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**WP4 Final Report**

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Coordinator: Nick Winder, University of Newcastle
COMPLEX D4.5

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Report for COMPLEX
“Knowledge Based Climate Mitigation Systems for a Low Carbon Economy”
Seventh Framework Programme, Theme [env.2012.6.1-2]
Grant agreement 308601
WP4 Objectives

WP4 was intended to provide process understanding and instruments for support of the transition to a low carbon society by 2050 - with application to the Stockholm-Mälar region of Sweden. This region consists of two NUTS 2 regions and is one of the highly dynamic regions in northern Europe. The primary objective was to analyze strategic societal choices and their consequences. The work was divided into several tasks, connected with specific deliverables, as listed below.

Tasks (with deliverables denoted by “D”)

Task 4.1: Literature study on the state of art with regard to land use and ecosystem services, as well as governance and behaviour, and policy instruments, including their design, implementation, and enforcement. Exploring the portfolio of relevant existing and future methods and models. D4.1

Task 4.2: Stakeholder identification and contacts.

Task 4.3: Cost-benefit analyses of technologies for fossil free energy and its national and international context; assessments of investment and operational costs and risk profiles over time. Development of a numerical dynamic land use model (forest, arable land, wetlands, lakes, and urban areas) within a chance constrained programming framework for optimal allocation of different outputs such as food, fibre, feed, energy, biodiversity, and carbon and nutrient sequestration, and assessment of conflicting interests. Analysis of model compatibility, comparability, standards, and space-time scales. D4.2

Task 4.4: Developing a computational model for cognition and spatio-temporal perception, combining cognitive mapping and neural network theory with spatiotemporal modelling techniques for decision support. This allows for investigation and prediction of relations between different interacting scales and factors. D4.3

Task 4.5: Survey on place-based information and data demands and potential retrieval across stakeholders, such as local entrepreneurs, governmental authorities, project participants, and general modelers/scientists. Develop, together with stakeholders, scenarios on paths and endpoint 2050 for the Stockholm-Mälar region. Factors to be considered include expectations on green technology development, climate mitigation legislation at national and EU levels, lifestyle changes, priorities of regional decision makers in public and private spheres etc.

Task 4.6: Analysis of environmental, institutional, technological, and economic time dependent factors, ensuring long term productivity of land, including empirical assessments of implementation and enforcement of policies and drivers for voluntary initiatives at different hierarchical scales. Explore and develop policy instruments aiming at regional, county, municipality and individual levels. Econometric analysis for determining initiation, implementation and enforcement success where data are obtained from surveys and official statistics.

Task 4.7: Develop geographical and land-use-linked GHG accounting model, including the
urban/infrastructure/transport and rural nexus. Model future regional GHG emissions until 2050 for the various scenarios, including optimal mitigation options. Develop and implement a method for production and consumption-based GHG accounting dissemination exercise to elicit stakeholder response and buy-in D4.4

Task 4.8: Analysis and presentation of final results, including model and simulation results. D4.5

Task 4.9: Workshop on the COMPLEX project, including a first evaluation of the provisional models in the light of systems analysis understandings and for policy development. D4.5, D4.6, D4.7

**Deliverables** (brief description)

D4.1 Scoping report for Sweden case study: A Scoping report setting out a thorough documentation of the proposed Sweden case study as a first step in the analysis.

D4.2 Land use simulations with report: Program codes and data for simulation of optimal land use options under different scenarios for climate change, economic growth, energy demand, and human preferences. A report is included.

D4.3 Cognitive spatio-temporal model and simulation: Construction of cognitive spatio-temporal network model with simulation results

D4.4 GHG models for optimal mitigation: GHG models applied to land use change issues

D4.5 Web portal with models and simulation results: Web portal providing revised computational models

D4.6 Final report on socio-economic and land use dynamics in the Stockholm-Malar region

D4.7 Policy briefing on case study model, simulations, and options: Policy briefing, discussing options for GHG emission reduction, mitigation and innovation opportunities.

Most of these deliverables were on time, but some were delayed of reasons described.

![Stockholm City Hall at the lake Mälaren. (Photo, H. Liljenström)](image)

Figure 1. Stockholm City Hall at the lake Mälaren. (Photo, H. Liljenström)
Issues addressed and work done

The Stockholm-Mälar region studies within the COMPLEX project provides a process understanding and instruments for support of the transition to a low carbon society by 2050. This region consists of two NUTS 2 regions and is one of the highly dynamic regions in northern Europe. It is also very much in the front with regard to sustainability, climate change and the transition to a low carbon society. For example, in 2016, Stockholm was ranked number third of the world’s most sustainable cities, and Västerås was this year appointed the Swedish environmental city of the year and also the most energy efficient city. The Uppsala Climate Protocol, which we in WP4 have been involved in throughout the entire project period, has also been successful in engaging a large number of private and public institutions in developing a Roadmap for pathways to a low-carbon society in Uppsala. In addition to these examples, the Stockholm-Mälar region has several collaborative initiatives between municipalities and counties to reach the climate objectives, and e.g. has the largest number of bioenergy plants in Sweden.

Figure 2. The Stockholm-Mälar region, with the six counties and major cities marked. (Lantmäteriet). To the right is the bioenergy/waste power plant in Sigtuna and one of the biogas buses outside SLU administration building in Uppsala (Photo, H. Liljenström).
In COMPLEX WP4, various strategic societal choices and their consequences have been analyzed. This included the design of a toolkit for analysis 1) of emerging and optimally selected land use patterns, 2) of economic development and the impact of policy instruments, and 3) of the processes connecting the scientific support to the decision making functions at various levels, including policy processes at shorter and longer time scales.

Focus was on finding integrative forms of support to guide the path to a low carbon society under varying climate scenarios and world situations. The integration of social science, natural science and technology has been an important theme.

Different land use patterns will have different effects on the climate, and the climate, in turn, will constrain the options for land use. Whether land is used for agriculture, forestry, housing, industry, energy production, or infrastructure will depend on regional, national and EU policies, but also on cultural values and (sometimes conflicting) interests of various stakeholders. The dynamics of land use change and its environmental and economic impacts require analysis and models that can capture the complexity arising from irreversibilities, thresholds and nonlinearities involved.

The studies explored existing models and developed new ones where needed, taking into account conditions of uncertainty and asymmetric information. The models were intended to aid stakeholders in their decision making, linking policies at the (sub-national) regional level to those at the levels of households and municipalities, as well as at national and supra-national levels. We will pay particular attention to decisions made under uncertainty, using e.g. risk cognition and risk-management approaches.

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**Figure 2.** The main WP4 activities in the three phases of the project. Delivery and milestones reports are given in parenthesis in the various boxes.
1. Societal transformations facing Climate Change

The population of the Stockholm-Mälare Region amounts to approximately 3.6 million, which constitutes about 1/3 of the total population in Sweden. It is divided among 6 different counties and involving 77 municipalities. One of the main characteristics of the region is the location of the capital of Sweden, Stockholm, which has a population of approximately 1 million.

A particular challenge for the Stockholm-Mälar region is the heterogeneity among counties with respect to economic prosperity and environmental performance. This may be perceived as an argument for delegation of decision rights on policy choice and implementation from central to local jurisdiction. One important justification is the gains obtained from local knowledge on economic and environmental performances and formation of local communities pursuing sustainable use of resources. However, the literature points at potential costs; the neglect of impacts on other jurisdictions and the risk resource exhausting competition among jurisdiction.

The main task and challenge in reaching a carbon neutral Stockholm-Mälar region is then to identify, quantify, and balance advantages and disadvantages of different policy instruments and jurisdictional delegation levels. A specific consideration is then the current lack of a strong jurisdiction in between the national state and local municipalities.

There is a strong focus in the political and planning communities in the region (but also among industrial actors) on transport and physical mobility in combination with issues around workplaces and housing. It is not surprising that an indicator system is given high weight in regional policy that is focused on commuting times to the Arlanda International Airport from different spots in the region. In the current discussions these concerns are slowly also being broadened to include the entire energy-climate-water-food nexus. This nexus is closely connected to the spatial bio-geographical concerns that relate to climate change impacts on the biomass production (i.e. the future of agriculture and forestry issue). It also relates to matters concerning carbon sinks and in general terms the competition of land uses. Here the concept of ecosystem services has been articulated as an important and emerging indicator to be included in transition models. This means that other types of indicators as those for mobility have only rudimentary been developed (although there are signs of other interests in e.g. ecosystem services approaches).
Culturally oriented drivers for change and the topic of what could in the future constitute “social status” is something that is under emerging concern. This connects to how the GDP measure is used as indicator of progress, and what it reflects (and not). Another concern for further elaboration is the need to innovate novel policies in ways that are informed by cultural perspectives. Given the cognitive landscape of expressed types of interests, a number of policy-oriented concerns are rising as well as the need for reformed indicators of change. The consumption issue is articulated as a very important topic related to this.

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Full references: COMPLEX reports D4.1, MS46-47

2. Cost effective attainment of a low carbon economy

This study investigates if and how the Mälar region in mid Sweden can achieve a low carbon economy in 2050. A low carbon economy is then operationalized as a cost effective achievement of the EU target of 80% reduction from the 1990 emission level to be reached in 2050. We include three classes of abatement measures; reductions in the use of fossil fuel (gasoline, diesel, oil), investment in renewable energy (wind power, solar cells, electric cars, bioenergy, biodiesel, ethanol), and creation of carbon sinks (prolongation of forest rotation period, afforestation). We account for uncertainty in implementing measures, and for technological development. To this end, a numerical dynamic model with uncertainty and technological development is constructed. Uncertainty is accounted for in a safety-first decision framework where decision makers are concerned about reaching the target, which increases costs because of the safety margin in reaching the target. Technological development is modelled as learning from doing where unit costs of abatement decreases as cumulative abatement increases.

Figure 4. Emissions of CO₂ from fossil fuels. (Source: Swedish Statistics, 2013)
The results indicate that a cost effective solution can be reached and the total abatement costs would then correspond to 1% of cumulative gross regional product in the region when both technological development and uncertainty are acting. Without technological development the cost would be doubled. All classes of abatement measures are needed, but bioenergy, biodiesel, and electric cars are of significant importance. However, because of the asymmetric allocation of emissions in the business as usual case and in abatement costs, the main financial burdens are born by 1/5 of the municipalities in the cost effective solution. Another finding is that only a few counties and municipalities make gains in the overall cost effective solution compared with decision making in isolation. A majority faces lower cost when they implement abatement measures within their own jurisdiction.

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3. Climate impact of willow energy considering spatial variations in a landscape

Bioenergy is one strategy to substitute fossil based energy and thereby mitigate global warming by decreasing emissions of greenhouse gases. Locally produced biomass can also increase the energy security in a region by reducing the dependency on imported fuels. Growing short rotation coppice willow for energy is one option that has shown potentials to produce energy while sequestering carbon from the atmosphere to the soil. The aim of this study was to assess the impact of growing willow on fallow land in a specific region in Sweden, considering spatial variations in terms of transport distances, soil textures and initial carbon content. A time-dependent life cycle assessment method was therefore combined with GIS mapping. Uppsala County was chosen as study site since around 10% of the agricultural land in the region is fallow land, which could be utilised for willow without displacing land used for food production.

Figure 5. Left: Distribution of fallow land in Uppsala county. (Lantmäteriet). Willow energy farming in the same region. (Photo, H. Liljenström).
The result showed that even when considering spatial variations in the region, the climate impact of growing willow for energy purposes was negative, meaning that due to increased carbon content in standing biomass and soil (Fig. 1a), more carbon dioxide is taken up than released which gives a cooling effect on the temperature (Fig. 1b). Willow energy can thus be grown on all fields in the region to supply the local community with as much energy as possible, while being beneficial for the climate. If the effect of replacing fossil fuels (coal or natural gas) is considered, the climate mitigation potential is even higher.

Figure 6. Left: Soil organic carbon stock (Mg/yr/ha) as function of time. Right: Temperature response of willow energy, fossil carbon and natural gas per MJ and year.

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4. Modelling the future energy system and climate impact of Uppsala, Sweden
In 2010, the municipality of Uppsala initiated the Uppsala Climate Protocol (UCP) with the purpose to involve local and regional stakeholders and decision makers in a joint effort to reach the local energy and climate goals. The 25-30 private and public organizations, including Uppsala’s two universities, participate in energy and climate efficiency actions that are accessed through collaboration (http://klimatprotokollet.uppsala.se/). The UCP members commit to systematically reducing climate impact within its own operations, implementing and declaring climate mitigation measures, contributing with knowledge and collaborating with other members to reach their own as well as the municipality’s climate targets. Short-term targets for climate impact reduction are set every three years and the progress is reported at advisory round table meetings that are held at least once annually with top executives and environmental managers. Cooperative projects take place in working groups in areas such as solar energy, waste management, sustainable transports, communication and energy
management, which are open also to organizations outside the UCP. The UCP is managed by a project management group and a group of environmental managers.

The Uppsala roadmap project was initiated in 2013 within the framework of the UCP, aiming to analyze potential pathways and measures to reach the municipality’s long-term climate objective. It was funded by the Swedish Energy Agency and COMPLEX. As a central piece of the project, the Uppsala roadmap model was developed with the intention to provide an overview of the current energy system and indicate possible trajectories towards the realization of a low-carbon society. The roadmap contains a number of future scenarios where emissions and energy demand are simulated. An inclusive process was initiated, bringing together members of the climate protocol and adopting a ‘whole system’ approach, including technical requirements, social learning and adaption, policy and legislation. The stakeholders involved include universities, the municipality, local energy companies, politicians, non-profit associations, local residential corporations, academic building corporations and municipal companies including waste and water management. Workshops were organized to identify possible measures for local future scenarios, focusing on issues such as electricity generation, smart grids, bioenergy production and district heating generation. Results from the workshops fed into the scenario building and modeling of future energy systems, which was performed by the researchers in the project.

Figure 7. Top: The biogas plant in Uppsala. Bottom right: Flow chart of the Uppsala Roadmap project.

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Full reference: COMPLEX D4.4 and D6.5 reports
5. **GAMING approaches Bridging decision makers and models**

The task to focus on a general level process to explore how decision makers in a practical case could make use of a very large decision support model with regard to path decisions of overriding political nature in order to move towards a low carbon society. The target of this study was the relationships between the decision makers and the model. Thus we used a gaming approach, adapting an off-the-shelf computer game (Democracy) and “trimming” it to serve our specific purpose (i.e. Swedish decision making with regard to tasks related to low carbon societal transitions - especially oriented at centrally positioned political actors, or actors with tasks across sectors). We arranged a sequence of small theme-oriented seminars for experts in various fields in order to identify the required changes in the Democracy software package (i.e. to make it more “Swedish” in relevance and to improve and expand its sectorial coverage to better mirror the climate change issues).

Some of the findings around this experiment with the stakeholder-model interaction (with regard to our target of non fossil societal path decisions) are:

- The interplay with the model was used to support reflections about conditions to political choice. Thus it is not primarily the predictive power (which may be limited under the complicated and unsettled circumstances at hand) that is at the center for the exercise, but the capacity of the specific experimental gaming environment to be used as a didactic reflective tool.

- The systems aspects were strongly highlighted. This was less due to the specificities of the large model, but more through the initiation of reflections about the limitations that the model world exposed, e.g. causality related issues, not least connected to risk assessment and handling of uncertainties of different kinds.

- The use of the software model interaction experiences with regard e.g. to the importance of time sequencing of policy and in general the role of “timing” in application of policy action are examples of issues emerging in the discussions. Specifically attention arose towards an improved understanding of subtle aspects of what could be meant by “political capital” (which under certain circumstances could be lost very quickly, whereas under other circumstances such losses could be avoided or limited - or the time development of this “capital” may be different). The model served as an introducer to the topic and provider of a “playground” for reflection, but less as a predictive tool.

- Another realm of experience dealt with how the particular focus on the path to low carbon society is embedded in a broader political frame (e.g. more general
environmental policy concerns, foreign and national policy general considerations, economic and financial policies and styles under which these are exercised – and with regard also to an understanding about which policy features may not be so central or having limited impact under certain conditions for the low carbon policy arena).

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Full reference: COMPLEX D6.5 report

6. A Cortical Network Model for Cognitive and Emotional Influences in Human Decision Making

A central issue related to climate change and the regional path to a low carbon society is how we can change our mind-sets, including our associated behavioral patterns.

Individual decision making is a complex process that involves both cognition and emotion. This part of the study concerns the development and application of a neuro-cognitive model with a focus on the decision making process (DM) of an individual in a social context. The objective is to contribute to an understanding of the relation between individual decisions of citizens and the decisions to be taken by policy makers. Our computational model includes effects of personal factors, behavior and environmental factors, based on neural structures, dynamics and functions. Based on the developed neuro-cognitive model, we also model interaction of several individuals for social decision making, exemplified by choice of transport and with consequences for climate change.

Figure 9. Commuters may have difficult decisions to make regarding how to travel between home and work. Here bicycles, cars, buses and trains are options. (Photo, H. Liljenström)

Our model is intended to give insights on the emotional and cognitive processes involved in DM under various internal and external contexts. We are also interested in the relation between short and long term decisions, where individual preferences and attitudes play a crucial role.
Knowledge and experience of the outcome of our decisions and actions can eventually result in changes in our neural structures, attitudes and behavior. In such a feedback loop between individuals and environment/society trust is an important parameter that we explore further. Our trust to public transport systems is important if we, for example, are to change our travel behavior from using car from home to work, to taking bus or train instead. Simulations with our model suggest that individuals may be more or less sensitive to reliability of public transport, depending on attitudes and preferences – and can shift behavior more or less rapidly if external circumstances, such as cost, time and availability changes.

Figure 10. Schematic flow chart of the subsystems and information flow in the modeled decision making process.

Conclusions

The WP4 research activities in the Stockholm-Mälar Region has provided a deeper understanding of the sophisticated governance structure at different levels (national – regional – county – municipality – individual), including complicating issues as overlaps of power, influence and roles e.g. at the regional and sub-regional levels. The importance of the value aspects and the political dimension of the change needed at various levels, are also to be
addressed. These understandings are something that is instrumental to consider in any effort of stakeholder participation aiming for using modeling as support of decision-making in relation to present day wicked, globalized challenges, such as transformation to low-carbon society.

The main importance of our research is the demonstration of combining model support over a range of topics and scales, and involving stakeholders of different kind throughout the project period – relating to transition towards a low carbon society. The sub-national region, as a meso-scale area of land and population, has shown to be an appropriate level of implementing many of the policies and necessary means for transforming our society to low-carbon one. It can serve as an intermediate level between decisions taken at national and super-national levels, and the decisions taken at a household and individual level.

We have demonstrated an example of how the co-production of knowledge - with researchers together with various other stakeholders - on project relevant issues can be conducted. This could serve as an important stepping stone when European (and other) societies almost immediately will have to move forcefully on this challenge – and at several levels simultaneously. This will concern not only energy systems and other technological changes, but also urban, infrastructure and transport systems, agriculture, environmental and climate challenges, but also how society at large may be perceived. It opens for new types of European competitive solutions at world level and is thus central for the future of what we in Europe could consider our possible livelihood. It will evoke calls for clever interplay between governance levels, including a framing EU-level, the national one and the subnational regional entities with their parts where so much of future possibilities will have to be formulated, tested and become consolidated.

Key messages for politics towards a transformation to low carbon society in Sweden

1. The challenges are “glocal”, where local action needs to address global complexities
2. Simultaneously address multiple policies at multiple scales
3. Cross-sectoral interactions are necessary
4. Define new roles and responsibilities to be integrated, combining formal and informal
5. Develop mechanism that connect top-down with bottom up approaches
6. Focus on incentives for realizing the implementation of policies
7. Support inter-disciplinary knowledge generation over time
8. A need for highlighting and addressing normative aspects of transformation from individual to societal level.
9. Applying an experimental approach for adaptive capacity by continuous learning
10. Acknowledging the time aspects by a combination of urgency and long term sustainability
References


