INTERDISCIPLINARY COOPERATION AND SYSTEM MODELLING AS MEANS TO GOVERN THE ANTHROPOCENE

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ABSTRACT

The global development has now come to a critical state where humanity act as a new geological force and it is obvious that there are numerous of environmental problems which arise from the present geosphere-biosphere-anthroposphere interactions which urgently need to be addressed. This paper argues that systems analysis and modelling of environmental systems is one necessary part in successful governing of societies towards sustainability. In the 1960th many observations and data made it evident that the environment in most countries was in a bad state. To get a holistic view of the complex problems and to clarify the relationships of structure and function, systems thinking was applied e.g. modelling, cybernetics, systems analysis, life cycle assessment and energy and material flow analysis. Such tools used collectively, conceptualized as 'integrated assessment', can help to communicate fundamental knowledge, and to support decision-making when identifying, developing and implementing precautionary measures and solutions. There are good examples demonstrating the strength of such approaches; Solutions to the ozone depletion by replacing CFC's with more chemically reactive compounds that are degraded within the troposphere. Acidification of European low buffer soils and lakes, sensitive to acid rain, has decreased due to concerted action on Sulphur emission control in large parts of Europe. The handling and recycling of solid waste has resulted in a considerable reduction of deposits in large parts of the world. This basically natural scientific knowledge has also influenced the development within e.g. economy and jurisprudence and today ecological economy and environmental law assume ecological systems as fundamental.

The complexity of ecosystems and environmental issues can only be understood by use of advanced scientific tools such as modelling as a base for establishing interdisciplinary co-operation. Each component of such models will of course be an approximation, but validation and verification of the models will serve to make them useful. An ongoing research project at Mid Sweden University aims at building a complete carbon and energy balance model of an entire Swedish region, based on the Danish Samsø-model. Such models will make it possible to refer to a robust scientific base, thereby making it easier to argue for appropriate measures and actions. At the same time it will be clear what data these actions rest upon thereby making it easier to identify possible errors or limitations.

Systems analysis and subsequent modes are constructs. According to systems theory and model development they are strategies as the best representations of nature, we can make. At the same time it must be assured, that a continuous adaptation and improvement in a studied area is possible - i.e. that model outcomes are matched with phenomenological observations and that empirical work also is carried out. Model development can therefore be characterized as a dynamic and iterative process.

Governance in the Anthropocene will have to understand the problem picture at hand, to learn how to appropriately address increasingly complex issues. For identifying potential solutions and consequences of policy implementation, systems modelling on relevant levels will be one necessary tool. The current project developing an environmental regional model, illustrates how modelling can provide decision support regarding management and energy resources and planning of future infrastructure, as well as serving regional and national information purposes.

Keywords: Integrated Assessment, Regional sustainability, Governing Anthropocene, Ecological modelling, Interdisciplinary cooperation

1. INTRODUCTION

Vladimir Vernadsky (2012) wrote 1938 about man as a geological force due to the development of the human brain and of conscious reason. He saw this as an embracement of the entire biosphere in a transition to 'the Noösphere', through the growth of what he called "cultural biochemical energy" (pp. Ch VII, §103 ff). The newer concept of 'Anthropocene' underlines the fact that humans not only have the responsibility to gain deeper understanding of the ecosystems of earth, but also need to prevent irreversible effects in the environment by governing this era in the most efficient way possible. Being aware of this responsibility we have to increase our scientific understanding and to take the necessary action. History has proven that large scale problems can be solved when humans agree about (1) the problem formulation, (2) the importance to find a solution and (3) the way to carry through the solution. The phasing out of CFCs thus reducing the ozone depletion "remains the best success story for global cooperation on a worldwide environmental threat" (Prather & Blake, 2012), with US EPA banned the use of CFC in aerosol cans 1978 and a complete phasing out 1990 (Montreal Protocol) following the results of the presentation 1974 of Molina and Rowland's paper in Nature.

The Convention on Long-range Transboundary Air Pollution, signed in 1979, is regarded as the first legally binding convention to deal with non-regional air pollution problems (UNECE, 2015). The base for the convention was scientific studies and modelling of central European sulphur dioxide emissions long range effects, causing acidification of low buffer soils and lakes in Scandinavia. The governance of the problems resulted in international agreements to reduce emissions in Western Europe during the period 1980-1989, followed by reductions in Eastern and Central Europe during the period

1990-1999 and continuous reductions (at a lower level) in the unified Europe after year 2000 (Vestreng, Myhre , Fagerli, Reis, & Tarrason, 2007).

The work done by IPCC is an interesting example demonstrating a very complex procedure that slowly force nations globally to accept scientific environmental boundaries that comes from modelling of future outcomes of GHG emissions. In the latter case, the necessary conditions stated above are not yet fulfilled, especially regarding point 3 above. It can be seen that the scientific base presented by IPCC gives strong evidence for anthropogenic climate impact accepted by most nations.

Remembering that most of the environmental degradation that occurs on earth actually is legal, we need to find ways to integrate scientific findings with legal procedures to reach sustainable societies. An efficient way to do this can be by use of different methods of modelling in an interdisciplinary context (Carlman, Grönlund, & Longueville, 2015). But laws is not the only means to govern ecological boundary problems. People all over the world seemingly try to reduce their direct negative environmental impact. Still such initiatives are not enough as long as they are not part of a broader global cultural pattern. We also need good examples; as Margaret Mead says “never doubt that a small group of thoughtful, committed people can change the world” (Ramage & Shipp, 2009, p. 38).

The German philosopher Ulrich Beck (known for his concept of the ‘risk society’) discusses the tendency that science gets more and more fragmented, breaking up homogenous understanding. This tendency has a negative effect of authority as it serves to decrease public trust, breeding distrust of ‘the scientific establishment’ as well as governmental ambitions and democratic processes (Barry, 1999, pp. 151-165). According to Beck democracy should be developed, and extended into science and technology, thus preventing an increasing distrust towards scientific and technological developments. The tendency of fragmented science can be seen quite clearly from Internet based information and ‘hobby-research’ through easy accessible sources. A recent example is the spread of the results by Professor V. Zharkova of solar activity showing a minor ice-age coming up 2030-2040 (Astronomy Now, 2015). Such reasoning can become a basis for non-scientific articles, in papers and at Internet, to accuse IPCC for not having done correct models, disregarding the fact this model shows a possible and limited effect during a 10-year period only. Helen Popova says “However, even if human activities influence the climate, we can say, that the Sun with the new minimum gives humanity more time or a second chance to reduce their industrial emissions and to prepare, when the Sun will return to normal activity” (Astronomy Now, 2015). It is obvious that the scientific community has to meet the challenge, how to communicate the increasing flow of complex information, preventing fragmented knowledge among laymen and media – not to forget among scientists. In the past, information of different kind most often had to be printed and delivered through e.g. libraries or shops. This is no longer the case. A massive explosion of information flows out from institutions, organizations and individuals, increasing knowledge, but at the same time fragmentizing science into postmodern pieces, delivered in large quantities without directions on how to connect them. It is without doubt obvious that governance and policy making, with increasingly complex and interconnected systems aiming at sustainable societies, is a most challenging task (Carlman, 2010) (compare also the concept of “Post-Normal Science” and methodologies for dealing with increased complexity (Ravetz, 2006)). It is important to recognize the value and limitations of all scientific fields; realizing that they are complementary and will give the right picture on solution only if they are joined in a compatible way.

The outline of this paper is as follows; section 2 gives the basis for modelling and how modelling of systems can be considered to be an important part of shaping a scientific understanding of the Anthropocene. Section 3 discusses how integrated assessment tools can help governing the Anthropocene. Chapter Section 4 gives an example how structuring information in models supporting complex decision making, is done based on an ongoing project-modelling in a mid-Swedish region, using the sustainability indicators derive from analyses of the energy and carbon flows of the society.

2. BASIS FOR MODELLING IN THE ANTHROPOCENE

Plato worked out the basis for conceptual modelling about 2.500 years ago, by dividing the vision of an object (the human apprehension of it as a projection in mind), and the ideal form (or idea) of this projection (Plato, 2003, pp. 288 ff (no 510d-511e)). He argued that the ideal forms cannot be visualised, since they are pure abstractions, and mathematics is a science through which we can gain knowledge about the physical reality, and that arithmetic is a way (actually the only way) to express the projection in the soul made from the object of reality. Later, Kant concluded that we can never gain knowledge about nature itself (reality), but we are limited to grasp nature as a sensation. A mathematical expression of a physical event is an objective explanation, as it appears in consciousness, not only in single individuals, but in a group of individuals with a common belief (Kant, 2004 (1781), p. 111). Thus, both Plato and Kant differentiate the abstract description of an object from the actual object itself, and point at the limitations of the human mind to what degree knowledge about reality can be gained. In this manner an abstract description of nature is formed in mind from a projection of awareness. Carolyn Merchant (1994), among others, has argued dualism between nature and culture is a key factor in (European) human dominance over nature, enhancing mechanistic views and (male) rational control (p. 165 ff). The scientific revolution around the 17th century, symbolised as Cartesian dualism, meant a mechanistic apprehension of nature was accepted and is being taught in schools today (p. 213 ff).

The mathematical language is not directly connected to nature, but describes projections of mind. The projection itself is a model of nature. Applying mathematics has philosophical implications. Steiner (1995) distinguishes three major type problems: semantic problems (and interpretation of language), metaphysical problems (objects of mathematics and their relations to objects of reality) and one third group; why is mathematics useful in describing empirical reality? Even though this last group obviously, inherently presupposes arithmetic as useful to describe objects of nature, few would question this. The question is still even today very interesting and should be taken in consideration when models are constructed. Why does arithmetic work? How come that nature seems to follow certain casual laws?

Following the successful development of physics by the end of the 19th and the beginning of the 20th century, the power of mathematics to express a complex reality was spread to several sciences (Shapiro, 2000, s. 124 ff). Cybernetics was a result from developments of logic in philosophy and later in technological regulating systems and computer programming. Further development into complex systems can be found for example in von Bertalanffy (1950), emphasizing the necessity of unifying sciences using a common language. He points at the need to be attentive, when leaving the mechanistic view, not to “slide into ‘biologism’, that is, into considering mental, sociological and cultural phenomena from a merely biological standpoint.” (p. 165). Von Bertalanffy’s idea to work across the scientific disciplines, is today widely accepted. Margaret Mead, with her anthropological approach to environmental issues, highlights the need to work with over-all systems in a language easy to understand and to use for clear communication (Ramage & Shipp, 2009, pp. 35-43). The dream of a common language across disciplines was also the aim with Norbert Wiener’s work in cybernetics (Ramage & Shipp, 2009, pp. 19-26).

One problem is how to gain systemic knowledge and how to connect such knowledge into a logical wholeness, making it possible to claim that a holistic approach is used. The idea behind systems modelling is to clarify individual, often partial mental models, thus building models which demonstrate detailed connections and functions. This has been stated e.g. by Forrester (1971, p. 112) as: “Any concept or assumption that can be clearly described in words can be incorporated in a computer model. When done, the ideas become clear. Assumptions are exposed so they may be discussed and debated”. (Italics added)

In a way this statement by Forrester can be regarded as taking a positivistic turn. At the same time everyday experiences indicate that this has to be regarded as at least partly true. The new thing is that models allow test and falsification of what we previously had to take as a preliminary (for granted). The fact that we succeed to describe a certain system in terms of mathematical expressions (functions) does not necessarily mean we actually understand the system, at the same time deviations between hypothesis and model predictions indicate need for new knowledge (Jorgensen & Fath, 2011). Considering understanding, Ludwig Wittgenstein (1981, p. 60e §152) said; “’He understands’ must have more in it than: the formula occurs to him. And equally, more than any of those more or less characteristic accompaniments or manifestations of understanding.” (Italics added).

If we are to have true interdisciplinary discussions and make an interdisciplinary analysis of a complex system, we need also to discuss the fact that ‘understanding’ is a complex process in itself, not necessarily showing equality between “Now I understand the principle” and “The formula… occurs to me” (Wittgenstein, 1981, p. 60e §154). It might also be the case that knowing the formula or equation as such creates a belief of understanding, without actually giving any (deeper causal) understanding. However, we nevertheless often regard this situation as ‘understanding’, but we need to be careful not to exclude those who do not create ‘understanding’ from the mathematical language. One should not think one is more right just because a mathematical language is being used. “The hypothesis may at first be no more correct than the ones we are using in our intuitive thinking. But the process of computer modelling and model testing requires these hypotheses to be stated more explicitly." (Forrester, 1971, p. 136).

There might be those believing a model itself will solve problems, but the modelling process can turn out to be just as important – or even more – than the model (Ramage & Shipp, 2009, p. 103). During the process of creating the model, discussions with different scientists and stakeholders should take place to verify the understanding of the different parts of the model. Sterman (2002) says "All decisions are based on models, and all models are wrong" (s. 525), continuing; "To help people open up to a new perspective, a new model, and change deeply entrenched behaviors, we must often first help them see the limitations of their current beliefs. Doing so is difficult." (s. 526). (Italics added)

It becomes increasingly important to understand the philosophy behind modelling as well as to find ways how to communicate across disciplinary boarders during the modelling process. Governing societies must be regarded as mainly a matter of appropriate communication. In this paper, though, we focus on the understanding of complex problems, their causes and the consequences of proposed solutions. We will just touch on the issue of implementation.

3. INTEGRATED ASSESSMENT FOR GOVERNING THE ANTHROPOCENE

Successful solutions to complex environmental problems need a systems understanding, as discussed above. All systems analysis starts with defining the problem to be addressed and choosing the appropriate systems level. The type of problem to address has to guide us when choosing appropriate tools for a system analysis. Those involved in systems analysis and those expected to use the results of the analysis, need to accept the tools chosen. The system as such is supporting the decision-making process, but it cannot be expected that ready-made answers will be obtained from a systems analysis. Taking into consideration the shortcomings of any model (Sterman, 2002), as well as the conclusion that the modelling process as such is a most important part of knowledge building (Ramage & Shipp, 2009, p. 103), the striving should be to involve as many stakeholders and individuals as possible in the analysis of a system ((discussed in-depth for the case of development of more sustainable products in (Clancy, Fröling, & Svanström, 2013)). This will spread information, increase the substance and quality of the outcomes, increase the input to the system and make the verification process more efficient, thereby also improve the analysis. If the main focus is too much on having a fixed model, there is a risk ending up with a model telling us nothing, and with no substantial changes ever implemented. Experiences from Samsø (Nielsen & Jorgensen, 2015) indicate the importance of considering self-governance, self-leadership, self-ownership, etc. creating strong forces toward self-responsibility towards the projects – than if dictated from the outside.

For many decades after the 1960s, when environmental questions surfaced as a political issue, social science showed little interest of environmental problems. Generally speaking, natural scientists were the ones defining the problems and upon this technicians were to come up with solutions within socio-economical frameworks based on neoclassic or centrally planned economic theories. The law served as a helping hand to exploit natural resources, and to promote industry, trade and freedom. Social scientist were, after the Second World War, seemingly very much occupied with issues reflecting fear of the past; of consequences and oppression of different social political systems – socialism, capitalism, fascism, Nazism, racism, etc. One example worth remembering pointed out by Ferry (1995) is the Reichsnaturshutzgesetz implemented in Germany by the Nazi-government 1935 as the world's by then most far-stretching legislation regarding nature protection and animal rights (p. 137 ff) demonstrating there is no necessary connection between humanity and willingness to protect nature. Implementation of the well-fare state and unequal distribution of power and means, human rights and participation, theory of justice, theory of communicative action, critical theory and critical legal studies were and are all important issues, but mirrored an intergenerational perspective, which have tended to overshadow the longer sustainable and intergenerational question.

However, over the years researchers within e.g. economic science and jurisprudence have developed new theories reflected in ecological economy and environmental law. They have disputed the fundamental mainstream economy based on the notion of economic growth and worked from a perspective and with an approach of recognizing ecological principles and the logic of thermodynamics laws and systems theory (Daly & Cobb, 1989), (Daly, 1996), (Daly & Farley, 2003), (Constanza, 1997), (Westerlund, En hållbar rättsordning (A sustainable legal order), 1997), (Westerlund, Sustainable balancing,, 2000), (Decleris, 2000). This underlines the interdependence and coevolution over time and space of ecosystems, human economy and rule of law, reflecting strong sustainability with an intergenerational perspective. Within jurisprudence Westerlund (1997) developed a theory for a sustainable legal order and chiselled out a theory and method for implementing environmental policy goals. This has been further developed by Carlman, Grönlund and Longueville (2015), (Figure 1 below). Decleris (2000), an international well known judge with deep knowledge in systems theory, developed general principles for sustainable development.

Figure 1 shows management and control of societies for sustainability (Carlman, Grönlund, & Longueville, 2015): Natural scientists define existing or upcoming problems or at worst severe threats, which form the basis for setting environmental sustainability goals to achieve a sustainable Earth (a). If biosphere shrinks in productive and assimilative capacity, i.e. under the level of sustainability (d), there is a call for a control system (b), which is sufficient for controlling the societal system (c); i.e. the world community with all its subsystems – nations and communities with all their actors. The biosphere (d) is the recipient and reactor to all anthropogenic impact, which means that its ecological capacity and functions may be damaged (d). So measurements have to be made to inform about the environmental situation and that the control system has to be constructed so as to manage the collective environmental impact. The feedback function must be active and adapt to the control system all the time and all the way until sustainability is achieved and the earth's capacity is restored (a). Then the control system can go back into monitoring mode. This means that natures' non-linear reactions require a monitoring function in the control system. The information is to be directly fed into the societal system (e) and into the control system (f), in order for actions to be taken. The control system must therefore be flexible and adapt by itself to sustainability deficits. There must also be mechanisms within the legal system, which makes it mandatory for authorities to take actions should e.g. environmental quality standards be violated.

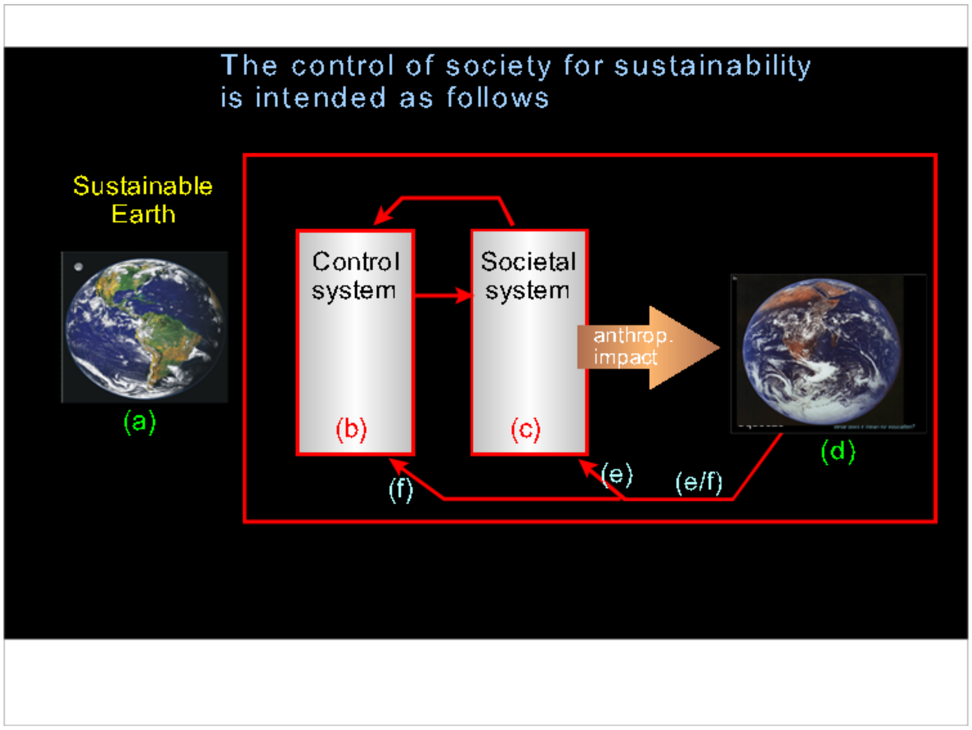

Figure 1 Scheme describing how societies are to be managed and controlled regarding collective environmental impact, to reach sustainability (Source: (Carlman, Grönlund, & Longueville, 2015)).

This brings us to a situation where an interdisciplinary research within e.g. environmental science, sustainable science or science of the Anthropocene, within which integrated assessment is useful as a basic and fundamental tool. The keyword here is communication, which connotes as well as implies the importance of having the same understanding of the problems, compatible theories and portable knowledge. Physicists e.g. have to handle questions regarding resource degradation in a way that is justifiable from physical theoretical standpoints and concurrently make it useful for environmental science, i.e. compatibility. Communication must allow for portability of knowledge from one discipline to the other. A natural scientist must furthermore understand the importance of and need for statements under uncertainty regarding vital facts from an environmental point of view. This underlines that the natural scientific part is set out as the scientific fundament in such a way so the social scientific part can build on a firm understanding of man´s dependence of nature.

Donella Meadows (2001) gives some valuable recommendations about how to work in practice and how to treat the interdisciplinary dilemma about systems thinking (Italics added):

“Defy the disciplines. In spite of what you majored in, or what the textbooks say, or what you think you're an expert at, follow a system wherever it leads. It will be sure to lead across traditional disciplinary lines. To understand that system, you will have to be able to learn from while not being limited by economists and chemists and psychologists and theologians. You will have to penetrate their jargons, integrate what they tell you, recognize what they can honestly see through their particular lenses, and discard the distortions that come from the narrowness and incompleteness of their lenses. They won't make it easy for you. Seeing systems whole requires more than being ‘interdisciplinary,’ if that word means, as it usually does, putting together people from different disciplines and letting them talk past each other. Interdisciplinary communication works only if there is a real problem to be solved, and if the representatives from the various disciplines are more committed to solving the problem than to being academically correct. They will have to go into learning mode, to admit ignorance and be willing to be taught, by each other and by the system.”

Evaluating and analysing systems are complex tasks in themselves, and by applying certain methodologies one can ensure that one does not draw rash conclusions about what is “the truth”. One such alternative is the Critical Systems Thinking (CST) approach, that offers methodologies for complex problem situations through “Creative Holism” (Jackson, 2006). This approach suggests considering the perspectives of four different paradigms; functionalist (“Hard system thinking”, positivistic), interpretive (“Soft systems thinking”), emancipatory and postmodern (both based on sociological paradigms) (p. 653 ff). The idea is to study the system from these perspectives, thereby forcing mind into different directions.

Vital, to communicate to all participants, is that all systems thinking involves approximations and assumptions, especially when working with sustainability issues and forecasts about the future. This is discussed by Kates et al (2001), who states: “Combining different ways of knowing and learning will permit different social actors to work in concert, even with much uncertainty and limited information.” (p. 641). They also claim that sustainability research has to be based on (1) a wide discussion within the scientific community, (2) be connected to the political agenda, and (3) focus on nature-society interactions.

It is tempting thought to try to address and model all the gigantic environmental and human problems all at once, to get ‘the answer´, but such an approach will most certainly prove to be counterproductive due to excessive complexity and adjacent accumulation of (statistical) uncertainties. To serve as a support tool for governance, the appropriate level for modelling needs to be chosen. In the process of developing a model which may support the development to reach a sustainable level of the county of Jämtland, Mid Sweden University has chosen to work at a regional level. By doing so, a more detailed, downward scale model can be created, regional stakeholders have the potential to be involved including their own relevant processes, and there is a possibility for closer cooperation regarding policy issues to emerge. It is vital to strengthen the regional participatory process and stakeholder involvement (as discussed above). Ferry (1995) sees a risk for democratic degradation in the field of tension between the local – the national – the international (and just like Beck) he highlights this democratic dilemma when nations have less influence and abstract international institutions seem to decide more and more (p. 183 ff). Multinational companies must of course be included in these kind institutions. Taking the problems with the Greece economy as an example, we can see peoples´ reactions and mistrust towards international institutions and governments. This gives evidence that a very important issue actually is communication of as objective information as possible.

4. A REGIONAL MODEL SUPPORTING SUSTAINABLE STRATEGY MAKING

Mid Sweden University is currently developing an environmental model of the Jämtland county in Sweden based on model developed for the Danish island Samsø at the university of Aalborg in Copenhagen, (Denmark) (Nielsen & Jorgensen, 2015). In Jämtland ten different sectors (see Figure 2) have been identified as suitable to work with to give a realistic overview, without losing details, which is a risk or rather guarantee as models per definition deal with simplifications of reality. It is essential and crucial to make the right/proper simplifications. For each sector the sustainability indicators energy balance and carbon flows were chosen. Compared to Samsø, Jämtland is more complex and also much larger, however, still small in terms of population in relation to the area. The Jämtland county has about 127.000 (2 persons/km2) inhabitants and Samsø has about 4.000 (33 persons/km2). The geographical area of Jämtland is comparable to the German region Baden-Württemberg (with more than 10 million inhabitants; 300 persons/km2).

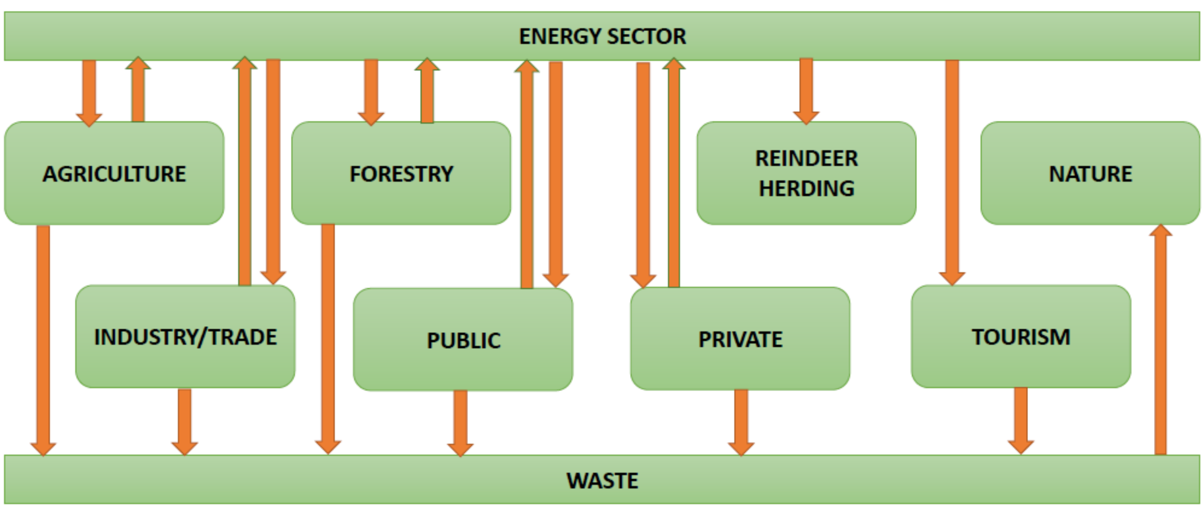

Figure 2 Sectors used in the model of Jämtland. The waste sector energy output is not part of the regional energy sector since the waste is being exported to another region of Sweden. Arrows show flows of energy and/or matter.

Due to the size and the complexity of Jämtland compared to rather limited society of Samsø, there are several challenges that are to be overcome when the Samsø model is to be expanded. Each sector has its own deeper complexity and knowledge within broad fields are needed to capture, thereby mapping each sector as detailed as possible, still within certain time limitations. Manufacturing industries, reindeer herding, dairy farming etc needs to be understood and this understanding are to be transferred into flows of energy and carbon. The idea behind the modelling is to find out the possibilities to become a sustainable region, and by cooperating with the county administration and local stakeholders help governing the strategies for future possibilities. Visiting “reality” is a most important aspect to gain full understanding as well as making meaningful verifications possible.

Figure 3 shows energy balances in Jämtland for the energy sector, including distribution of energy from this sector to the other sectors (however, the Industry/Trade sector from Figure 2 has been divided in two different sectors; industry and services). Energy is stated as work energy, e.g. available energy delivered from the producer. For the infrastructure the approximated accumulated energy input in the manufacturing of the equipment, the dams etc is used. The chemical energy, in for example the crystalline structure of steel, is not regarded as being part of the work energy. The logic behind this is that the accumulated energy is the energy needed for the manufacturing of new equipment as well. Most basic data have been found in databases in (Statistics Sweden, 2015), (Energimyndigheten, 2015), (Trafikanalys, 2015). The total output from the sector is 45,5 PJ (45,5· 1015 Joule), which does not include the use of biofuel by private forest owners or biofuel export from the region, which is part of the forestry sector. Hydro power is totally dominant in the region.

The sectorial infrastructure consists of dams, generators, wind mills, transmission lines etc. All this needs to be continuously renewed, and from an expected service life of the equipment, a total investment of about 3 PJ/Year can be expected. Part of this is imported into the region as material. The total calculated work energy of the infrastructure is 140 PJ. The energy sector produces electricity and heat. Furthermore imported liquids are mainly used for transportation purposes, and only a minor part is used in old oil heating burners for (about 0,2 PJ). Based on available statistics about driving patterns and vehicle types, usage of liquids have been calculated per type.

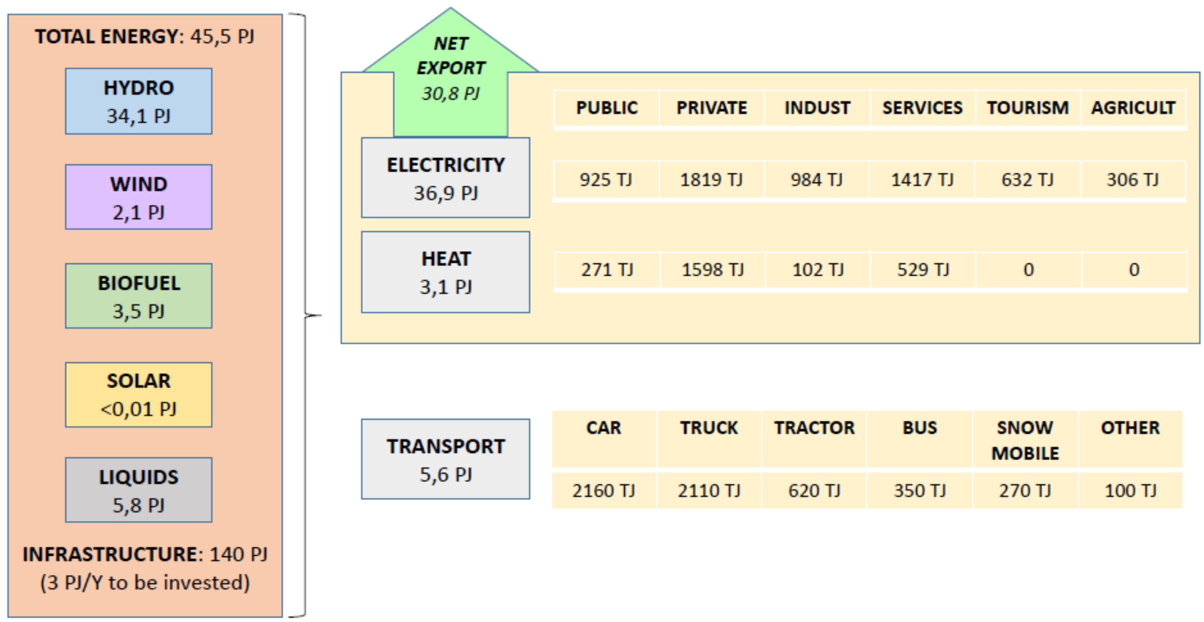

Figure 3 Work Energy Balance for the Energy sector in Jämtland (2013)

The region generates much more electricity than needed in the region. Hence the region becomes a net exporter of energy with 30,8 PJ. About 45% of the Swedish electricity production comes from hydropower and the major part originates from the northern part. The exploitation of the many northern rivers took place during the first part of the 20th century and the excess electricity generation capacity in the region cannot be used as an argument for sustainability, the usage in the region has rather to be studied separately. Hydropower becomes, however, more and more important, not only to Sweden, but also to EU serving as regulating power to wind and solar energy being installed. Power transmission links (HVDC) are being built between Scandinavia and EU to make such regulation possible on a larger scale.

In complex decision situations different stakeholders often have different intuitive apprehensions of the actual situation. Due to seemingly constant lack of time such intuitive apprehensions are used in discussions, and this is often not clarified. The first step to correct this is to clarify, as far as possible, facts regarding the present situation. The following example shows how data from a model can be used in a decision tree structure, supporting governing discussions.

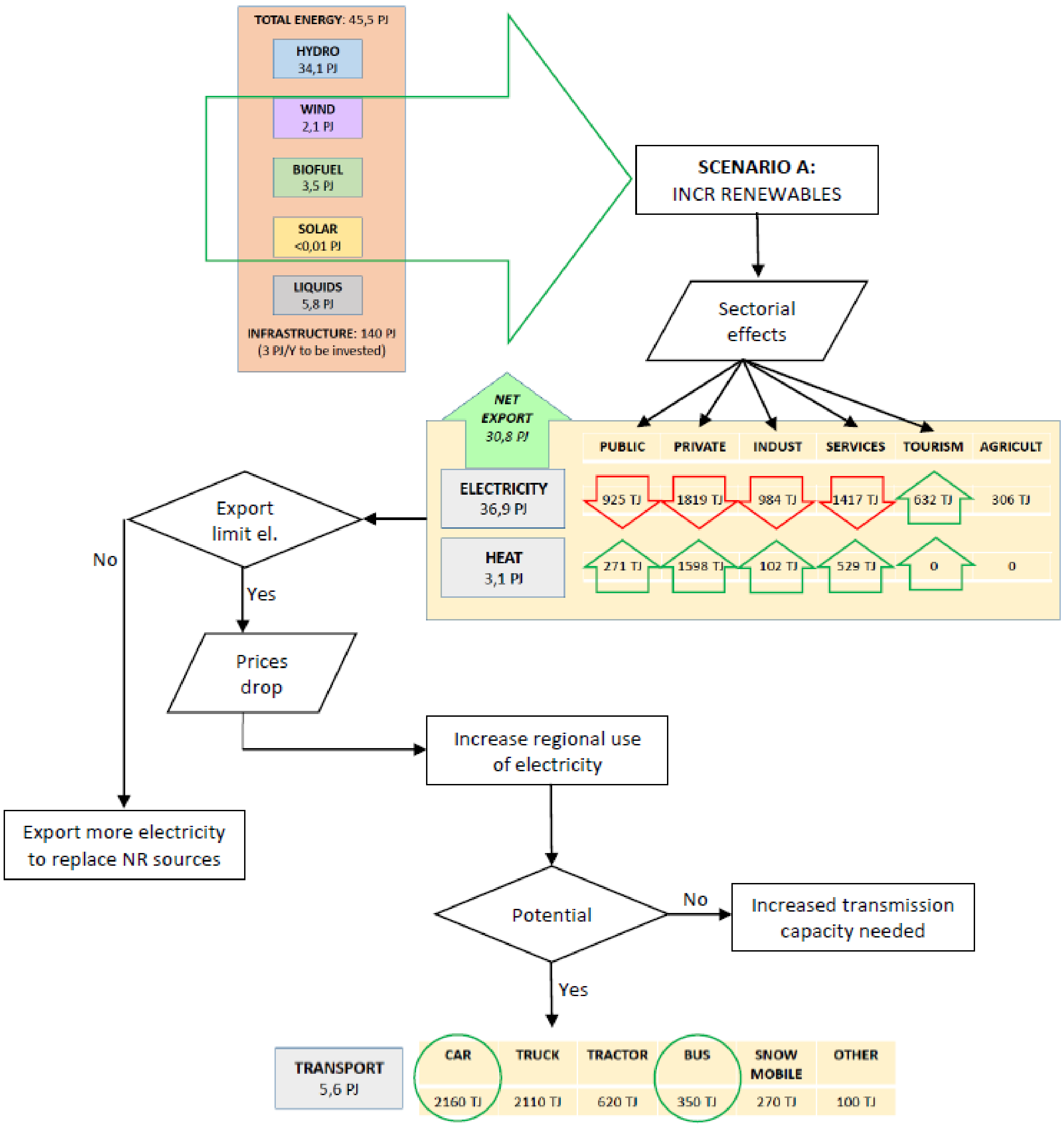

Figure 4 Decision tree example for communicating connections out from data from the model. See text for explanations.

Just as models can forces us to clarify functions and data, and map “reality”, decision trees (or similar methods) can clarify decision complexity, and at the same time communicates connections of data. The example demonstrated in Figure 4 is not very complex, but can still serve as an example on how to communicate complex environmental decision situations.

A probable scenario for the nearest future (e.g. 10 years) is that production of renewable energy will increase. Permissions for wind mills show such a tendency, just as requests for photovoltaic installation subsidies from the Swedish government do. Usage of biofuels from the forest can also be expected to increase due to an increased interest from private households to reduce environmental impact, reducing energy costs. Increased usage of biofuels will transfer use of energy from electricity to heat (decreases shown with red arrows and increases shown with green arrows). Within the tourist sector electricity use is expected to increase, and tourism in this case is cottages used for tourism. The tendency is a continuous increase of number of tourists and cottages, and tourists normally do not use much biofuels but use rather electricity, and this for simplicity reasons. The cottages are normally situated in places where district heating will not be available. Regarding the population of the county, a general increase is not expected for the nearest 30 year period, therefore constant population has been presumed in the model.

One issue about power export possibilities out from the region, is transmission capacity limitations from the region to other regions and Norway. 7.300 MW is the maximum capacity to southern Sweden, 3.300 MW to northern part (which just as mid Sweden has an excess power generation), and 1.000 MW to Norway (where there also is an excess power generation) (Svensk Energi, 2014, p. 38). As long as the maximum transmission capacity is not reached, all excess generated power can be exported from the region, thus making a transfer of power generation from non-renewables to renewables in other parts of the country or abroad. However, often the transmission capacity is a bottleneck. This means the prices for electricity may drop and the usage of electricity in the region needs to be increased (which partly will be an outcome of lower prices) as long as the power transmission capacity cannot be increased.

There is a possible transfer from fossil fuels to electricity in the transportation sector for cars and (city) buses. By studying driving patterns for cars it is possible to estimate the proportion of the car fleet, which can be transformed into battery vehicles. An alternative to battery vehicles is fuel cell (hydrogen gas), which in Japan is regarded as a better technology compared to battery vehicles. Toyota has declared they are sceptical that battery efficiency will improve to increase range and decrease costs (see for example (Automotive news, 2014)). In Japan governmental subsidies aim at building a net of hydrogen gas stations across the country (The Wall Street Journal, 2014). (Electricity can be used to produce hydrogen gas).

New questions are being generated from scenario studies as the one above; Presume there will be 5.000-10.000 battery vehicles around 2025. What are the alternatives for such individual investments, which would be more beneficial to the environment? Would it be better if people bough photovoltaics instead? Or wind mills? An even more interesting question arises when taking photovoltaics into consideration, and broadening the view to include Europe Would it be more efficient if a person in Jämtland could make an investment in photovoltaics in for example Cassablanca instead of the home region. Installing photovoltaics in Sweden has the drawback that when the need for electricity is high (during winter) the production is limited. From a global perspective there is a need to find solutions to make investments as productive as possible, thus reducing resource extraction as far as possible and optimising efficiency in service. This is why there also is a need to consider how monetary systems can be used more efficiently between nations.

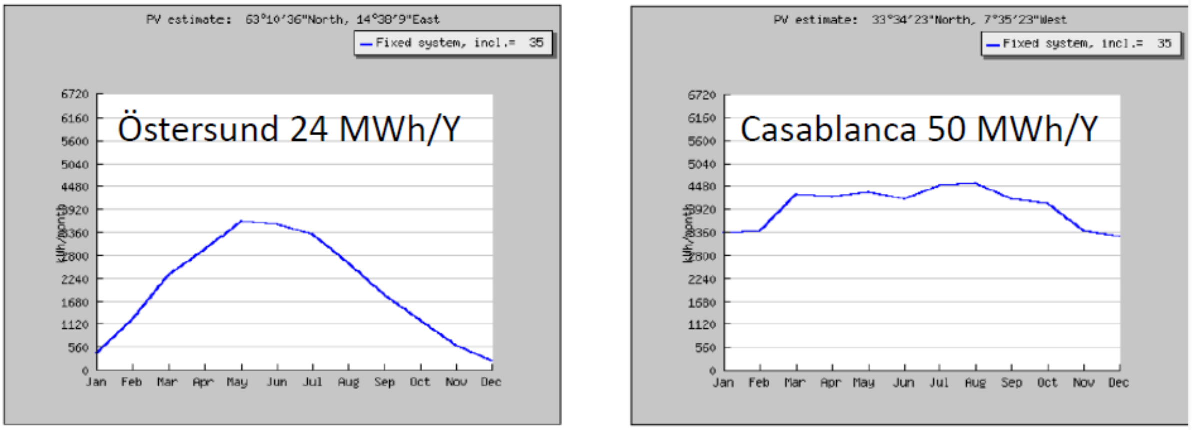

Figure 5 Simulated power generation as monthly energy output from a 28 kW photovoltaics installation in Östersund and Cassablanca (28 kW installation corresponds to photovoltaics installed at the roof of the Mid Sweden University and was therefore used in the simulation to compare real output with data from the simulation).

As can be seen in Figure 5, if the same installation of photovoltaics was made in Östersund and in Casablanca, the latter installation would generate twice as much energy per year (simulations made with (JRC European Commision, 2015)). From a global environmental perspective, it would obviously be a better alternative to install such an equipment in Casablanca instead of in Östersund. This might indicate the need for international cooperation, trying to find ways to solve future energy demands. It is obvious an increasing amount of regulating power balancing wind and solar power production, will be needed in the future (typically hydropower is suitable for such regulation, balancing the continuous variations out). Price differences in EU for electricity will probably increase even more in the future due to variations in the production from sun and wind (and maybe increasing tidal power).

Globally connected power transmission grids would make it possible to even out day and night time production and consumption patterns. At the same time it will be more and more complex as well as out of local and national control. It is most probably not possible to really optimize energy production and thereby reduce environmental impacts, as long as there is mistrust between nations (Today´s global oil and nuclear situation speak for itself).

The example discussed here shows clearly how legislation issues needs to be connected to a scientific base and a sustainable policy. Furthermore, the people in a region need solid information about possibilities and alternatives when it comes to investment-decisions. Systems analysis and modelling can play a part in such a process, but it is important to clarify alternatives, mapping the situation, showing future outcomes of different scenarios etc. A genuine understanding of human behaviour and of business conditions together with ecological aspects of various energy sources, calls for a more integrated interdisciplinary approach. Models are most useful tools in such approaches.

5. CONCLUSION

Systems analysis and subsequent modes are constructs. According to systems theory and model development they are strategies as the best representations of nature, we can make. At the same time it must be assured, that a continuous adaptation and improvement in a studied area is possible - i.e. that model outcomes are matched with phenomenological observations and that empirical work also is carried out. Model development can therefore be characterized as a dynamic and iterative process.

Governance in the Anthropocene will have to understand the problem picture at hand, to learn how to appropriately address increasingly complex issues. For identifying potential solutions and consequences of policy implementation, systems modelling on relevant levels will be one necessary tool. The current project developing an environmental regional model, illustrates how modelling can provide decision support for the county of Jämtland regarding management and energy resources and planning of future infrastructure, as well as serving regional and national information purposes.

The science to this not only needs to be multi-, trans- and interdisciplinary in it basis but also needs to incorporate many other issues such as sociology, ethnographic, religious, economical, political perspectives as well. Although all the latter needs to acknowledge the physical boundaries imposed by solar radiation, composition of earth crust, etc.

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