



LETS 2050

Final Programme Report

Governing transitions towards low-carbon energy and transport systems

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Preface

Near zero emissions by 2050 in industrialised countries, required for staying below the two-degree target, is a challenging but also liberating thought. It may first seem like an impossible task. But a growing number of studies show that such a transition is possible from a resource and technology point of view, as well as economically feasible.

The LETS program on *Governing Transitions to Low Carbon Energy and Transport Systems* takes this as a starting point for exploring the policy and governance challenges that may be associated with making a low carbon transition.

LETS started in January 2009 and finished in June 2013. The research has involved more than 25 researchers from thirteen different departments and groups. This report summarises the key findings and presents some overall conclusions from LETS. For a complete account of publications and activities we refer to the website: www.lets2050.se

We would like to thank everyone who has contributed to the program: participating researchers, other colleagues, stakeholders, participants in the advisory board and reference groups, and many others. We especially thank the funding agencies whose farsighted cooperation on a joint research call made LETS possible: the Swedish Environmental Protection Agency, Swedish Energy Agency, Swedish Transport Administration, and Vinnova: the Swedish Governmental Agency for Innovation Systems.

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Executive Summary

The LETS program studied the societal and institutional changes implied by a climate transition to near zero carbon emissions by 2050 and how such a transition can be governed. LETS has Sweden as its main focus but many of the results have general implications. Future studies show that low carbon transitions are possible from an energy resource and technology point of view, as well as economically feasible. However, governance and institutional aspects are often overlooked in future studies.

The LETS program focused on the Swedish case. Sweden has reduced its emissions from 1990 levels through, for example, using bioenergy in district heating, expanded use of ground source heat pumps and renewable electricity. With existing policies (2011) emissions are projected to be 18 % lower in 2020 compared to 1990. Emission reductions of 20 to 40 % by 2020 to 2030 seem viable without fundamental or major technology, system or infrastructure changes. Steps must nevertheless be taken to prepare for more profound cuts in emission levels post-2030 through, for example, research and technology development, and infrastructure planning and investments.

Whether we can reach short term emission reductions at lowest marginal cost is not the most pressing issue in a longer term climate policy perspective. The key question is what type of society we want and how the vision and development can be made consistent with a low carbon transition. Climate objectives need to be developed along with other changes in society. While this is desirable, it is also doable because there are many co-benefits and potential synergies between greenhouse gas mitigation and other environmental and societal objectives.

A future low carbon economy requires a structural transformation of the present economy. The pace and direction of long-term economic development and growth cycles is an outcome of a complex interaction between technical, social, political and institutional innovations, which together form the set of basic rules within which all economic activity takes place. It is easier to initiate a transformation process during periods of economic structural crisis or weakness when the economy is reorienting anyway.

Social norms will change over time but economic incentives and factual climate arguments are, by themselves, not strong enough motivators of change. Stronger social motivation may come from, for example, peer pressure or health benefits from more physical activity and dietary change. Soft and hard policy measures can be sequenced (as in the case of smoking) to generate long term changes in mainstream norms and increasingly binding policy.

The research in the LETS program also point to a number of obstacles and one is short-term thinking. Climate policy in Sweden is heavily oriented towards reaching short-term emission reduction targets at lowest marginal costs, despite a general consensus among Swedish policy makers and politicians on the importance of long-term climate goals. Such goals require much more long-term thinking and sequential policy strategies.

There are also potential conflicts. Some of the greatest potential environmental conflicts result from the increased utilisation of bioenergy. Bioenergy can be more or less sustainable, depending on the scale of and methods for biomass production and use.

Carbon pricing is important but not sufficient. Complementary policies (e.g., building codes for simplicity and predictability) and flanking policies to handle side-effects (e.g., land-use regulations for biodiversity) are needed to govern a low carbon transition. Another example is targeted technology innovation policy in key technology areas.

The climate issue cannot be dealt with as a discrete environmental problem. It coexists with other environmental but also other societal goals that call for the attention of policy makers. Multiple and sometimes conflicting goals must be balanced in broad and coherent policy strategies, e.g., for sustainable transport, greening industry and sustainable cities.

One way to conclude our research would be to provide lists of recommendations for policies and measures, including carbon pricing and tax reforms, renewable energy support, bonus-malus for cars, new planning approaches, green public procurement, and so on. There is no lack of ideas. Lack of implementation is the main obstacle. This may be due to conflicting interests, e.g., between winners and losers, conflicting goals in different policy domains, or different ideas on what the role of government should be. Therefore, and instead, we conclude by making four general and interconnected recommendations for governance that appear to be particularly salient for making a transition.

First, there is a need to develop long-term innovation and industrial development policies aimed at preparing for extensive emission reductions post 2020 and 2030. The main options in terms of resources, technologies and system elements of a transition are relatively well known. These include high energy end-use efficiency, clean power production, and electrification of transport and industrial processes. Selected areas can thus, be targeted through government policies and development strategies.

Second, to assure legitimacy in the governance of low-carbon transitions it will be useful to explore mechanisms for greater transparency and increased public participation and also to monitor policy. In many policy areas there are established control mechanisms and “watchdogs” that monitor, evaluate and report. Independent national audit offices are one example. In addition, new policy evaluation approaches are needed for comprehensive assessments with multi-objective and long term perspectives.

Third, it is important to reconsider whether existing administrative structures, organisations and jurisdictions in government are suited to govern the transition. For example it is important to coordinate between different policy levels, sectors and domains and to keep in mind that suitable solutions may be highly contextual. Continual development of scenarios and roadmaps may be used as a mechanism for learning and strategizing about policy, as well as for policy integration.

Fourth, policy makers should consider ways of creating new pathways and long term lock-in situations that are consistent with low carbon transitions. Climate legislation, similar to the UK Climate Change Act, is an example of such an attempt which also increases transparency. Long term lock-in could satisfy the need for long term stability and clear direction in industry’s investment decisions.

Our research has identified some important aspects to consider in the governance toward low-carbon transitions. The precise details regarding what types of mechanisms, structures and policies are needed should be part of a continuous transformation toward low-carbon governance.

Introduction: In the light of low carbon futures

The climate issue is an environmental problem that in many ways differs from other environmental problems. Many environmental problems are limited in their spatial scale (e.g., local and regional air pollution) or have a technical solution (e.g., replacing ozone-depleting substances). Climate change is a global problem and greenhouse gas emissions originate from a very wide range of human activities. Thus, mitigating climate change requires measures across all sectors. It has implications for what we do and how we do things in essentially every sector of society.

Under the UN Framework Convention on Climate Change the countries of the world have agreed on a climate policy objective: The increase in global average temperatures by 2100 should not exceed two degrees Celsius. This requires global emission reductions by at least 50 % by 2050. For industrialised countries it translates to more than 80 % reductions, or near zero emissions by 2050. This provided the backdrop for the overarching research question of the LETS program:

What societal transitions are implied by low-carbon futures and how can these transitions be governed and implemented to meet challenging climate policy objectives?

Emission reductions of 20 % to 40 % by 2020 to 2030 seem viable without particularly fundamental or major technology, system or infrastructure changes, at least in a Swedish or European context. Such targets can probably be reached by tweaking the existing energy and transport systems with improved energy efficiency and some fuel shifts. But going beyond that presents a greater challenge.

Near zero emissions by 2050 in industrialised countries, required for staying below the two-degree target, is a challenging but also liberating thought. It may first seem like an impossible task, but a growing number of studies show that such a transition is possible from a resource and technology point of view, and that it is also economically feasible. It requires investments but these are largely recouped through lower expenditures on fossil fuels. The thought is liberating because it makes us shift our focus away from thinking about mitigation measures with the lowest marginal costs for reaching Kyoto or 2020/2030-type reduction targets. Instead, or in addition, it forces us to think about societal changes and major technology shifts, including energy and transport system changes, that are likely to be required in the long term.

Various low carbon transition pathways have been explored and presented in several studies. These are typically based on engineering-economic knowledge and modelling approaches with a focus on quantifiable technical, economic and environmental implications. The deeper political and institutional implications, beyond the obvious observation that better policies are needed, have been left largely unattended (Nilsson et al, 2011; Söderholm et al, 2011). For example, institutionalized norms and cognitions both shape policy formation and tie into the larger framings of the field. Shifts in dominant or influential coalitions may lead to shifts in dominant framings and what types of governance approaches and policy instruments that are seen as appropriate.

Realising low carbon transitions requires attention to governance issues. What is the role of government in making the transition? What organisational and institutional changes, e.g., in regulations and social norms, may be important? What will be the key goal conflicts, or conflicts of interest, and how can they be dealt with? How can transitions be instigated and then upheld through creating new pathways and low carbon lock-in? These represent some of the governance questions that were addressed in the LETS-program.

In this final report we summarise the research, the work process and our results. The next chapter provides a general overview of the LETS-program. The following chapter presents the research activities and results from the different work packages in some detail. Overall results, synthesis and recommendations are presented followed by a discussion on future research needs. The program was rather unique in its disciplinary breadth and diversity and we therefore share our experiences from this inter- and multidisciplinary effort in the final chapter.

About the LETS 2050 research program

The LETS research program (Governing transitions towards low-carbon energy and transport systems) started with a kick-off meeting February 2-3, 2009 at Lund University. The initial research team included ten academic research groups and a research based consultant. A fifth work package (WP5) focusing on logistics and goods transport was added in early 2010 and included two new research groups.

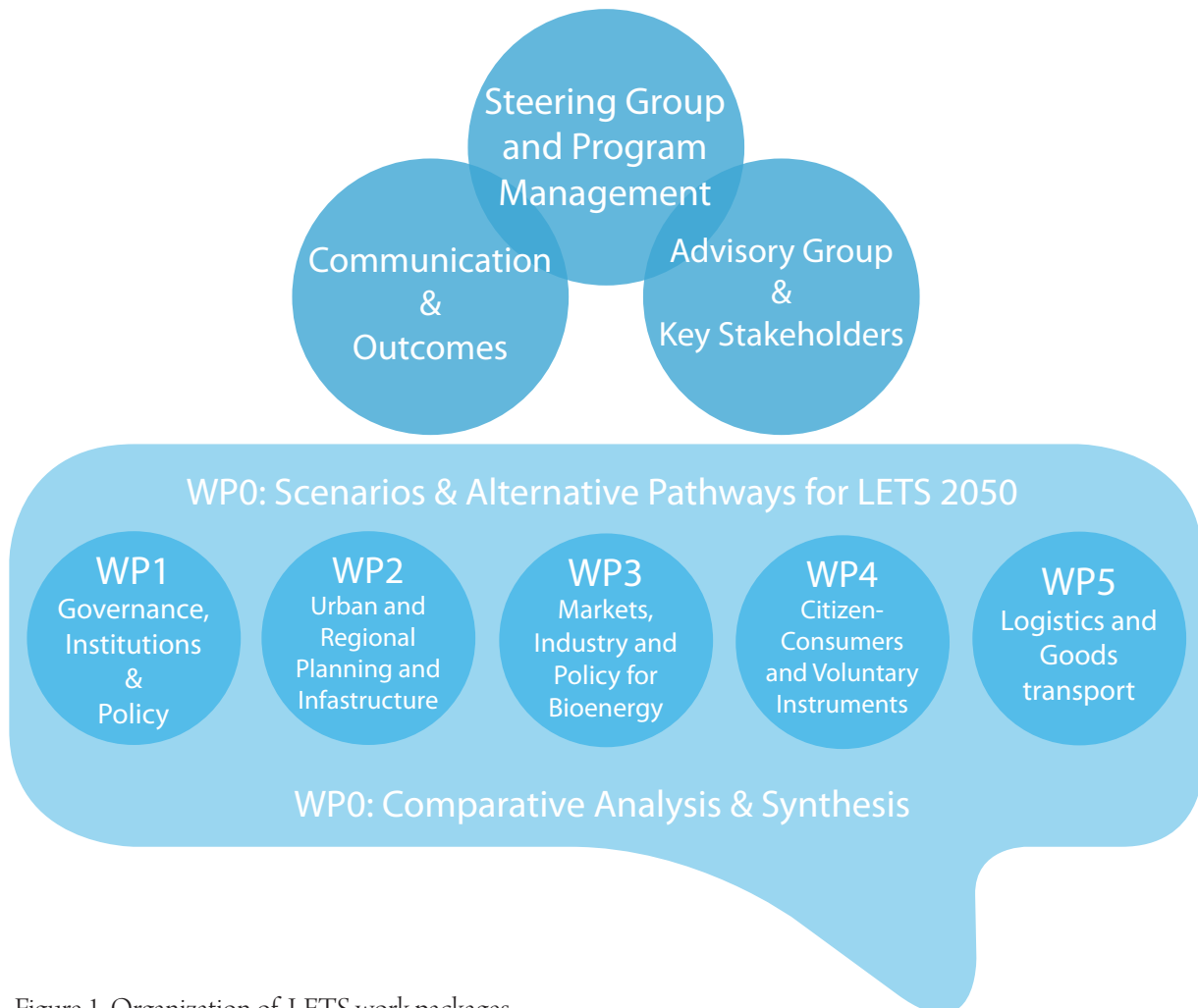


Figure 1. Organization of LETS work packages.

In the organisation of the program we took care to involve different people and, or, disciplines in more than one work package, for the purpose of fostering interdisciplinary collaboration. Similarly, each work package had a leader and deputy leader from different groups. The researchers had backgrounds in the social sciences, law, economics, and engineering¹. With one exception, all the groups are based in Lund and the geographical proximity was important for building close collaborations. The interdisciplinary experiences are further discussed in chapter 5.

The core mission of LETS as formulated in the original proposal was to identify, explore and suggest ways forward, i.e., *roads to implementation of low-carbon energy and transport systems for 2050*, in order to reach ambitious climate policy objectives such as expressed by the 2 °C target. The overarching research question was formulated as:

1. The participating groups and departments included the Division of Environmental and Energy Systems Studies, Department of Political Science, Department of Economics, Division of Economic Geography, Division of Transport and Roads, Department of Law, Division of Packaging Logistics, Division of Engineering Logistics, the Research Policy Institute and thereafter the Department of Sociology, the International Institute for Industrial Environmental Economics, the Sweden Institute for Food and Agricultural Economics, the Division of Economics at Luleå Technical University, and Trivector, a research based consultant which took part in research but also took responsibility for administrative project management and communications.

What societal transitions are implied by low-carbon futures and how can these transitions be governed and implemented to meet challenging climate policy objectives?

A vantage point for LETS was the multitude of scenario studies that have suggested that low-carbon futures are possible from a resource, technology and economic point of view. Our research focused on transition governance, i.e., a reflective and strategic steering by the public sector in collaboration with other societal actors in order to make the transition to a low carbon society. For practical purposes, this implies essentially zero greenhouse gas emissions in Sweden by 2050. In the research we have studied conflicts of interests and goals and other governance challenges that follow from the necessary changes in technical systems and behavioural patterns that are implied by the climate policy objectives.

Rather than trying to cover each and every aspect of a transition, the original proposal identified four main areas of research organized in WP1-WP4 (with WP5 added in 2010 through additional funding). These WPs represent one of many possible ways of “slicing the cake.” But it was one which we found purposeful and aligned with the ambitions of the program to generate new inter- and multidisciplinary research into key “governance challenge” areas. They were formulated so that a suitable number of disciplines could gather around a common set of research questions. Herein lies what we consider an important added value of LETS: entirely new constellations of research groups have been created. To some of those groups the concept of a low-carbon society was entirely new at the outset. The task of unpacking the implications of reducing emissions to zero in the next forty years is thought provoking and has generated a great deal of interest and enthusiasm.

Another important added value follows from the sincere interest and engagement of the four funding agencies. In addition, each work package engaged with many other stakeholders in various ways, through workshops, reference groups, focus groups, etc. The level of involvement was been high from the start and an inspiration to the LETS researchers who felt that the research and the results matter. It also helped ensure the practical relevance and usefulness of the research. Communication, within LETS, with funding agencies, other stakeholder and the scientific community, has been a high priority from the start and benefited the program.

The topical nature of the research has presented the LETS researchers with several opportunities to reach a broader audience through op-eds, interviews in newspapers, invited participation in debates and seminars, talks at conferences, etc. One example: in the beginning of LETS, early spring 2009, we were invited to host the first high level workshop organized by Atomium Culture (a Brussels based network of research universities and newspapers in Europe). The workshop in December (scheduled before COP-15 and under the patronage of the Swedish Presidency) provided us with an excellent opportunity to bring our research questions to a broader audience, including representatives from academia, business and media. Another example, towards the end of LETS, we made several contributions to the work on a Swedish low-carbon roadmap by the Swedish Environmental Protection Agency for the Swedish Government.

LETS' success has partly been contingent on our ability to draw on and synthesize research in contexts outside LETS' immediate research community. That is why we nourished the links to other research networks and adjacent or similar research fields. This openness was an explicit strategy of LETS. More concretely it meant that we included researchers not employed in the LETS program in different activities. For example, at Lund University there are other researchers working on bioenergy issues who we invited to workshops, seminars and other activities. Although such external researchers were not salaried through LETS, their contributions helped raise the academic quality of the LETS program, make our research known in a larger context at the same time as it provided these researchers with a valuable network and a chance to get feedback on their own research.

Research activities and results

The LETS program has covered a broad range of issues at different levels ranging from macro-economic implications and governance approaches to local planning procedures and enforcement of building regulations. WP0 worked as an umbrella work package, providing the broader background and a space for synthesising work emerging from the other five work packages where researchers delved into specific issue areas. The following sections report briefly on the research, findings and overall conclusions from each of the work packages.

Future policy scenarios and alternative pathways (WP0)

The function of WP0 was to create a common framework for the research within LETS and coordinate the synthesis of the research results. The following research questions guided the work in WP0: *What are the pathways towards a low-carbon society? What are the main governance challenges for a low-carbon transition and what are the policy implications today?* The research was carried out by a multi-disciplinary group consisting of researchers from Environmental and Energy Systems Studies, Economics, and Political Science. An important part of WP0 was also to facilitate a dialogue between all researchers of LETS.

Research approach

The work within WP0 was carried out in two main parts. Initially, we critically analysed existing low-carbon scenarios and explored two possible low-carbon development paths for Sweden. The aim of this work was to investigate how issues of governance can be brought into scenario studies and create a common framework for the research on specific areas and challenges in the other WPs of LETS. A meta-analysis was carried out. It consisted of a critical review of 20 quantitative and qualitative scenario studies, all relevant for meeting long term climate objectives (Söderholm et al, 2011). In another study, political and institutional parameters were combined with scenarios studies in order to explore how proposed future system changes and policy paths are conditioned by political and institutional factors (Nilsson et al, 2011). In the first part we also analysed the possible effects on the Swedish environmental objectives of different pathways to a low-carbon transition (Hildingsson and Johansson, 2014). In the second part of WP0 we focused on integrating knowledge from the other work packages in LETS and analyse the main governance challenges and policy implications of moving towards a low-carbon society. The results of this have been presented in three policy reports (Khan et al 2011a, Khan et al 2011b, Nilsson et al 2013).

A key aspect of the research approach in WP0, and in the whole of LETS, has been dialogue between researchers and with policy makers as well as other stakeholders. The initial work with developing tentative low carbon scenarios had an important function in bringing together researchers from different disciplines into thinking future oriented. The process was, in some ways, more important than the end result. Several workshops were organised in the start-up of the project with participation also from the four funding organisations. Workshops with participants from policy making, industry and NGOs, were also held in connection to the development of the three governance policy reports. In the second policy report (Khan et al, 2011b) researchers from all work packages of LETS engaged directly and produced chapters about governance challenges in their areas of expertise.

Research findings

One finding from the review of scenario studies was that governance aspects have been treated poorly (Söderholm et al, 2011). In the 16 quantitative scenario studies reviewed, policy processes were implicitly viewed upon as logical and linear step-by-step procedures. In addition, attention was mainly paid to the impact of well-defined and uniform policy instruments while fewer studies factored in the role of policy and institutional change. This

approach neglects the time dimension, the dynamics of policy processes and the influence of different actor constellations engaged in a given policy area. The complexities of policy processes call for a climate policy arsenal that is more diverse than the uniform carbon pricing policies that prevail in most quantitative scenario studies. The four qualitative scenario studies examined in the paper included more detailed analyses of politico-institutional factors and a broader assessment of policy instruments but were poorly connected to quantitative accounts of future low-carbon energy and transport systems. The explorative study (Nilsson et al, 2011), combining political and institutional parameters with scenario analysis, showed the potential of this approach. Starting out from low carbon policy paths in five key areas (wind power, biomass, energy efficient buildings, electrification of road transport, industry) it was shown how they were differently sensitive to and dependent on institutional conditions, such as regulation, cognitions and norms. This analysis highlighted that institutional aspects must enter future studies and illustrated *one* way this can be done.

The study on potential synergies and conflicts between greenhouse gas mitigation and other Swedish environmental objectives (EOs) showed that environmental impacts appear in all steps of the energy chain, from land-use effects (both direct and indirect) of renewable energy extraction to emissions at end-use energy conversion (Hildingsson and Johansson, 2014). Of the studied energy alternatives, the greatest potential conflicts with other environmental objectives come from the utilisation of bioenergy. The conflict depends, however, on both the magnitude of the future expansion and the methods used for biomass production. Therefore, in order to allow a large scale expansion of biomass, the development of adequate policy instruments that govern land-use both nationally and globally will be essential. For wind power on the other hand, there seem to be no fundamental obstacles from the EO perspective to allow large scale expansion although conflicts may be significant locally. Strategies for reducing energy use and transportation demand generally lead to less conflicts with other EOs and give improved conditions for achieving all of them. It is not possible today to guarantee that low carbon mitigation scenarios are compatible with reaching other EOs as it depends on what methods and technologies that are used, the successful development of new technologies and the development in other sectors of society such as the food sector. It is vital that systems of governance are implemented on the adequate level (as close to the environmental impact as possible) in order to keep the development of the transport and energy systems within sustainable borders. These systems of governance have to be flexible enough to be able to react on new knowledge and new priorities within society.

The three governance policy reports sought to answer the second question of WPO: *What are the main governance challenges for a low-carbon transition and what are the policy implications today?* In the first report, two tentative low carbon scenarios were presented which focused on technical solutions vs. behavioural changes (Khan et al, 2011 a). The aim of the scenarios was not to be fully comprehensive but rather to identify major governance challenges of different low carbon pathways. The report introduced the concept of low carbon governance and discussed this in a Swedish context with examples from different policy areas. The second report deepened the analysis of specific sectors and topics such as bioenergy, wind power, energy efficient houses, decarbonisation of industry, freight transport, future energy carriers in the transport sector, planning for reduced transport and the emergence of climate reflective citizens (Khan et al, 2011 b). The need for policy changes were analysed at (i) the *policy level* (policy instruments, measures, resources), (ii) the *institutional level* (legislation, organisational structures) and (iii) the *paradigm level* (basic norms, discourses, values). One important finding was that general economic policy instruments that regulate the price of carbon are and should be a main pillar of climate policy. However, for a low carbon transition, they need to be combined more purposefully with other policy instruments which support technology innovation and facilitate low carbon practices. Another finding was that institutional changes are needed. An illustrative example is that regional and urban planning needs to be used much more in order to reduce transport demand and change mobility patterns. In the third report, the main conclusions from the LETS program were presented (Nilsson et al, 2013). These are discussed in the chapter on “Overall conclusions and recommendations”.

Governance – developing institutions and policy (WP1)

WP1 has analyzed *what type of governance, in terms of institutions and policy, that is necessary to enable a transition to a low carbon society*. Special attention has been given to analyze the dynamics of the political and economic processes and its implications for the implementation of an efficient climate policy. The research team has consisted of researchers from Environmental and Energy Systems Studies, Economics, and Political Science.

Research approach

The initial work included a research overview of different theories and perspectives on governance, transitional theory, long term economic growth and climate change, which were presented at conferences and in research reports. The work continued by analyzing the importance of institutional innovations in climate-, energy- and environmental policy (Khan et al, 2010). Using economic theory we highlighted the importance of dynamically consistent policy (e.g., that policy is stable with clear direction over time) and the importance of initiating the transition to a low carbon economy as quickly as possible to minimize the social cost.

Two important research fields that needed further attention were identified during this initial work: understanding the rationales behind the Swedish climate policy, and understanding the dynamics behind long term economic growth and structural change. The remaining work was devoted to these two research fields.

Our research has been published in international journals, been presented at international conferences and discussed with representatives from the business sector and the political parties.

Research findings

Within the first research field we have developed a general understanding of transition governance and the political challenges associated with large scale and long-term system transformations. An important finding is that it is not sufficient to focus only on instrumental questions such as policy design and efficient policy instruments. Although important, that will not lead to transitional change unless more fundamental questions are addressed such as the institutional set-up and underlying norms. What is at heart is the role of politics in steering low carbon transitions over the long term.

An interview study, carried out in 2011, with 60 climate policy actors provided interesting results (Kronsell et al, 2012). A striking finding was that, at the time of the interviews, there seemed to be a limited long-term and transitional focus among policy makers and politicians, despite a general consensus on long-term climate goals. National climate policy is focused on reaching near-term policy goals at lowest possible costs (Khan et al, 2012). This might change with the recent initiation of policy processes around a low carbon road map and a fossil fuel free vehicle fleet but it remains to see what they will lead to in terms of policy practice. A clear impression is that Swedish policy has lost its ambition to be a frontrunner but is content to do well enough in relation to climate action by other nations.

Another finding is that the traditional Scandinavian corporatist policy style is very much alive in the climate policy arena with a dominance of established actors and interests (Kronsell et al 2013). There are particularly strong links between policy makers and market actors coupled with a strong belief in market based solutions, while there is hardly any mention of engaging civil society and citizens in the transition. This indicates little belief in the possibilities of norm change and instead the main focus is on technical solutions. Also the gender perspective is largely lacking in the climate policy arena (Kronsell, 2013). However, the interview study also revealed an alternative discourse on low carbon transition governance that addresses a more proactive role for state institutions and other

societal actors (Hildingsson 2012). In this perspective a low carbon transition permeates all sectors in society and calls for policy action that goes beyond carbon pricing.

The second research field has resulted in three main findings. The first one is that building a low carbon economy requires a structural transformation of the economy. It is questionable if large reductions in emissions are possible within the present economic structures (Andersson and Karpestam, 2013) and changing the economic structures such that the profitability of both investments and R&D in green innovations increases is a key policy challenge. The pace and direction of long-term economic change is an outcome of a complex interaction between technical, social, political and institutional innovations, which together form a set of basic rules within which all economic activity takes place. Changing these rules also changes how the economy functions. Historically, there have been substantial changes to the rules but the change is slow and can take several decades.

The second main finding is that the government has a role to play in changing these rules. Putting a price on carbon is likely to have an effect on emissions but is unlikely to cause a major transformation of the economy (Andersson and Karpestam, 2012; 2013). A wider set of co-ordinated policies including not just economic policies but also areas such as social policy and institutional reforms are needed. In other words, climate policies should not be viewed as a separate policy field but rather as an issue that unites all other policy areas.

The third main finding is that initiating a structural transformation of the economy is difficult and the timing is important. The economy goes through periods of structural weakness every 40 to 60 years. Initiating a transformation process is easier during these periods of weakness than during periods of strong growth.

Overall conclusions

Generally, our research has illustrated the importance of institutions, norms and political leadership in creating the right conditions for a transition towards a low carbon economy. Specifically our research has also shown that Swedish climate policy lacks a long-term perspective, that the interest among policy makers to actively engage the civil society in the formulation of policy is weak, that government policy too often is guided by narrow short-term economic considerations rather than long-term interests and there is little belief that changing norms are possible. Overall these results illustrate the lack of understanding of the long-term economic development processes. For Swedish climate policy to be successful a greater understanding of the complex and evolutionary nature of economic and political development processes is important.

Urban and regional planning and infrastructure (WP2)

The work in WP2 focused on the role played by the development of the built environment in a transition to low carbon energy and transport systems. The overarching research question guiding the work was: *How do we govern to travel, transport, build and live more sustainably?* This question was broken down in three research areas: i) tools and policy instruments for increased energy efficiency in buildings ii) regional and urban planning for transport, mobility and accessibility iii) industrial and regional development; structural changes and climate impact.

Research approach

The research team consisted of researchers from Environmental and Energy Systems Studies, Transport and Roads, Law, International Institute for Industrial Environmental Economics and Economic Geography. The individual members of the research team were primarily involved in projects covering one of the research areas. A continuous dialogue and interaction within the entire research group was established by frequently recurring WP meetings. In addition several seminars and workshops (internal and external) were organized within the different

research areas where the entire research team participated. Engagement with practitioners was a central element of the WP and a number of workshops were held involving officials from several municipalities, the County Administrative Board, The Swedish National Board of Housing, Building and Planning, the Swedish Transport Administration, other public agencies as well participants from the private sector and NGOs.

Research findings

The research on tools and policy instruments for increased energy efficiency in buildings was further divided in two sub-projects; one focusing on energy efficiency improvements in existing buildings and one focusing on energy efficiency in new buildings.

The research on energy efficiency in existing buildings covered inventories of legal instruments to improve energy performance in existing buildings, a critical analysis and discussion of current legislation and a discussion on how this may be improved (Weber, 2012). A main finding here is that current Swedish legislation concerning energy performance in existing buildings is not aligned with the Swedish parliament's objective to reduce energy use in buildings with 20 % by 2020 and 50 % by 2050. A conclusion is that the requirement for energy declaration of buildings is a good attempt, and a first step, to address this objective. But the legislation is not designed to ensure that cost effective measures for improvement of energy performance is taken; possible cost effective measures shall be *suggested*, but there is no requirement to actually *implement* the measures. An overall conclusion is that the legal requirements need to be tightened if the policy objectives regarding energy efficiency in existing buildings are to be achieved. We present and discuss two models for how to supplement current legislation with an obligation to take cost effective measures to improve energy performance in existing buildings.

The sub project looking at new buildings focused on urban governance in two studies, the first one concentrated on the role of dialogue in planning to foster sustainable urban development in general and energy efficient construction in particular. The aim was to assess a joint initiative being developed in six different municipalities. From this study, it was concluded that the collaborative processes to promote relationship building were highly appreciated and that processes of knowledge exchange and knowledge enhancement were quite successful. However, capacity building in terms of mobilisation for a sustainable development was less successful. The results show that the capacity of the dialogue to enable mobilisation around sustainability issues through the creation of common visions and goals was weak (Smedby and Neij, 2013).

The next study examined the role of local programmes for sustainable construction. Swedish municipalities do not have the jurisdiction to put local energy requirements on buildings, but when they own land they can put requirements through land allocation agreements. The study mapped the occurrence of this form of bottom-up initiative and studied the effectiveness of one particular programme. An overall conclusion on energy efficiency in new dwellings is that municipalities play an important role for fostering energy efficiency. Limited jurisdiction in combination with a strong municipal interest for energy efficiency in buildings at the local level has spurred innovative governance approaches; these often include knowledge- and relation building aspects. The study concludes that local energy efficiency requirements are increasing and apply to a large share of new dwellings being built in Sweden. The requirements have taken different forms in different municipalities but there is a regional effect where neighbouring municipalities apply similar standards. The results from the assessment of one of the programmes indicate positive effects in terms of energy efficiency.

The research on regional and urban planning for transport, mobility and accessibility was also carried out in two sub-projects. The first sub-project aimed at increasing the understanding of the correlation between transport, energy use and CO₂ emissions on a regional level (Holmberg, 2011). Important results include: an extensive

literature review with a specific focus on the regional scale; and a study based on a quantitative model contributing to the knowledge on how transport related emissions vary in a regional perspective, and how these variations correlate with different variables such as density, degree of self-sufficiency of work places and access to public transport. These results can provide a basis for understanding how different regional development scenarios will impact transport CO₂ emissions (Holmberg & Brundell-Freij, 2012).

The second sub-project focused on the interaction between land use-, transport and infrastructure planning. This includes one study on the handling of conflicting interests in regional infrastructure planning and one study on the introduction of alternative funding models for transport infrastructure and sustainability. Key findings in these studies are that the planning discourse is strongly growth oriented and dominated by certain concepts (e.g. regional expansion). This leads to a framing of problems that emphasize the lack of money (chiefly for investments in regionally prioritized rail investments) as the main barrier for resolving conflicts with environmental objectives (Pettersson, 2013). The study on funding models examines the potential of user fees as a means to raise capital as well as a means to influence sustainable travel behavior. The results illustrate that meeting this dual objective implies several policy and institutional challenges that have to be addressed very carefully. Key issues at stake concern the allocation of power over pricing and the consequences of the institutional arrangement of the funding model concerning physical and operational integration with the existing transport system (Pettersson, 2014).

How structural change and climate policy impact the linkages between industrial location, transportation and regional vulnerability was studied within the research area on industrial and regional development. The main issue has been whether the increasingly knowledge-intensive industry has lost focus on transport costs, and whether, as a result, policy-driven transport costs in the future will lead to any significant relocation of industrial production and influence the planning of an energy-efficient transport infrastructure. Within the subproject, demographic changes and the national regional system's ongoing development was also studied as regarding the impact these changes may have on future traffic flows, infrastructure investments and climate effects. The results from these studies were used as input into the analytical model developed in WPS, which was used to suggest how future freight in the short and long term can be directed towards substantially reduced carbon emissions.

Overall conclusions

Given the rather different nature of the topics studied in the three research areas of WP2 it is hard to provide overall conclusions addressing the overarching research question in any great detail. How to govern to travel, transport, build and live more sustainably is a highly complex question and the work carried out in WP2 highlight the importance of understanding the complexity involved in a transition of the built environment towards a low carbon future. The interplay between governance arrangements, the different means of influence at different levels, the dynamics between public and private actors and the types of knowledge that underpin various planning and policy processes are all providing important pieces of this puzzle. A key challenge faced in all three research areas concern the municipal "planning monopoly" characterizing the Swedish planning system. What can be concluded from the studies is that the planning monopoly can both pose an opportunity and an obstacle for a transition. To get all these aspects in sync towards a low carbon and sustainable future while simultaneously achieving various other policy objectives (concerning e.g. labor market, housing, trade and industry etc.) is of course a formidable challenge.

Markets, industry and policy for bioenergy (WP3)

WP3 has analysed the role of bioenergy in the transition to a low-carbon energy and transportation system, focusing on the following key questions: *What are the business and societal challenges and opportunities following an increased use of biomass from agriculture and forestry for energy purposes? Which instruments and policies are needed to give a sustainable and efficient use of biomass for energy purposes?* The research has been conducted in a multi-disciplinary team of researchers from Economics, Agricultural Economics, Environmental and Energy Systems Studies, and Law, in fruitful cooperation with a stakeholder reference group.

Research approach

The research work was structured in three parts. An increased demand of biomass for energy use give rise to enhanced competition for land and biomass resources, affecting the forestry and agricultural sectors. Therefore, in the first part, the *effects of increased resource competition* on the agriculture and forestry sectors was analysed using economic simulation models. For agriculture, the consequences of the EU 2020 renewable energy targets were analysed using the CAPRI model. CAPRI is a detailed partial equilibrium model of the European agricultural sector. For forestry, the focus was on how the competitiveness of the Swedish pulp- and paper industry has been affected by the increased use of forest resources in the energy sector. For this analysis, a partial equilibrium model of the Swedish forestry and energy sectors was constructed.

In the second part, different *measures and policy options* were discussed and evaluated. The work started with a review of existing policy instruments to reduce emissions, such as carbon taxes, and policies to promote biofuel demand and production, such as blend-in mandates. As different forms of land use, like land conversion, cultivation, harvesting and felling of forest, cause greenhouse gas emissions, policies for a sustainable biomass production is needed. A number of such measures have been evaluated, with a focus on measures that can be implemented at the farm level in Sweden. Although LETS has a focus on Sweden, the markets for fuel, food and fibre are international and the interconnections between geographic regions through trade and policy are important to consider. We therefore also studied EU external governance and the policy for sustainable fuels for countries exporting biofuels to the EU. Finally, the impact of energy and climate policy on the Swedish pulp and paper industry was analysed.

Third, potential *conflicts and opportunities* of increased demand of biomass for energy purposes were addressed. The focus here was mainly on conflicting demands of land use affecting food security and other environmental concerns than reduced GHG emissions, like biodiversity. Regarding opportunities, the development and commercialization of Swedish technology has been analysed from an innovation-oriented perspective.

Research findings

Biofuels production has increased rapidly the last decade stimulated by various public policies particularly in the USA and the EU. Such policies could lead to increased resource competition between the energy sector, the forest industries and agriculture. Our research, however, show modest impacts so far. For instance, current climate and energy policy instruments have not caused any significant resource competition to the disadvantage of the Swedish pulp- and paper industries. It is important to note, however, that the results are valid only for moderate changes in current levels of existing policy instruments. For more pronounced changes, increased price competition is likely to occur; influencing availability and prices of raw material for the forest industry. Our research further shows that the impact of increasing the production of biofuels from current (2010) levels to the production levels indicated in the action plans to reach the 2020 target of 10 percent renewable fuel, would result in a limited increase in land used for agricultural purposes in the EU (Wilhelmsson and Jansson, 2013). However

there are reallocations of the land use within the sector and a substantial increase in imports of primary agricultural products. This implies that the policy will affect land use outside the EU.

In the promotion of a sustainable production of biofuels, it can be noted that emissions of greenhouse gases vary considerably from farm to farm because of differences in local conditions. Hence, policies should allow farmers the choice of measures that are most appropriate for their farms. The implication is that legislation and subsidies may not be the most effective policy instruments except in special cases. Taxes and emission trading, both of which influence the cost of greenhouse emissions, but leave the choice of measures to the farmer, are generally more successful; i.e., they are more suitable for steering choice towards more effective measures (Berglund et al., 2010). In an international perspective, our research showed that the effectiveness of EU policy for sustainable fuel production in countries outside EU deteriorated due to lack of inclusion of the participating country in the policy process, in our case study Mozambique (Di Lucia, 2010).

The Swedish pulp and paper industry has gone through a strategic change in its approach to electricity production and consumption over the past decade. Our analysis showed that this strategic reorientation has been driven by changes in the underlying economic conditions for the pulp and paper industry, in particular increases in the price of electricity following the Swedish energy market reform in 1996, and the introduction of the EU ETS (Ericsson et al, 2011).

Our analysis finally showed that the design of a climate-oriented innovation policy is a complex task, since we are dealing with several different market failures at the same time. Innovation policy cannot replace the "engine" of climate policy, a positive price on carbon, but it is needed to run the engine more efficiently. There are a number of important technology-neutral measures that can act as a foundation for an effective innovation policy in the climate field. However, more targeted support for specific technologies and energy sources is also needed, due to the presence of network externalities. Further, the return on public R&D support often increases when R&D support is integrated in practical applications. Uncertainties regarding the potential of future technologies should not motivate a passive policy stance as a climate-related innovation policy largely works as insurance against high mitigation costs in the future, when global climate policy can be expected to become more stringent.

Overall conclusions

A system for pricing greenhouse gas emissions provides a direct, technology-neutral and cost-effective incentive to reduce emissions and is thus a basic instrument of effective policies. For agriculture, additional targeted measures to reduce greenhouse gas emissions are also needed. From a global perspective, it is reasonable that Sweden takes some responsibility for technology development in bioenergy, particularly regarding a more intensive use of forest products (like new products related to bio-refineries). For this to happen, additional public and private investments in pilot- and demonstration plants are needed.

Citizen-consumers and voluntary instruments (WP4)

A central governance challenge is the fact that the general public's willingness so far not sufficiently materialised when it comes to changes in consumer patterns, everyday habits or support for policies and technology geared towards substantial reductions of climate gas emissions. The general research question of WP4 has been *how voluntary policy measures addressing citizen-consumers could become a more powerful part of this ambition. How could the readiness of citizen-consumers be strengthened, both in terms of daily life activities (as consumers and users of goods and services), and in terms of a stronger support for environmentally progressive policies?* The team consisted of researchers from Sociology, Transport and Roads, Economics, and Political Science.

The work process

The work was initiated by extensive knowledge sharing between the researchers from their respective disciplines and studies. Theories on voluntary and mandatory policy measures were explored and further developed in relation to concrete cases of Mobility Management² (MM) and various climate-oriented policy measures (climate offsetting, dieting, labelling, etc.). Moreover, cases in entirely different areas were examined, for instance changed norms and regulations of smoking, cases that seem to be well suited for extrapolation to cases of dramatic climate gas reductions in the decades to come. In MM, a couple of reports have been published based on a close investigation over time of MM activities, their challenges, opportunities, and public reactions. As to climate-oriented policy measures, researchers in WP4 have delivered several international publications. What was originally planned to become a synthesis work report was instead developed into an international book monograph, published by Palgrave Macmillan, on citizen-consumers and social motivation. Finally, this WP has been active in terms of Swedish communication in public agencies and seminars on several occasions.

The role of factual climate information

Information from public authorities 'top-down' is certainly needed, but state and local authorities must also find ways to encourage climate-oriented norm diffusion between citizen-consumers. Such horizontal transmission is often more efficient than if citizen-consumers are to take in information from above³. A factual, reason-based trust in official information is necessary but not sufficient. It needs to be combined with efforts to stimulate a more social and emotional trust in other people who are on the same, or slightly higher, socioeconomic level, in order for people to be motivated to change routines (Klintman, 2012). Imitation between people and households has proven to be far more efficient and powerful than information and instructions from authorities.

The relation between carrots and sticks

Current mainstream norms have not yet reached the stage where the public generally advocates tougher measures, other than for the individuals and groups that impact the environment far more than the average individual in Sweden. For instance, to improve and expand public transport is a carrot that has strong popular support⁴. Still, the popular preference for *soft* instruments and encouraging environmental friendliness is not fixed or unchangeable. Rather, this merely reflects where the current mainstream norm in the Western world lies. This could very well change, for instance as a result of proactive regulatory measures taken by authorities (e.g., restrictions on car use or flight transport), something that we have seen in norm changes about smoking in public areas.

Economic (dis)incentives are important but insufficient

Carbon taxes are often embraced by public authorities as the most efficient regulatory measure to reduce climate gas emissions (cf. Attari et al., 2009). Directed towards practices of citizen-consumers, these measures have been shown to have a good potential, yet in combination with other measures that help change the mainstream norm into preferring alternatives to fossil-fuel transport, heating systems, etc. It is crucial that green taxes and other financial (dis)incentives are combined in such ways that the instruments do not merely address people's economic interests. In the best cases, economic instruments have stimulated people to change habits completely, for example from daily car use to bicycle use, which has made people discover additional benefits than merely the

2. Mobility Management (MM) is a concept to promote sustainable transport and manage the demand for car use by changing travellers' attitudes and behaviour. At the core of Mobility Management are "soft" measures like information and communication, organizing services and coordinating activities of different partners. For more information, visit www.epomm.eu.

3. Mesoudi, A. (2011). *Cultural Evolution: How Darwinian Theory Can Explain Human Culture and Synthesize the Social Sciences*. University of Chicago Press.

4. Jagers, S. C., & Hammar, H. (2009). Environmental taxation for good and for bad: the efficiency and legitimacy of Sweden's carbon tax. *Environmental Politics*, 18(2), 218–238.

economic ones, for instance to their health (Hiselius, 2011). In such cases, the positive change of action may be maintained.

The role of policy sequences

Instead of falling into a principal preference for either carrots or sticks, it has turned out productive to combine soft and hard regulatory measures according to a policy sequence⁵. Historically, this does not seem to have been done through deliberate, strategic, long-term planning by the authorities, but has been developed in close connection to social norm change (e.g., against smoking, hitting children, sexism and racism). It is quite possible that everyday practices, such as travel habits, diet and other consumption, will follow a similar standard of development in the coming decades. Governments, businesses and NGOs can accelerate this development by drawing lessons from past norms changes, and the problem frames that have proven successful.

The limited power of climate arguments

It is far from clear that a negative impact on the climate is the most effective problem framing when citizen-consumers are addressed. Nevertheless, there are several other possible framings that may prove to be powerful catalysts towards a standardized development on climate change⁶. Health aspects are central here: Improved health through cleaner local air quality, health (and mood) benefits of bicycling, and health benefits through a reduction in meat consumption, have turned out to be more powerful motivating factors than connecting one's own micro practices with a reduced risk of global warming. Moreover, the health aspect becomes an even more powerful one when developed into social goal setting among friends, colleagues, and so forth.

The role of trial periods and demonstration projects

The need for pilot projects and trials is crucial in order to stimulate a public support for various climate-oriented policy changes. During such periods, people do not have to worry that changes are decided over their heads. Instead, they get the opportunity to get used to new procedures, and to exchange experiences with their peers, towards new 'normal' routines (Paterson and Stripple, 2010). The soundness of trials has been shown over and over in the social psychological literature, indicating that action change is a much better trigger of norm change than the other way around. One example is the congestion charges in Stockholm, where a trial period led to a public norm change from negative to positive (Winslott-Hiselius, Brundell-Freij, Vagland, & Byström, 2009).

The role of the state towards norm change

It is well known that environmental problems involve a situation, where the state, market realm and civil society expect 'the others' to be the proactive ones. Through our extensive primary and secondary data we have seen that state actors often conceive of the current mainstream public norm of modest environmental concern as fixed and permanent. There seems to be a fear among state actors of upsetting the public by suggesting environmentally progressive policy changes. Yet, in our publications and communication this WP has tried to show how bolder policy changes, preceded by demonstration projects, campaigns and deliberative processes, are likely to be perceived as refreshing by the public, who has repeatedly indicated a strong environmental concern that may, through such nudging⁷, be turned into practice.

5. Pierson, P. (2000). Not just what, but when: Timing and sequence in political processes. *Studies in American Political Development*, 14(01), 72–92.

6. Naturvårdsverket (2011). Klimatomställningen och det goda livet. Stockholm: SNV, Rapport 6458.

7. Thaler, R. H., & Sunstein, P. C. R. (2008). *Nudge: Improving Decisions About Health, Wealth, and Happiness* (1st ed.). New Haven: Yale University Press.

Logistics and goods transport (WP5)

WP5 has focused on the interaction between the development of freight transportation, logistics and CO₂ emissions with the following primary questions: *What are the challenges, opportunities and incentives of companies and society regarding long-term sustainability in freight transportation and logistics solutions that can enable and support the transition to near-zero emissions? What policy instruments and policies have sufficient effect, relevance and feasibility to make the transportation of goods sustainable?*

The research was conducted in an interdisciplinary group consisting of researchers from Packaging Logistics, Engineering Logistics, Economic Geography, and Transport and Roads. One challenge and contribution to the development of the questions in the project was the need to amalgamate the different researchers' paradigms, frames of reference and competence into one united perspective.

Research approach

The work in WP5 was run in a variety of subprojects, which were continuously discussed and reviewed in the project team. Towards the end, the subprojects were woven together into a whole, which is synthesized in a report (Pålsson et al, 2013). The subprojects addressed three areas.

The first area focused on *the transportation of goods, availability and supply structures* and involved assessing the existing knowledge about freight transportation and its interaction with logistics. The assessment resulted in a description of the current challenges, opportunities and incentives related to making freight transportation and logistics systems sustainable in the long term, as well as reasons why today's transportation and systems are structured and run as they are. Up to now this knowledge has been limited, so a clear theoretical and empirical assessment was necessary for the project to continue. The assessment is based on goods owners and deals with the interaction between logistics companies, transport companies and the community.

The second area focused on *policy instruments and policies* for sustainable transportation of goods, both existing and conceivable, up to the year 2020. It also focused on an analysis of related potential problems in the period 2020–2050. A key subject of this analysis was the dynamics of governance – how adaptability develops over time in relation to changed conditions while targets are maintained and secured. The dynamics are based on the complexity of the contextual situation – aspects such as changes over time, multiple contradictory targets, compromises and a large number of different players. The governance part of the project highlights financial effects and other challenges for companies and society to achieve sustainable transportation of goods. Other topics of discussion are how technology development can be influenced and the use of technical solutions, especially based on the interaction between the business community and the public sphere; where there is particularly great potential to find common solutions that benefit business as well as society and its citizens.

The third and final area focused on *challenges and dilemmas when implementing regulations*. This ties in with the analysis of problems through a discussion of critical factors and alternative paths of action in the interaction between companies, authorities and citizens/consumers for sustainable freight transportation solutions. A first such factor is acceptance by the general public, the business community and politicians. A second factor is the opportunity to combine the driving forces and motives of these players to reduce emissions from the transportation of goods. A third critical factor is the political and government agency-based international coordination of goods flows, because supply structures are often global.

Research findings

The research in the project contributes with a novel approach by combining growth theory, logistics and freight transport emissions. This is thoroughly reported in Pålsson et al. (2013). In our approach, the theoretical framework and calculation models are not based on linear growth projections, which is the predominant assumption in the existing literature and reports in the field. The cyclical view that we promote offers a completely different scope for action and opportunities at various times in comparison with what we see from a linear perspective. This has led to the insight that there is a need for different types of policy instruments in different phases of a growth cycle. It has also been shown that linear growth projections for transportation emissions can be misleading and lead to incorrect conclusions about the relationship between growth and transportation emissions which, in turn, increase the risk for inappropriate choice of policy instruments in different periods of time (Andersson and Elger, 2012; Pålsson et al., 2013).

Further, we framed the problem in a new way regarding the importance of relationships between factors at macro and micro levels, which is unusual in transport research. A result of this is that we have been able to highlight transportation emissions both in the system with a direct effect on the scope of emissions, i.e. in the combination between freight owners' material flow and transport providers' transport flow, and in the interaction with external factors that affect the emissions indirectly by providing prerequisites and setting limits. The external factors include, for instance, energy systems, infrastructure, institutions and vehicle technology. For instance, transportation emissions are affected by available energy for transports in the form of electricity or fuel. This requires both production and distribution, which, in turn, require production plants and infrastructure.

According to our analyses Sweden is in the final stage of a growth cycle, which is expected to end around 2020. The period until 2020 is relatively foreseeable from both a macroeconomic perspective and a company perspective. Thereafter, a new growth cycle is expected to begin with some principal characteristics that we may foresee, but the exact direction and course of events are completely unknown to us all. Thus, the results of the project consist of theoretical and empirically well-informed standpoints regarding opportunities and challenges until 2020 both from a macroeconomic perspective and a company perspective, while the governance and development 2020-2050 are problematized on a relatively high level of abstraction.

Our analyses of the development of transportation emissions until 2020 shows that a substantial but insufficient reduction can be achieved by direct action on and improvement of the system. From a company perspective, the results show perceived potential, intention and barriers for emissions reduction, such as improved transportation planning, packaging design and logistics structures. The results also show that corporate strategy has a greater impact on reducing emissions than stakeholder pressure, even though both are needed. Governance implications of these findings are discussed especially when it comes to developing policy instruments that can further strengthen corporate motivation for strategies that are consistent with emissions reductions.

External factors consist of structures that often take a long time to change. Our results indicate that these structures must start to change in a low-carbon direction relatively soon to be able to achieve the long term goals. Our research also problematizes eight external factors that indirectly affect transportation emissions and how these in principle need to be developed in different periods of time. This has implications for certain existing governance principles, such as the four step principle⁸ for infrastructure investments, conceptual models for governance and policy challenges.

8. The four step principle is a national policy approach for the implementation of measures in the Swedish transport sector. The four steps are defined in the following way: Step 1 - Actions that can affect the need for transports and choice of mode of transport; Step 2 - Actions that makes use of existing infrastructure and vehicles more effective; Step 3 - Limited reconstruction measures; Step 4 - New investments and larger construction measures. Measures in step 1 and 2 should be considered before infrastructure investments (step 3 and 4).

Overall conclusions

A conclusion is that governance for the period now until 2020 and the period 2020-2050 should be dealt with based on different principles. During the first period, the system needs to become more efficient with a direct impact on transportation emissions. The governance should be directed at increasing internal motives for freight owners and transport providers to reduce transportation emissions in the same time as restrictions and long-term requirements continuously are increased.

Even though the time periods are dealt with differently, they need to be handled in parallel. Based on insights from the growth cycle theory, it is likely that there is a generally high propensity to change sometime in the 2020s. For freight transport emissions to reach the target for 2050 our conclusion is that external factors must be changed in a low-carbon direction. However, the uncertainty about what will be possible, necessary and proper choices is great. Yet, we believe that it will be possible to identify positive and negative directions of transportation emissions. Our proposal to govern the external factors is to close doors for carbon-intensive alternatives and keep low-carbon alternatives open to let the competition, global changes and other unpredictable events affect the final direction. At the same time, the system with direct impact on emissions needs to be continuously adapted to changes in the external factors.

Overall results and recommendations

A transition to a low carbon society in 2050 requires a vision and long term direction that goes beyond normal time perspectives in society and politics. It likely requires some sort of 'social contract' that can lay steadfast the direction of development. To maintain this over time requires a coherent vision and a positive narrative for the low carbon society. A transition can probably not be motivated by climate change mitigation alone. The vision must encompass a broader idea about the development of society, including a better life, good health, work, justice, equity and other aspects that most people associate with a desirable society. A transition must also interplay with recurring structural crises and growth cycles in the economy, and lead to new businesses, sectors, markets and jobs.

A transition to low carbon energy and transport systems in the next 40-50 years may seem dramatic, revolutionary and transformative. But such a transition may also be considered as a relatively un-dramatic and evolutionary process where technology and behaviour co-evolve with changes in social norms. It probably means that new consumption and travel patterns become the norm, partly due to changes in relative prices. The norms and expectations of future generations are formed in the society in which they grow up, and there is nothing to say that zero emissions is fundamentally incompatible with a good life. The past 50 years have been transformative in many ways but we, and younger generations in particular, seldom think about the past in that way.

There is always some sort of social contract between the state and its citizens, dividing responsibilities with mutual demands and expectations on each part. This is changing over time and is subject to continuous renegotiation. For a large part of the 20th century in Sweden and many other countries it was about building the welfare state, with access to decent housing, health care and schools for all citizens. The basic ideas were embraced by most political parties although ambition levels and ways of getting there varied. Sustainability and zero emissions are presumably important parts of the future social contract if climate policy goals are to be achieved.

Climate change is often presented as the greatest threat of our time to society and the ecosystem services that human society depends on. Threats and crises generally lead to mobilisation and that action is taken. But crisis awareness also tends to fade fairly quickly. Therefore, a transition is probably difficult to make if it is motivated only by climate change and associated mainly with hardship and sacrifice. A low carbon transition must build on a positive future vision of a better society. Perhaps such a vision is already forming through low carbon scenarios and roadmaps, as well as ideas about sustainable cities and a green economy. The idea that it is possible to continue a positive development of society within the 'planetary boundaries' seems to be growing stronger.

A note on policy and economics

Carbon pricing, of some sort, is necessary but certainly not sufficient for governing a transition. Complementing and flanking policies, and changes in institutions (e.g., rules, norms and cognitions) related to the different mitigation options are needed to maintain momentum in the transition, and to handle goal conflicts and conflicts of interests, as well as unintended side-effects. Planning and permit procedures, and combinations of regulation, economic incentives, information, and R&D efforts are important elements of coherent policy packages, in addition to carbon pricing. Voluntary (e.g., carbon offsets) and experimental (e.g., climate labelling) approaches can be a testing ground for policy learning and a mechanism for empowerment and increasing public awareness. Voluntary and 'soft' approaches can also precede increased acceptance for future more binding policy.

The appropriate design of policy packages will vary across geographical and sectoral boundaries, as well as technology areas and system solutions. To exemplify this: energy efficiency in buildings, wind power, and CCS

are three low-carbon energy solutions with very different characteristics in terms of, technology, stakeholders, markets, and institutions. Experience shows that straight forward regulation can be justifiable and effective in some areas (e.g., building codes and appliance standards), benefit sharing schemes are often important to ensure stakeholder buy-in (e.g., for local acceptance for wind power) and public-private partnerships can be important for risk sharing and to leverage funding and capacity (e.g., in the case of CCS and other major demonstration projects under the EU NER300 program⁹).

Climate change economics has been dominated by two perspectives. From an engineering-economic perspective mitigation costs have been calculated bottom-up to construct mitigation cost curves (including negative cost or 'no-regret' options). Another perspective is macro-economic modelling that shows how mitigation (often through carbon pricing in the models) leads to a modest reduction in future GDP growth. But due to the dynamic nature of economic development in the long term, with path-dependencies, growth cycles and recurring structural crises, these perspectives should be complemented with more evolutionary economic perspectives.

In economic history, the development is characterised by growth cycles associated with the advent of new 'general purpose' technology, e.g., the steam engine, electricity or information and communications technology. Climate change mitigation requires investments, money that could have been spent on something else and thus have an 'alternative cost', but these investments are likely to shape new development paths and growth cycles in the future. There are many signs that most industrialised countries are now, 2010 to 2020, in economic structural crisis. This creates opportunities to change the direction of economic development. In contrast, when the economy is in a growth phase with high returns on capital, it is much harder to change direction. It is not possible to know beforehand what will drive the next economic cycle but it would be prudent to try and make it green.

General conclusions

One way to conclude from such a broad and encompassing research program as LETS could be to provide lists of policies and measures. Such lists typically include carbon pricing and tax reforms, renewable energy support schemes, bonus-malus (fee-bates) for cars, changes in planning regulations, stricter building codes, green public procurement, and so on. However, such policies and measures have been analysed and presented in numerous papers and reports already, they need not be repeated here. There is no lack of ideas. The main problem seems to be lack of implementation due to, for example, conflicts of interest, e.g., between winners and losers, conflicting goals in different policy domains, or different ideas on what the role of government should be. We think it is important to take one step away from the policy analysis and also consider the broader framing and understanding of the relation between societal development and low carbon transitions.

Sweden has reduced emissions from 1990 levels through, for example, using bioenergy in district heating, expanded use of ground source heat pumps and renewable electricity. Further measures to reach 20 % or 40 % emission reductions by 2020 to 2030 seem viable without requiring fundamental or major technology, system or infrastructure changes (at least this seems to be the case in a Swedish context where existing policies in 2011 were expected to deliver 18 % lower emissions in 2020 compared to 1990). Such targets can probably be reached by continued tweaking of the existing energy and transport systems with improved efficiencies and some fuel shifts.

In the next 10 to 20 years, however, we need continued RD&D to develop the technologies, systems or in-

9. NER300 was originally conceived to raise funds through auctioning of emission permits under the ETS and give investment grants to major CCS demonstration projects. It was extended to include other major sustainable energy projects such as smart grids, wind parks and biorefineries.

infrastructure solutions required for deeper cuts post-2030. A limited set of possible primary energy sources and energy carriers means that we can be quite certain about what represents key low carbon technologies in this longer term. Energy efficiency and renewable energy technologies are well known examples. Other examples include electro-thermal processes and perhaps hydrogen in industry, electro-fuels (from electrolysis) for transport, alternative cements, and process technologies to produce bio-based materials and chemicals (Åhman et al, 2012)¹⁰. Some technologies are modular, e.g., for energy efficiency (e.g., lighting and appliances) or distributed generation (e.g., ground source heat pumps and PV systems). In other cases the transition involves major infrastructure investments in CCS, super-grids or hydrogen systems, as well as new transport infrastructure with rail or electrified roads. These are very different contexts from a governance and policy perspective.

Post 2020 and 2030 decarbonisation of activities that are heavily dependent on fossil fuels, such as transport and parts of industry, presents new challenges in terms of making major technology shifts and evolving new social norms and consumption patterns. It requires not only technology RD&D but also new approaches to policy design, monitoring and evaluation, mechanisms for policy integration and coherence, and perhaps a general shift in perspective on the role of government and how low carbon transition can be an integral part of the social contract. Society is constantly changing and it will continue to change until 2050, irrespective of the climate issue. The key question in a longer term climate policy perspective is not how we can reach short term emission reductions at lowest cost. The key question is what type of society we want to live in and how this vision and development can be consistent with a low carbon transition.

The transport sector is a good illustration that the climate issue cannot be reduced to an isolated environmental problem or one that can be solved by technology alone. First, some technical solutions, such as electric vehicles or public transport systems, are associated with changes in norms and behaviour. Second, climate change is only one of many problems associated with transport together with noise, physical barriers, other air pollution and accidents. In addition, there are health aspects related to the urban environment and opportunities for physical activity, e.g., through walking or cycling. High complexity, several problems, and multiple goals speak in favour of broad coherent strategies, which in the case of transport may include:

- New vehicles and fuels through a range of policies to develop, introduce, and deploy improved technologies.
- Changes in behaviour, travel patterns and demand, choice of travel modes and acceptance for new technical solutions through a range of measures at different levels and across sectors.
- Changes in planning processes, for example to better integrate planning of transport and buildings, to facilitate the above.
- New policy paradigms where improved accessibility rather than increased mobility becomes the guiding principle.
- Changes in goals and mission statements (e.g., the recent change in wording from being a 'builder of roads' to being a 'builder of society' by the Swedish Transport Administration)

The list is no recipe for a more sustainable transport policy. This must be shaped through broader political processes. The point is that climate policy must be deeply integrated with other policy domains, and that technical and transport infrastructure change co-evolves with changes in norms and behaviour.

10. Åhman M., Nikoleris A., and Nilsson L.J. (2012) Decarbonising industry in Sweden, an assessment of possibilities and policy needs, Division of Environmental and Energy Systems Studies, Report #77, Lund University.

A few observations and recommendations

In addition to the general results and conclusions presented above we would also like to highlight a few observations, or insights, as well as provide some general recommendations concerning ways forward. A short list of pertinent observations and insights include:

- Climate policy cannot be dealt with as a discrete environmental policy problem. A low carbon transition must be part of a broader vision for a sustainable society, including all relevant policy domains.
- The ‘social contract’ should preferably develop to include a clear and long term vision for a sustainable society, where climate neutrality is one integral aspect.
- It is important to complement the current dominant economic perspectives with more long term and evolutionary economic perspectives.
- It is possible, even necessary, to “pick winners” in terms of energy sources and carriers, and basic technical solutions for future energy and transport systems.
- Scenarios and roadmaps are important tools to (i) learn about, (ii) develop strategies and build support for, and (iii) prepare with foresight for a sustainability transition where zero carbon emissions is an important part.
- Social norms, practices and behaviour will change and evolve over time. It is important in this context to understand the social motivation for change.
- An open and revitalised societal dialogue concerning development pathways and strategies is important to build support and get broader agreement behind the transition to a sustainable low carbon society.

In Sweden, as in much of Europe, there is broad political support behind the climate policy goals. This should provide a good foundation for discussing approaches to and principles for governing a transition. What types of approaches and mechanisms that might work to facilitate a transition is likely to be a very contextual issue – depending on political tradition, culture, policy style, etc. Nevertheless we can make four rather general and strongly interconnected recommendations for governance that appear to be particularly salient for facilitating a transition:

- Develop long term innovation and industrial development policies aimed at preparing for deep emission reductions post 2020 and 2030.
- Develop mechanisms for greater transparency and monitoring of policy in a transition context.
- Reconsider whether administrative structures, organisation and jurisdictions in government are well suited to govern the transition.
- Consider ways of creating new long term lock-in situations and pathways that are consistent with low carbon transitions

Long term development policies: One recommendation is to develop a clear and long term policy for industrial development and innovation. This is a challenge to the conventional wisdom that governments should not pick winners and that the market should rule. But the main technologies and system elements of a transition are relatively well known through scenarios and roadmaps. Energy efficiency, emissions free power production and electrification of transport and industry are important elements. Thus, it is possible to know with great certainty that some technologies and systems will be important. Selected areas, e.g., in infrastructure development or basic industry processes, can therefore be targeted through government policies and development strategies.

Transparency, monitoring and evaluation: A transition requires long term direction and governance at all administrative levels. Do we have the appropriate instruments for monitoring, transparency and accountability in relation to climate policy targets? In other areas, there are control mechanisms and ‘watchdogs’ that monitor, evaluate

and report. One example is national audit offices. Could low carbon transitions entail a new or expanded role for such bodies or do we need new institutions? A transition also requires new approaches to policy evaluation in order to assess developments, and the preparedness or prospects for developments, in a multi-objective long term perspective.

Administrative structures and mechanisms: Administrative structures and organization is important for coordination between levels, sectors and policy domains. The need for policy mainstreaming, integration and coherence is well recognized. But it is debatable and probably highly contextual what the best approaches are for doing this. A more specific issue in this context is how roadmaps, scenarios and carbon budgets can be used as tools or mechanisms for governance, for learning and strategizing, as well as for policy integration and asking questions about governance and policy strategies. Should roadmaps be institutionalized as important tools for long term climate governance? If so, who should be responsible, who participates, and what should the process look like?

Creating the low carbon lock-in: The need for long term stability and direction raises the issue of whether there are mechanisms that can answer to this need? This could be mechanisms that put some aspects of climate policy at arms-length from short term political demands and priorities. The EU ETS, although presently weak, represents an attempt to create such stability. Some feed-in and quota-based systems for renewables support also provide long term stability to investors and once established such systems may be difficult to change overnight. Some countries consider climate legislation, similar to the UK Climate Change Act, as a way to deal with this aspect and increase transparency.

Research can identify the types of important governance aspects that we have presented here, but research cannot answer what these types of mechanisms, structures and policies should look like in detail. That is fundamentally a political question and transition policies must be developed and shaped through democratic processes. Broad participation, beyond organized economic interests, in policy processes and decision making is important for gaining acceptance and legitimacy for the strategies and measures needed to make a transition.

Research needs

The idea of low carbon transitions can generate a very large range of research needs. Obviously it motivates an array of technology R&D needs across all sectors (e.g., in energy, transport, water, forestry, etc.) as well as research across dimensions or disciplines relevant to transitions (e.g., economic, social, innovation, legal, political, etc.). We have no ambition to paint a complete picture of such needs but based on the LETS programme a few observations are made here.

The results of the LETS program clearly show that low carbon transition governance cannot be restricted to the climate or environmental policy arena. Instead it is essential that all policy areas, and all societal actors, become involved. In fact it can be argued that we are in the middle of a transition towards a new kind of society, which has to evolve in a low carbon setting. This includes the questions of how to deal with carbon emissions but also how the economy should be organised and what we think a future welfare state should look like. An important future research task is thus how to reconcile the challenge of a low carbon transition with a societal development that is attractive for citizens and major groups in society. This connects to the growing interest in concepts such as the “green economy” and “green growth” as well as to ideas about “greening the welfare state”. The question here is not so much about how to design efficient policies to reduce climate emissions but how to conceptualise low carbon developments in a good and attractive society, and how to steer such transitions. This could also be formulated as how to develop a renewed social contract for the low carbon society. There is a need for more research going beyond the present market focus in climate policy and looking at how to combine a mix of policy instruments and to involve a variety of actors in the governance of low carbon transitions. One aspect of this is to further develop ways to include policy and governance aspects in low carbon scenario studies, so that these become more meaningful from a policy perspective. It should also be further explored how scenarios are, and can be, used as tools for learning and strategizing in policy making processes, and how policy evaluation needs to develop in order to evaluate over much longer time horizons than is typically the case.

Issues concerning coherence and integration across policy domains and jurisdictional levels are highly present not least in the area of transport and built environment. This is a governance context characterised by high complexity and fragmentation, and there is a need for more research addressing the nexus between governance and planning processes. In the area of bioenergy we would like to forward two research areas. One is the need for more knowledge concerning the design of support schemes, ranging from support to R&D, pilot- and demonstration plants to carbon pricing and other general policy, in the context of making the transition to a bio-based economy. The second is in the intersection between natural and social sciences in order to better understand the conditions under which emissions take place in the context of natural variability and scientific uncertainty associated with land-use, forestry and agriculture. For the social dimension of low carbon transitions it is important to understand in more detail how soft and hard policy measures can be sequenced to generate changes in mainstream norms, how niches of environmentally oriented practices of citizen-consumers may be transformed into mainstream, and how state and municipal authorities may become more receptive to progressive initiatives by citizen-consumer groups geared to reduced environmental harm. The greening of logistics and goods transport is a relatively new research field where a number of research needs can be identified. These concern both the development of slow infrastructures (e.g., roads, harbours, railroads and energy supply) and the possibilities for short term changes (e.g., through E-trade, locating production, new supply chains, city logistics and packaging) in the context of economic cycles.

A special note on interdisciplinary research in practice: Learning from the LETS experience

This chapter discusses the interdisciplinary experience from LETS. The objective is *to document the lessons learned and insights from this experience for future research in similar programs*. This discussion is based on several sources of information: a web-based survey to the researchers in April 2013. The results of the survey that had a bearing on multidisciplinary research was summarized and used as the starting point for a smaller two hour workshop. The citations in the text stem from the workshop material. This discussion provides most of the material with the contribution of insights from a final seminar in May 2013, involving most LETS researchers. Finally, a draft of this essay was circulated among the researchers for their verification, comments and reflections. The essay is organized into three themes. The first focuses on why and how interdisciplinary work is relevant. The second theme presents the most important lessons learned about how to build an interdisciplinary research environment and the third theme relates some of the major challenges that were highlighted by the LETS experience.

The LETS researchers find that it was the complexity of the subject matter, i.e., how to govern transitions, that made a multidisciplinary approach both desirable and suitable. In the workshop several researchers pointed out that even though there is a potential that research with a multidisciplinary team can deliver more interesting results that are also relevant for society, this is not to be taken as a given because certain conditions must be fulfilled. A basic benefit is that in a multidisciplinary research team the common research problems and questions are discussed from many angles. This leads to an increased understanding of the complexity of the issues at stake and improves the ability to frame and reformulate the research problem(s). New and creative ideas are often expressed in the process. For the process to become interdisciplinary, it is important not only that different perspectives, theories and ideas are expressed, but that different perspectives are allowed to confront and challenge one another. This research should not aim to be consensual “It should be ok not to agree with one another”. What is needed is a process of cross-fertilization between perspectives. For this to occur it is important that the involved researchers are comfortable and confident in their own discipline at the same time as they should have a genuine curiosity for other perspectives and “a readiness to give up ones hobby-horses”. In turn, interdisciplinary research can benefit the individual researcher who by taking on a broader view enhances learning about problem complexity while being better informed about the individual disciplines’ contributions and where there are knowledge gaps. When the ambition is to produce interdisciplinary research it is important to put together a multidisciplinary research team where the individual researchers are willing to broaden their horizon and have a curiosity to learn from other views and perspectives.

The second point discussed what it takes to create a successful interdisciplinary research experience. Two general aspects were highlighted. On the one hand, it is about enabling a certain research ‘spirit’ and on the other hand, about ‘doing’ things that makes such research possible. In a sense this is about team-building and the key responsibility of the leadership. The LETS 2050 used a twinning approach with two directors from different disciplines. They came into the program with different skills and both had previous experience of working with multidisciplinary research that was useful in the process.

The ‘spirit’ is about creating an atmosphere that is permitting and respectful of different fields of knowledge. It has to be an atmosphere of openness where everyone can feel confident to express themselves. The ‘spirit’ is about communication, “getting to know one another” through discussions. It requires that everyone listens to and genuinely tries to understand one another while at the same time allowing for the challenge between different disciplinary views. This process must be allowed time “it cannot be done under stress”. Interdisciplinary research seems more time-consuming as it takes time to develop a research team with this kind of open communication and ‘spirit’.

The focus on common problems and research questions that the group had discussed and agreed upon in a fairly extensive and transparent pre-project phase was beneficial as “a common point of departure” to stimulate a collaborative spirit in the research group. To create this ‘spirit’ it was deemed important to honor the integrity of the researchers “it is important to trust the researchers, to trust that they will do a good job.”

To “do things together” was considered important and various activities creating opportunities for interactions were organized. To be successful, care should be taken that the activities are considered meaningful and interesting to the researchers involved. Throughout the research years these activities took different form, for example in internal seminars inviting all LETS scholars to participate but circulating the responsibilities for hosting and the topic between the project teams. While the seminars were formalized as a regular activity, the topics were not.

The experience from LETS was that it was crucial that new initiatives could evolve throughout the research process and then be included as part of the research agenda. In turn, this was facilitated by a set of only loosely defined deliverables which, could be re-directed during the course of the research process as new ideas developed. Another enabling factor for the ‘doing’ of interdisciplinarity was a special post in the budget for unforeseen expenses to be used when new research ideas were formulated as a result of fruitful interactions. This allowed pursuing such ideas.

To “write things together” was highly important to develop communication across disciplines. From the outset there was a clear ambition that one of the six work packages within the LETS 2050 program would have as its task to synthesize the results of the other work packages. An inclusive writing process was initiated, topics were drawn up together in workshops, and draft papers were commented and critiqued broadly, before they were hammered out in concrete details in different chapters. Vägval 2050 (At the crossroad for 2050) was the first midterm report and the final report I ljuset av framtiden (In light of the future) was developed through a similar procedure and published at the end of the project in May 2013. The reports were the result of a broad collaborative process and written in a relatively popular fashion. There were also many examples of researchers writing conference and academic papers together. The researchers found the experience highly valuable: “For example, to work together with articles makes it [interdisciplinarity] tangible. It becomes more real when you have to write together.”

Although the researchers all seem to agree on the importance of both the ‘spirit’ and ‘doing’ for interdisciplinary research to become successful, many pointed to the importance of the researchers being “well-grounded in their own discipline”. While the interdisciplinary ‘spirit’ and ‘doing’ encouraged the broader discussions of the research puzzles, strong disciplinary competence allowed for what was considered highly valuable namely, “the possibility to retain a depth in the discussions”.

The final point raised in this essay concerns the experiences of the difficulties in conducting interdisciplinary research. The challenges are interrelated but are found at different levels, they relate to the design of the research project, to the individual researcher’s capacity, and to the academic and funding structure.

One major challenge is how to design a project that continues to be stimulating and relevant to actively engage all the researchers during the entire project time. Many noted that in LETS there has been a certain lull in activities with certain researchers being less engaged. While this remains a challenge, the LETS experience has suggested that a common problem definition, inspiring and meaningful research activities and the development of common frames of reference may be a way to retain the momentum.

Another aspect raised by many was the frustration in not finding enough time to dedicate to the necessary but essential task of collaboration, communication and dialogue. It seems particularly difficult to allow enough time to

advance an understanding of other perspectives that goes beyond simply listening. It is time-consuming when the confrontation of perspectives is to become a real learning process that allows for the questioning and re-construction of one's own thinking, established concepts and theoretical understanding.

That interdisciplinary activities in general require more time goes against both current practices of academia and of research funders. Both tend to favour the quick publication of research results. While many funding agencies and foundations underline the importance of multi- and interdisciplinary research they seldom allow for longer research projects nor do they seem to be very flexible to open research designs that for example make it possible to modify research questions, methods and deliverables in the research process. The most serious concern may be the difficulties that remain regarding how interdisciplinary research remains less valuable in terms of academic merits and the difficulties researchers have in finding channels for publication. A suggestion from a LETS researcher to this problem was that interdisciplinary research should to a large extent involve senior researchers. They are secure in their own disciplines and not dependent on academic merits and publication practices to the same extent as young researchers are.

This short essay has had as its focus specific lessons learned from the LETS program on the merits and difficulties in trying to conduct interdisciplinary research. The experience of the LETS researchers which is the material used for this essay discusses also other relevant aspects that have been left out here, for example regarding the challenge and opportunities with conducting research that is to be policy relevant and to be in close collaboration with relevant agencies. The conclusions made here are limited because they relate only to the experience of one single research program. It would benefit from being compared with experiences of other similar research programs and above all with an academic literature on interdisciplinary practice.

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Near zero emissions by 2050 in industrialised countries, required for staying below the two-degree target, is a challenging but also liberating thought. It may first seem like an impossible task. But a growing number of studies show that such a transition is possible from a resource and technology point of view, as well as economically feasible.

The LETS program on Governing Transitions to Low Carbon Energy and Transport Systems takes this as a starting point for exploring the policy and governance challenges that may be associated with making a low carbon transition.

LETS started in January 2009 and finished in June 2013. The research has involved more than 25 researchers from thirteen different departments and groups. This report summarises the key findings and presents some overall conclusions from LETS. For a complete account of publications and activities we refer to the website: www.lets2050.se.

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