% per year of additional energy savings.

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■ *S. Thomas*

Introduction

Energy efficiency provides multiple benefits. However, most citizens, managers, and policy-makers are unaware of these. This is just one of the many barriers, which are the rationale for policy support to markets in order to harness the benefits. This article therefore presents some evidence on the multiple benefits; provides a methodology to develop appropriate policy packages and governance to overcome the barriers; highlights a few policy packages but also research needs; and draws a number of conclusions.

Communicating the multiple benefits of energy efficiency

Energy efficiency does not only save energy and costs for citizens, companies, and nations. It is also the fastest, largest, and usually profitable way to reduce greenhouse emissions, and therefore is crucial for achieving a low-carbon society. But it also has many more benefits.

Analysis for the Global Energy Assessment [1] found that worldwide energy consumption for space heating and cooling may grow by 33% from 2005 to 2050 under current, suboptimal policies. Harnessing the full potential, in contrast, could outperform growth in floor space and reduce that consumption by 46% in 2050 compared to 2005 consumption.

IEA [2] finds that for large-scale energy efficiency programmes:

- the GDP growth rate can be + 0.25 to 1.1% per year higher;
- employment will grow by 8 to 27 job years per EUR 1 million invested;
- energy efficiency in buildings in the EU could bring revenues and savings of EUR 67 to 128 billion to public budgets;
- health and well-being impacts may quadruple economic savings compared to energy cost savings alone;

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- productivity improvements may be worth to companies 2.5 times the energy cost savings alone.

Analysis by the Wuppertal Institute found that Thailand could limit the share of energy import costs in GDP to 20% through energy efficiency (baseline projection: almost 30%) [3].

Communicating these and other benefits in a targeted way to citizens, companies, and policy-makers could significantly boost awareness, interest, and action towards energy efficiency. However, while the literature and tools for calculating energy savings, greenhouse gas reductions, and net economic benefits is abundant, much less is known about the other benefits. There is, therefore, a pressing need for more research on benefits, such as employment, health, and productivity in all sectors.

Overcoming the barriers to energy efficiency through governance and policy packages

Lack of awareness on the multiple benefits of energy efficiency is just one reason why it all too often will not be harnessed. There are many other market barriers and failures. First of all, energy efficiency is not just a handful of technologies like for conventional or renewable power plants. It is embedded in hundreds of types of systems, equipment, and components, and virtually in all our decisions for investment and use of equipment. Oversight is thus easily lost, financial gains may often be small, and lack of priority the consequence. In many cases, funds for the often higher up-front investment in cost-effective energy efficiency may lack. And developers and buyers, or landlords and tenants have split incentives over the costs and benefits of energy efficiency.

Policy and governance are therefore needed to overcome these and other barriers. The goal is to make energy efficiency easy, attractive, and eventually the default for all market actors. Because of the many barriers, this will require policy packages with more information, practical guidance, regulation, and financing support (“the sticks, the carrots, and the tambourines“). For developing such sector- and technology-specific policy packages for buildings and appliances, the Wuppertal Institute has used a four-step analysis in the bigEE project.

It combines (1) a three-step analysis of the policy instruments needed to tackle the barriers, but also to strengthen market-inherent incentives for each of the actors in a sector needed to make an energy efficiency action (such as insulation of an existing building or the purchase of an energy-efficient appliance) happen with (2) an assessment of the policy instruments that countries with an advanced and effective energy efficiency policy have combined in their policy packages [4].

Figure 1 presents the overview of the types of policy instruments in the package. While the lower part is sector-specific, the upper part is the overarching governance framework for energy efficiency. It includes (1) the energy saving and greenhouse gas reduction targets and policy roadmaps, (2) the infrastructure and funding for the sector-specific policies, such as energy agencies, energy efficiency funds, and energy saving obligations for energy companies, and (3) energy taxation, emissions trading, and the reform of energy subsidies that will eliminate distortions in energy prices, which are an economic barrier to energy efficiency.

In Figure 2, the specific policy instruments for energy-efficient renovation of existing buildings are grouped according to their function in the two-dimensional optimisation problem: (1) Achieving very energy-efficient and comprehensive, “deep” retrofits whenever a building is renovated, and (2) increasing the rate at which buildings undergo such “deep” energetic renovations [5].

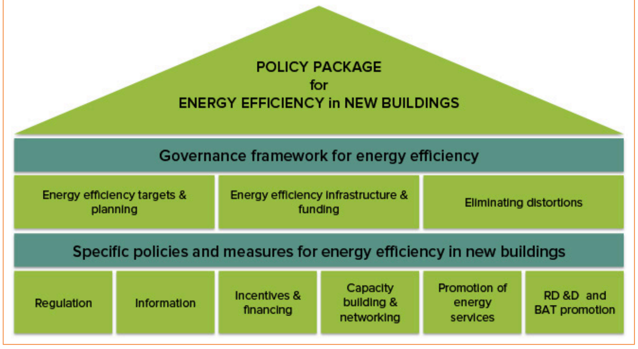

FIGURE 1 The bigEE recommended policy package for energy efficiency in new buildings
Source: www.bigee.net

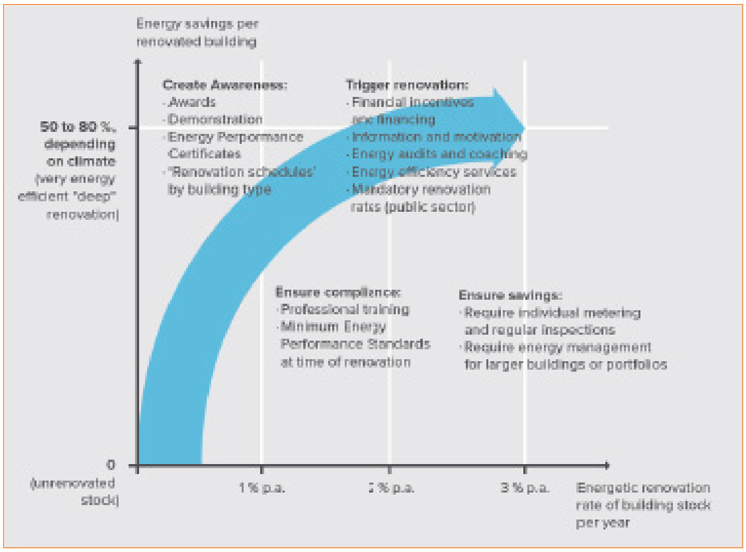

FIGURE 2 The bigEE recommended specific policies and measures for energy efficiency in the renovation of existing buildings
Source: www.bigee.net

On bigee.net (http://www.bigee.net/en/policy/guide/buildings/package_examples/), detailed information can be found on the policy packages of five advanced countries, which have all implemented packages very similar to the one recommended by the bigEE project. What is the status of research on such sectoral policy packages in general, and where is more research needed?

- New buildings: package is well developed.
- Energy-efficient renovation of buildings: developed but further proof needed.
- Appliances: well developed.
- Industry: further analysis needed.
- Transport (avoid – shift – improve): further analysis needed.
- Integration of energy efficiency and sufficiency: research at the initial stage only.
- Integration of energy and material efficiency: research at the initial stage only.

Conclusions

Energy efficiency has multiple benefits. It usually is a win-win option for all aspects of sustainability – environment, social objectives, and economy. It is also crucial for achieving a low-carbon society.
Therefore, we need much more evaluation and communication of these multiple benefits – to citizens, companies, and policy-makers.
Even then, energy efficiency will still only partially happen by itself, because of the manifold and strong market barriers.
Governance and policy packages for energy efficiency are therefore needed to tap the full potential and develop energy efficiency markets. More research is needed to develop our understanding on effective policy packages and how to better integrate citizens and companies into energy efficiency governance.
Evaluation shows effective policy can achieve around 2% per year of additional energy savings. We need more policy evaluation too, in order to know and communicate these benefits.

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How to deliver better policy integration?

Several challenges and possible ways forward in reconciling the delivery of energy policy goals including security and affordability are presented, based on the recent analyses by the International Energy Agency (IEA). This article addresses five topics: multiple challenging policy goals of the IEA's 3 E's (energy security, economic growth, and environmental sustainability); needs in the transformation to low-carbon societies in the energy sectors; major policies and measures for energy sector transformation; multiple related policy goals and multiple benefits of energy efficiency policy; and realising climate and energy policy integration. Overall, this article explores how to better deliver climate and energy policy integration in the real world.

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T. Hattori

Introduction

Can low-carbon societies deliver on energy policy goals including security and affordability? To address this question, this article will present recent analyses by the International Energy Agency (IEA) and will draw your attention to several challenges and possible ways forward in reconciling these different objectives.
This article consists of five parts. First, it explains how the IEA's 3 E's have worked on multiple challenging policy goals simultaneously. Second, it illustrates what is needed in the transformation to low-carbon societies in the energy sectors. Third, it explains major policies and measures for energy sector transformation. Fourth, it touches upon multiple related policy goals and the multiple benefits. Finally, it puts forward three necessary components for realising climate and energy policy integration.

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IEA's 3 E's

The IEA was found in 1974 as a coordinated response to the 1973 oil crisis for its member countries. Thus energy security has been the core goal of the IEA since the beginning. However, since then, it has evolved into an organisation with a much wider scope. When the climate change issue arose, the IEA expanded its goals to 3 E's: energy security, economic growth, and environmental sustainability. The IEA has been trying to promote the integration of these goals within policies. From data collection to modelling to policy analyses, the IEA has expanded its efforts to address these policy goals in its work. It should be noted that the IEA has included a fourth E, that is engagement worldwide: working closely with non-member countries.

Transformation to low-carbon societies

The Energy Technology Perspectives [1] shows a trajectory for 2050 in a scenario which is largely an extension of current trends (6DS), as well as a trajectory in the 2 degree path (2DS).

Achieving the 2DS will require contributions of emissions reductions from all sectors, and the application of a portfolio of technologies. In the 2DS scenario, the share of fossil fuels in the global primary energy supply drops by almost a half – from 80% in 2011 to just over 40% by 2050. In the 6DS case, CO_2 emissions keep increasing. Carbon intensity of the energy system, which has been stable for the last 40 years, must be dramatically lower in the future. To do so, decoupling energy use from the economic activity is necessary. What is needed in the transformation to low-carbon societies in the energy sectors are shifts in both energy supply and energy demand.

Policies for energy sector transformation

We are not on track for the energy sector decarbonisation. The only exception to this – a meaningful deployment of renewables – is not enough to meet long-term sustainable energy goals. Without progress in developing and deploying a wide range of technology, it will not be possible to meet the long-term climate, energy security and economic development goals for energy systems [1].
We often hear that climate actions will have negative impacts on economic growth. However, the World Energy Outlook [2] identified four measures that can be implemented at no net economic cost and can cover 80% of the emissions reductions required for achieving the 2 degree path.
But, are these measures enough? The World Energy Investment Outlook [3] shows that the overall investment need in the energy sector is not much in the 450 ppm Scenario compared to the current path, but low-carbon investment will have to be significantly scaled up.
Existing energy sector infrastructure is expected to remain in operation for many years. This infrastructure can be considered as lock-in. Therefore, we need to consider how to "unlock" high emission assets [4].

Multiple goals and multiple benefits

Air quality, climate change and energy are all related to greenhouse gas emissions reductions. We need to find and explore cross-disciplinary synergies among them [4]. Many countries recognise the potential to address these multiple priorities within the air pollution-GHG nexus.
Let me also draw your attention to the multiple benefits of a specific policy measure, such as energy efficiency improvement [5]. Multiple benefits of energy efficiency illustrate why we should explore specific policies in a wider context and the importance of synergy and policy integration for obtaining multiple policy goals.

Components for realising policy integration

I here put forward three necessary components for realising climate and energy policy integration.
First, we need to consider timeframes. Short-term actions should take implications for longer-term decarbonisation into account. Technologies need early action to be developed "on time".
Second, we need to explore what kind of metrics we use. Energy sector actions are critical for achieving GHG targets, but GHG targets are not the only, or primary, driver of energy sector actions. Thus, we need to include energy sector metrics.
Third, we need systems thinking. A sustainable energy system will be more integrated and efficient, but also more complex. Government at all levels has a key role to play in putting the right market structures in place so that investors and the private sector can get on with delivering infrastructure and services.

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Challenges of electricity-based decarbonisation

Due to significant success in technology development and cost reductions, the electricity system is now widely perceived as the part of the energy system to be first in decarbonisation. This means a double challenge for the system: Firstly, it will undergo significant change due to rapidly increasing shares of fluctuating renewable generation; Secondly, there will be an expansion of electricity into other fields of the energy system such as heat generation and transport.

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S. Lechtenböhmer

Introduction

One of the major fields of success on the way towards sustainable energy systems in recent years has been renewable energies in electricity generation. They grew by 5.5% annually from 2006 to 2013, and are expected to grow even faster over the next few years. RES generation technologies have seen huge cost decreases, and in 2013 they amounted to a share of more than 20% of electricity generated ([1], p. 64ff).
This strong trend has added to the expectation that the electricity sector will be the leading energy market segment in decarbonisation. This proposition has already been included in several scenario studies, and refers not only to the current situation but also to developments within the next decades. Due to the potential of decarbonising electricity, its role in the overall energy system will step by step increase through the electrification of heat generation, transport, and possibly even industrial processes [2, 3, 4, 5, 6].
The most recent IEA's energy technology perspectives report expresses this in its programmatic title: "Harnessing electricity's potential" for decarbonising the energy system [1].
The fact that a large share of the new renewable technologies uses fluctuating energy sources, such as wind and solar radiation, results in the integration of high shares of variable generation into the electricity system. This integration is a technological as well as institutional challenge with the potential to significantly transform the electricity system itself.
In the following, some core challenges for this change as well as for the internal transformation of the electricity system will be sketched.

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Electricity generation as a forerunner for decarbonisation

While the recent ETP study sees RES shares in global electricity generation rising from 20% in 2011 to 65%

by 2050 ([1], p. 11), other studies ([4], p. 118) expect such shares as early as 2040. Moreover, they anticipate a full RES electricity supply by 2050 in the context of an increase in electricity generation by 277%, thereby achieving a share of 50% of final energy by 2050.

For Germany a recent study by the Federal Environment Agency [7] even sketches an almost fully electricity-based energy system. Here, on top of a direct share of electricity of almost 40% of final energy demand, the remaining fuels for transport as well as industrial feedstock are supplied by electricity-based hydrogen and derived synthetic fuels (methane, methanol). These are expected to be indirectly produced from electricity via renewables-based hydrogen. This vision not only assumes an increasing share of electricity in the final energy demand but, on top of this, also further electricity demand for the production of hydrogen, methane and synthetic fuels. Eventually, this would mean a tripling of electricity demand by 2050.

Core challenges for the expansion of low-carbon electricity

As shown before, scenario studies generally agree that electricity will be on the centre stage of decarbonising energy systems over the next four decades. Such a development, however, would require a reversion of several recent trends. Furthermore, it would impose a number of significant and interlinked challenges to the electricity system. Six of the most relevant of these challenges will be briefly discussed in the following:

(1) The first challenge is to foster the recent trend of increasing renewable electricity generation and at the same time phase out fossil generation. Fossil generation is not only dominating current generation but also still has the lion's share in new generation investments. In order to break such a trend, high incentives and significant investment into renewable generation technology as well as a rapid stop in developing fossil, and here particularly coal-based assets in all parts of the world, are needed. These developments must be asserted against strong interests and often (at least seemingly) attractive economies of fossil-based electricity generation. So far this issue has been rarely tackled by governments. NGOs, however, are lobbying for fossil fuel divestment, e.g. to convince investors to withdraw from new and existing assets in fossil power generation (http://gofossilfree.org).

(2) A successful expansion of RES electricity generation will in most countries be based on wind (onshore and offshore) and solar energy. This can be inferred from their importance in recent developments as well as the current and projected costs of generation. Due to the fact that their generation characteristics are directly dependent on the availability of wind and sun, the electricity system will need to adapt to the bulk of fluctuating electricity generation, which cannot be directly controlled. To accommodate these characteristics as well as local differences in natural potential and demand, electricity can be exchanged over long distances and be stored centrally or decentrally. This means that an expanded electricity grid plus several options to store electricity, including a flexibilisation of demand, have to be implemented as enabling technologies for a RES-based electricity system. These needs, however, are quite in line with the needs and options of a significant expansion of electricity into other energy markets.

(3) Besides (fluctuating) renewables other low-carbon electricity generation options, such as fossil power plants equipped with carbon capture and storage technology, as well as nuclear generation are or will be available. These, however, are characterized by low flexibility due to their technical and particularly economical characteristics with very high shares of investment costs. It is thus another challenge to design electricity systems in a way that results in an effective and economic combination of these technologies with fluctuating renewable generation [8].

(4) The conversion of the electricity system will also impose strong challenges on liberalised electricity markets in many countries. Due to the characteristics of wind and solar generation, they are producing at zero marginal costs. This complicates the al-location of costs and refunding of power generation via market systems. As already visible in leading markets, renewable expansion thus requires significant reforms of electricity markets, including appropriate instruments for capacity remuneration of low carbon as well as back-up capacities [8].

(5) Another challenge will be to solve the potential contradiction of achieving high efficiency gains in traditional uses such as electrical appliances and lighting while, on the other hand, expanding the use of electricity into new fields such as heat supply with heat pumps, the transport sector, and possibly also industry.

Increasing the efficiency of electricity use is a major strategy. Lechtenböhmer and Samadi [3] show that most climate protection scenarios for the EU expect high electricity savings of at least a third vs. business as usual developments. Such a policy would, among other instruments, benefit mainly from high electricity prices, which increase the economic incentives for electricity saving. However, substituting fuels by electricity in heat generation and transport would require lower electricity prices as compared to fuels. In this context this could mean increasing the prices of the competing fuels, e.g. via tax exemptions in the transport sector, in order to make electric technologies competitive [3].

(6) Finally, electricity for low-temperature heat generation and mobility is not only a potentially attractive low-emission energy carrier, but it also offers higher efficiency of the end use technologies. However, it cannot be applied in all energy sectors. For example, large shares of the transport sector (long distance freight transport, air transport) cannot be directly supplied by electricity. This holds also true for several industrial processes, e.g. conventional primary steel making and particularly the feedstocks for the chemical industry, which are mainly supplied from natural gas. In principle, however, natural gas, which mainly consists of methane, can be produced from electricity, which is first used to produce hydrogen via electrolysis of water. Then, the hydrogen can be directly used, e.g., in steelmaking or ammonia production, or be further combined with CO_2 to produce renewable synthetic methane or fuels. These processes offer a technical route to substitute fossil fuels by electricity-based renewable fuels, with the advantage of very small changes in the characteristics of the energy carrier. The disadvantage of this route, however, are its high costs. They result from the two conversion steps needed to transform renewable electricity into fuels which come with high losses as well as high costs for the necessary technology. Such a strategy, which enables in principle a full decarbonisation of an industrial economy, as sketched by UBA [7], is therefore very expensive and also needs high amounts of green electricity [6].

Conclusions

The recent successes in expansion and particularly cost reduction of renewable electricity generation, mainly from wind and solar energy, are promising. They put the electricity system at the center stage of strategies for achieving a low-carbon economy. Electricity is not only expected to become the leading energy segment to be decarbonised but is also expected to expand into other (if not all) energy markets in order to supply low-carbon energy. While techno-economically justified, the studies promoting these visions make clear the huge technical but also regulatory challenges to be overcome for realising an electricity-based, low-carbon energy system.

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Theme 2: Common challenge in resource efficiency improvement

Energy efficiency and technology improvements on their own will not achieve the Low Carbon Societies (LCS) goals. Thus, resource efficiency and a circular economy are keys to a low carbon society. Resource efficiency improvement potential has been analysed from the industrial and territorial management perspectives. Exploring synergies between LCS and the larger area of sustainable development and green economy, highlighting co-benefits and trade-offs, is of utmost importance to pave the way to a more equitable and largely participated low carbon transition.

S. La Motta, M. Peronaci

Background

The transition towards Low Carbon Societies must consider resource and energy efficiency as one of the main pillars to be successful: such a transition cannot be achieved by only reducing energy consumption and developing innovative solutions to improve energy systems.

Similarly, this transition will be very difficult –or even impossible– to achieve if any mitigation and adaptation action to respond to climate change is not seen in the general context of sustainable economic development.

In addition to that, if such components – the use of energy and natural resources, the need for mitigation and adaptation actions to respond to the challenges of climate change– are treated as a whole in a sustainable and equitable economic development perspective, this will create the necessary general consensus so that the population behavior could be modified accordingly.

Therefore also the efficiency of resources has become a priority for environmental and economic reasons as well.

Three are priority components to be considered when promoting strategies and policies to face resource efficiency improvement:

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- reduction of the natural resources used;
- improvement in the different sectorial uses of them;
- reuse and recovery of raw materials.

This can be achieved through a transition from a linear economy model to a circular economy model, in line with the strategies towards a green economy model.
Even though those issues must be analyzed holistically, a more schematic approach leads to consider two different sectors: the industrial one and the territorial one.

Key findings

Three sets of key findings are identified. The following is a list of key findings, related to the main issues discussed in this section:

- The past great transformation has contributed to substantial economic development but also to substantial increase in resource intensity. A new transformation to a more sustainable social and economic system must be sought.
- A wide range of economically attractive low carbon measures are available and they could lead to significant reductions in energy use and carbon emissions. At the same time, transition to a circular urban economy cannot be realized within the current economic paradigm. A new transformation with a shift of main drivers is required.
- Building circular economy can synergize low carbon transition and resource efficiency improvement but there is no immediate solution to realize it. It is important to build momentum through implementing economically attractive low carbon saving options and encouraging transdisciplinary science to engender actual transformation.

The issues below are more specifically related to the industrial sector:

- Resource efficiency and circular economy are a key to low carbon societies.
- Energy efficiency and technologies improvements are not enough to achieve the goals for the LCS.
- Actual improvement for transition towards LCS can come from challenging and breakthrough modifications of the today's model of production and consumption.
- Strategies tailored to systems for the production of basic materials and materials in general.

The following issues are more specifically related to the territorial management:

- At city scale, it is difficult to transpose solutions from one city to another: local characteristics are very important (e.g. cultural heritage and tourism in Rome are a huge constraint), and lead to different policy opportunities, and GHG measurement choices (the choice of GHG accounting scope depends on the characteristics of cities).
- Bottom-up vs. top-down approach in urban climate policies design.
- There is the need to build pragmatic databases and tools, to harmonise protocols, and ease the accounting.
- There is the need for a combination of technical and social innovation.
- Are existing GHG reduction initiatives and policies sufficient enough, if generalized, to reduce GHG emissions? Or will we need new strategies?
- Changing behaviours and lifestyles.

- More consistency shall be given in transition processes between time (short, medium, long terms) and spatial scales (from individual to global level).

The past great transformations (e.g. industrial transition, mobility transition) have contributed to economic development but also to a substantial increase in resource intensity. Therefore, a new transformation to more sustainable social and economic system is now needed, with a shift of three drivers: from centralized control mechanism to distributed panarchy based on guidance and facilitation, from fossil fuels and exhaustible resources to renewable resources, and from linear system to circular system. The current sustainable development policies/targets focus on decreasing negative impacts and improving efficiency; instead, emerging alternatives are likely to create a radical shift to low-carbon and resource efficient society.

Both bottom-up social innovation and new kind of top-down mechanism are necessary to realize transformation. It is also important to prepare a phase-out strategy from fossil fuel and exhaustible-resource-based system.

With regard to resource efficiency improvement in the industrial sector, there is the need for new technologies, new management and business models, but also new tools with low-tech components, such as the industrial symbiosis, training of new, high-level professional skills, dissemination of BAT, etc. New updated control policies and legislations are also needed.

As to resource efficiency improvement in the territories management, the territorial component is also important as cities consume 75% of natural resource and 67-76% of energy, and urban population is rapidly increasing, particularly in developing countries. Even though the spatial definition of "Urban territories" varies from Country to Country, it is recognised that these areas are very complex systems, since almost all human activities are developed within them. The main sectors to be considered are: the environment, resource management (waste cycle, water cycle, etc.), economy, energy, logistics, mobility, social and cultural aspects, buildings. In addition, some other horizontal sectors must be considered as well, as the role of ICT, training, and public awareness.

The main actors involved in implementing any strategy/policy to manage such areas are central and local public Authorities, private industrial and tertiary sectors, public and private research institutions/bodies, financial institutions, citizens.

Another key factor in resource efficiency improvement is urban mining, i.e. the process of reclaiming compounds and elements from products, buildings and waste used in our cities; innovative technologies in this context must be implemented to recover primary/secondary materials as well.

This brings us to consider how important is, in an LCS strategy, the eco-innovation of systems, technologies and methodologies; in the light of this, it must be treated in a holistic "smart areas" perspective.

Way forward

Exploring and reinforcing synergies between low carbon society goals and resource efficiency improvement in both the industrial territorial management perspectives can accelerate the dynamics involved in a Low Carbon transition. There is large scope for the research community in exploring the opportunities that will arise in combining LCS together with the more general area of sustainable development and green economy, highlighting co-benefits and trade-offs.

There are several main strategies/actions that must be improved to facilitate a Low Carbon transition. Synthetically these are:

- The transition from a linear to a circular economic model must be sped up within over the short-medium term with appropriate strategies, innovative technologies, and methodologies and legislations.
- There is the need to invest financial resources to promote a local circular economy, also by implementing economically attractive carbon saving options; new carbon pricing strategies must be thought.
- There is the need to invest more on the human capital, promoting research and networks on innovation technologies and methodologies as well as creating new professional skills able to manage complex systems through a holistic approach.
- Sustainability cannot be achieved by simply improving efficiency: it requires a new transformation. For this purpose, transdisciplinary science must be promoted to create new realities, identify breakthrough points, mobilize and empower alternatives and disempower regimes in order to realize transformation.
- Enhance resource efficiency and circular economy with both B2C and B2B approaches.
- Boosting circular economy at the urban level, in connection with industries, through the systematic valorisation of urban mines with the actual involvement of each stakeholder along the value chain.
- Foster co-operation among all the stakeholders/actors potentially involved (central, local authorities/decision-makers, industries, public and private research institutions/bodies, financial institutions, citizens).
- Tailor any developed strategy/policy/action plan to the actual situation of each urban area being considered.
- Carry out ex-ante, ex-post analyses of each strategy/policy/action plan adopted, and eventually modify/adjust them.

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Basic materials in the low-carbon society transition

A deep decarbonization of basic materials production fundamentally requires new process technologies. The current climate policy framework tends to preserve industrial structures and reward incremental improvements rather than prepare for a low-carbon transition. G8 countries should develop policies that shift the focus from compensating carbon cost and incremental change to developing technologies and policy strategies for zero carbon emissions by 2050.

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Introduction

Industry is responsible for roughly 30% of global GHG emissions. The main share of these emissions originates from the energy- and carbon-intensive production of basic materials such as steel, cement, basic chemicals, paper and pulp and aluminum. Several studies have been analyzing the potential and consequences of reduction strategies in the short and medium term up to 2020 and 2030, focusing on increasing energy efficiency and other best available technology options. But 2050 and beyond targets require a nearly complete decarbonization. This changes the perception of what is needed and what is possible, and extends to solutions beyond the marginal reduction within the current industrial structures. As regards electricity, housing, and transport sectors, visions and ideas for decarbonization have existed for several years. However, for the production of basic materials this is new, and the work on elaborating vision and ideas for a long-term decarbonization has just begun. The call from the EU commission for business association to develop "industry road maps" started a first and necessary push and development of ideas in identifying opportunities, as well as threats and challenges for a decarbonized industrial sector in the EU [1].

Basic materials are essential to the economy, and global demand is projected to grow even in a low-carbon society (LCS). For building the LCS we need several low-carbon building blocks such as electricity and heat, liquid fuels, agricultural products, but also access to sustainable and decarbonized steel, plastics, aluminum, paper and pulp, and fertilizers.

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The production of basic materials – challenges for decarbonization

From the work done so far, three main technical strategies for decarbonising the production processes can be identified (see e.g. [2]):

- ***Biomass as fuel or as feedstock***: Biofuels can replace fossil fuels in most processes and be used as feedstock for producing bio-based chemicals and materials, e.g. polymers. Biomass is readily available in the pulp and paper industry and has already replaced much oil use. If used in cement production, emissions can be reduced by about 50 per cent but the process emissions from calcium carbonate conversion remain. In principle, bio-coke can replace coal-based coke for reducing iron oxide to pig iron. But biomass and land is a limited resource and there are competing uses (for food, feed, fibre, chemicals, etc.) as well as conflicts with other environmental objectives such as biodiversity and recreation. Bioenergy accounts for about 50 Exajoule (EJ), or ten per cent of current global primary energy use. The potential 2050 deployment levels have been estimated at 100 to 300 EJ [3] so the contribution compared to future global energy demand is limited.
- ***Carbon Capture and Storage***: CCS for industrial application can reduce a large share of industrial emissions including process emissions. But applying CCS to industrial facilities, especially the existing ones, is more complicated than applying CCS in the power sector. Typically, an industrial plant has several different source emissions with differing concentrations, and the physical space for post-process capture CO2-scrubbers may be limited. The technologies currently proposed do not capture all the CO2 in the flue gases, and they increase the consumption of heat and electricity. To capture more than about 80 per cent of all emissions from an industrial plant with CCS will require deeper integration into the core production processes. However, there are also some "low hanging fruits" in terms of relatively pure CO2-streams in some industrial processes. Many issues remain, concerning CCS, including the technical challenges, costs, large-scale infrastructure needs, legal aspects, and lack of public acceptance.
- ***Electrification***: Electrifying the process completely, or using hydrogen, is a radical solution that could eliminate the industrial contribution of fossil-fuel-related emissions. A number of electro-thermal processes for industrial heating in different temperature ranges are possible (using, e.g., microwaves, infrared radiation or plasma). Hydrogen from electrolysis can be used for reducing iron oxide or replacing hydrogen from natural gas in fertiliser production. Through co-electrolysis of water and carbon dioxide, or by making hydrogen react with carbon dioxide, a synthesis gas (mainly CO and H_2), or methane, can be produced, from which a range of hydrocarbons and platform chemicals can be generated. Such "power-to-gas", "electro-fuels" or "electro-plastics" processes are technically possible but relatively expensive. Industrial emission reductions from electrification rest on the assumption that electric power supplies are fully decarbonised.

As can be seen, all major routes for decarbonisation have their limitations and barriers. CCS, by many regarded as a back-stop technology for electricity, is more complicated and costly when introduced to the large and complex integrated process industries [4]. Biomass is, by definition, a limited resource. Competition and thus prices of biomass will increase in a low-carbon scenario. Electrification and other routes for a complete decarbonization of the process (including, e.g., using magnesium-based instead of Portland cement) are still uncertain and require major research and development efforts before being technically proven.

A complementary and equally important strategy is to use more recycled and, thus, less virgin materials. In some cases this will enable greater electrification (e.g., for steel) or require greater integration between sectors, e.g. cascading biomass from chemicals to fuels, to heat and eventually, via electrification and CCU (Carbon Capture and Usage), back to chemicals again.

A different transition challenge

Decarbonizing the basic materials industry poses a different transition challenge compared to decarbonizing the power, housing and transport sectors. The scale of individual facilities and each investment decision are huge. For any major investment that includes changing the core process steps (necessary for a complete decarbonization), a single investment decision could easily be more than 1 billion USD. Linked to this, the investment cycles for core process steps in energy intensive industry is typically 20 to 40 years or more. 2050 targets may seem distant, but for energy-intensive industry 2050 is only 1 or 2 major investment decisions away.

Decarbonized basic materials offer few if any co-benefits, and will be substantially more costly to produce compared to ordinary produced carbon-intensive materials [1]. It will thus be difficult to find any "niches" prepared to carry the initial high costs for development (compared to, for example, Solar PV), especially since goods are traded globally with countries that may have no or lower carbon constraints. Another transition challenge compared to other sectors is that this transition will most likely need to involve the incumbent companies and actors. Energy-intensive industry has co-evolved with both energy systems, infrastructures and society, creating a lock-in into current systems. Changing this capital-intensive industry within the given timeframe requires the engagement of incumbents. Energy-intensive industry has gone through major technical changes before (e.g., from hearth to blast furnace) but this time the transition is purpose- and policy-driven.

The combination of large scale, long investment cycles, and the need to develop new core process technologies makes this transition extra challenging. Apart from major R&D, investments in decarbonized production routes for basic materials also requires a market environment with demand pull, including specific policy support, that can ameliorate the inherent risks and provide reasonable investment security.

The global climate policy response and industry

The global climate policy framework is deeply rooted in the principle of "common but differentiated responsibilities" (art. 3 in UNFCCC) that so far has divided parties into two groups, one with clearly defined emission reduction targets (developed countries in Annex 1 of UNFCCC) and another group with no emission reduction targets (developing countries, so called Non-Annex 1).

This principle is understandable from an equity perspective but problematic in the context of basic materials with high exposure to carbon cost and globally traded. Since the early 1990s, several Non-Annex 1 countries such as China, Brazil, and India have gone through a remarkable transition and increased their industrial output several times (and so did their emissions). This transition has been fuelled by substantial subsidies to both fossil energy and investments in process industries [5]. Due to fear of carbon leakage and loss of competitiveness, Annex 1 countries have also refrained from imposing strict mitigation polices directed towards industry. Policy interventions in the G8-countries have been directed toward promoting energy efficiency and compensating increased carbon or energy costs. Unfortunately, this policy response tends to preserve industry rather than prepare it for a long-term transformation (Åhman and Nilsson forthcoming).

As a result, the global response to climate change has had a relatively modest impact on global industrial emissions. Industrial emissions on a global scale keep rising due to unabated growth in several non-Annex 1 countries, whereas emissions in Annex

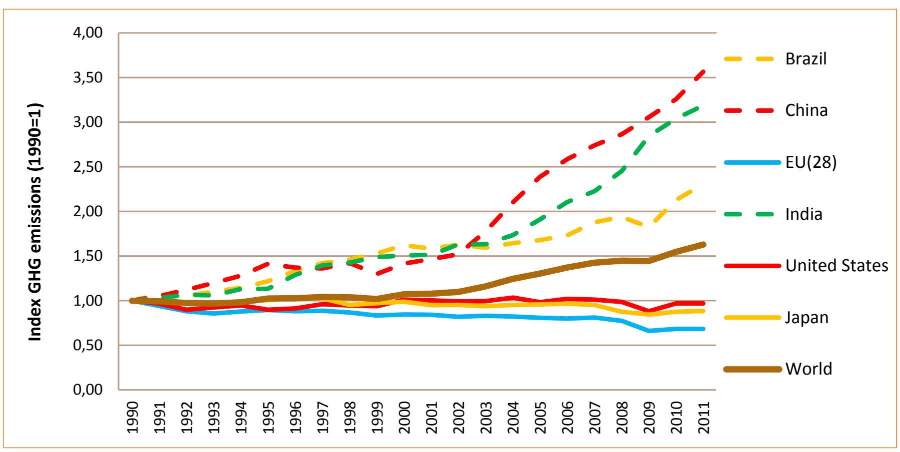

FIGURE 1 Global industrial direct emissions

Source: Adapted from WRI, CAIT 2.0. 2014, Climate Analysis Indicators Tool: WRI's Climate Data Explorer, Washington, DC, World Resources Institute. Available at: http://cait2.wri.org

1 countries have stabilized, see Figure 1. It is obvious that more ambitious emission reduction targets will put trade and industrial policies on a collision course with the current global climate policy framework.

Options for future development of the global carbon regime

If the global climate policy framework is to be effective and to induce long-term transformational change in the industrial sector, the emerging conflicts between trade, Annex 1 mitigation ambitions and non-Annex 1 views on equity have to be resolved. This could include a revised and longer-term interpretation of the right to development in Art. 3. Hopefully, a new global climate policy framework will emerge from COP 21 in Paris 2015 but the differentiation between countries, based on their technical and economic capabilities, will remain in some form or another within the UNFCCC, and this has implications for industry. Based on the challenges facing the basic materials industry, we argue that an effective G8 climate policy response needs to consider three different and interlinked strategies for inducing transformational change in energy-intensive industry: trade-related policies, consumption-based policies, and technology development policies.

- ***Trade-related policies*** include, but are not limited to, carbon border tax adjustments(CBA). Few governments in G8 countries are interested in introducing more trade barriers but a similar trade-related response could be sought in, e.g., policies for reducing unfair subsidies to energy or capital, or in a wider discussion on the suitable use of industrial policies.
- ***Consumption-based climate polices*** shift the burden of "carbon cost" from producer to consumer, ideally putting imported and domestically produced goods on an equal footing. Examples of potential consumption-based policies for basic materials are taxes, public procurement rules and feed-in-tariffs for basic materials. Policies encouraging reuse and recycling can also be included in this category.
- ***Technology development policies*** are the key long-term response. After 2030, all major investment decisions in energy-intensive industry need to involve a shift to low-carbon technologies. This gives G8 countries roughly 15 to 20 years to develop, demonstrate, and pilot new process technologies for decarbonizing the production of basic materials.

Decarbonising and keeping industry in G8 can be seen as part of the right of these countries to sustainable development. The alternatives are clearly unsustainable. G8 investments made in developing low-carbon process technologies will later benefit other countries, analogous to the development of renewable energy technologies, and thus be seen as major contribution to the overall objectives of the climate convention (UNFCCC).

An immediate concerted effort to increase the investments in R&D for energy-intensive industry with a focus on radical decarbonization is a first and necessary policy response. In the medium term, it is important for global climate policy to create an enabling market environment to ensure the demand for low-carbon materials. A balance needs to be struck between technology push and demand-oriented policies which also includes that the problem of long-term equity and carbon leakage need to be adequately considered in the global climate policy framework after Paris in 2015.

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Reuse and recovery of raw materials: Towards the achievement of a resource-efficient society

Resource efficiency plays a key role in the transition from a linear to a circular economy system. During the last few decades a rapid growth in the number of materials used across complex products has occurred. Given the high economic importance of critical raw materials combined with relatively high supply risk, securing reliable and undistorted access of certain raw materials is of growing concern across the globe. Development of eco-innovative approaches devoted to closing the loop of resources is strongly needed, allowing the connection between production cycles and their territory.

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Introduction

Resource efficiency is increasingly becoming a global priority, playing a key role in the transition towards the achievement of a total recycling society, for economic, environmental, and strategic reasons. From an economic point of view, resource efficiency is fundamental for ensuring economic growth and competitiveness of the production systems. With regard to environmental issues, resource efficiency is fundamental to the achievement of resource preservation, which is no longer an option. Finally, from a strategic point of view, resource efficiency is necessary to ensure the supply of essential resources even in those geographical areas that are poor in primary resources.

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Economic importance of raw materials

The economic and strategic importance of resources, especially raw materials, is well recognized at the global level. In particular, the European Commissionhas launched, for some years by now, the European Initiative on Raw material, identifying a strategic implementation plan for the safe and sustainable supply of raw materials. Its 3 main pillars are: sustainable mining, equity for raw materials market access and the efficient use and recycling of resources. The economic importance of raw materials is underlined in Figure 1, showing the weight of costs from materials, energy and labor on the sales price of products. The weight of energy costs on the overall cost of the production process is widely known. However, it is worth mentioning that in some specific manufacturing sectors the load of material costs over the sales price is even much higher than that of energy costs. In the particular case of basic metals and transport equipment, the weight of material costs is even higher than 60% of the overall sales price.

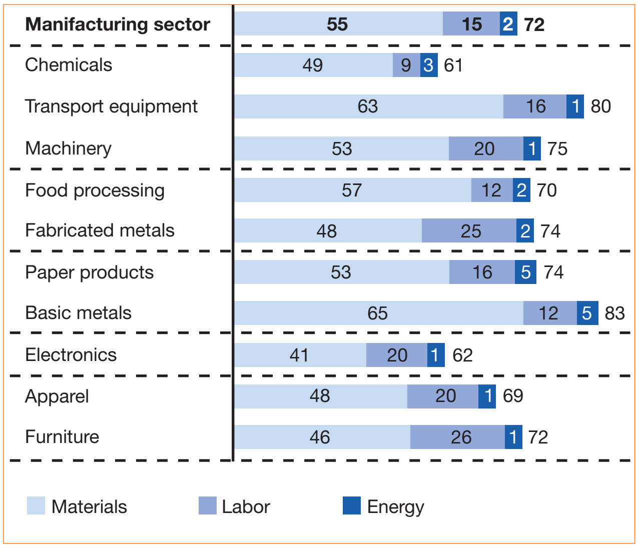

FIGURE 1 Costs over Sales price (%) in manufacturing sectors
Elaboration from "Manufacturing the future: The next era of global growth and innovation" (2006 data), McKinsey Operations Practice, McKinsey Global Institute, 2012

Eco-innovation as the driver for the shift from linear to circular economy

For both economic and environmental reasons, it is necessary to shift from the existing linear economy system, where primary resources enter into the production cycle and residues are disposed as waste, to a circular economy system, where residues are valorized and not disposed as waste. This transition is needed at any level, within the factories and even between production cycles and territory in industrial areas, as well as within the territory, for instance in the cities.
The driver to achieve this transition is eco-innovation, that is any new product, process, management system and services that allow to reduce resource and energy consumption as well as emissions to the environment. Eco-innovation is an essential tool for green economy, with the main objective to achieve a radical change towards a low-carbon and resource-efficient society, thus aiming at the total decoupling among economic growth, environmental impacts and resource consumption. However, in order to attain the highest beneficial effects for economy, society, and the environment, eco-innovation should not be limited to the so-called eco-industries, but rather be extended to any production cycle (even the so-called brown industries) and to any service and people lifestyle.

Industrial symbiosis – resource-efficient, eco-innovative solution within industrial areas

One of the most innovative and powerful tools for resource efficiency in industrial areas is represented by industrial symbiosis, i.e. a set of resource exchanges between two or more dissimilar industries. In opposition to traditional linear production systems, industrial symbiosis allows the transition to a circular production system, where the inputs are both primary and secondary resources and residues of an industry become, after proper treatment, valuable resources for dissimilar industries. This system allows the achievement of both economic and environmental benefits, consisting in the reduction of costs for energy, materials and waste management, and in the decrease of polluting emissions, energy consumption and disposed waste.
The results of the United Kingdom National Industrial Symbiosis Programme (NISP) (http://www.nispnetwork.com), obtained over an 8-year period, show interesting figures from both an environmental and economic point of view. Besides the highly consistent reduction in carbon dioxide emissions (39 million tons industrial carbon emissions less) and in water and raw materials consumption (45 million tons of materials recovered and reused, 71 million tons of industrial water savings obtained), it is worth mentioning how the 40 million pounds public investment has achieved a return of private investment around ten times higher. Furthermore, over 10,000 jobs were created or safeguarded.
As a practical example, ENEA has implemented an Industrial Symbiosis Platform (http://www.industrialsymbiosis.it) in Italy. As shown in Figure 2, its core is the cooperative database containing information provided by registered enterprises and industries' resource needs and residues produced. A

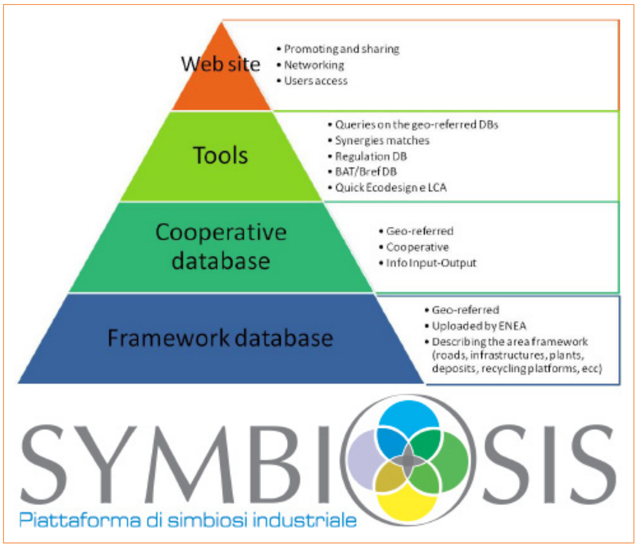

FIGURE 2 Industrial symbiosis platform structure implemented by ENEA

pool of experts, coordinated by the ENEA Technical Unit for Environmental Technologies, evaluates this information and proposes exchanges of resources among different industries.

Urban mining – resource-efficient, eco-innovation within cities

Another example of eco-innovation as related to cities is urban mining. In the past urban waste has been widely recognized much more as a problem to be solved than as a resource. It is time to start appreciating waste and exploiting all the potentialities of urban waste to become a valuable resource. In fact, cities can be considered as open pit mines, and construction and demolition materials, municipal waste, electronic waste, end-of-life automotive components are all valuable sources for plastics, metals, energy and other raw materials. Further added value is also represented by the creation of business and jobs in the recycling sector.

As a specific example, if we consider electronic waste, as shown in Table 1, the potential of secondary recovery is comparable to and in some cases even higher than primary extraction.

In addition, in some specific components such as printed circuit boards, the average content of precious metals is much higher than the average content of ore grades. In particular, it is 5 to 10 times higher for platinum and palladium, and even 20 to 100 times higher for gold. Electronic waste is not only interesting for the high content of single valuable metals, it is also particularly interesting for the wide range of metals that are contained in the components. As an example, the raw materials that can be recovered from an end-of-life personal computer by the application of an integrated product-centric approach include precious metals, specialty metals, rare earths, plastics for the recovery of chemicals and the production of syngas and energy.

	Primary extraction in 2011 [t]	Estimated world reserves [t]	Potential secondary recovery from WEEE [t]	Average content in medium grade ore [g/t]	Average content in printed circuit boards [g/t]
Gold	2.700	51.000	4.000	5-10	80-1.000
Silver	23.800	530.000	10.000	200-400	200-3.300
Platinum	192	66.000 (PGMs)	1.000	4-6	20-40
Palladium	207	66.000 (PGMs)	2.500	4-12	50-120
Copper	16.100.100	690.000.000	8.000.000	6.000-45.000	160.00-345.000

TABLE 1 Urban mining potential from WEEE
Adapted from E Waste Lab Final Report, Remedia, PoliMI, 2012

From an environmental point of view, many studies have been carried out to compare the ecological footprint of mining and recycling. In the study reported in Table 2, it is evident how carbon dioxide emissions are much higher for primary extraction than for recycling, in the case of palladium and gold even 20 and 40 times higher. These figures are even more important if we consider

Metal	Scenario 1 primary mining	Scenario 2a Manual dismantling/ smelting India	Scenario 2b Mechanical dismantling/ smelting India	Scenario 3 Manual dismantling/ smelting Europe	Scenario 2d Mechanical dismantling/ smelting Europe
Aluminium	10	0,87	0,94	0,75	0,82
Nickel	20	4,8	6,7	4,7	6,6
Copper	3,4	1,2	1,5	0,98	1,2
Gold	17.000	710	1.330	690	1.300
Silver	140	20	40	20	40
Palladium	9.400	210	730	200	720

TABLE 2 Emissions per metal in ton of CO_2: Mining versus recycling
Adapted from F. Eisinger, R. Chakrabarti, C. Kruger, J. Alexeew, "Carbon Footprint of E-waste Recycling Scenarios in India", 2011

that the study is related to recycling processes conducted at high temperature. In the case of recycling processes at room temperature, such as those based on hydrometallurgy developed by the ENEA Technical Unit for Environmental Technologies, the recycling emissions are even much lower.

Conclusions

There is a need to shift from the existing life cycle of materials, where natural primary resources enter and residues exit to be disposed, to a closed cycle of materials, where the quantity of primary resources entering is much lower and the residues are ideally fully valorized within the loop. Eco-innovation represents the driving force for the achievement of a radical change towards a low-carbon and resource-efficient society aiming to achieve the total decoupling among economic growth, environmental impacts and consumption of resources.

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Towards a new transformation and new governance

While a consensus seems to exist on the need to move towards a sustainable development pathway, we seem to be unable to develop the appropriate policy and governance responses. From a transition perspective, this inability to create fundamental change is related to existing path dependencies and associated interests that help to sustain existing societal regimes. This paper offers a new governance perspective that might help to develop new governance approaches that focus on institutionalizing emergent social innovation along with managing the breakdown of unsustainable systems and structures [1].

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D.A. Loorbach

Introduction: From the great to the new transformation

The era of industrial revolution or Great Transformation, beginning in the mid-19th century, can be understood as the aggregated process of a multitude of underlying shock-wise transitions [2] in our societal systems such as mobility, energy, food/production, housing, health care and welfare. In hindsight, these historical transitions can be described as revolutionary systemic changes, but in everyday practice they were more incremental processes of experimentation, breakthrough, institutionalization, behavioral and cultural change, and so on. As such processes of "evolutionary revolution", the transitions of modernization and industrialization completely altered society. Strikingly, it seems that many of these historical transitions were driven by a few very fundamental common drivers that provided the basis for the transitions of modernity: central mechanisms of coordination, fossil energy and resources, and linear models of innovation. These historical transitions brought us welfare, well-being, democracy and justice.

Yet by now, we are confronted with systemic problems deeply embedded in these historically developed societal regimes. We are increasingly experiencing growing tensions in our societal regimes, based on centrally organized control over and distribution of resources, and on end-of-pipe problem solving. It seems difficult, if not impossible, solving these problems through the traditional means of regulation, liberalization or negotiation. This lock-in is evident in many societal systems now increasingly confronted with the changing societal context and the economic crisis. Efficient waste-management, health-care, energy system, food production, and building have all been thriving upon demographic and consumption growth but are now completely locked in regimes focused on growth, efficiency and problem-treatment.

In other words: we have developed societal regimes based upon (past) problem solving through central (government) planning and control, based on cheap fossil resources and linear modes of innovation. This perspective predetermines

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a particular way of addressing problems such as health problems, lack of education, poverty, hunger, waste, access to cheap energy, and so on. It inevitably leads to solutions that are based upon singling out problems, quantifying them, and implementing planned solutions through policy (or market-based strategies). Environmental policies, much alike the Sustainable Development discourse, have become part of these established regimes and have primarily served to optimize these regimes, making them "less unsustainable".

While at the level of regimes the focus is on optimization, consensus building and incremental improvement, simultaneously all sorts of alternative niches have been developing for years. Since the 1970s alternative currencies, renewable (energy) technologies, local democracies, and sustainable community initiatives started to appear. For long these were small, expensive and often ridiculed as too alternative. Yet, over time and with experience they grew, developed, and matured. By now, many of these alternatives are starting to touch mainstream, from urban gardens and farms to energy producing buildings and from renewable energy cooperatives to credit unions and collective health care insurances.

By now, the old stability of the welfare state providing growth, security and governance is destabilizing, but an alternative direction is still diffuse, fragmented, suboptimal and uncoordinated. This state of confusion is bound to persist for some time, expressed by social feelings of unrest and a negative attitude towards the future as well as increasing tensions between the dominant mechanisms behind the modernistic regimes and the emergent new mechanism of a New Transformation. The new mechanisms are hybrid and mixed forms of governance and coordination, renewable resources and systemic innovation. The transformative social innovations that emerge responding to our global challenges are in this sense undermining existing power structures, dominant interests and paradigms, not least those of national governments.

New Governance for the New Transformation

As individuals, networks, institutions, companies, collectives and all sorts of other types of agency are increasingly self-organizing societal functions in alternative ways, it is no wonder that the "bottom-up", "participation" or "big" society is dominating public, political and scientific debates. However, much of these emergent transformative social innovations are countering existing interests and stakes, and do not necessarily (or by definition not) pursue (inter-) national policy goals. I argue that this emerging context of hybrid forms of governance fit to complex local problem contexts (governance panarchy) implies a more fundamental re-shift of power relationships and structures coordinating society. Also, we are only in the first phases of this shift, in which current (governmental) regimes are still able to frame the bottom-up society as part of a strategy of decentralization, austerity and efficiency increases. If indeed it is inevitable that this more structural trend towards governance panarchy will continue, and that it could also provide more effective ways to organize society in terms of ecological, social, and economic value, the question is: what type of governance and government could help to realize this? But also what is the role of science in these emergent, and by definition uncertain, explorative, and disputed processes of transformation?

The challenge I put as central to governance for sustainable development in general, and transition management [3] specifically, is to develop new understanding and mechanisms to use the current period of instabilities and disruptions, allowing to shift towards a new and sustainable equilibrium. We need to move away from innovation policies, experimentation, envisioning and formulating ambitions, towards achieving institutional change, facilitating advocacy coalitions, building transformative networks of networks and finding new ways to identify, measure, and explicate value. In other words, a focus towards reconfigurating social systems based on principles of inclusivity, circularity, and true value. In this understanding of desired futures, the question is not so much how to safeguard the interest of future generations but rather how to collectively deal with the loss, instability, uncertainty and new values, services and profits, that I associate with the New Transformation.

This will require not only adaptive policies and institutions but transformative ones: institutions and meta-governance arrangements that ensure basic values and social services based on emergent social economies and governance panarchy. Such meta-governance institutions need to be able to deal with diversity, surprise and uncertainty, but also to transition themselves. In a way, these institutions need to be able to destruct as much as they help to innovate, to facilitate as much as they direct, and to be able to work within a specific as well as generic context-. To me, this is the logical next phase in the development from a central state model by facilitating agency and network-governance actor towards "non-linear government". The dominant and linear planning model is found to work only in some cases, being replaced by hybrid context-specific and temporary forms of co-creation. It is in such contexts that effective solutions can be found and implemented at a much higher pace, but also that the values fundamental to a democratic nation such as accountability, transparency, equity and equality are put to the test.

Transformative science?

Acknowledging that the future is uncertain and ready-made solutions to our global challenges are absent requires also a different type of science that is more engaged, normative in its ambition to address unsustainability in a fundamental way, and explorative in its approach. This line of thinking is part of a broader debate in science under the headers of "post-normal" [4, 5] or "sustainability" [6, 7] science: the thought that inherent ambiguities and uncertainties in the social domain, when it comes to persistent and complex challenges, are so structural that they require novel, inter- and transdisciplinary processes of knowledge co-creation, embedded in practical experimentation.

This by definition requires the use of broader concepts providing a frame of reference to discuss and direct differences in perception, ambition, and understanding between actors, such as Sustainable Development, transitions or the New Transformation. The rationale behind this assumption is that new solutions can only be considered to be legitimate, diverse, resilient and effective when they are (co-)developed, implemented, and sustained by societal actors [8]. This means that developing scientific knowledge in the context of the New Transformation is not a goal in itself but rather a means to achieve progress through influencing its speed and direction. Scientists in the process of sustainable development are not providers of objective truths but part of the enquiry process. Scientific, as well as political and social knowledge becomes as subjective as the solutions and outcomes [9].

Outlook

The perspective I sketched out implies a new direction for policy. As solutions are emergent in societal contexts, the challenge is not so much to reach consensus on goals and targets, but rather to facilitate the desired emergent alternatives. Policy can do so by engaging with these alternatives and institutionalizing the new emergent structures through regulation. But, perhaps. even more importantly by addressing the own dependence upon existing (unsustainable) systems and developing break-down and phase-out policies, in which existing interests are compensated for the losses in, or made part of, the New Transformation. This would not only require visionary and daring leaders but also an engaged scientific community. That is, a scientific community which both provides the basic, unsustainable science-understanding systems and their impacts and ensures sustainable emerging transitions.

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Cities in a post-carbon society. A French perspective

Cities are key players for a transition towards a post-carbon society; nevertheless, there is a wide variety of pathways they may follow to achieve it. As a consequence, the use of foresight methods is important to evaluate the triggers cities can use, and the obstacles they can face, in such a perspective. This article aims at presenting a four-year research program work, where six contrasting scenarios were designed to tackle climate and energy issues at the urban level, from today to 2050.

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A. Rivière

What is the role of cities in climate and energy issues? How can urban areas achieve transitions to lead to a post-carbon society? These are the questions this brief article will discuss, using a French perspective.

Cities and climate-energy issues

Bearing a responsibility of two thirds of the world primary energy consumption and of over 70% of global CO2 emissions [1], cities play a major role in current climate change and energy issues. Their demographic weight and their economic impact is surely at stake. For instance, in France, about 80% of the population live in urban areas, the latter representing about 20% of the whole French area [2]. Regarding French cities' economic activity, more than half French GDP is achieved in the 15 biggest metropolitan areas (>500,000 inhabitants), while they also contribute to 75% of GDP growth [3]. Eventually, it appears that, in France, 95% of the whole population lives in a sphere of urban influence [4].

On the other hand, cities are also vulnerable to climate change consequences. Indeed, they can be struck by direct impacts of climate change: global warming, change in precipitation patterns, higher frequency and intensity of extreme events or sea rise. In the future, these expected risks are extremely likely to increase, and will be borne by local authorities, which will have to face their cost [5] and adapt to them [6].

The availability and price of energy are also two essential issues for French cities, which import almost all their primary energy needs. Again, beyond this direct impact, the most important issue is that urban areas will have to deal with uncertainties since they are hardly able to predict to what extent they will be affected by this sort of events [7]. Energy issues and sensitivity to its price (expected to rise and be more volatile) will also have clear negative socio-economic impacts on the inhabitants' well-being. Constrained

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mobility, energy poverty and vulnerability are the main troubles they will face. These consequences may increase inequities since they tend to have negative distributional impacts across revenues [8], and may be more severe for people leaving in semi-urban regions [9]. In other words, the whole urban metabolism may be threatened in the medium term.

To sum up, cities are both perpetrators and victims of climate change. Beyond the strong inertia they are facing, unique opportunities still exist.

Rethinking cities in a post-carbon society

Based on these evidences, the Foresight Unit of the French Ministry in charge of Sustainable Development and the French environment and energy management agency (Ademe) led together a four-year research program entitled "Rethinking cities in a post-carbon society" [10]. Focusing on the French case, it analyzed the role cities can play in a transition towards a post-carbon society, from today to 2050, through a comprehensive research action on six local authorities, combining thematic seminars, building scenarios and applied territorial research.

A post-carbon society would achieve three main objectives by 2050: dividing by four its GHG emissions, adapting to climate change, and almost no longer relying on the burning of fossil fuels (especially oil). In addition, solutions must be compatible with a sustainable development, so that suggested measures are effectively driving towards a better future.

Six scenarios for a transition

One part of the research program consisted in developing scenarios. The goal was to create, compare, and partly evaluate a number of possible strategies for achieving a post-carbon society. The aim was not only to produce and describe pictures of the post-carbon city in 2050, as this would only have limited significance, given the wide variety of existing cities. Actually, the main purpose was to go further by bringing these strategies up for discussion, to develop new ones, and to assess the players' degree of flexibility considering opportunities and obstacles. At the end of the exercise, some trajectories from today to 2050, which seemed consistent across all key players involved, were obtained.

The backcasting method allowed to devise transition pathways within a timeframe of 30 to 40 years.

Formally, the procedure consisted in starting with the ultimate objective (i.e., the three components of a post-carbon society in 2050), and to identify the pathways to reach this objective. At the same time, a forecasting method was used to make projections about megatrends, i.e. variables tightly linked to the context.

Considering the distant time horizon, uncertainty and the large variety of representations of the future naturally play a major role in the design of strategies. The main and basic assumption adopted to design scenarios was that the transition pathways mainly depend on how stakeholders (in particular local authorities) perceive the uncertainties associated with the situation, as well as on how they identify their own opportunities and their degree of flexibility. Having this in mind, six differentiated scenarios were constructed, which can be represented in a 3×2 matrix, according to the level of flexibility perceived – on economic tools, urban infrastructures and planning, or on lifestyles and urban forms – and the type of context – trend vs. pro- innovation (Table 1). Thus, economical, technical, cultural and social aspects of the city can be – at least partly – considered across the various scenarios.

		Degree of flexibility for action		
		Through technology and price signal	Action on urban investment and urban planning	Action on urban forms and lifestyles
Context	Baseline	Scenario 1 Smart wait-and-see attitude *(low carbon price)*	Scenario 3 New climate and energy infrastructures *(centralized)*	Scenario 5 Self-contained city *(urban forms)*
	Disruption: fosters innovation	Scenario 2 Carbon creativity *(high carbon price)*	Scenario 4 Biopolis *(decentralized)*	Scenario 6 Urban frugality *(lifestyles)*

TABLE 1 Six contrasting scenarios towards a post-carbon city

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From Table 1, it appears that: (1) picking up a line (i.e. context), the more we go to the right, the more the perceived degree of flexibility; (2) choosing a column (i.e. degree of flexibility for action), the second line offers more freedom for disruptive change while the first one sets up more constraints. In the following, we will present scenarios using columns as entries, that is by stabilizing the degree of flexibility for action. More detail is available upon request.

In an initial configuration (scenarios 1 and 2), little flexibility is given for transformational policies at the urban level. Instead, local authorities, businesses and residents adapt to incentives, constraints and opportunities in a smart – but reactive – way. Actually, these incentives are mainly imposed to local authorities, that is to say coming from national or international policies, and are especially related to energy and carbon prices, new technologies, technical standards, etc. In other words, price-signals are a decisive element in these two scenarios. Scenario 1, Smart wait-and-see attitude, is based on a low carbon price. The priority is thus given to no-regret strategies and to other measures that do not require massive investments. Scenario 2,Carbon creativity , faces a strong price-signal on carbon, and economic agents tend to change their habits to greener activities. Although economic instruments are used at a national and community level, local authorities play a role for driving local innovation as well as setting up pricing policies (e.g., urban tolls).

A second configuration envisions a massive transformation of urban and energy infrastructures, in a more or less decentralized setting (scenarios 3 and 4, respectively). Massive investments are realized in the retrofitting of buildings to ensure their very low consumption of energy; in energy systems so that they can be based on a larger share of renewables; and finally in all types of general infrastructures, such as public and collective transportation, infrastructures to tackle climate change impacts, etc. In brief, the transformation of territories is here at the heart of these two scenarios. Still, this second configuration does not properly consider any change in lifestyles, nor in the ways of using space.

A third and final configuration (scenarios 5 and 6) explores the conditions and the expected impacts of large-scale changes in lifestyles and the ways of using space. In scenario 5, Self-contained city (), local authorities and town planner are leaders in the transition towards post-carbon cities, while in scenario 6, Frugal urbanity, inhabitants themselves are at the heart of deep and disruptive changes.

These two last scenarios allow the minimization of vulnerability to climate change and fossil fuel dependence. They also offer unique opportunities to design and rethink, with the participation of inhabitants, urban areas so that they can be more attractive, resilient and sustainable. However, they consider economical transitions that are hardly conceivable today.

The importance of territorial application

Above all, the research program "Rethinking cities in a post-carbon society" sought to build on the myriad of initiatives, on climate and energy issues, that already exist in exemplary cities across the world. What is really at stake is, indeed, the dissemination of such a movement at all scales and for all actors. As a result, designing scenarios consistent with post-carbon objectives is an attempt to gather ambitious local experiences in order to foster their diffusion at a wider scale.

In addition, practical insights were given in the research program thanks to the involvement of six French local authorities , namely Lille, Tours, Plaine Commune, Fontainebleau, Mulhouse, Grenoble. For instance, the city of Lille analyzed how to address the social challenge through redistribution, in a context of high carbon price (scenario 2). As for the city of Fontainebleau, the role of social innovation and the importance of the local fabric was explored in the perspective of scenario 4 (Biopolis).

Conclusions

Qualitative and quantitative assessements of the scenarios were conducted and led to the following conclusion: none of them reached the post-carbon society by 2050 (i.e., they failed at least in one of the three criteria). In other words, a solution would lie in the combination of scenarios, when they are compatible with each other.

Beyond this analysis, three issues clearly appear to be crucial in the transition towards a post-carbon society. Firstly, the combination of technical and social innovation will be required to address the challenge of sustainability. Secondly, the role of changing behaviors and lifestyles is also important. Thirdly, more consistency shall be given in transition processes between time horizons (short, medium, long terms) on the one hand, and spatial scales (from the individual to global level) on the other.

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Urban GHG emissions and resource flows: Methods for understanding the complex functioning of cities

This paper sums up the recent developments in concepts and methods being used to measure the impacts of cities on environmental sustainability. It differentiates between a dominant trend in research literature that concentrates on the accounting and allocation of greenhouse gas (GHG) emissions and energy use to cities, and a re-emergence of studies focusing on the direct and indirect urban material and resource flows. The availability of reliable data and standard protocols is greater in the GHG accounting field and continues to grow rapidly.

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Introduction

By 2050, the world is projected to be two-thirds urban and one-third rural, which is roughly the reverse of the urban-rural distribution in the mid-twentieth century [1]. Rapid urbanization has led to an emergence of urban sustainability assessment methods that can help practitioners to find solutions for policy development and city planning. These may help to both prioritize environmental aspects, locations or sectors in which to take action, and design policy solutions at different governance levels.

Findings

Two interconnected fields of research can be observed [2]: on the one hand, a dominant trend of literature on the accounting and allocation of GHG emissions and energy use to cities (often called carbon footprinting) and, on the other, a re-emergence of studies focusing on urban metabolism or, in other words, the material and energy stocks and flows through cities.

Both fields of research are inherently linked as they originate from a system approach - the UM field takes the city ecosystem as the fundamental unit of analysis, and much of city GHG accounting literature applies the same notion. For example, they both can consider cities as either producers or consumers (see Figures 1 and 2). The two fields also show considerable divergence, in particular regarding the degree of application of the existing knowledge on the ground. Mutual learning between the carbon inventorying field and UM field is desirable [5].

Urban energy and GHG accounting began in many cities in the 1990s (see, e.g. [6,7,8]). The recent introduction of the Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC) [3] – jointly created by the WRI, C40 Cities, ICLEI, the World Bank, UNEP, and UN-HABITAT – aims to overcome the challenge of the much

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contested incoherent approaches between cities, and is designed to replace earlier protocols. However, systematizing different approaches and methodologies remains a challenge, in addition to the practical problems of widespread implementation. International consensus on methodologies for the accounting of cross-boundary emissions is currently sought.
Urban metabolism has a longstanding history and has made a major contribution to methods for accounting for material and energy flows, providing a basis for the optimization of the city "ecosystem" (see, e.g., [9, 10, 11, 12]). However, it has been limited by the lack of standardized methods and paucity of data. Due

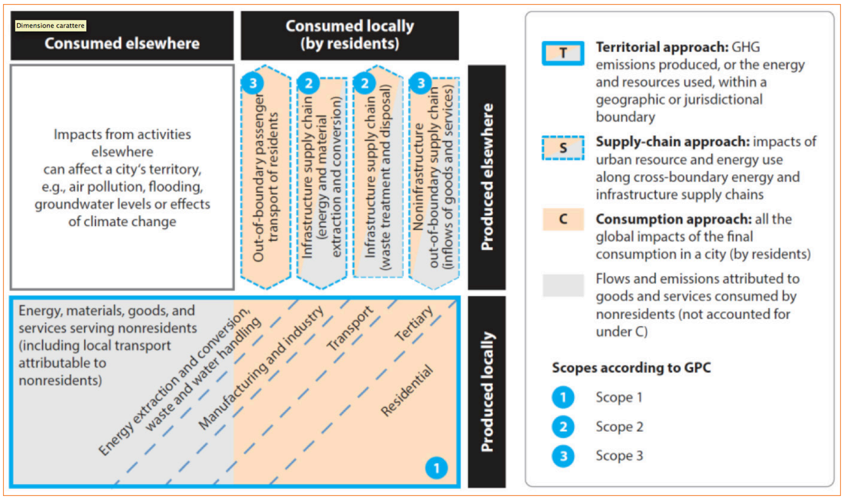
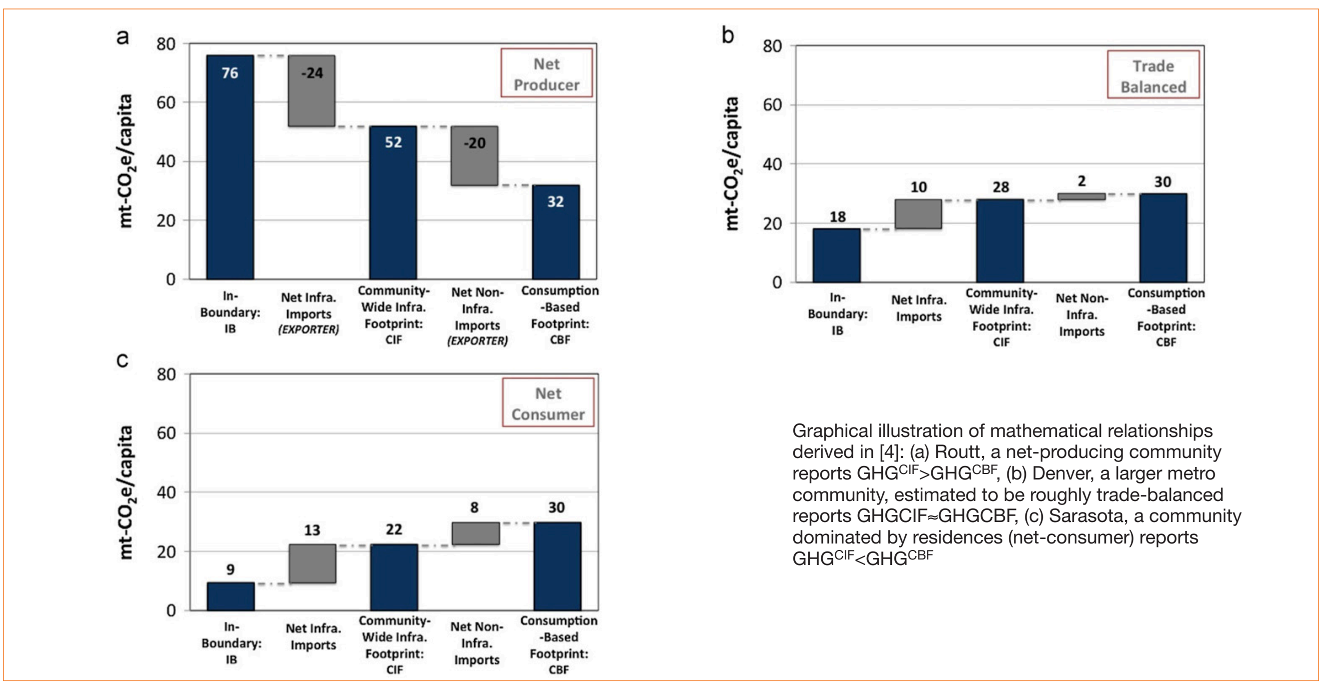


FIGURE 1 Approaches to accounting methods used to measure the environmental impacts of urban systems. The sectors within the city's territory (diagonal fields) provide goods and services that are either consumed locally (peach) or elsewhere (grey). The cross-boundary supply chains shown are examples, and their impacts may be associated with inflows (peach) and outflows (grey)
GPC stands for Global Protocol for Community-Scale Greenhouse Gas Emissions [3]
Source: [2]



Graphical illustration of mathematical relationships derived in [4]: (a) Routt, a net-producing community reports $GHG^{CIF}>GHG^{CBF}$, (b) Denver, a larger metro community, estimated to be roughly trade-balanced reports GHGCIF≈GHGCBF, (c) Sarasota, a community dominated by residences (net-consumer) reports $GHG^{CIF}<GHG^{CBF}$

FIGURE 2 City typologies according to GHG emission balances: net producers, net consumers, trade-balanced cities in the US
Source: [4]

to data intensity and complexity of this field, there are relatively fewer applications of the method than in the energy/GHG accounting field, and most studies lack repeated data collection over time, or limit themselves to the study of single flows.

Territorial-based approaches may help best in understanding urban and regional planning needs, supply-chain approaches may help to identify the role of the process chain, whereas consumption-based approaches may reveal policy needs for behavioral and macro-economic changes [13]. A complementary use of all the approaches is warranted.

A fundamental problem for all approaches is the definition of the urban system's boundary to use in the accounting. Cai and Zhang [14] exemplify this effect with a case study in the city of Tianjin (see Figure 3).

Conclusions

- The methods reviewed can not only aid in understanding of policy options by providing more transparency, but also affect the perception of responsibility for impacts.
- While the data situation is improving rapidly in the climate and energy fields, comprehensive data for quantifying urban resource flows is as yet rarely available. The availability of reliable data and standard protocols (such as the GPC) is greater in the GHG accounting field and continues to grow rapidly. This is likely a reflection of the greater interest and momentum that urban responses to climate change currently have on the policy agenda, in contrast to the aspects of a wider resource use.
- One promising field emerging in the literature is

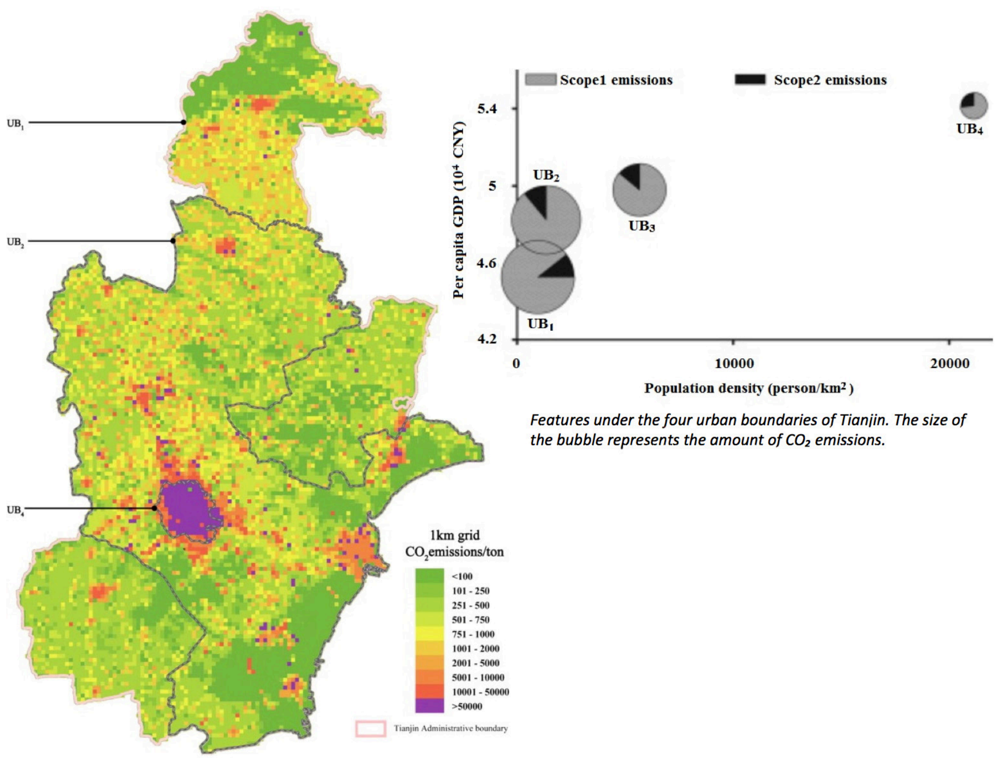


FIGURE 3 Impact of measurement boundary on GHG emissions. More densely inhabited central districts have 60% lower per capita emissions than the city's administrative area. Share of scope 2 is almost double in the city centre
Source: [14]

that of the measurement of synergies (co-benefits) and trade-offs between city sustainability goals.

- A universally accepted definition of what is "urban" is not practical, as cities in different countries exist in very different contexts. However, there is a need to delve deeper into the consequences of considering different boundaries (e.g., administrative vs. land-use) when carrying out research.
- Data collection involves costs and institutional requirements that are unknown or poorly researched in this area. Financially, the setting up of data collection systems by beneficiary cities should be considered over a timeframe of decades. Additionally, cities would benefit from joining national and international efforts to further develop databases usable at city scale, including subnational, multi-region input-output tables that resolve to finer geographical scales [15, 16].
- In both GHG accounting and the urban metabolism field we recognize a dominance of (existing) published research on large global metropolises, rather than on mid-size or small cities, which is where most urban growth is expected over the next decades. Moreover, studies that go beyond a limited number of city case studies are rare, and international comparative approaches are almost non-existent.

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Theme 3: Making low-carbon and resilient investments: A leverage to renovate the economy in crisis

Adequate financial flows are urgently needed in the near future to support mitigation and adaption efforts in order to meet the 2 °C stabilisation target and to prevent developing countries from locking in carbon intensive development pathways. Climate finance can play a significant role in mainstreaming climate challenges into sectoral policies and decision making at the global and local levels albeit the adverse contexts of economic crisis, common public debt (most OECD countries), environmental urgency and current climate negotiations. This includes the development of financial mechanisms supported by established institutions, public and private interests. It is therefore imperative that international negotiations should provide a framework to climate finance initiatives.

C. Cassen

Background

A "global peaking of GHG emissions" compatible with the 2 °C target demands a deep restructuration of the existing capital stock in developed countries and massive redirection of infrastructure investments in developing countries to prevent them from locking in carbon-intensive development pathways. Climate finance can play a significant role in the low carbon transition despite the fragile economic recovery in the OECD countries, constraints on public budgets, deleveraging in the banking system, and securing funding for the Green Climate Fund. Problems have been encountered at all scales of intervention, calling for the need to identify effective public funding mechanisms tailored to the specific requirements of climate change policy.
Three components have to be considered when dealing with climate finance:

- The re-orientation of existing 'mainstream' financial flows so that they support climate change actions across economies through new financial mechanism. Proposals for financing climate change mitigation and adaptation as well as the transition towards sustainable energy have been elaborated and should be taken into account.
- The involvement of both public and private stakeholders to foster long-term investment and innovation processes entailed by the transition to a low carbon economy.
- How climate finance can support low carbon initiatives and new forms of cooperation.

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Key findings

Three set of key findings:

A first set relates to the ***role of low-carbon and resilient investments to renovate the economies in crisis***

- Low carbon development will require significant changes in the way that economic and financial systems operate, for example by establishing a new financial mechanism which is able to redirect the funding of investments towards low carbon projects;
- Considering the adverse effects of previous policies (e.g., regarding urban planning/ energy dependency of households) in terms of social acceptability of Green tax reforms, climate finance by stimulating investments in low carbon projects could make taxes more palatable.

A second set relates to ***barriers and opportunities of financing/investing in mitigation and adaptation***

- Public funding mechanisms to support mitigation and adaptation efforts have shown to be ineffective in satisfying the short-term climate change agenda;
- More risk-sharing structures, involving both public and private stakeholders, are required to foster long-term investment and innovation processes entailed by the transition to a low carbon economy.

A third set relates to ***building consensus to support climate change policies***

- A broad participatory approach to develop climate action plans based on an iterative process is one way to integrate expert know-how, maximize transparency, acceptance and public engagement, and stimulate new cooperation schemes and joint approaches;
- Identifying the underlying social values that inform public attitudes to energy gives the opportunity to develop energy systems that maximize the potential for public engagement and consent.

A new financial mechanism is envisaged to redirect the funding of investments towards low carbon projects (LCP), as attaching a price to carbon alone does not efficiently spur the transition towards a LCS. This proposal should be incorporated as part of a general reform of the financial system. Climate policies for their part can stimulate sustainable and inclusive climate finance, in line with calls for a paradigm shift in climate negotiations in the Cancun Agreement. In the light of the world's glut of savings specifically earmarked for prudent investments, the mechanism proposed utilizes carbon pricing (based on an agreed notional price) to trigger a wave of low carbon investments throughout the world and release such savings, thus providing the lever for equitable access to development for developing countries and for a green economy in developed ones. This new financial system could be complemented with the implementation of environmental fiscal reform to foster the low carbon transition and a more inclusive growth.

The discussion addresses the barriers and opportunities for financing/investing in mitigation and adaptation. Although public finance is considered essential to implement climate change policies, public funding has proved to be largely insufficient, with major gaps in developing countries. Climate agreements are still key drivers of investment, yet effective policy implementation cannot be viewed as a mere reaction to regulatory pressure. In complement to established financing structures it is of overarching importance to mainstream climate change considerations into sectoral policies and decision making. Public-Private Partnership (PPP) can act as building blocks for comprehensive risk-sharing structures so as to convey

additional private funds aimed at fostering innovation over the long term towards a sound transition to a low carbon economy.
Additionally, we point out that policies and measures can be designed and implemented based on broad, innovative participatory approaches aimed at maximising transparency, acceptance and public engagement. Climate change and energy policies can also be shaped based on underlying public values, which express preferences over future energy system configurations. Local low-carbon initiatives containing (some of) the basic features of a broader and more complex transition to environmentally sustainable ways of producing, consuming, and distributing energy within Europe (the so-called "Anticipatory Experiences") show that a system of risk management is crucial when dealing with the myriad forms of opposition, conflict, tension and resistance that can emerge in the energy transition process.

Way forward

The works point out that it is of overarching importance to consider simultaneously the issues of carbon emission mitigation, financial system stability, and global economic growth objectives. It is not possible to await the re-emergence of a stable growth regime before making decisions about climate policies. In the absence of rapid redirection of their investment dynamics, emerging economies will soon be locked into carbon-intensive development pathways, which will re-ignite the argument for inaction in developed countries, with deleterious consequences for all. Current works and actions can be oriented in three main directions:

- ***Improving the evaluation of climate finance needs***. Huge literature is emerging on the issue but most climate and energy scenarios are not designed for the finance sector. Thus, while including many useful assumptions, they need to be 'adapted' to inform investment roadmaps, in particular to other industries important in terms of sustainable energy / energy efficiency.
- ***Improving the design of new financial devices/mechanisms able to redirect investments towards the low carbon transition***. In the emerging body of literature on the finance-climate nexus, there is a significant need to define what a sustainable asset and a sustainable investment portfolio is, and to develop assessment frameworks in order to allow financial institutions to measure their 'performance' and set progress targets vis-à-vis energy-climate goals. Notwithstanding the vast literature on the principles of PPP management, only limited efforts have been made to investigate existing business models capable to attract the private party into investment activities, characterized by high public interest and higher business risk, like the projects on climate mitigation and adaptation.
- ***Fostering the dialogue on sustainable energy investment between investors and policy-makers***:
  - At the local level, the social dynamics of low carbon initiatives have to be considered in order to provide adapted and shared financial solutions.
  - At the global level, climate policies can stimulate sustainable and inclusive climate finance. A broader process of reflection on climate finance and sustainable energy for all has to be launched in view of contributing to the process which will lead to the Paris COP 21 in late 2015. A future agreement in Paris could hence provide a framework for this new system of financing.

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Local experiencies in energy transition

Energy security has recently become a policy priority for the European Union due to growing concerns about environmental challenges and the fact that EU covers about half of its energy needs through imports. Policy-makers in Europe are struggling with the need to achieve energy security and promote a transition towards decarbonised energy sources without undermining wellbeing and patterns of consumption. The collaborative MILESECURE-2050 VII Framework project provides scientific knowledge on these issues and develops models at the European, national and local scales. This article focuses on the analysis developed at the local scale, related to a set of case studies on energy/ social systems in transition. The methodological foundation of this work is shortly illustrated as well as the main findings. These highlight the leading role of the human factor in supporting the transition toward a low carbon society.

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P. Lombardi

Introduction

Security of supply, sustainability, and competitiveness are the three complementary pillars of the European energy policy [1], and have been translated into the main goals of the more recent EU energy strategy [2]. However, while the EU has successfully institutionalized a climate policy, it has not yet been able to formulate a successful energy security policy, although the importance of energy security has been growing in the political agenda as a result of various factors such as, for example, accidents associated with gas imports from Russia and the rise of fossil fuel prices. According to European Commission [3], "if not properly designed, policies aimed at the reduction of GHG emission may affect the resilience of the energy system and its ability to tolerate disturbance and deliver stable and affordable energy services to consumers".

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In addition, energy security is "frequently used to justify various policies or actions at the same time, with far reaching interventions in the market often without any economically rational justification" [4].

The EU FP7 collaborative project "MILESECURE-2050 – Multidimensional Impact of the Low-carbon European Strategy on Energy Security, and Socio-economic Dimension up to 2050 Perspective" provides new scientific knowledge on these issues and the general objective of regional, territorial, and social cohesion by developing new European models, which support and enable energy security at the European, national, and local scales. More specifically, the project aims to understand and overcome the political, economic, and behavioral traits and trends that led Europe to its difficulties in reducing fossil fuel consumption, and in diversifying its energy balance at rates which guarantee European energy security at the horizon 2050, reduce the threat of climate change, and diminish the risk of an energy gap in the coming decades. The 2050 timeframe is used to assess the legitimacy and efficacy of policies in terms of capacity for societies to transition to energy security, and to consider the long-term, socio-economic impact of such options.

To better understand the current situation, the MILESECURE-2050 research team adopted the definition by which a secure energy system is one evolving over time with sufficient capacity to absorb adverse uncertain events, so that it is able to continue satisfying the energy needs of its intended users, with "acceptable" changes in volume and price.
Potential threats to energy security were defined from three perspectives: temporality, provenance and society [5]. First, transient disruptions or shocks based on their temporality, such as extreme weather conditions, accidents, terrorist attacks, or strikes can be differentiated from more enduring pressures, or stresses which compromise the long-term ability to develop adequate physical and regulatory conditions to deliver energy supplies to end-users. Secondly, the provenance of threats was defined to allow a distinction between internal and external threats that directly inform the types of strategies that can be put in place for different situations. The third perspective is the role of society, which is crucial to a secure energy system as part of a transition towards a low-carbon economy. The whole process has to be understood as "societal"; as an organic process that is both the result of intentional actions and the product of the interactions of multiple actors and of the intended and unintended consequences of these.

Methodology

In order to build possible scenarios towards the development of low-carbon societies, the MILESECURE-2050 project has assumed a number of methodological concepts from the transition management theory, the path dependency theory and the vision of creative destruction developed by Schumpeter [6]. Such theories are relevant to examine transitional societal processes based on technological changes, and how these changes impact the transitional processes. Future scenarios can be based on complex interactions at different levels of society as a whole between technology (innovative vs end-of-pipe), the social nature of society (individual vs collective), environmental progress, economic situations, and political choices.
The Transition management theory is a concept for developing a paradigm shift within a society, by guiding it through a gradual and ongoing process from one equilibrium to another [7]. Within the transition management theory several approaches for examining societal transitions towards energy security exist, such as socio-technical transitions research, technological innovation systems, and co-evolutionary dynamics.
Socio-technical transitions research combines technical, social, and historical analyses to examine past- and present-day societal transitions, and uses a framework of three different levels: landscapes, socio-technical regimes, and technological niches [8, 9]. The technological innovation systems approach differs from the socio-technical transitions idea in regard to long-term socio-technical changes in that it focuses on understanding innovation from a systems perspective, as opposed to the interaction between technological and social elements. The approach claims that firms and actors innovate mostly in response to incentives coming from the wider innovation system. Hence it studies feedback mechanisms and interactive relations used in the development and application of new knowledge by science, technology, learning, production, policy, and demand. Finally, co-evolutionary approaches seek to explain long-term process of change, claiming that dynamics are determined by casual influences between mutually evolving systems.
In addition to the transition management theory, the concept of creative destruction, as visualized by Schumpeter in economic innovation, argues that processes may need disruptive processes of transformation that accompany radical innovation in order to make efficiency gains [6].
MILESECURE-2050 builds upon and expands the above mentioned approaches used to understand and explain societal transitions, and ultimately demonstrates how this new knowledge base can be applied to European policies. Currently, while these concepts are in a process of development, they do not fully explain nor allow for the induction of a societal energy transition. Indeed, in many ways current research places an unequal focus on a limited number of factors, be it the individual, society as a whole, technology, history, political, economic or other factors. A holistic approach to studying societal transition is instead needed. MILESECURE-2050 takes the approach that multiple interrelated and co-evolving perspectives (environmental, geopolitical, lifestyle and cultural, political, technological, economic and combined) must be examined to explain possible modes for societal transition. And both present day and

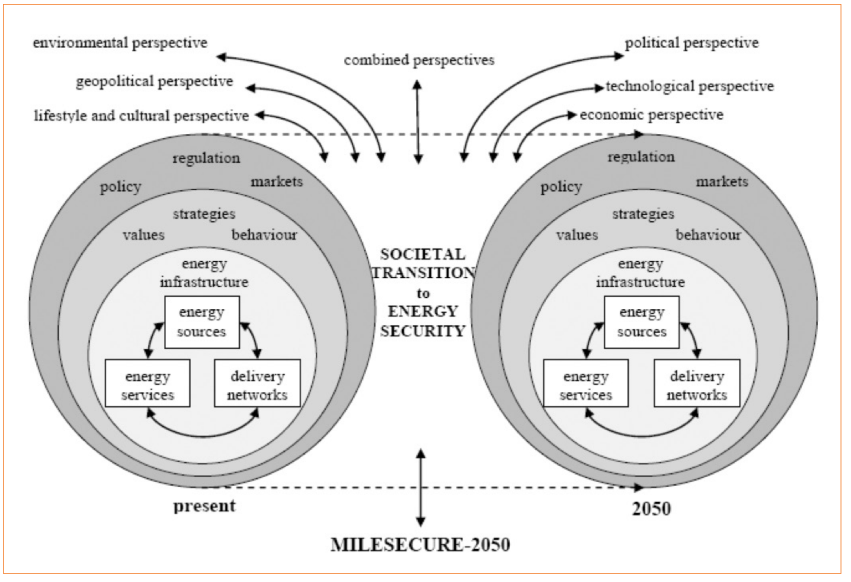

FIGURE 1 Multiple perspectives on societal transition
Source: MILESECURE-2050 DoW, 2012

historical factors play a critical role. These perspectives can be viewed independently or in a combined manner, and each perspective can be used to understand certain aspects of how a society can change, though a society ultimately moves down a path according to elements from all perspectives (see Figure 1). MILESECURE-2050's hypothesis is that while societal transition is dependent upon changes within these independent perspectives, it is ultimately the combination of these perspectives which leads to societal transition (or stability). In this context, it is possible that multiple pathways for transition exist, or can be created by a number of various combinations.

Therefore, a major objective of MILESECURE-2050 has been the identification of both the options and factors influencing the energy transition processes and its societal effects. This has required the evaluation of a set of concrete experiences on energy transition at the local level, named Anticipatory Experiences (AEs), that anticipate the basic features of a broader and more complex transition to environmentally sustainable ways of producing, consuming, and distributing energy within all European societies. The approach adopted considers the AEs as energy systems in transition and, then, as social systems in which energy management is considered primarily as a social world that is changing.

Starting from 1500 projects found in different databases both of the European Commission and independent bodies, 90 AEs from 17 different European countries were selected, concerning different sectors (energy production, but also mobility, housing, services and industry) [10, 11]. They are all local experiences, but they have different size: from small towns to big cities.

All experiences developed environmentally sustainable ways of producing, consuming and transporting energy. Their anticipatory character may be assimilated to their ability, at the present time, to take decisions and develop practical solutions to resolve issues related to the future, first of all those of climate change and the depletion of "carbon" energy resources. Because of their anticipatory character, AEs have been considered as a basis for the empirical study of what might happen in the context of energy systems in transition.

Results

The main result of the analysis of AEs is that energy transition does not seem to present itself as a gradual change. In fact, it does not take the form of the mere penetration into society of new greener and efficient technologies (technological drive); nor it is "merely" the introduction of new rules or restrictions that citizens must accept (normative drive or consent drive); neither it consists only in new attitudes toward consumption (and savings) to be interiorised by the population (ethical or lifestyle drive). Each of the above drives is present in the experiences considered, but all three are based on a vision of change in which both the social and the anthropological/individual dimensions are relegated to a function of "acceptance" of measures and decisions that come from the outside.

Although these visions of energy transition recognize the importance of social and anthropological impacts and feedback, they tend to consider the human factor as a mere receptor, not an agent of change. Therefore, what is actually lacking is the perspective of human agency, as a constitutive element of the transformation of the energy systems.

In short, the human factor becomes the driver of energy transition in at least three distinct levels:

i The set-up of energy production and consumption becomes more visible and closer to citizens. In this framework we witness citizens gaining the ownership of the means of energy production; the spread of new technical skills; the activation of social networks for the installation and maintenance of low-carbon technologies.

ii The energy issue becomes a direct interest of citizens who actively participate in the regulation, orientation, management (also in economic terms) and monitoring of measures and policies of energy transition.

iii There is a strong personal effort on the energy transition through an intense emotional involvement; a highest attention to several aspects of everyday life (food, waste collection, energy consumption, body care and health); an increased use of physical effort in the field of mobility (but not only), i.e. through the use of bicycles or with an increased inclination to move on foot or by public transport.

Conclusions

While the leading role of the human factor is a chance to concretely put to effect a transition toward a low-carbon society, the MILESECURE-2050 research team has observed that it can be accompanied by the emergence of new risks such as: conflicts, tensions, resistances and oppositions that may put energy security in danger. This means we are facing a new risk typology which needs to be taken into account in the governance of the energy transition.

In order to deal in an appropriate manner with this "leading role" of the human factor both in respect with energy transition and with the risk to security, a paradigm shift is needed, both in the study and in the governance of energy systems in transition.

In conclusion, the adoption of a "human energy" approach is proposed, which is able to properly consider the leading role of the human factor in the heart of the energy systems themselves.

Acknowledgements

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A monetary plan for upgrading climate finance and support the low-carbon transition

This article examines how carbon finance can be part of a general reform of the financial system. Climate policies can indeed stimulate a sustainable and inclusive climate finance, in line with the call of the Cancun Agreement for a paradigm shift in climate negotiations. The mechanism described in this article is based on the adoption by Parties to the negotiations of a social value of carbon to trigger a wave of low-carbon investments in the world. Central banks offer credit lines for commercial banks backed by this social value of carbon, which are then used to cut the risk to invest in low-carbon investments. A future agreement in Paris next year should support this type of mechanisms.

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Introduction

The Cancun conference (COP 16) statement for "building a low-carbon society that (...) ensures continued high growth and (...) an equitable access to sustainable development" [1] clearly calls for a paradigm shift in the climate negotiations. This would depart from an adversarial game about sharing the remainder of a global emissions budget to a cooperative exercise linking climate and development policies, in recognition of the diversity of domestic agendas. To serve this new paradigm, the 2010 Cancun Conference establishes a Green Climate Fund (GCF), devoted in part to funding low-carbon development projects (LCPs) in non-Annex 1 countries, and their adaptation and capacity build-up. Yet, there is a huge gap between the USD 100 billion per year that Annex 1 countries have pledged for the GCF by 2020, and the USD 15 billion per year envisaged by EU member States in a first step. The World Development Report [2] estimated the financial needs for mitigation and adaptation at USD 140–175 billion per year by 2030 (this actually corresponds to USD 264–563 billion of upfront financing needs). A "global peaking of GHG emissions" compatible with the 2 °C objective [3] requires indeed a deep restructuration of existing capital stock in developed countries, and massive redirection of infrastructure investments in developing countries, to avoid their lock-in in carbon-intensive development pathways.

This article first examines how climate finance can play a significant role in the low-carbon transition, albeit in an adverse context. It then presents a mechanism bringing a way-forward to continuing world development through massive low-carbon investments based on previous works [4, 5, 6, 7] before examining the conditions required to include it into the negotiations.

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Turning the constraints of an adverse context into a fulcrum for action

The Kyoto Protocol prescribed a single type of mitigation commitment for developed countries (absolute, economy-wide emission targets), which was interpreted by most economists as preparing a global carbon market generating the same carbon price for all individual carbon emitters [8]. However, carbon price alone is not sufficient to redirect investments towards a low-carbon transition. Its impact can create adverse effects for high dependent fossil fuel countries, in particular emerging and least developed countries (a 50 USD/t-CO_2 for instance doubles the price of cement in India). Developed countries will also probably be reluctant to accept to compensate the losses in these countries.

Against this background and pursuing the objective to provide equitable access to development, it is necessary to envisage complementary financial systems to redirect investments towards the low-carbon transition. The GCF is one of them but its implementation occurs in an adverse context. First, pressures on public budgets in Annex-1 countries (the industrialized countries which committed to emission reduction objectives under the UNFCCC convention) after the financial crisis cast doubts about the amount of funds the GCF will effectively mobilize. Second, the financial flows for a transition towards the 2 °C objective cannot be provided by the GCF alone. Third, the context of "depression economics" [9] and of re-equilibrium of economic forces at the global scale undermines the political acceptability of large North/South transfers. Fourth, in this context, many Annex-1 countries will be reluctant to really engage their own transition towards decarbonization, because of social resistance to explicit or implicit carbon pricing, of concerns about competitiveness and employment, and the priority given to debt management and banking system stability.

Low-carbon investments are currently not blocked by a lack of available financial resources rather by the over-cautiousness of financial intermediation over the two last decades vis-à-vis long-term investments and by its preference for liquid assets. This behavior raises specific barriers against low-carbon projects (LCP), which look riskier than business-as-usual investments due to higher upfront costs, lack of a carbon-prices and missing records on their financial performances.

From our perspective, the challenge is to reduce the investment risks of LCPs by sending a credible signal to investors about the "social value of avoided carbon emissions" without hurting the existing capital. In so doing, climate finance could provide a lever to a sustainable economic recovery if it results in efficient intermediation bridging long-term assets and short-term cash balances. Based on this pre-requisite, it becomes possible to build an innovative financial device that is apt to: a) lower investment risks of low carbon projects, b) redirect dramatically world savings towards climate finance, c) surmount both the public budget constraints and the vulnerability of the banking systems through a form of carbon-based monetary instrument.

Rationale for carbon-asset-convertible carbon certificates (C4) mechanism

Along with taxation, public credit is one of the few possible macroeconomic "lubricants" to major economic and technological transitions. Several monetary proposals have been suggested, including the use of Special Drawing Rights (SDR) issued by the IMF [10], and the implementation by central banks of "green quantitative easing policies" [11]. Each of these proposals seeks to leverage private climate finance without direct public money disbursement. Yet, in the absence of a carbon price they are not sufficient to make most low-carbon projects more attractive than their high-carbon alternatives.

The mechanism presented here (C4) is designed along the same lines but with a carbon-value mechanism improving the LCPs return on investment and reducing their risk by including a social value of avoided carbon emissions (SVACE).

Its basic principle, as shown in Figure 1, consists in central banks injecting liquidities into the economy, in the same fashion as the "unconventional monetary policies" implemented after 2008, but provided

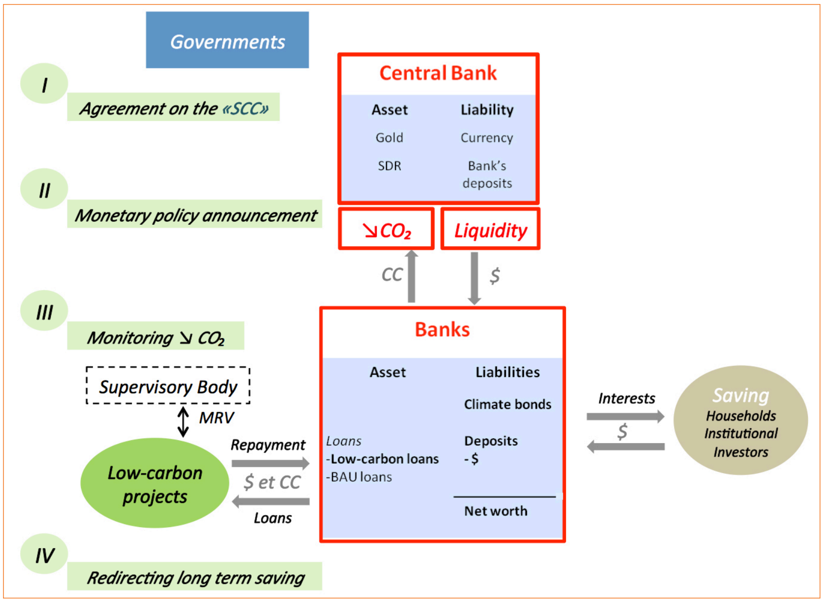

FIGURE 1 The key elements of a climate-friendly financial architecture

that the money is used to fund LCPs. Governments provide a guarantee on a given amount of "carbon assets" that will allow central banks to open credit lines. The reimbursement of the credits are made by "carbon-certificates" (CC) certifying the reduction of GHGs emissions, valued at the pre-determined SVACE and ultimately swapped into carbon assets. The Central Banks announce that they will accept the CC as repayment after due verification of the actual reduction of investments by an independent body. These CC are then converted into carbon assets while entering the central bank's balance sheet. This comes to a money issuance based on the guarantee that "something of value" has been created in the form of low-carbon equipment. Banks or specialized climate funds can use the carbon-based monetary facility to back highly rated climate-friendly financial products, such as "AAA" climate bonds, in order to attract long-term saving. Institutional investors could be interested in safe and sustainable bonds instead of speculative financial products for both ethical and regulatory purposes. Part of the CC could also be used to scale up the Green Climate Fund in order to secure multilateral cooperation around climate policies and the funding of NAMAS (Nationally Appropriate Mitigation Actions) [12] without crowding out overseas assistance by each individual country.

From principles to climate negotiations

The current process of climate negotiations is supposed to achieve a legally and universal agreement on climate at COP21 in Paris which also solves the issue of financing the low carbon transition. The mechanism described above could be included in a climate regime adopted in Paris in order to align climate and development policies without abandoning the 2 °C stabilization objective provided that [13]:

a) it relies on voluntary initiatives by a "club" of countries [14];
b) it is not seen as a full-fledged global architecture but as a support to a diversity of bottom-up initiatives and as a way of hedging against the economic and political costs of their fragmentation;
c) it incorporates no penalty for a defaulting country other than being *de facto* excluded from the access to investments facilities provided by the system.

To meet these conditions the C4 mechanism necessitates an agreement of volunteer countries around a common set of principles agreed within the UNFCCC and periodically adapted:

1. A mutually agreed SVACE for the sake of the overall consistency of decentralized initiatives.
2. Rules to determine the "quantity of carbon assets" issued by central banks (and guaranteed by their states) and the "access rights" of the recipient countries to the opened credit lines.
3. A credible Monitoring Reporting and Verification (MRV) process under an Independent International Supervisory Body, in charge of determining the conformity of the projects to the NAMAS presented by the Parties, attributing carbon certificates to projects and certifying their completion.

FINANCE

4. A "share of the carbon assets" considered as a contribution to the GCF. This will then support the financing of NAMAs considered as implementation tools to achieve the INDCs [15].

Conclusions

The journey to COP 21 will be successful only if it lays the foundation of a new global "social contract", which would include the protection of our global commons. Upgraded climate finance has to be part of this contract. This can happen if it also contributes to equitable access to development and to long-term investment adapted to a low-carbon economy. The C4 mechanism provides the opportunity, not to be missed, for a large alliance around climate policies. In addition to LCPs, this system could support any recognized "club" of actors in developing initiatives recognized by the UNFCCC. This could be the case for sectoral agreements in energy-intensive industries and for initiatives taken by cities and local authorities to improve the synergies between climate policies and local development. In addition, as this carbon-based monetary instrument embarks economic partners in a forward contract, this device would create a reference for carbon pricing mechanisms, progressively facilitating their social acceptance.

Acknowledgments
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[15] Parties decided at COP19 in Warsaw to invite all Parties, developed and developing countries, to prepare "intended nationally determined contribution" (INDC) for the period post-2020 by the first quarter of 2015.

The Role of Public-Private Partnerships (PPPs) in Scaling Up Financial Flows in the Post-Kyoto Regime

The climate change agenda requires adequate financial flows in the near future in order to support mitigation and adaptation efforts and the low-carbon development of emerging and new economies. The potentials of Public-Private Partnerships (PPPs) – as a risk-sharing structure bringing private funds on the table – are presented in the new climate change context. This article discusses and provides recommendations on PPPs as a good financing model to mainstream climate change into the development agenda of emerging and less-developed economies.

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Introduction

The 17th UNFCCC Conference of the Parties (COP), held in Durban in 2011, reaffirmed the urgency of adequate financial flows in order to support both mitigation and adaptation efforts. On this occasion, convened Parties confirmed the commitment to reach the financial goal of USD 100 billion investments per year by 2020 from developed to developing countries.
For the first time this year, in its Fifth Assessment Report IPCC includes a specific chapter on cross-cutting investment and finance issues and states, with medium evidence and high agreement, that: *Resources to address climate change need to be scaled up considerably over the next few decades both in developed and developing countries*.
Recognizing that a global effort is needed to enhance ambition and close the current gap effectively, participants in the COP highlighted several ways in which this could be achieved, including the role of national governments, international cooperation, the private sector and how to mobilize resources.
In a period of shrunk public resources, the emphasis given to the potential role of the private contribution appears obvious.
As a form of cooperation between the private and public sectors, the public-private partnerships are not a new phenomenon or a new way of doing public policy. Incorporating the technical expertise, innovation, financial capability, cost-effectiveness and economic efficiency of the private sector when providing public goods and services is not an idea of the last century.
The involvement of private sector in the traditional public policy investment has encountered different degrees of acceptance and resistance during the world development history. There has been a golden age of concessions contracts in Europe during the century following the industrial revolution; it was the time of the expansion of cities, the development of public services for water and energy supply, and the construction of big transport networks.

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PPPs are strictly connected to the infrastructural development of countries. Countries like Italy, Spain and France, they have all utilised the PPP model in order to develop their national transport system, the quality of which is often used as criterion to judge the country's competitiveness. Data from the Private Participation in Infrastructure (PPI) project database of the World Bank and the Public-Private Infrastructure Advisory Facility (PPIAF) shows a steadily growth of investments in infrastructures in the developing countries (Fig. 1).
Notwithstanding the low recovery faced by the developed countries, developing nations are expected to continue to grow and will need massive investments in energy, urban systems, transport, agriculture. There is scope for developing countries to invest in a low-carbon future without sacrificing their growth.
This article focuses on PPPs opportunities in developing countries and on the role that PPPs can play in meeting their development goals.

The PPPs data analysis

In order to present the current evolution of PPPs we used the most comprehensive database available, the Private Participation in Infrastructure (PPI) Database (http://ppi.worldbank.org/index.aspx). The PPI Database is managed by the World Bank and the Private-Public Infrastructure Advisory Facility (PPIAF). The PPI database offers a collection of more than 6000 infrastructure projects in developing countries. Its purpose is to identify and disseminate information on private participation in infrastructure projects in low- and middle-income countries, as classified by the World bank, recording data on the contractual arrangements used to attract private investment, the sources and destination of investment flows, and information on the main investors.
We analysed a representative sample of 4324 PPP projects operating in sectors that are affected by climate mitigation and adaptation policies, such as the energy, water and transport sectors. The selected sample include 4,324 projects for total investment commitments of USD 1,212,935 million (see figures and tables below).

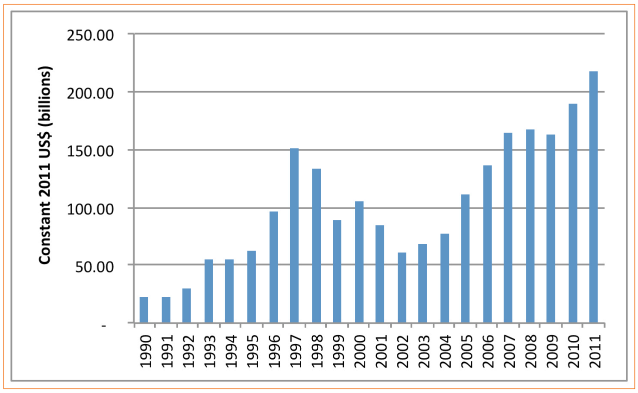

FIGURE 1 Investment commitments to PPI in developing countries, 1990-2011

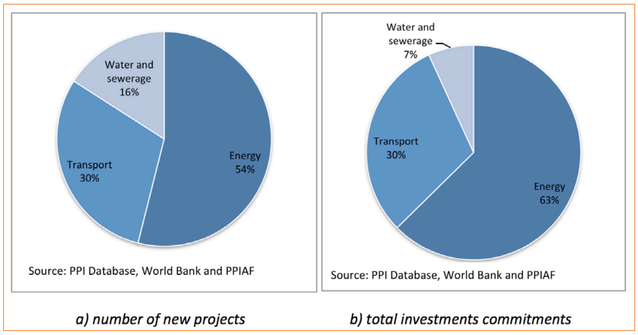

FIGURE 2 Total PPPs sample by sector
Source: PPI Database, World Bank and PPIAF

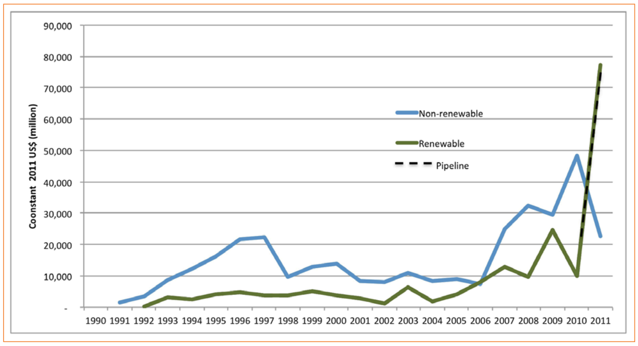

FIGURE 3 Renewable and non-renewable PPP energy projects in the electricity generation segment (total annual investment commitments,including pipeline projects)
Source: Authors sample based on PPI Database, World Bank and PPIAF

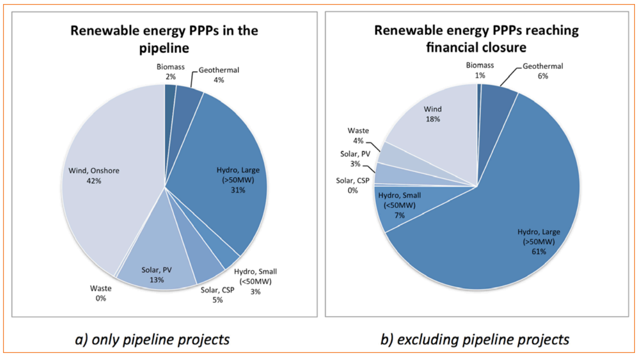

FIGURE 4 PPPs investments in renewable energy generation by energy sources
Source: Authors sample based on PPI Database, World Bank and PPIAF

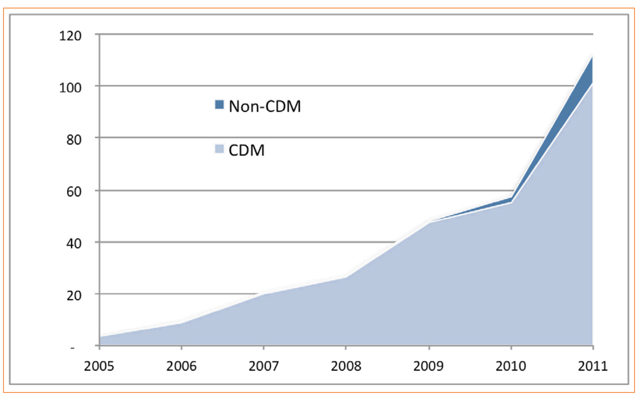

FIGURE 5 Installed capacity (GW) of PPP and CDM projects in renewable energy in 2005-2011
Source: Authors sample based on PPI Database, World Bank and PPIAF

As expected, in terms of numbers of projects the energy sector represents by far the largest share of the sample, followed by the transport sector (Fig. 2).
The in-depth analysis of trends and characteristics of the selected sample provided us with the following main findings:

- The analysis performed of the two decades panel data presented global evidence that international climate agreements are among the key drivers of PPP energy investments in developing countries.
- In particular, the energy sector represents an important arena for the PPP private players; these, in turn, can represent an important resource for the policy makers involved in the deployment or in the definition of a developing country's climate agenda.
- Future energy investments in electricity generation segment in the renewable sector will exceed investments in the fossil fuel energy sectors, thus showing the evidence of a progressive switch toward low-carbon sources of energy (Fig. 3).
- PPPs in renewable energy have been traditionally used for the construction of large hydro-projects (>50MW); looking at the future trend (Fig. 4), private investors in pipelines projects seem to prefer to be engaged in PPPs in the wind power sector, followed by large hydropower plants. Results are consistent with the Energy Technology Perspectives drawn by IEA, which foresees a shift from hydro- to wind power in the renewable sources development in non-OECD countries.
- The presence of PPP CDM projects shows the role played by the carbon market in stimulating private investments in the renewable sector (Fig. 5).

	Energy		Transport		Water and sewerage		Total	
PPP contract type	No. of projects	Total Investment commitment	No. of projects	Total Investment commitment	No. of projects	Total Investment commitment	No. of projects	Total Investment commitment
Concession	202	125,406	792	204,082	295	52,943	1,289	382,431
Partial divestiture	290	116,420	57	18,909	24	11,203	371	146,532
Greenfield project	1,823	517,548	428	141,191	318	17,425	2,569	676,164
Lease contract	17	494	26	5,760	52	1,554	95	7,807
Total	**2,332**	**759,867**	**1,303**	**369,941**	**689**	**83,126**	**4,324**	**1,212,935**

TABLE 1 Selected PPPs projects by contract type and sector (number of projects and total investment commitments in constant 2011 USD million)

Region	Energy		Transport		Water and sewerage		Total	
	No. of projects	Total Investment commitment	No. of projects	Total Investment commitment	No. of projects	Total Investment commitment	No. of projects	Total Investment commitment
East Asia and Pacific	745	182,100	352	102,184	410	39,159	1,507	323,443
Europe and Central Asia	408	113,710	58	23,418	33	4,170	499	141,299
Latin America and the Caribbean	631	249,786	461	151,200	212	35,046	1,304	436,032
Middle East and North Africa	38	28,520	27	7,873	13	4,033	78	40,426
South Asia	377	153,755	315	68,309	7	391	699	222,455
Sub-Saharan Africa	133	31,995	90	16,958	14	327	237	49,280
Total	**2,332**	**759,867**	**1,303**	**369,941**	**689**	**83,126**	**4,324**	**1,212,935**

TABLE 2 Selected PPPs projects by region and sector (number of projects and total investment commitments in constant 2011 USD million)
Source: Authors sample based on PPI Database, World Bank and PPIAF

Status	Energy		Transport		Water and sewerage		Total	
	No. of projects	Total Investment commitment	No. of projects	Total Investment commitment	No. of projects	Total Investment commitment	No. of projects	Total Investment commitment
Canceled	63	17,402	61	26,132	47	23,464	171	66,998
Concluded	39	6,633	46	3,712	15	705	100	11,050
Construction	447	194,694	242	82,161	169	8,756	858	285,611
Distressed	27	24,560	12	4,183	12	5,731	51	34,474
Merged	55	149	-		-		55	149
Operational	1,349	461,551	942	253,752	446	44,470	2,737	759,774
Under development	352	54,878	-		-		352	54,878
Total	**2,332**	**759,867**	**1,303**	**369,941**	**689**	**83,126**	**4,324**	**1,212,935**

TABLE 3 Selected PPPs projects by status and sector (number of projects and total investment commitments in constant 2011 USD million)

As a complement to the numerical analysis we analysed best and worst case studies, which helped us to provide further recommendations:

- The climate change issue shall be mainstreamed into the PPPs decision making process.
- Climate policy instruments shall include PPPs to promote the right investment for the right objective.
- The integration of climate and PPP communities and practices shall be promoted.
- A better integration of databases, and the creation of a specific climate PPPs focus would help future research and dissemination of the lessons learned.
- Climate does not change PPPs good governance rules.

Conclusions

There is a vast literature on PPP's management principles on one side, and a huge literature is emerging on the climate finance needs, on the other. However, if we exclude the today mature discussion on the Kyoto Protocol market-based mechanisms, only limited efforts have been made to investigate existing business models capable to attract the private party into investment activities, characterised by high public interest and higher business risk, like the climate mitigation and adaptation projects.

The PPP business model, by its nature, brings private and public parties together in a long-term formal union, where both parties cooperate during the whole life of the project. Such form of cooperation therefore represents a good framework in order to involve the private sector (usually acting with a shorter time frame) in climate-related investments that require a long-term perspective.

PPPs – which have been extensively used in the past to promote the countries' infrastructure development – today represent an interesting business model that needs to be more extensively explored in its capacity to serve the implementation of the climate mitigation and adaptation agenda of developing nations.

In the near future, policy makers will take more and more into account the opportunities offered by PPPs to best combine the public and private interests, while the climate action plans will represent for private investors a new "good business" opportunity to bring their ingenuity and innovation.

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The participatory process to a low-carbon economy in the German state of NRW

This article gives a short overview of the specific approach of the participatory development of the climate protection plan in the German state North Rhine-Westphalia. It will start by discussing the motivation for the specific setting; then it will highlight the methodological approach and will briefly show the main results; additionally it will particularly reflect the added value of this complex process. Last but not least, the lessons learned by this process will be specified and discussed on whether and how they can be transferred.

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Introduction

The implementation of the intended energy transformation pathway in Germany ("Energiewende") is a complex process and consists of various challenges. Achieving the targets requires more or less a complete reorganization of the energy system, which has to be implemented within only a few decades and with a strong focus on deployment of renewable energies and energy efficiency improvements. Thus, the "Energiewende" is not only a technological challenge (particularly with regard to the system integration of renewable energies with a variable supply characteristic), but goes along with infrastructure requirements, a necessary change of investment characteristic, a political challenge (e.g. better integration of different policy levels: European Union, Germany, States, regions and cities), innovation challenge (the need for system innovations linking technological innovations, smart infrastructure solutions with social innovations, e.g. new business ideas, in a proper way), and last but not least a social challenge (e.g. public acceptance).

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Methodology and ongoing activities

With regard to the social challenge, participation plays a key role. It is not only the on-site discussion on the project level, but also the question of how to involve people already in the planning and concept development phase. Against that background, the state of North Rhine-Westphalia (NRW) – the biggest state in Germany, comprising the highest amount on fossil fired power plants and energy-intensive industries in the country – started to develop the so-called "Klimaschutzplan" (climate protection plan) as broad participatory process. With more than 400 different stakeholders (coming from energy utilities and industry as well as from NGOs, labor unions, consumer associations) amongst others, the following was discussed in a very systematic process over a two-year period:

- which technologies are appropriate to contribute significantly to ambitious GHG mitigation targets (long term perspective 2050);

- how these technologies can be linked in consistent pathways for the energy system;
- what impacts can be expected when realizing the pathway (e. g. economic impacts, employment effects, security of energy supply); and
- what policy instruments are available to support the implementation process and empower the relevant stakeholders.

The process was based and triggered by a climate protection law (Climate Protection Act) of the NRW state, where concrete mitigation goals for greenhouse gas emissions have been fixed for 2020 and 2050 with -25% and -80%, respectively, in comparison to the 1990 level. There have been a number of various reasons why NRW government decided to follow a participatory process. First of all a maximum of transparency should be guaranteed, public acceptance should be achieved and public engagement triggered. Further goals are the creation of an appropriate implementation culture, the stimulation of new cooperation schemes and joint approaches (e.g. between industry and NGO), as well as the integration of the external competence of the stakeholders. Against that background, the stakeholders involved in the process become pro-active members of the process and can help to shape the future energy system of the state.

The tasks for the climate protection plan process can be described as follows:

- specification of central (technological, infrastructure and behavioural) strategies and needs to achieve the "Energiewende" goals at state level;
- identification of relevant system interdependencies and implementation barriers between relevant strategies;
- bundling of strategies and measures in consistent scenarios/pathways showing how the climate protection goals outlined in the Climate Protection Act can be achieved;
- linking of mitigation and adaptation strategies and measures;
- specification of the climate protection contribution: temporally, sectorially and regionally;
- specification of the necessary support for all stakeholders to implement GHG mitigation measures and to adapt to climate change.

The state government, in cooperation with an accompanying scientific institute and a communication agency, conducted a complex process comprising a stakeholder platform organized along six working groups (energy conversion; energy-intensive industry; construction; trade and commerce; transport; agriculture and forests; private households) and a steering committee, dealing with cross-cutting issues and potential conflicts (Fig. 1).

In addition to this stakeholder platform the results of the process have been discussed in various workshops with local authorities, enterprises and in selected citizen dialogues. Furthermore, an online-forum was established to integrate a broader spectrum of stakeholders in the process.

Within the process, the stakeholders developed ten scenarios in total, describing possible pathways being able to significantly reduce

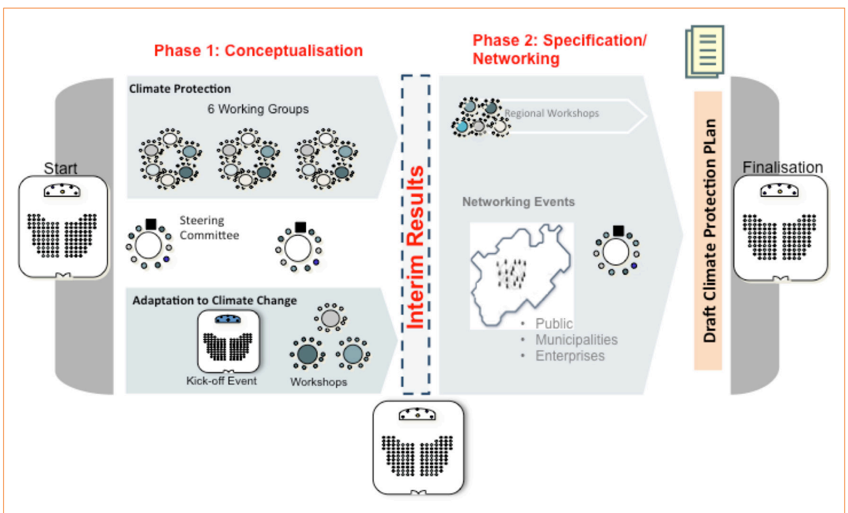

FIGURE 1 Schematic description of the NRW climate protection plan process
Source: IFOK, Wuppertal Institute, Presentation material for the NRW "Klimaschutzplan" Berlin, Wuppertal, 2013

	Mitigation scenarios										Baseline	
Scenarios	A	A1	A2	B	B1	B2	BCCS	C	C1	C2	0,6	0,8
Electricity production												
Development renewables	low		high	high		100%*	low	high	low	100%*	very low	very low
Demand of electricity**	constant			constant				decreasing			constant	slightly decreasing
Industry												
Growth	1,2%			1,2%				0,6%			0,6%	1,2%
Technology	best available technology			low carbon technology				low carbon technology			cost-efficent available technology	
Usage of H2 in PJ 2050	-			140		280	140	200		280	-	-
Buildings												
Reconstruction rate	1,4%	0,7%	1,4%	2,0%	1,4%	2,0%		2,0%			0,7%	
Mitigation of GHG-Emission in NRW* **												
1990-2020 (Target -25%)	-21%	-20%	-25%	-26%	-26%	-27%	-22%	-29%	-24%	-29%	-21%	-16%
1990-2050 (Target -80%)	-57%	-57%	-60%	-65%	-64%	-79%	-67%	-69%	-68%	-82%	-51%	-40%

* 100% of electricity production from renewables
** electricity demand are scenario results
*** domestic mitigation in North Rhine-Westfalia excluding emission trading

TABLE 1 Selected results of the scenario process
Source: Prognos AG, Entwicklung und Durchführung einer Impactanalyse für den Klimaschutzplan Nordrhein-Westfalen Basel, 2014

greenhouse gas emissions in the state. The different scenarios very well reflect the distinguished judgments of the group with regard to the meaning of single strategies, or the availability of specific technologies over time. The following table gives an overview of the most important results.
In addition, during the process appropriate policy instruments have been discussed and assessed by the stakeholders with regard to public acceptance, cost-benefit ratio, employment effect, etc.
Approximately two thirds of the 265 proposed measures have got the full support by the stakeholder community, while one third has been discussed as controversial. For transparency reasons, all pros and cons have been reported and are available online for the public, as is the full set of other relevant material.

Conclusions

With the process of the development of the climate protection plan, the government of North Rhine-Westphalia decided to intensively engage relevant stakeholders already in the development phase. After following and steering the process over two years, several added values could be detected:

- specification of the stakeholder family being relevant for the implementation and monitoring of ambitious climate protection policy in North Rhine-Westphalia;
- significantly improved knowledge base about mitigation potentials and scenarios in North Rhine-Westphalia (scenario corridor as orientation mark for the assessment of options for action);
- sound foundation and stakeholder assessment for the selection and implementation of mitigation measures (policy instruments);
- lighthouse effect beyond North Rhine-Westphalia for similar participatory processes abroad;
- highly productive discussion and culture buildup within the working groups;
- raising awareness on different perspectives by stakeholders;
- confidence building between stakeholders and ministries, especially between industry and ministry for the Environment;
- better chance to implement mitigation measures if jointly developed with the relevant stakeholders;
- starting point for further structures of dialogue with stakeholders (e.g. industry dialogue).

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Public engagement with energy system change

Public acceptability represents a major challenge for delivery of energy policy, in the UK and internationally. This article sets out three arguments about public engagement with energy transitions derived from research into public perspectives of whole energy system change. It argues for the need to consider values that underlay preferences, the importance of understanding problem and solution framings, and the significance of considering views on process as well as outcomes. Overall, insights are offered into how to better approach public engagement with energy system change.

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C. Butler, K. Parkhill, C. Demski, N. Pidgeon, A. Spence

Introduction

At present, there is vociferous debate in the UK and internationally about how to achieve energy system change. The debates concern the need to address the sustainability of energy systems, while maintaining service provision in ways that are affordable. Of central concern in this is the extent to which various visions of energy system change will be acceptable to publics. Publics are deeply implicated in energy system configurations (e.g. as consumers and producers of energy, as active protesters or proponents of infrastructures), and will therefore be central to the successful implementation of change. Indeed, several commentators have posed that the development of a new social contract – i.e. an unspoken reciprocal agreement between state and citizenry – will be key to achieving change of the scale required [1, 2]. In this regard, public engagement is likely to be significant for a number of reasons - not least in developing understanding of public concerns and expectations about system change. This article sets out arguments arising from research that examined public acceptability of energy system change and addressed questions concerning how to build meaningful engagement that can aid in the delivery of successful transition processes.

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Public engagement: Debates and approaches

The research builds from existing debates about public engagement wherein it has been asserted that there is a need to consider the social dimensions of technological innovation in ways that move beyond so called 'deficit' thinking [3]. The 'deficit' approach has been extensively criticised for: 1) assuming the neutrality of information and privileging certain

forms of knowledge; 2) discounting the role of values, situational context, and other types of knowledge; and 3) framing publics as a problem in terms of their ignorance, trust or ambivalence, and engaging in order to correct rather than to reflect divergent perspectives [4].
In this context, a shift has been identified from a focus on information provision to more participatory and inclusive processes, which place emphasis on two-way dialogue and mutual learning. The rationale for these forms of public engagement tend to coalesce around two broad lines of reasoning: 1) involving publics in debating the path and nature of technological development is seen as a good thing in and of itself; and 2) opening up insight into public characterisations that can then be fed-back into key decisions or activities of scientists and engineers. The research and related assertions summarised here can be situated as having aims consistent with these two rationales.

Research methodology

The research aimed to gauge public views on, and contribute more widely to, the debates about public acceptability of energy system change. The project involved day-long deliberative workshops across the country and an on-line GB nationally representative survey to examine public views. A scenario tool ('My2050') developed by the Department of Energy and Climate Change and Sciencewise was utilised in both research phases [5]. In the remainder of the article we set out three key arguments pertaining to public engagement with energy system change that are based on the research findings.

Findings argument 1: Public values for energy system change

The first argument concerns the importance of thinking about the values which underlie peoples' preferences and help us to understand why preferences are the way they are, rather than simply what they are [see 6, 7, 8]. To illustrate this, our research shows that there is a strong public preference for solar energy (85% are favourable). The things which people value about solar energy are that is perceived as 'fair', 'just', 'clean', 'safe', 'renewable' and 'secure', and as delivering benefits in terms of 'affordability'.
However, we assert that if solar power was deployed and developed in ways that did not correspond with the underlying characteristics that people value, it would no longer fit with the public preference for this technology. To clarify, we might imagine a solar energy development supplying the UK but residing in North Africa, being revealed as causing local environmental contamination and land-use disputes. This 'version' of solar energy would not fit the public preference for this form of energy provision, as in this instance it would no longer be seen as 'fair', 'just' or 'clean'. That is to say, it is not solar energy per se that people are favourable toward but rather the ideals of fairness, cleanliness and so forth that they associate with the energy source. A major lesson from this analysis is that technologies currently regarded favourably or unfavourably can be formulated in ways more closely aligned with public values. For example, certain forms of bio-energy, namely grown for purpose bio-fuels provoke concerns about land conflicts, governance, regulatory failure, and pollution – these issues result in public uncertainty, ambivalence, and, in some cases, unacceptability of bio-fuels. However, it may be possible to envisage a development trajectory commensurate with the ideals that publics value through concerted and transparent efforts to ensure bio-fuels meet these concerns (for example, developing them in ways that do not put them in conflict with land for food production).

Findings argument 2: Understanding public framings of energy transitions

The second argument asserts that public engagement is required at the stage of problem formulation, as opposed to only at the point of deciding solutions. This is based on the premise that how problems are understood has profound implications for the kinds of solutions that are appropriate, possible, or desired. With respect to energy system change, the research highlights how publics formulate their own problematisations of the energy system and reasons

for why it requires transformation. These are related to policy and expert framings but also differ in many respects, with implications for how people perceive the appropriate solutions.
To give an example, climate change is one of the major policy imperatives for energy system change, and although climate change is incorporated in public views as one reason for change, it represents just one element within a much wider set of concerns related to environmental degradation and human/nature relations. Policies that fail to engage with this understanding of the problem risk presenting narrow solutions that do not account for public perspectives and may therefore result in contestation. To illustrate this we use the example of Carbon Capture and Storage (CCS). Although CCS might address some concerns around climate change, when broader environmental concerns are drawn into the framing, it no longer constitutes a solution because it represents a continued use of fossil fuels and other forms of environmental degradation (e.g. production of effluence and the need to store 'waste' carbon).
As such, our research shows that public framings of energy transitions are much broader and subtler than those presented in policy contexts. Public framings include additional concerns around social justice, fairness, quality of life and the environment more broadly. We argue that engaging with the wider concerns publics bring to bear on energy transitions will help create solutions that are more acceptable to society.

Findings argument 3: Public engagement with processes of energy system change

A final argument concerns the need to pay attention to how publics perceive processes of development, implementation, governance, and regulation in relation to energy system change. For example, in the case of development and implementation, whether such processes include genuine and early community engagement also forms an important part of public preferences and attitudes.
Within our research the importance of responses to processes became particularly apparent with regard to perceptions of different actors in energy transitions, and their perceived responsibilities in delivering change. Take, for example, the role of energy markets, which were perceived as not operating in ways that would ensure desirable transitions that would be inclusive of public concerns/values. Indeed, publics were doubtful that the market could deliver change that would ensure a fair price for all consumers, given the profit-motivations of energy companies and lack of transparency in the cost of energy. This has implications for the acceptability of some mechanisms for financing energy system transitions, including adding costs on to consumer bills. This, then, raises fundamental questions about the role of regulation and different actors' responsibility for ensuring energy transition processes are delivered in ways that are commensurate with, and inclusive of, broader societal interests and concerns.
As such, our research shows that it is vital to pay attention to public values to energy system change in relation to processes in addition to outcomes. By doing so, insights into processual issues, and possibilities for mitigating against these, can potentially be found.

Conclusions

In this paper we have set out three linked arguments pertaining to public engagement with energy system change. We will now briefly draw together some insights based on these findings. First, it is our contention that it is vital to consider the values underlying observed public preferences to be able to inform the development of robust energy policies that are more responsive to the concerns of publics. Second, we argue that it is vital to engage with publics as early as possible to account for public values in a meaningful way – preferably at the problem forming rather than the solution stage. Indeed, we suggest that publics can offer valuable broader, yet subtler, framings, which in turn could help develop energy policy imperatives that take into account wider sustainability concerns.
Finally, we have highlighted that public perspectives must be considered not only in terms of outcomes,

but also in terms of the processual issues involved in energy transitions. Not doing this would risk ignoring other vital dimensions that, in addition to values associated with specific components of the energy system, underpin public preferences for energy system change.
Although adhering to the lessons these three arguments encapsulate would not guarantee the absence of public contestation, we suggest they are essential in engendering a more inclusive and fuller engagement process. Something that is perhaps essential if the UK and global society are to successfully develop transitions to alternative energy futures.

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Theme 4: Win-win strategies in directing low-carbon resilient development path

This section explores big win-win strategies in directing low carbon resilient development path. There are lots of "leapfrog" development possibilities in developing countries, which go directly from a status of under-development through to efficient and environmentally benign lifestyle. To achieve low carbon resilient paths, not only technology development but also institutional and behavioral changes are required. Science-policy nexus is also discussed.

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Background

Greenhouse gases (GHGs) are expected to grow without adequate policies, which could cause significant impacts on social and eco-systems. However the required policy actions could have severe economic losses if not properly designed. This section explores big win-win strategies in directing low carbon resilient development path. There are lots of "leapfrog" development possibilities in developing countries, which go directly from a status of under-development to efficient and environmentally benign lifestyle. Such kind of lifestyle is supported by low-carbon technologies. Technology RD&D and technology transfer are required to meet the target of GHG emissions.

Key findings

- Technology RD&D are a key to achieve a low carbon transformation. However it is not enough; significant institutional and behavioural changes will also be needed.
- While there is a popular view that technology transfer can happen between developed and developing countries if enabling conditions are in place, adequate

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financial flows should be in place. Creative solutions will be needed, as collaborative agreements should be beneficial for all involved parties.

- Research community can be a catalyst in supporting developing countries gear towards low carbon development pathway. This can be done by serving as a provider of tools and guidance, helping countries to make informed decisions.
- Both "top-down" approaches, such as the allocation of global carbon budget based on equity indicators, and "bottom-up" approaches, such as the technology-based energy system modeling, can serve as an important source of information to attain a good understanding of Intended Nationally Determined Conditions (INDCs). Early planning and action is essential to achieve long-term deep decarbonization toward 2050.

To achieve low carbon resilient paths, not only technology development but also institutional and behavioral changes are required. The discussion is focused on: "How can the scientific community help align climate policies with economic development in order to realize a low carbon resilient development path?", and the importance of science-policy nexus is stressed. Also the direction of RD&D for mitigation of GHG emissions is debated by introducing UNFCCC Technology Mechanism (TM) and it is pointed out that for TM to be effective, links with financial institutions should be in place. With regard to developing countries, the main questions are: what are practical challenges and opportunities in gearing developing countries towards low carbon resilient development pathway, and what are potential niches and means for research communities to respond to the stated challenges, filling in the research-implementation gap. Challenges such as national capacity constraints for implementation, policy gaps including limited mainstreaming of the climate change agenda into the existing policy frameworkare pointed out.

An additional discussion item is how modeling emission pathways can contribute to raise ambition levels of INDCs. Many modeling teams have already developed pathways towards low carbon societies at the global, regional, national, and city levels. The pathway to peak out GHG emissions by 2040 in Thailand is illustrated. Low carbon pathways from the Deep Decarbonization Pathways Project (DDPP), consisting of 15 countries teams, is also presented and discussed.

Way forward

Having identified a wide spectrum of practical challenges, lessons and good practices throughout this section, the following concrete steps have been extrapolated for the research community to meet their needs and address the observed challenges:

- ***Design and develop tools*** to guide developing countries in undertaking robust policy making processes and support the design of its implementation framework. Such guidance and tools can be provided in the form of manuals, checklists, training curricula, platform for knowledge exchanges and projection models, but they need to be simple enough to be harnessed widely. Accumulating success stories the is also required to demonstrate the effectiveness of the tools and guidance, and to build confidence.
- ***Strengthen scientific basis for national low carbon planning*** by supporting

robust dataset and scientific analysis to establish emission projection, policies and measures (PAMs), thus allowing to make informed decisions on the low carbon pathway.

- ***Strengthen science-policy nexus*** by providing end-to-end solutions to policy relevant issues raised by the scientific community and receiving feedbacks from policy makers. In addition to policymakers, engagement with the general public is crucial. It is the role of the scientific community to empower and educate the public about available development pathways, so that they can make informed decisions.
- ***Provide the necessary information to better understand Parties' INDCs***, which are expected to be submitted over the first quarter of 2015. Modeling research community can help stakeholders to better understand Parties' INDCs by providing a "narrative" scenario, i.e., a storyline on underlying macroeconomic drivers, mitigation potentials and other national circumstances.
- ***Develop the capacity to provide support to developing countries*** at all levels (from individual to institutional) through transfer of knowledge, skills, and experiences, and facilitation and provision of fora for knowledge exchange and peer-to-peer learning.

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Assessing ambition of nationally determined contributions

A key for a successful new international climate agreement by December 2015 will be the collective assessment of ambition of individual proposals by countries on how and how much to reduce their greenhouse gas emissions. We conclude that there is nothing right or wrong in choosing one or several of these approaches to assess the level of ambition of contributions. An approach using several of many methods described can take into account the difference in national circumstances.

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N. Höhne

Introduction

The international community has embarked on negotiating a new international climate agreement by December 2015. A key element of the new agreement will be individual proposals by countries on how and how much they are willing to reduce their greenhouse gas emissions. Countries already agreed to "initiate or intensify domestic preparations for their intended nationally determined contributions" (INDCs) so that they can be submitted well in advance of the conference in December 2015 [1].
Such contributions could take various forms:

- National long-term emissions goals (USA: 83%, or Mexico: 50% below 2005 level in 2050)
- National short-term emissions target (EU: 20% below 1990 level in 2020, or South Korea: 30% below business as usual in 2020)

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- Sectoral/energy targets (Peru's renewable energy for 2020)
- Policies and projects (Ethiopia several renewable energy projects)

Once countries have submitted their contributions, all other countries will have to assess the level of ambition of these contributions.
This article provides an overview of the methods that can be used to assess the level of ambition of the contributions.

Methods to assess the level of ambition of mitigation commitments

A number of different approaches exist for evaluating whether a contribution, or elements of a contribution are ambitious:

- ***A comparison to business as usual (BAU)*** indicates the degree to which a country plans to deviate from an assumed future overall greenhouse gas emissions trend. Using a BAU as a counterfactual places importance on the credibility of the underlying assumptions, including for example the level of policy implementation and the resulting impact, the rate of future economic development, as well as the level of the related modelling capacity. Using the same (old) BAU pathway for comparison over time is well suited for comparing different contribution possibilities for a country, or the strengthening of a contribution over time. BAU's will more and more include currently implemented and planned mitigation measures, so this scenario may not represent a "no effort" scenario.

- ***A comparison to "effort sharing"*** calculations would assess a contribution in the light of how the future mitigation effort needs to be distributed among countries, based on a) an agreed endpoint or total carbon budget, and b) an effort-sharing methodology. Different effort-sharing methodologies focus on, or combine, elements like historical responsibility, capability (e.g. expressed in GDP/cap) etc. [2]. Given the different focus of the methodologies, the range of possible outcomes is wide. Thus a convincing argument for the chosen effort-sharing approach is necessary. Using an effort-sharing approach consistently among countries' contributions ensures that the overall endpoint (e.g. 2 °C target) is likely to be met.
- ***A comparison to mitigation potential*** evaluates whether a country's contribution makes use of the mitigation opportunities that are available, and whether resources for mitigation are spent in a cost-efficient manner. For example, a contribution could be assessed as to whether it captures a) at least all mitigation options with negative costs; b) mitigation options with net-neutral or lower cost when considering co-benefits; c) mitigation options at positive costs based on country capability; d) mitigation options beyond domestic country capacity conditional to receiving international support [3]. Mitigation potential and costs also rely on a comparison to a counterfactual business as usual scenario. Shorter-term mitigation targets can be developed based on mitigation potentials, and therefore this kind of approach can be a good way to evaluate contributions formulated in this way, provided the necessary information exists.
- ***A comparison to decarbonisation benchmarks***, for example CO_2 per kilometer travelled, CO_2 per megawatt hour electricity production, or GHG per ton of cement or steel produced, can be made. These indicators are forward looking and do not rely on business as usual or other counterfactuals and their underlying assumptions. Decarbonisation indicators, on the one hand, could compare contributions among countries if these indicators are included as domestic targets. On the other hand, as targets they can also show the ambition of a contribution when they increase in stringency beyond a business-as-usual projection, or at least the

	Comparaison to business as usual (BAU)	Comparaison to Effort sharing	Comparaison to Mitigation potential	Comparaison to Decarbonisation indicators	Comparaison to Good practice policy package
National long term emissions goal					
National short term emissions target					
Sectoral/ energy targets					
Policies and projects					

TABLE 1 Suitable approaches for evaluating the level of ambition of different national contributions (main approach: dark, secondary: light shading)

national historical trend. Decarbonisation indicators are often formulated in sectoral or technological terms, which renders them particularly useful for evaluating contributions in terms of energy targets and other sectoral mitigation actions.

- ***A comparison to a good practice policy package*** or a policy menu is possible, which could be agreed upon by Parties or elaborated by technical experts. As a type of white list, policy packages or menus do not rely on BAU scenarios, but rather on the public acceptance of the policies that are included in the packages/menus. Contributions would be seen as ambitious if they include concrete and comprehensive plans for the implementation of nationally appropriate variants of best practice policies for certain sectors, or go beyond these.

Conclusions

There is nothing right or wrong in choosing one or several of these approaches to assess the level of ambition of an INDC. However, individual approaches lend themselves better to assess and show the level of ambition of certain elements of a contribution (Table 1).
We find that an approach using several of the many methods described can take into account the difference in national circumstances.

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Modeling the roadmap of Thailand's NAMAs 2020 and raising ambition levels of INDCs

Thailand NAMA, in line with national development plans, reveals a GHG reduction target of 7-20% related to BAU emissions by 2020. Both domestically and internationally supported NAMAs need MRV to ensure emission reduction.

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B. Limmeechokchai

Introduction

The Nationally Appropriate Mitigation Actions (NAMAs) concept was first introduced in the "Bali Action Plan" in COP13 in 2008. There are two types of NAMAs in Thailand: 1) Domestically Supported NAMAs; 2) Internationally supported NAMAs. Both need measurable, reportable and verifiable (MRV) processes to ensure the quantified emission reduction. The first study by the Thailand Greenhouse Gas Management Organization (TGO) shows that Thailand has high potential of GHG emission reduction by both domestically supported and internationally supported NAMAs: in 2020 about 23-73 million t-CO_2 per year, or approximately 7-20% of the total GHG emissions. The abatement costs of NAMAs vary from zero to 1000 USD/t-CO_2. However, most of these CO_2 reduction actions will be voluntarily taken by Thailand. There are limited internationally supported NAMAs in Thailand.

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The GHG mitigation actions include measures in: i) renewable energy; ii) energy efficiency; iii) biofuels in transportation; iv) environmental sustainable transport. Since 2012 Thailand's mitigation pledge to UNFCCC has been prepared on the basis of these measures. Co-benefits of NAMAs are also assessed, and they reveal positive aspects of GHG mitigation under the NAMA framework. The MRV process of these NAMAs needs cooperation among the relevant ministries.
The AIM/Enduse model is used to construct emission pathways for analysis of "Roadmap to Thailand's NAMAs 2020". The roadmap to Thailand's NAMAs 2020 has been laid out by Office of Natural Resources and Environmental Policy and Planning (ONEP), Thailand Climate Change Focal Point, to achieve the CO_2 reduction target of 7-20% in 2020. In addition, the peak CO_2 scenario is fine-tuned to provide the reality of Thailand's INDC scenario.

Methodology

The energy system of Thailand is modeled using the Asia-Pacific Integrated Model (AIM)/

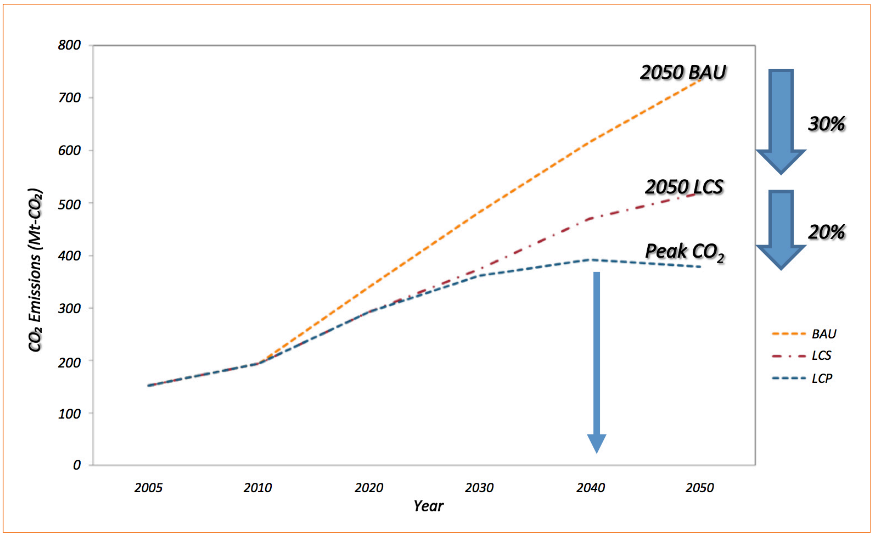

FIGURE 1 Emissions in the BAU and peak scenarios

The "Roadmap to Thailand's NAMAs 2020" shows that current Thailand's domestic MRV processes already achieved a CO_2 reduction target of 7% in 2014, and are expected to get a minimum reduction of 7% by 2020 if the present MRV process is still continuing until 2020. The additional strengthening of MRV processes in energy efficiency in buildings and industries, due to several domestic barriers, will increase the level of CO_2 reduction up to 20% when compared to the BAU, resulting in CO_2 emissions decreasing down to 295 Mt-CO_2 in 2020.

Enduse, which is a recursive dynamic, bottom-up optimization model [1]. The economic sectors included in modeling are: 1) residential sector; 2) commercial building sector; 3) industrial sector; 4) transport sector. The power sector is modeled as supply side. The base year in the modeling is 2005 and the target year is 2020 for the NAMA scenario, 2030 for the INDC scenario and 2050 for the peak CO_2 scenario. The socio-economic information on the existing energy demand and GHG emissions are obtained from government offices [2] and [3].

In addition, the co-benefits of GHG mitigation are also assessed, as well as energy security. These indicators are: 1) diversification of primary energy demand; 2) oil or gas share; 3) renewable fuel share; 4) carbon intensity; 5) social benefits.

Results and Findings

Results from modeling show that CO_2 emissions from the energy system in Thailand will increase from 193 Mt-CO_2 in 2005 to 360 Mt-CO_2 in 2020, 480 Mt-CO_2 in 2030, and 730 Mt-CO_2 in 2030, respectively, in the BAU scenario.

Co-benefits of Thailand's NAMAs 2020 have been assessed. All indicators of co-benefits show that GHG mitigation under Thailand's NAMAs will result in: increasing diversification of the primary energy demand, decreasing imported oil and gas share, increasing renewable fuel share, decreasing carbon intensity, and increasing social benefits.

However, modeling results show that Thailand's NAMAs 2020 will contribute to a CO_2 reduction by 30% in 2050, and CO_2 emissions will decrease from 730 Mt-CO_2 in the BAU down to 520 Mt-CO_2 in 2050. However, Thailand cannot meet the peak CO_2 emissions yet (see Fig. 1).

In the peak CO_2 scenario, results show that Thailand has to cut CO_2 emissions by 50% from the BAU in 2050. Peak CO_2 emissions will happen in 2040 at 400 Mt-CO_2. However, the CO_2 countermeasures in the peak scenario are not realistic and not compatible with the existing national climate change plans among the relevant ministries.

In modeling Thailand INDC 2030, there are several key issues to be clarified: baseline scenario vs. 2030 scenario, policy/actions, projection methodology in modeling, data sources, sectoral approach for emission/reduction, integrated modeling for the whole energy system, exclusion of land-use and

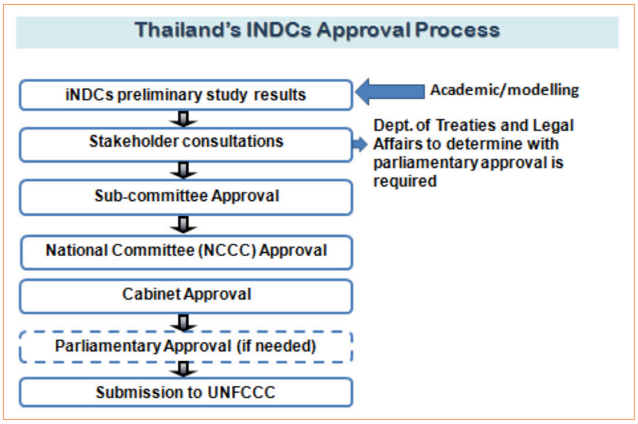

FIGURE 2 Thailand's INDC approval process

forestry, annual GHG reduction as well as cumulative emission reduction by 2030, avoiding double counting of actions. Figure 2 shows Thailand's INDC approval process.

Results of Thailand INDC 2030 will be robust, realistic and achievable. Additional effects of Thailand INDC 2030 will be investigated, such as co-benefits, energy security, social and economic impacts, to ensure sustainable development. In addition, MRV processes of Thailand's INDC will be prepared to confirm their transparency.

Conclusions

The CO_2 countermeasures in the NAMA and INDC scenarios will result in transformational changes not only on the supply but also demand side. To achieve the peak target, Thailand needs: i) capacity building; ii) sustainable Feed-in Tariff scheme for renewable electricity; iii) enforcement of energy efficiency laws in buildings and industries; iv) co-funding of the LCS actions on both demand and clean supply side. The peak target will not be achieved if it is not planned & implemented in the early stage. In addition, MRV processes of LCS actions are necessary.

It is found from modeling that peak CO_2 emissions in Thailand will not happen before 2040, due to the lock-in selected technologies according to the existing government plans. This information will activate the Thai government to be concerned with the long-term national climate change master plan 2050.

Finally, the MRVs of energy efficiency actions in Thailand's NAMAs 2020 and Thailand's INDC 2030 need improvement to show the transparency of CO_2 reduction pathway. Both capacity building and financial supports will enhance the transparency of MRV processes in Thailand.

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The role of research community in facilitating the implementation of the low-carbon Society Blueprint in Malaysia

The Malaysian government recognises that climate change and the adverse consequences arising from it are real, and has taken positive policy actions to address climate change. Researchers are working together with regional policy-makers to prepare a baseline study and formulate 12 Action Plan to promote a low-carbon society for the fast growing regional economic corridor to reduce GHG emissions, while pursuing the national goal of economic growth towards a high income nation status.

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C.S. Ho

Introduction

The research project on the Development of Low Carbon Society (LCS) for the Asian Region using the case of Iskandar Malaysia aims to showcase how the research community in developing countries like Malaysia is able to contribute to reduce CO_2 emission intensity in a fast-developing metropolitan economic corridor.

The research project began with a pilot study in Iskandar Malaysia and showcases the LCS best practices for the Asian Regions, thus benefiting not only the case study area and Malaysia, but also the Asian Regions. It will be a hands-on project where researchers and government officials of Asian countries work together in implementing research outputs within the cities or regions involved, leading to the eventual establishment of an Asian Low Carbon Society network.

The long term objective of this research project is to develop suitable policies and guidelines for the nation in environmental conservation and energy consumption needs. The Project is expected to develop research methodology and design, LCS scenarios are created and utilized for policy development in the case study area Iskandar Malaysia. Ultimately, it hopes to set up an organizational arrangement for capacity building and a network for LCS in Asia.

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Major characteristics of the region

Iskandar Malaysia covers an area of 221,634 hectares (2,216.3 km²), about 3 times the size of Singapore and twice the size of Seoul Metropolitan Area. Iskandar Malaysia is the largest single development project ever to be undertaken within the Southeast Asia region. Strategically located at the southernmost tip of Mainland Asia to tap on a vast market of about 1 billion people within a 6-hour flight radius, Iskandar

Malaysia is set to become an integrated global node that synergizes with the growth of the global City-state of Singapore and Indonesia. The population in Iskandar Malaysia is projected to double from 1.5 million in 2005 to over 3 million by 2025, supported by a stable 7-8% annual GDP growth that is primarily driven by services and manufacturing.

Malaysian policies and transformation to low carbon societies

In an effort to curb the nation's contribution to climate change, at the 2009 United Nations Climate Change Conference (COP15), Prime Minister Datuk Seri Najib Abdul Razak committed to "conditional voluntary reduction of carbon emission intensity per GDP of up to 40% by the year 2020 compared to the 2005 levels".

In line with the National Government Policy as spelt out in the Ninth and Tenth Malaysian Plan (2010-2015) to combat climate change, it is important to introduce a sustainable development approach to reduce the negative environmental impacts of a rapid development. As such, one of the approaches is to promote a sustainable low carbon society policy. Low Carbon Society (LCS) can be defined as a society that consumes sustainable and relatively low carbon energy as compared with our present day practices to minimize adverse climate change effects. Conscious efforts need to be taken in both energy consumption and supply sectors. Society will adopt a lifestyle that makes more use of alternative renewable energy, depends less on fossil fuels and practices the 3R's (Reduce, Reuse and Recycle) in their everyday life.

Iskandar Malaysia as economic corridor is undergoing a rapid industrialization process and has huge investments in manufacturing and infrastructure development and hence has high demand for energy consumption. Although it has been blessed with relatively large tracts of agricultural and natural tropical wetland (designated as Ramsar site), the green areas may be converted into other urban uses to generate job opportunities for the growing population.

Low Carbon Blueprint and collaborative aspects of local and future research partnership

This blueprint is one of major research outputs of our SATREPS (Science and Technology Research Partnership for Sustainable Development) project on the Development of Low Carbon Society for the Asian Regions, sponsored by Japan International Cooperation Agency (JICA) and Japan Science and Technology Agency (JST). The main universities involved in this collaboration work are Universiti Teknologi Malaysia (UTM), Kyoto University, National Institute for Environmental Studies (NIES), and Okayama University. The research team uses a scientifc methodology based on data collection, scenarios development, CO_2 emission modelling with AIM (Asia Pacific Integrated Model) and consensus building among stakeholders to develop the LCS bluprint.

Conclusions – The role of researchers in the preparation of LCS Blueprints to facilitate urbanization

In line with the Malaysian Government's effort and pledge in COP15 to achieve a 40% voluntary reduction of CO_2 emission intensity by 2020, the implementation of the blueprint will facilitate the low carbon development of metropolitan areas. The case study region, Iskandar, is one of the fastest growing regions in Malaysia; this demonstrates how a low carbon society can be achieved by decoupling CO_2 emissions and economic growth.

The lessons learned from the research work can be summarised as follows:

a) A development approach needs to be people-centered and buy in from policy makers. It is easier and more effective to plan an LCS blueprint for a regional corridor instead of a single city. The study area will have critical mass to develop green policies for energy and other infrastructure development to facilitate green environment, green economy and green community.
b) The adoption of a more scientific methodology

by the researchers to provide a good baseline quantitative study on carbon emission on current and future development scenarios is important. A scientific baseline study followed by consensus building among policy makers, the public, and business stakeholders will ensure better and objective decision making by the local planning authorities. In other words, researchers should look beyond the sole policy perspective, that is starting from science-knowledge-policy to finally achieve the implementation stage.

c) Researchers/scientists have to work with local implementation agencies and make an international collaboration effort for capacity building opportunities to disseminate the knowledge and skill of developing LCS policies and monitoring them.

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GIZ approaches on Low-Emission Development Strategies. The need for support from research

First results of GIZ support on the development of Low-Emission Development Strategy (LED) in Costa Rica are promising and have motivated key ministries to integrate the climate policy into their structures. Awareness of the issue of climate change among the general public is increasing, the competencies of the National Secretariat for Climate Protection have been strengthened: its capability for strategic planning has been improved.

The most important challenges still remain, like the manifold "LEDS" documents on national level, weak connection of existing development strategies, weak integration across ministries, the limited financial capacities or the fragmented international support.

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B. Zymla

The context

As a federal enterprise, GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) supports the German Government in achieving its objectives in the field of international cooperation for sustainable development. GIZ main activities are focusing on sustainable development and resource management in a wide range of sectors.

GIZ contributes to the development of Low-Emission Development Strategies (LEDS) as national, high-level, comprehensive, long-term strategies, which aim at decoupling economic growth and social development from greenhouse-gas (GHG) emissions growth. In some cases these projects and activities use different denominations such as Low Carbon Development Strategy, Climate-Compatible Development Plan, or National Climate Change Plan. GIZ provides different forms of capacity development support for mitigation strategies, according to their needs. In some cases the contributions are limited to some components, e.g. baseline GHG emissions analysis and projections, prioritization of key mitigation sectors and measures for designing NAMAs and MRV frameworks. In other cases the support is more comprehensive, including integrated help with the development of Low-Emission Development Strategies.

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Example: Low Emission Development Costa Rica

One example for a comprehensive approach is the project: Low Emission Development Costa Rica – Supporting the national climate neutrality strategy in Costa Rica as a model for low carbon development. The project is commissioned to GIZ by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Society (BMUB) within the scope of the International Climate Initiative (ICI) with an overall term of four years from 2011 to 2015. The lead executing agency in Costa Rica is the Dirección de Cambio Climático (DCC) del Ministerio de Ambiente y Energía (MINAE).

Context

Costa Rica has set itself the target of achieving a zero emissions status by 2021. As a result, it has committed to adopting policies sustainably and over the long-term that will help reduce emissions. This politically ambitious goal requires making a tremendous effort as well as using demanding, innovative approaches – particularly as emissions in key sectors are currently on the rise. Current scenarios show that greenhouse gas emissions (CO_2) are expected to increase, a fact largely due to the rise in motorized private transport and to higher consumption of fossil fuels in industry and power generation. By contrast, CO_2 emissions in waste management are increasing at a much lower rate and have even decreased a little in agriculture.
The objective of GIZ support is to strengthen Costa Rica's ability to implement strategies that will significantly reduce greenhouse gas emissions. Besides the impact at the national level also a benefit for the region is expected as the country can use the experience it has gleaned from the process of becoming a low emission country to usefully inform regional and international strategy discussions on low carbon development.

Approach

The "Low Emission Development (LED)" project works at the political and institutional levels to provide advice on developing strategies and designing framework policies as well as for programs and action plans, such as the Nationally Appropriate Mitigation Actions, or NAMAs. In addition, industrial companies and small- and medium-sized enterprises (SMEs) are receiving advice on how to plan and implement measures for reducing emissions and how to use environmentally- and climate-friendly technologies.
Key activities include:

- Developing and strengthening institutional competencies and capabilities:
  - strengthening the management abilities of the National Secretariat for Climate Protection of the Ministry of Environment and Energy;
  - establishing a cooperative platform: Plataforma Climatica;
  - supporting cooperation between different ministries.
- Integrating climate goals into the medium-term National Development Plan (2014–2018).
- Supporting the implementation of an ecological tax reform that focuses on climate financing.
- Several Nationally Appropriate Mitigation Actions (NAMAs) have been developed for:
  - low carbon coffee, resource efficiency and waste management, an integrated, low emission public transport system;
  - technology transfer between industry and the green economy, environmentally friendly urban development;
  - projects in cooperation with the private sector (development partnerships with the private sector): developing climate strategies in the production chains: milk and cheese processing, soft drinks manufacturing, energy efficiency in the transport sector and energy efficient ways of travelling (eco-driving).
- Providing advice on standardization processes for climate neutrality certification.
- Developing management abilities and resources as well as guidance programs in the chambers of commerce and industry.
- Training sessions and awareness-raising measures.

The results so far

The competencies of the National Secretariat for Climate Protection have been strengthened: its capability for strategic planning has been improved, its organizational structure has been streamlined and it can use the cooperative platform Plataforma Climatica to successfully coordinate the work with the agricultural, urban development and transport sectors. The agricultural (coffee, milk and meat production) and the urban development, waste and transport sectors have all been developing NAMAs since 2012.
Awareness of the issue of climate change among the general public is increasing, as indicated for example by the rising number of special reports on climate change in the media. Costa Rica is able to proactively pass on its experiences of becoming a low emission country at the international

climate negotiations. This encourages developing and emerging countries to follow its example.
The voluntary commitments, which Costa Rica will publish at the next series of negotiations, have motivated key ministries such as the Ministry of Housing and Ministry of National Planning to integrate the climate policy into their structures.

GIZ's LEDS-Toolbox developed bottom up

Based on the project experience in Costa Rica and other countries, GIZ started to identify key success factors as well as pitfalls and started to develop a toolbox to guide practitioners through the process of developing and implementing a LEDS.
The toolbox provides a structure for the planning process divided into six steps to help users with checklists, "How to" guides, and links to detailed information. These tools form the groundwork for NAMA, MRV trainings and LEDS Workshops that GIZ is now offering to interested partners. However, this toolbox is just a first step.

The need for support from research

The most important challenges still remain:
- Many countries have several "LEDS" documents, e.g., National Action Plan on Climate Change, 5-year plan, report of Expert Group on Low Carbon Strategies for Inclusive Growth etc.
- Some of the existing development strategies (e.g. industry, job creation) are not at all connected with LED Strategies or even have conflicting goals.
- Integrating across ministries is a common challenge. Everywhere!
- Financial capacities are limited. What is affordable? How to keep costs down?
- Support from the international community is fragmented over many programs, facilities, sectors and time frames.

Hence, there is still a wide field for research. Expectations of researchers focus on the support for the practical application or implementation. A lot of research has been done and documents are available. However, practitioners need simple tools, for different working levels, that answer questions as:
- How to organize the complex process of LEDS development? Where are the incentives for the cooperation of ministries? How to assess and illustrate the cost (effort) / benefit ratio for the effort invested into the development of LEMS?
- How to implement and monitor the LED Strategy in such a way that sector-specific organizations can act efficiently and flexibly while contributing to the overall goal?
- How to calculate or weigh the effect of different activities that contribute in a consistent way to the overall goal, or that may have adverse effects (e.g. biomass and land for food or energy)?
- How to identify action gaps systematically?
- How to improve access to financial sources (e.g. GCF, International Finance Institutions)?

Possible types of instruments or methodologies that may help practitioners could be: sets of best practice examples, not so much models but success stories, country-specific facts and figures; stories with emotional content ,and the possibility of South-to-South exchange at the working level; tools to define roles and responsibilities for organizing the process of strategy development and their effective implementation as well as for the monitoring of this process; tools to search and identify the potential change agents and positive alliances as well as for the moderation of conflicts and stakeholder dialogues. These tools may have the form of manuals, checklists, training curricula, cooperation platforms. However, in any case, they should be short, easy to understand and directly applicable.

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Emission pathway modeling to analyze national ambition levels of decarbonization

The Deep Decarbonization Pathways Project (DDPP) is a knowledge network comprising 15 Country Research Teams and several Partner Organizations which develop and share methods, assumptions, and findings related to deep decarbonization. It analyzes the technical decarbonization potential, exploring options for deep decarbonization, but also better taking into account existing infrastructure stocks. It shows the possibility to reduce total CO_2-energy emissions by 45% by 2050, with bottom-up analyses by 15 Country Research Teams.

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Introduction

According to the fifth assessment of IPCC [1], global GHG emissions levels in 2020, based on the Cancun Pledges, are not consistent with cost-effective, long-term mitigation trajectories that limit the temperature change to 2 °C relative to pre-industrial levels. Meeting this goal would require further substantial reductions beyond 2020. The Deep Decarbonization Pathways Project (DDPP) analyses the technical decarbonization potential, exploring options for even deeper decarbonization, but also better taking into account existing infrastructure stocks [2]. The DDPP is a knowledge network comprising 15 Country Research Teams (Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Japan, Mexico, Russia, South Africa, South Korea, United Kingdom, United States) and several Partner Organizations which develop and share methods, assumptions, and findings related to deep decarbonization.

DDPP aims to draw some lessons for the international negotiations leading up to the 21st Conference of the Parties (COP 21) of the UN Framework Convention on Climate Change (UNFCCC), based on emission pathway modeling analyses.

The 15 DDPs developed by the Country Research Teams share three common pillars of deep decarbonization of national energy systems: energy efficiency and conservation, low-carbon electricity, and fuel switching. Within the three pillars that are common to all countries, individual DDPs show a wide variety of different approaches based on national circumstances. Differentiating national circumstances include socio-economic conditions, the availability of renewable energy resources, and national preferences regarding the development of renewable energy, CCS, and other technologies.

Current estimates of DDPs show the possibility of achieving deep absolute emissions reductions by 2050. Total CO_2-energy emissions from the 15 preliminary

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DDPs reach a level of 12.3 Gt by 2050, down from 22.3 Gt in 2010. This represents a 45% decrease of total CO_2-energy emissions over the period, and a 56% and 88% reduction in emissions per capita and carbon intensity of GDP, respectively.

Economic growth and energy demand

All 15 DDPs assume continued—and for some countries rapid—economic growth by 2050. Assumed GDP growth rates are especially strong in today's middle-income economies, which start from lower levels of GDP per capita than high-income countries today, and therefore have room for catch-up growth. As a result of sustained economic growth, all 15 DDPs anticipate higher levels of GDP per capita in 2050 than South Korea today.

Across the 15 DDPs, average energy consumption per capita converges to two metric tons of oil equivalent (toe) by 2050. It declines in absolute terms in high-income countries, where energy efficiency improvements outweigh population and GDP growth. In middle-income countries, on the other hand, energy consumption increases in absolute terms as a result of improved energy access and rapid GDP growth, in part driven by energy-intensive industries. However, this increase is lower than it would otherwise be because of improvements in energy efficiency.

Energy efficiency and CO_2 intensity

All 15 DDPs achieve a large decrease in CO_2 intensity of GDP (t-CO_2 emitted per $ GDP) by 2050 compared to 2010: 88% on average. This is the result of the combined effects of: (1) a decrease in the final energy intensity of GDP (toe consumed per $ GDP) and (2) a decrease in the CO_2 intensity of energy (t-CO_2 emitted per toe of final energy consumed). On average, the energy intensity of GDP decreases by 70% between 2010 and 2050, and the CO_2 intensity of energy decreases by 60%.

The relative importance of these two elements in the DDPs changes over time (Figure 1). Reducing energy intensity of GDP is more important in the early phase, while reductions in the CO_2 intensity of final energy consumption play a larger role in the long term. The dynamics in Figure 1 are driven, in part, by the effects of electrification. All Country Research Teams use decarbonization of electricity supply and electrification of energy end uses as a strategy for deep decarbonization, to different extents. In the short run, electrification has only a small effect on the CO_2 intensity of energy, since electricity generation is still rather carbon-intensive. Though electrification plays a big role in the decrease of the CO_2 intensity of energy over the longer term as electricity supply is decarbonized. These kinds of sequencing challenges, and their implications for cumulative CO_2 emissions, will be further explored in the next phases of the DDPP.

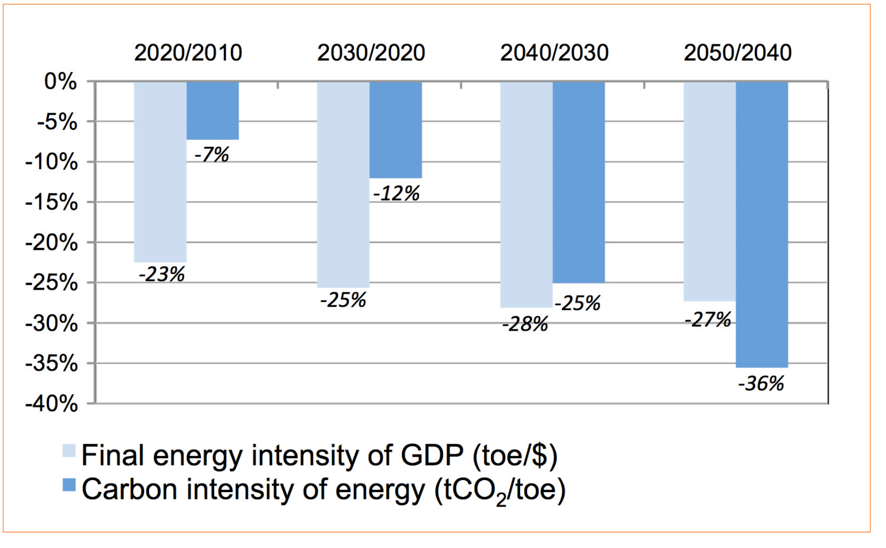

FIGURE 1 Decadal percent change in energy/GDP and CO_2/energy for the 15 DDPs, 2010 to 2050
Source: [2]

Power generation: switch to low-carbon electricity

Electrification and decarbonization of electricity play a central role in all 15 DDPs. Electricity has a much larger role in energy supplies. The share of electricity in final energy consumption almost doubles from 2010-2050, rising from 19% to 35%. Power generation is almost completely decarbonized in all countries. On average, the CO_2 intensity of power production is reduced by 94%, from 617 g-CO_2 per kilowatt-hour (kWh) in 2010 to 34 g-CO_2 per kWh by 2050.
To reach such a low level of carbon intensity, power needs to be generated almost exclusively from zero- or low-carbon sources in all countries: renewable energy, nuclear power, or fossil fuels with CCS. Across countries, the DDPs achieve the deep decarbonization of power generation through a diverse mix of low-carbon energy sources because countries have different potential for renewable energy, geological storage capacity for CCS, and social preferences and degrees of public support for nuclear power and CCS (Figure 2). For example, the DDP developed by the Indian team decarbonizes power generation using primarily renewable energy and nuclear power, but not CCS, because the scale of the potential for geological carbon sequestration in India is still uncertain. At the other end of the spectrum, the DDPs developed by the Canadian, Chinese, Indonesian, Japan, Mexican, Russian, UK, and US teams project a significant share of coal and gas-fired power generation with CCS by 2050. It is noted that some country teams have also developed scenarios with both a low and a high share of CCS. By 2050, almost all electricity in all 15 DDPs is expected to be generated from zero- and low-carbon sources.

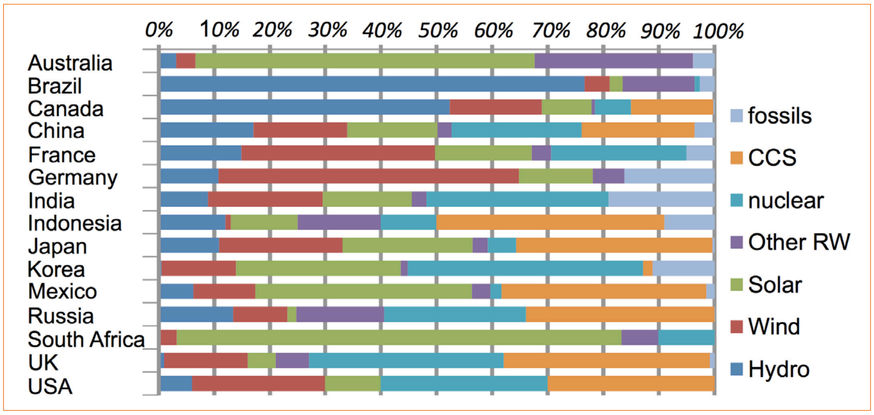

FIGURE 2 Characterization of electricity production in 2050
Source: [2]

Steps toward deep decarbonization

As the DDPP and many other analyses make clear, staying within 2 °C will require deep transformations of energy and production systems, industry, agriculture, land use, and other dimensions of human development. It will require profound changes in the prevailing socio-economic development frameworks. Many of the technologies that will need to underpin these transformations are available, but many others are not ready for large-scale deployment. Making critical low-carbon technologies commercially available and affordable, enabling countries to pursue long-term transformations, will require long-term international cooperation and trust.
Deep decarbonization of the world's energy systems requires the deployment of new low-carbon technologies to transform energy production and consumption patterns. This in turn will require accelerated research, development, demonstration, and diffusion (RDD&D) of these emission-reducing technologies to make them reliable, cost-competitive, and widely available in every country.
One of the important areas of RDD&D is energy storage and grid management. Recent sharp declines in the cost of solar photovoltaic modules, and more gradual declines in price of wind turbines, have reduced the direct costs of electricity from time-varying renewable energy resources to levels comparable to that from other fuels in many countries. The

cost of solar and wind energy, per se, is therefore no longer a substantial impediment. The main challenge remains the intermittency of these energy sources and therefore their inability to provide reliable power on a desired schedule.

Another important issue is to link national strategies with local ones. Lots of local efforts to reduce CO_2 emissions have been made in many cities world-wide. For example, Tokyo metropolitan government set a target to reduce CO_2 emissions by 25% by 2020 compared to the 2000 level. It also has a target to reduce final energy consumption by 20% by 2020, compared to the 2000 level. It has conducted climate change actions such as a cap-and-trade program for large facilities, requesting carbon reduction reporting and reducing tax for small- and medium-size facilities, sending energy saving advisers and delivering environmental education for the residential sector, providing subsidy for electric vehicles and plug-in hybrid vehicles. The total CO_2 emissions from facilities covered by the cap-and-trade program dropped by 22% from the base year (between 2002 and 2007 depending on the previous efforts by the facilities) to 2012. Such kind of local governmental efforts are also crucial to reduce CO_2 emissions from the end-use side.

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How can research serve international policymaking towards the low-carbon development path? Looking forward

Low carbon research aims to delineate climate policies in line with global sustainable development goals. IPCC reports offer birds-eye view on aggregate themes and issues. Low carbon research requires being specific, practical and granular, besides being holistic and integrative with the development agenda that vary across spatial and temporal scales. Given the complexity and speed of shifting global dynamics, low carbon research demands durable political cooperation, collaboration among stakeholders and persistent interface between scientists and policy makers. Looking forward, this paper argues to: rethink the current research perspective; make research cooperative and community-driven; orientate research to deliver the insights as well as numbers with end-to-end solutions.

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Introduction

Climate change is an extreme case of externality in both temporal and spatial dimensions. Low carbon development policies have to be framed keeping in view the spatial diversity (e.g. among the countries in terms of natural as well as socio-economic conditions) and multiple transitions (e.g. industrialization, urbanization), which the nations would go through during the long time span over which climate change would unfold.

International policymaking towards low carbon development path aims to discover development pathways that generate low greenhouse gas (GHG) emissions footprint, long into the future, and delineate solutions and means to deal with, and adapt to, residual climate change. Understanding the climate change phenomenon and its impacts, and assessing the policies to deal with it, requires

IPCC SAR: The balance of evidence suggests a discernible human influence on global climate

IPCC TAR: "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities".

IPCC AR4: Anthropogenic warming of the climate system is widespread and can be detected in temperature observations taken at the surface, in the free atmosphere and in the oceans. Evidence of the effect of external influences, both anthropogenic and natural, on the climate system has continued to accumulate since the TAR

IPCC AR5: it is "extremely likely" that human influence was the dominant cause of global warming between 1951 and 2010.

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knowledge from numerous disciplines belonging to natural as well as social sciences.
A formal avenue for policy-relevant research is the assessment by the Intergovernmental Panel on Climate Change (IPCC), which draws on the contemporary pool of research literature generated by scientific community. Such global level literature is pertinent to address important overall questions like confirming the causality between GHG emissions and climate change (Box 1), timing for peaking emissions to achieve desired stabilization targets, etc. But this beyond, policymakers seek answers to questions that are relevant to their own domains. The research on low carbon development policy and their implementation should be specific, and practical, and simultaneously holistic and integrative, so as to align with policies that deliver other development goals.

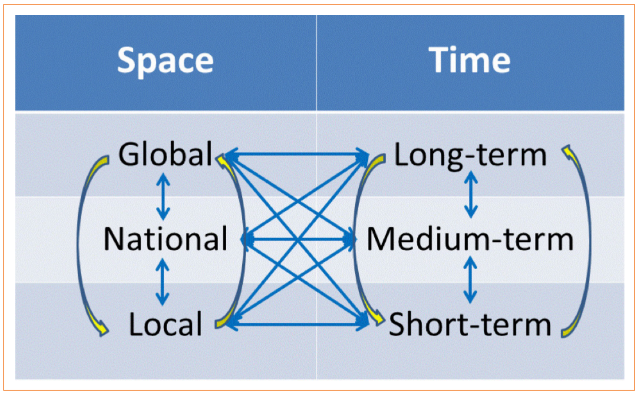

FIGURE 1 Policy-Science Nexus: Space/Time

Elements of the science–policy nexus

A basic element of the science-policy nexus is the "holistic and integrative perspective". The holistic vision is inclusive, i.e. it includes (Figure 1) upfront the context (what), space (where), time (when), how (method) and who (agent).
Integration is the hallmark of multidisciplinary sciences; it integrates information across disciplines, innovates and uses methods and tools (Fig. 2) that exchange information across scientific domains and find insights and answers to the specific policy-relevant questions.
The key idea is to make science policy relevant; i.e. aiming research to inform policy by addressing the key questions occupying policymakers' minds and use avenues such as policy forums as outreach platforms for research.

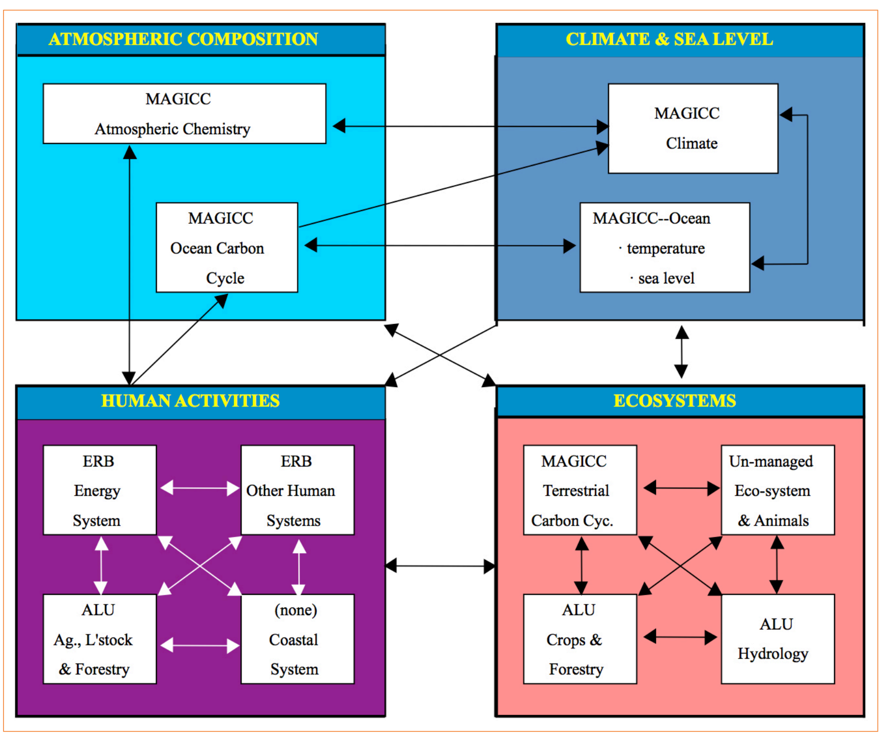

FIGURE 2 Integrated Science-Policy Framework

"Big win-win" into "low carbon resilient development"

In the integrated approach, whereas natural sciences

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discover numerous insights and multiple solutions, the social sciences show, among these, which are "big win-win" options for society. For instance, integrated assessment modelling research shows a different mix of technologies to mitigate GHG emissions in case of delayed mitigation; but the economic results also show that the delayed mitigation would impose significantly higher costs and risks to reach the desired (e.g. 2 °C) stabilization target.

Integrated science-policy research also provides very important information, such as the large co-benefits of GHG mitigation policies on health and other societal goals through improved air quality, especially in developing countries.

Looking forward

Looking forward, to begin with, the policy-science nexus should be viewed as an unending chain having policy and science as successive "Policy - Science - Policy" links. In specific, we propose the following to strengthen these linkages to make low carbon development research purposive and practical.

Rethinking research perspective

Conventional low carbon development research needs reorientation on the following counts:

a) The research paradigm and methods should follow a "horses for courses" approach, i.e. devise and apply scientific methods to the specific aspects of policy question.
b) Align the goals of low carbon scientific research with the development goals.
c) Look beyond the obvious (or conventional) options since low carbon development research has to discover out-of-box solutions.
d) Conventionally, the methods and models used by economists seek "efficient" solutions that result from competitive equilibrium. The development models should also consider "cooperation" among agents which lower transaction costs and risks, besides competition for the market efficiency.
e) Most research on policy instruments have been limited to conventional market instruments such as carbon tax and emissions trading. The climate issue is global. The countries are at very different stages of socio-economic development; in many developing countries, market institutions are weak and a sizable fraction of their economies operates through informal markets. Given the diversity, it is important to discover new policy instruments and also use multiple instruments in tandem to get best results.

Cooperative and community-driven research

There is plethora of research on the low carbon development pathway, yet it is fragmented and "non- inclusive", especially in terms of developed versus developing country perspective, emphasis, and participation. Future research can benefit from cooperative research, with teams of researchers from diverse countries. The scientific and political communities need to facilitate such research.

There are examples of successful community research and capacity building, such as the Japanese Government initiative over the past two decades, which is led by Japan's National Institute of Environment Studies (NIES), Tsukuba. This program, under the banner of "Asia-Pacific Integrated Model – AIM"[5], has created a sizable network of experts in Asia who are engaged in local (e.g. cities) as well as global studies [6] on low carbon development research [7].

Discovering "insights and numbers" with end-to-end solutions

Policy research contributes to understanding the process dynamics and related implications as well as to make targeted decisions. Since climate research is multidisciplinary and spans wide spatial and temporal scales, the policy hierarchy needs to be connected across the scales to propose end-to-end solutions. Insights are essential to link the processes across the scales and numbers are essential for delineating the activity levels at different scales. Looking forward, the low carbon development research can benefit from:

α) Research framing that delivers qualitative "insights" as well as quantified results, such as risks from different "levels" of climate change, investments needed to adapt or mitigate, etc.

β) Reframing research to address dynamics at "specific" spatial and temporal levels, and propose "end-to-end" solutions.

χ) Re-examining assumptions, e.g. economic models assume existence of "free" market competition that delivers economic efficiency; but for such markets to exist, the perfect "rule of law" institutions are needed. This assumption does not hold in developing countries and even in the case of global energy markets. Besides, the global context of the climate change phenomenon and the diversity of nations need to explicitly consider "cooperation", and not only competition, as part of the socio-economic framing.

δ) Greater stakeholder engagement which would cross-check to ensure recognition of "real" as opposed to "ideal" world dynamics. This is vital to minimize "transaction costs and risks" during implementation.

ε) Shared and inclusive vision, that is vital to propose and implement "end-to-end" solutions.

Conclusions

Low carbon development research has made eminent contributions to climate policymaking. Science has advanced to declare [3] that it is "extremely likely" that human influence was the dominant cause of global warming between 1951 and 2010. The emissions profiles of nations have altered since the negotiations of the Kyoto protocol in 1997, bringing into question the classification of countries under the original "annex" dichotomy. Issues like "peaking" of emissions, which looked not far in the future, have acquired urgency as the future emissions budget is shrinking. Whereas excluding the developing countries from carbon mitigation was earlier viewed as the necessity, e.g. in the Kyoto Protocol [8], this is no longer considered valid. Instead, facilitating developing countries to engage in low carbon development is now viewed as immediate priority, albeit with the necessary finance and technology support, to prevent long-term "lock-ins".

Going forward, the research context and questions to craft low carbon development pathways are shifting, as global dynamics continue to alter. The low carbon research now needs greater global engagement and local attention as well as long-term perspective and immediate actions. The altering low carbon research paradigm needs to be more sharing, caring and daring. Policymakers have shown keen interest in low carbon policy research and would support knowledge networks so long as research remains purposive, inclusive, practical, and adaptable to rapidly shifting contexts.

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The theory of no change

The article presents an analytical framework to identify relevant barriers to market transformation. The framework allows not only a consistent and structured stock taking, but comes with a visualization tool and allows to identify appropriate project interventions. The tool can assist policy makers and stakeholders to improve policies, projects or programs during the design phase, and to learn from past shortcomings to increase intended impacts.

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Introduction

During the evaluation of projects, programs, or policies failures or shortcomings are frequently reported, but the evaluation often does not provide a satisfying understanding of the reason "why" an intervention has failed. Frequently evaluations do not go beyond the assumptions and the logic that underlie the *evaluandum*. In such cases learning from the evaluation is limited.

Methodology

A meta-evaluation of climate change mitigation evaluations supported by a community of practice hosted by the Evaluation Office of the Global Environment Facility (GEF EO) identified a series of factors underlying failures. Rather than a classical theory of change, which postulates that certain causal linkages and assumptions make an intervention "work", a theory of no change (TONC) puts forward hypotheses regarding why certain causal linkages are in fact broken, or why implementation interventions mechanisms cannot (yet) work in identified circumstances.
The meta-evaluation led to the formulation of a framework that identified explicit barriers to change – in this case intended market changes – that had prevented the up-scaling of desired practices, i.e. energy efficiency measures. A case study of ten evaluations on energy efficiency projects, policies and programs in Thailand was undertaken to test whether the identified barriers helped explain market dynamics. A second case study in Poland was used for further testing [1]. The latter case study helped reduce the "Theory of no change" framework to twenty crucial barriers.

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The barrier circle

The "barrier" approach framework stipulates that it is not always the behavior of the target group of an intervention

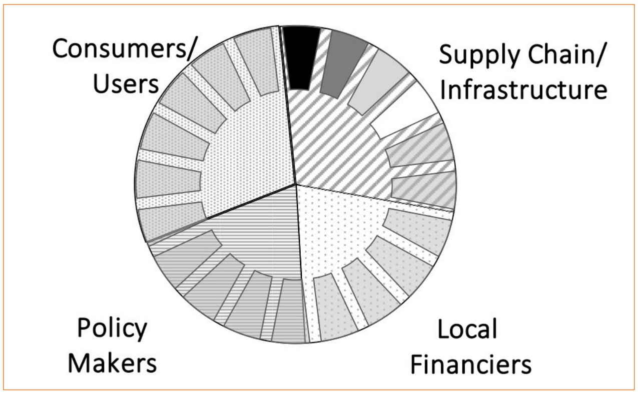

FIGURE 1 Structure of the barrier circle

Stakeholder	Barrier
Consumers/Users	Consumers Ignorance Lack of interest/motivation Lack of expertise Lack of access Lack of affordability Lack of cost effectiveness
Supply Chain and Infrastructure	Ignorance Lack of expertise Lack of access Lack of affordability Lack of cost effectiveness Lack of business model
Local financiers	Ignorance Lack of expertise Lack of cost effectiveness Lack of business model
Policy Makers	Lack of interest/motivation Ignorance Lack of expertise Lack of affordability

TABLE 1 Stakeholder groups and barriers

that makes an intervention fail. Our analysis suggests that most markets can be represented as a circle with four segments representing four stakeholder groups: (1) consumers/users, (2) supply chain and infrastructure, (3) local financiers and (4) policy makers (Figure 1).
Each of these actors faces four to six of the following generic types of barriers: (1) lack of motivation, (2) lack of awareness, (3) lack of access to the "better" technology, (4) lack of technical expertise, (5) lack of affordability, or (6) lack of cost effectiveness (Table 1). In some cases, the barriers may already be part of the intervention program. In most cases, where projects failed though, at least some relevant barriers were not part of the original considerations but merely identified as "contextual challenges" to project success. The barrier circle illustrates the relevance of these "overlooked" barriers to the achievement of intended outcomes using a specific color scheme. Specifically, the barriers that have proven to be effectively limiting change are marked in black. Those that exist, but are not decisive, bear grey shade colors while barrier-free dimensions are displayed in white.
To give an example: in the case of a market where the financiers' activities, attitudes and awareness levels slow down the change in the market, particularly due to a 'lack of business model', the barrier is symbolized by grey wedges in the financiers' part of the circle.
As markets develop, new barriers that used to be "not yet decisive" (grey color code) will then come up and become "limiting" (black color code). New barriers can also be created by external factors, such as changes in government, financial crises, failure of technical infrastructures, or new technological developments.

The intervention circle

A second visualization tool is the intervention circle, represented in a spider web diagram (Figure 2). The project interventions (shown as the spikes of the spider web) point in the direction of the barrier they are designed to address. The intensity of the barrier removal activity varies on a zero to five scale. The relative rank of the activity relates to its importance within the project or program. The spikes of the intervention circle are not calibrated with the intensity of the barrier in the market but are relative to the other activities in a project. The most important element of an intervention is given the highest ranking of five.
To visualize, for example, the case of a labelling policy for energy-efficient appliances each activity is illustrated as a spike of barrier removal activity on the

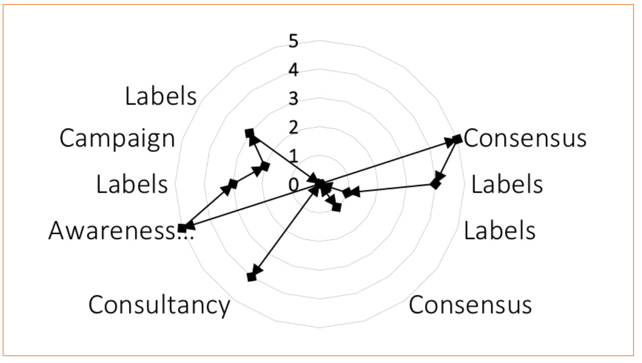

FIGURE 2 Intervention circle

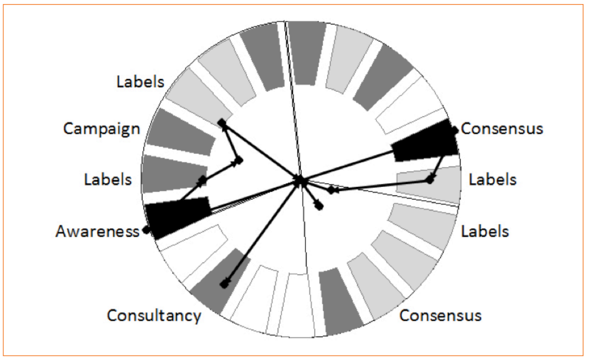

FIGURE 3 Combination of barrier and intervention Circle

spider web. The first activity addressed for instance the supply chain by building a consensus on a labelling system among manufacturers. The second activity addressed the barrier "lack of awareness among consumers" with an awareness campaign.

Project impacts on market barriers

The two tools can be combined to illustrate an intervention match with the existing barriers in a market (Figure 3). A simple overlay of the two diagrams illustrates the degree to which the activities align with the barriers. In the example presented here, the consensus achieved with the supply chain and the energy efficiency labels directly addressed the lack of awareness for this not-yet-cost-effective product and created a new business model, consisting of selling energy-efficient appliances in addition to the original appliances. However, the overlay of the diagrams shows that the black and dark grey barriers were not addressed by the project activities. It can be deduced that these barriers were not removed successfully through the intervention.

This example illustrates how the combination of the barrier circle and the intervention circle can give an indication of the likelihood for success of an intervention at the design stage of a project. When used in evaluation, the direction of the spikes of the intervention circle will be aligned with those barriers that they actually addressed (even if they might have been designed to address other barriers, or without an explicit barrier removal consideration). The tool is able to illustrate the sector in a holistic manner.

Conclusions

The barrier circle is a useful tool for the analysis of a market. When used for up-front project planning, it can help to identify the relevant barriers and design the appropriate barrier removal strategies. When the barrier circle is drawn for the situation before and after the project, comparing these two circles clearly illustrates the barrier removal impact of a project.

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[1] The original studies can be downloaded from the website of the Climate-Eval Community of Practice of the GEF Evaluation Office (http://www.climate-eval.org/?q=node/2).