LUCID

Lund **U**niversity **C**entre of Excellence for **I**ntegration of Social and Natural **D**imensions of Sustainability

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Abstract

Meeting global sustainability issues such as climate change, water scarcity, biodiversity loss and land use change, is an urgent challenge for society. Yet, the divide between natural and social sciences represents an obstacle to new creative solutions to such problems. First, while pursuing critical and problem-solving research strategies, LUCID aims at creating completely new and unique synergies across natural and social sciences in order to develop new integrated theories and methods for addressing complex sustainability issues. Organised in a three-dimensional matrix structure composed of: four sustainability challenges, three generic core themes, and two cross cutting research approaches, LUCID will develop a generic approach to the study of and solutions to sustainability problems. Secondly, making the faculty independent centre of LUCSUS a focal meeting point in research, LUCID participants, from seven disciplines in four faculties, will strengthen their co-operation in research and master education. Thirdly, LUCID will further develop and expand global networks of outstanding partners on sustainability research in order to provide a range of stimulating and challenging career opportunities for both young and senior researchers. Finally, LUCID will participate actively in national and international assessment processes on sustainability and become a strong collaborator in international research enterprises.

1. The problem and the vision

Strong messages about the state of the planet have recently been expressed by large scientific communities: the Millennium Ecosystem Assessment in 2005 [1], the Stern Review in 2006 [2], the Fourth Assessment Report by IPCC in Spring 2007 [3-5] and recently the fourth Global Environmental Outlook in October 2007 [6]. Their main conclusion is that the human impacts on global life support systems of the planet have reached a magnitude and complexity, unprecedented in human history, which may jeopardise the future well-being of humanity. Even the World Bank now joins the chorus and paints a bleak picture of future global food security [7]. This calls for action. We believe that LUCID will play a central and innovative role in research on sustainability.

LUCID's overarching aim is to build a research platform that advances as well as problematises the role of science in the transition toward sustainability. Building upon Robert Cox's [8] conceptual distinction between problem-solving and critical research strategies and traditions as a starting point, LUCID aims to find new ways of integrating knowledge across the divides between social and natural sciences as well as between critical and problem-solving research. This will be done in the context of major sustainability challenges emphasised by the recent messages above, such as climate change, loss of biodiversity, the global water crisis, and land use change.

Sustainable development as a political and scientific agenda emerged with the Brundtland Report 'Our Common Future' in 1987 [9]. The concept has evoked many meanings and aroused much political and academic debate since then. While many criticise sustainable development for its promise to 'square the circle' [10, 11] – to identify a new development model that will both further growth and an ecologically sustainable and more just world order – it has also been welcomed as a generative metaphor around which conflicting environmental and economic interests can meet [12, 13]. Although contested, the variety of definitions for sustainable development proposed over the past decades seems to converge around concerns for peace, justice, development and the environment [14]. If sustainable development is the process, sustainability is the goal.

In spite of profound changes of society and nature[1] the pursuit of scientific knowledge largely remains unchanged [15], characterised by a strong dichotomy of social versus natural science hampering the ability to cope with sustainability challenges. In part of the scientific community, there is a growing concern that social and natural sciences need to address sustainability issues more systematically. As a response sustainability science is an emerging field, loosely defined as:

> It is not yet an autonomous field or discipline, but rather a vibrant arena that is bringing together scholarship and practice, global and local perspectives from north and south, and disciplines across the natural and social sciences, engineering, and medicine. Its scope of core questions, criteria for quality control, and membership are consequently in substantial flux, and may be expected to remain so for some time. Something different is surely "in the air" – something that is intellectually exciting, practically compelling, and might as well be called "sustainability science" [16].

Sustainability science was consolidated as an international science policy project in the preparations for the World Summit on Sustainable Development in Johannesburg in 2002. The concept articulates a new vision of harnessing science for a transition toward sustainability [16]. Although heterogeneous in scope and practice, this emerging research programme draws upon scholarly attempts to rethink the interactions between nature and society [17-19], the global and the local [20], science and democracy [21-23]. By redefining the functions, mandate and scope of scientific inquiry,

[1] For example: for the last 50 years species extinction rate has been up to 1000 times higher than the background rate [1]; the rate of global temperature increase is unprecedented for at least 10 000 years [3].

sustainability science seeks to be responsive to the needs of society while preserving the life-support systems of planet Earth [24, 25].

While firmly grounded in the problem-solving tradition of the natural sciences, advocates of sustainability science have so far been less concerned with matters of justice, politics, power and central critical research traditions in the social sciences. It can thus be argued that the overarching aim to foster a coherent interdisciplinary system of research planning and practice [24] has to date failed to give room for research that calls the basic assumptions of modern society into question.

LUCID corresponds with strategic objectives to foster creative integration across disciplines and faculties in new forms of research cooperation as expressed in the Lund University strategic plan for 2004-2006. This was prioritised in the interdisciplinary research initiative on Global Sustainable Development and in the transition of Lund University Centre for Sustainability Studies, LUCSUS, into its current status in 2005, independent of faculties and disciplines. In the Lund University strategic plan 2007-2011, the commitment to sustainability and interdisciplinary science is strengthened further. The plan recognises that new knowledge is increasingly developed in the voids between disciplines thus calling for new forms of collaboration across faculties and disciplines. This is where LUCID fits in with its bold aim to combine commitment to sustainability with new types of collaboration across traditional academic disciplines and fields of knowledge. LUCID will cooperate broadly to integrate the critical academic project to rethink fundamental concepts and assumptions with the search for research approaches aiming at offering strategies and solutions to sustainability problems. In short, our vision for LUCID is to:

- Create a Centre of Excellence for strong trans-disciplinary research drawing upon the integrated expertise of researchers from LUCSUS and seven disciplines in four faculties.
- Integrate human, social and natural dimensions of sustainability as well as problem solving and critical research strategies for the development of new theory and methodology
- Expand the global network of outstanding partners on sustainability research.
- Provide through this network a range of stimulating and challenging career opportunities for both young and senior researchers.
- Become a major player of integrated knowledge in national and international assessment processes on sustainability.
- Attract major external funding from sources such as the EU Framework Programmes, UN-GEF and national research foundations.

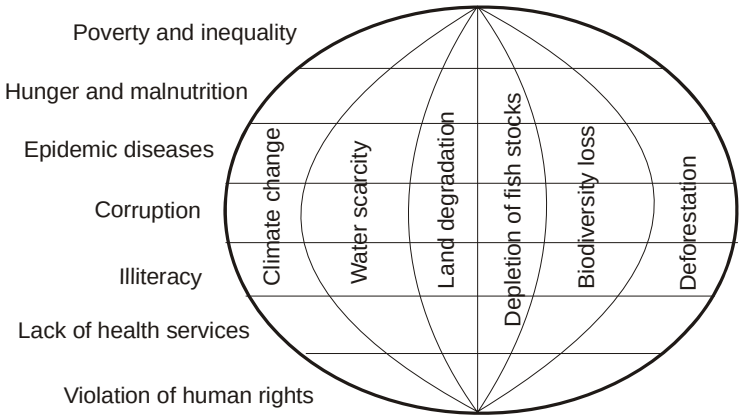
2. Challenges of sustainability

Historians and social scientists have shown how societies, over the centuries, struggle with social problems such as hunger, poverty, diseases and violation of human rights, many of which still remain. Recently, and in addition to this, science have identified a number of new or escalating urgent issues, such as climate change, water scarcity, biodiversity loss and land use change that create new and often conflicting challenges for society. For LUCID we have identified three important prerequisites for identifying and recognising such sustainability challenges:

- A certain degree of scientific understanding regarding causes and magnitudes of the consequences to be communicated beyond the scientific community
- The formulation of social goals negotiated in a dialogue with science[2]
- Political decisions on pathways and strategies to fulfil these goals[3]

[2] Examples of such social goals are: the Millennium Development Goals, the goals of eradicating epidemic diseases set by WHO; the stabilisation of greenhouse gases in the atmosphere set by UNFCC in 1992.

It is evident that many of these challenges are strongly interrelated therefore requiring integrated solutions. The contemporary scientific understanding is that these problems are complex, affecting multiple domains and scales from the local to the global. A schematic illustration of persistent social and urgent sustainability challenges is presented in the figure below.



The social and human effects on Planet Earth have during the past decades escalated to a stage that some would call the Anthropocene, i.e. a geological epoch when Humans are the dominant force shaping and reshaping the planet [26]. In the Anthropocene era, key environmental parameters have moved well outside the range of millennia scale natural variability and entered a non-analogue state [27]. An increasing number of environmental problems, such as climate change, have also advanced to a level where human welfare is directly and immediately threatened, while others, like the case of biodiversity losses, pose more of potential future threats to humanity. Rittel [28] has labelled environmental problems of this complex and pervasive kind *wicked problems*. Wicked problems are persistent not only because the solutions are not yet there but because they have incomplete, contradictory, and changing requirements; and solutions to them are often difficult to identify because of complex interdependencies. While attempting to solve a wicked problem, the solution of one of its aspects may reveal or create another, even more complex problem. Furthermore, the problems span local to global scales and several generations, and are characterised by lags and inertia, masking important causes and effects. As a consequence, our current social and political institutions are not well suited to tackle these issues [6]. We strongly believe that research can contribute to change this for the better and LUCID has a role to play.

Sustainability science speaks with the Anthropocene vocabulary. This means that the challenges of sustainability can only be met when the fundamental interconnections between nature and society are studied in a more systematic and integrated fashion [24]. The strong tradition of separating natural and social sciences in academic research has resulted in an inadequate understanding of nature-society interactions and the integrated dynamics of the 'Earth System' as a whole [17, 29]. In LUCID we take on this integration challenge by strengthening our collaboration across the natural and social sciences to develop joint methods by which nature-society interaction can be studied and applied to real-world problems. In parallel to these efforts we seek to maintain a critical and reflexive approach to the Anthropocene imagery and to problematise scientific representations of nature and society as an integrated whole.

LUCID will focus its integrated research efforts on a number of specific sustainability challenges, including climate change, water scarcity, biodiversity loss, and global land use change. The

[3] The Stern Review on Climate Change [2] provides recent examples of pathways, building on policies and measures in the Kyoto Protocol. See further section four on 'Creating new synergies'.

integrated approach strives to identify, explore and scrutinise complex drivers (social, economic, political, natural, technological) of societal and scientific change. The following interrelated sustainability challenges will be the initial research focus in LUCID:

- Climate change
  Global climate change is a reality confirmed by the 0.74°C increase in global average temperature over the past century and impacts are already evident [5]. Changes in water availability, decreased food security, sea-level rise, a reduction in ice cover and the increasing frequency and intensity of heat waves, storms, floods and droughts are projected to dramatically affect many millions of people. The likely range of human-induced warming over the current century is between 1.4°C and 6.4°C above present-day levels [4]. Climate change exacerbates the loss of biodiversity and degradation of land, soil, forest and water.

- Water scarcity
  It is estimated that over a billion people worldwide lack access to safe drinking water and if the current trend continues 1.8 billion people will be living in regions with absolute water scarcity by 2025 [6]. In addition climate change will exacerbate water scarcity in certain regions, such as Northern India, and put another several hundred million people in acute water crisis. As a result, global food security may be in jeopardy towards the end of the 21st century [5].

- Biodiversity loss
  The rate of species extinction is believed to be at least 100, perhaps as much as 1000, times faster than before the Industrial Revolution [1]. Sooner or later this may have disastrous consequences because biological diversity is a precondition for human well-being in terms of food production, health and immaterial values like aesthetics, recreation and spiritual activities. As an example, about forty percent of all pharmaceutical substances originate from biological organisms, and still only less than one percent of identified species have been screened for useable substances. Thus, people rely on biodiversity in everyday life often without realising it.

- Land use change and food production
  Given projections that the global population will increase to over nine billion by 2050, and in order to meet the MDG on hunger, a doubling of global food production will be required. In addition, a continuation of the shift from cereal to meat consumption, combined with over-consumption and waste, will increase food demand to between 2.5 and 3.5 times the present production. Yet, the production of cereals per caput peaked in the 1980s and has since slowly decreased despite the increase in average yields. Consequently, there is an obvious risk that other important ecosystem services, such as clean water, biodiversity and protection against natural hazards will be compromised in the search for agricultural land [6].

Common to these sustainability challenges is that they are usually defined and described primarily by the natural sciences, and only later recognised as issues of importance for society and the social sciences. The strength and innovation of LUCID is our multidisciplinary expertise and ability to re-conceptualise these issues in collaboration between the humanities, natural sciences and social sciences represented in our team. Our joint critical and problem-solving research strategy is a major strength in LUCID, so is our explicit effort to combine and create new methods for understanding complex issues and thereby generate new theory.

3. Mobilising existing expertise

In this section we present the current scientific expertise in the LUCID initiative for the purpose of demonstrating how these different fields of research can be mobilised to create strong synergies in

the pursuit of new integrated knowledge on sustainability issues, which is the bold ambition of LUCID.

The participating groups and researchers span a broad range of themes, disciplines, theoretical perspectives and methodological approaches. This provides a crucial starting-point for developing the understanding and managing the complexity of real world sustainability problems. Moreover, the groups all have strong records of research and a dynamic and topical research agenda with an important development potential. All the groups are also well-connected internationally and much research is pursued in the context of international projects and networks. Finally, many of our researchers have a long history of co-operation in research, graduate studies and teaching mainly at the Masters level. Consequently, we have strong reasons to believe that there is a solid and fruitful basis for further joint progress in our ambition and experience of integrated approaches. Our existing expertise can be categorised into the following fields serving to create further synergies:

- World system theories
- Earth system science
- Global sustainability and environmental politics
- Normative explorations
- Food, agriculture and development
- Sustainability in practice

4. Creating new synergies

This section presents how the scientific expertise outlined above will be combined and integrated in research in order to address urgent and complex questions of sustainability. As emphasised, the proposed initiative, LUCID, starts from the assumption that social and natural systems are strongly interlinked. Complexity, non-linearity and self-organisation are important characteristics of these linked systems. Yet, the fundamental difference between social and natural systems is that natural systems are driven by a set of fundamental natural principles, such as gravity, thermodynamics and natural selection, while social systems are driven by totally different dynamics. But much of the existing debate on linked social and natural system ignores this crucial difference, perhaps because most of the research has so far been dominated by natural sciences only. Therefore research needs to question the very foundation of the sustainability questions by starting from ontology and epistemology. The overarching research questions in LUCID are:

- How can sustainability challenges be understood, contextualised and studied?
- How can science (natural/social/humanities) contribute to transitions towards sustainability?

In order to operationalise our research on sustainability challenges *and* the role science plays in the transition to a sustainable society, LUCID will be organised in a matrix structure. We strongly believe that it will assist us in developing a generic approach that can be applied to many sustainability issues. The matrix is composed of:

The four **sustainability challenges**:

- Climate change
- Water scarcity
- Biodiversity loss
- Land use change

The three **core themes**:

- Scientific understanding

- Sustainability goals
- Sustainability pathways

The two **cross-cutting approaches**:

- Problem-solving approaches
- Critical research approaches

As a final research step attempts will be made to synthesise findings from both approaches in support of a new type of deep knowledge promoting transitions to sustainability and which therefore *'might as well be called "sustainability science"'* [16].

4.1 Theme one: Scientific Understanding

Sustainability challenges, be it climate change or biodiversity loss, are normally defined and framed in scientific terms. Whereas these cognitive products of science often shape how environmental problems are understood and acted upon in society, we know from many years of social constructivist scholarship that science is far from an autonomous space clearly demarcated from society, culture or the political. Rather, knowledge and beliefs about the natural world are closely linked to the social world in which they are embedded [20, 30, 31]. Building upon this insight, theme one explores ways in which links between natural and social systems are understood and conceptualised in the emerging field of sustainability science. LUCID will both critically examine conceptual models and explore how to improve them by more integrated research efforts.

- The Earth System metaphor.
  This sub-theme will examine emerging attempts to conceptualise and study natural and social systems as one interlinked Earth System. According to this scientific approach, the Earth System consists of two main components: the *ecosphere* with three subsystems (atmosphere, biosphere, cryosphere), and the *anthroposphere* that accounts for all human activity [17, 29]. Building upon a view from space provided by remote sensing technology, global databases and sophisticated computer models, the quest of Earth System Science is consequently to move beyond the study of each subsystem as a self-contained entity in favour of a holistic and interdisciplinary understanding of how they are connected and interlinked. While this new research agenda acknowledges the complexity, non-linearity and surprise built into 'the linked socio-ecological system', it also epitomises modern virtues such as rationality, control and predictability. This sub-theme will therefore scrutinise the tensions built into the Earth System metaphor and analyse their implications for the understanding of sustainable development.

- Theories of unequal exchange and world-system dynamics.
  Whereas conventional economic science seems unable to accommodate concepts of unequal exchange, except in the sense of monopoly (i.e., market power), several strands of trans-disciplinary ecological economics are currently developing new methodological tools for defining unequal exchange in objective, biophysical terms. Two of the most promising among these new tools for assessing asymmetric resource flows are Material Flow Analysis [32] and Ecological Footprints [33]. Such biophysical accounting tools (measuring, e.g., the physical volumes exchanged, or the land requirements of their production) tend to provide completely different perspectives on international trade than conventional economic statistics based on monetary value [34, 35]. When combined with the world-system perspective developed among social sciences such as sociology, economic history, and political science [36] these new approaches to global, societal metabolism are of crucial significance for the topic of sustainable development. Climate change, for example, will be one major, to some extent predictable, driver

of changes in the global distribution of vital ecosystem services, which we plan to integrate into existing frameworks for addressing and projecting exchange patterns.

- The concept of resilience of social systems and linked socio-ecological systems.
  Resilience, an analytical framework emerging in ecology in the 1970s in reaction to ideas of equilibrium, depicts incremental changes and capacity to preserve systems within given frames. However, in its original definition, resilience does not recognise that social change mainly implies transitions to renewed forms of production, consumption, and distribution with new combinations of technology, organisation, institutions and life styles [37]. In this sub-theme we will scrutinise the usability of the rapidly expanding resilience framework.

4.2 Theme two: Sustainability Goals

This theme explores the process of formulating and establishing various global sustainability goals including their very content. Since the publication of 'Our Common Future' in 1987 [9], the social goal setting has changed from a broad qualitative vision of a sustainable society to more precise policies including specific planning instruments and targets measurable in quantitative terms.

The Brundtland Commission [9] defined sustainable development as development that '*meets the needs of the present without compromising the ability of future generations to meet their own needs*'. The concept, comprising the environmental, economic and social pillars, has been subject to criticism on many grounds, especially for its ambiguity and the lack of tangible operationalisation. The eight Millennium Development Goals (MDGs), resulting from United Nations Millennium Declaration [38] is an example of a social goal setting linked to a delivery system that attempts to contribute an operationalisation of sustainable development. One criticism against the MDGs is that they emphasize planning in top-down processes rather than the agency and participation of the poor themselves [39]. Even more specific goals are set in the contexts of individual sustainability issues, such as the different UN conventions (UNFCC, UNCBD etc).

Common to all such goals is that they are formulated through a complex interaction between science, politics, industry, media etc. Goals are also intimately and mutually related to the scientific understanding. For example the formulation of the MDGs has triggered many research initiatives specifically aimed at fostering scientific understandings that support the goals.

In this theme, sustainability goals will be scrutinised on three dimensions of justice and fairness: the intergenerational, the international, the intersectional. Below we show examples of pertinent research topics on this theme in relation to the three dimensions:

- Intergenerational justice and fairness.
  In climate change, the dramatic difference between the conclusions from the recent Stern Review and previous investigation into the costs of climate change, actually stems from the different normative assumptions underlying the studies. The Stern Review [2] states explicitly that the welfare of future generations is as important as the welfare of this generation, while most previous studies implicitly assume that the welfare of the current generation is more important than the welfare of future ones. The utilisation of finite resources is another important example. Can it be taken for granted, for example, that minerals found in geological deposits belong to the current generation? The problem of one generation reaping the benefits of a technology while leaving waste to future generations should be one of the most burning issues today when there is a renewed interest in nuclear energy. Should we build intergenerational justice into the exploitation of such a technology and how can this be done?

These illustrations reflect theoretical challenges that will be approached in LUCID. In what sense can future agents have moral rights with respect to us and we have obligations with respect to them? How do collective obligations and responsibilities correspond to those of individual agents and how do the values of different aspects add up to values of wholes? An important component of these moral and legal problems is in fact descriptive and epistemic. How do we predict present and future needs and states of the world? How is this done in everyday life, in policy making, in science, and in law?

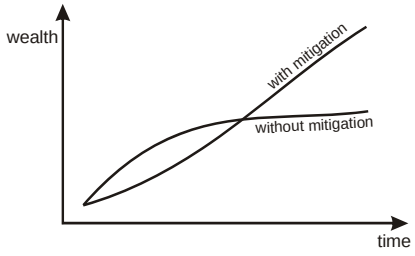
- International justice and fairness.
  This work will deconstruct different aspects of the sustainability discourse in order to reveal biases and constraints. For instance, concern has been raised that climate change might trigger a new kind of world order founded on "carbon colonialism" [40]. Global problems of climate change are to a large extent caused by the industrialized countries but will have much more severe negative impacts on developing countries. In the struggle to reduce emissions of greenhouse gases developing countries are increasingly coerced into development strategies that contributes to this polarization rather than alleviates it. In subjecting the globalised discourse on sustainable development to critical scrutiny, we aim to uncover such tacit agendas as may reflect the perspectives and knowledge interests of affluent sectors of world society.

- Intersectional justice and fairness.
  The concept and analytical category of intersectionality can be defined as 'the relationship among multiple dimensions and modalities of social relations and subject formations' [41]. Intersectionality thereby reminds us that nobody lives a uni-dimensional life to be described in terms of only one single aspect like: age, class, ethnicity, race, religion, gender or sexual orientation. Apart from stressing multi-identities, intersectionality also brings attention to power when it takes into account that individuals may suffer simultaneous and multiple oppressions and inequalities in accordance with their identity. However, while some argue that the advantage of the term intersectionality is its intentional neutrality others maintain that the political dimensions of inequality are washed away in the use of the concept. [42]

  Knowing that intersectionality, like many other terms, may be controversial we will explore dimensions of human identity in relation to sustainability goals. As an example the MDGs are sometimes defended for their gender awareness while others argue that by focusing mainly on material aspects in relation to gender many other discriminatory aspects are ignored or not understood [43]. Talking in method terms we intend to look at several axes simultaneously in a sort of 'diversity matrix' when scrutinising various sustainability goals [42].

4.3 Theme three: Sustainability Pathways

Science, politics, industry, media and civil society participate in complex multi-level dialogues to formulate strategies and pathways aiming at the fulfilment of sustainability goals. Such strategies are intimately and mutually related to scientific understandings as well as the political and economic context in which science is pursued. This means that there are contesting views resulting in very different pathways as recently illustrated by the main message from the Stern Review [2]. The figure here shows examples of two conceptual pathways from the Stern Review for dealing with climate change and their impacts on global wealth.



This theme scrutinises pathways to sustainability by investigating and critically analysing proposed mechanisms for and pathways to a sustainable society such as development, marketization, regulation, and democratisation.

- Development
  Development has a long mainly post-war history of ideology, theory, practice and prescriptions spelling out positive and negative links between rich and poor countries, making poverty reduction an overarching aim and debating roads to economic convergence versus the risks of divergence. Critical observers of development as a project of strategies and policies would argue that it has offered and still offers modernisation trajectories as a main way forward for overcoming poverty and other social challenges but very few solutions for sustainability transitions. But in the light of climate change the options for postponing environmental concerns while primarily concentrating on poverty eradication are rapidly closing when more and more developing countries face increasing vulnerability to climate impacts such as food, water and physical insecurity. The option of win-win-solutions, proposed already by the Brundtland report [9] as a way to overcome poverty while sustaining the environment, needs to be identified and elaborated which is also stressed by the IPCC [5]. Consequently, new research like that proposed by LUCID must critically scrutinise the development discourse from the point of view of sustainability approaches and thereby rethink and reframe development into pathways of sustainable development.

- Marketization
  The public sector is increasingly adopting both values and practices from the private sector in fields such as health, education and environmental management. This marketization trend is particularly strong in transitionary economies where industrialization is also rapidly increasing. As a response to the threat of global climate change we see the emergence of a global market for carbon and thereby a new 'carbon economy'. The current global climate policy regime relies to a large extent on market mechanisms such as emissions trading, joint implementation and the Clean Development Mechanism. In the discussion of adaptation to climate change, insurance as an adaptation strategy is a rapidly growing market where major financial players are increasingly active. In the development debate, market integration is often described as a panacea [44]. Proponents of marketization argue that the market is the most effective mechanism for dealing with problems while opponents fear that this will compromise values related to democracy, citizenship [45] and equity [46]. LUCID will scrutinize marketization as a response to sustainability challenges both in terms of effectiveness and impacts on justice.

- Regulation
  There are several fundamental challenges for a legal regulation towards a sustainable development. Still much of the regulation is based on nation state law, although environmental problems have a quite other character. In response to that, new forms of regulative bodies transgressing the nation state have to emerge. Law is contemporary, and the demand for intergenerational rights challenge the law since there is no legal bearer of such a right. Furthermore, more effective – spontaneous – regulation have to develop; command and control-regimes are to ineffective and not adjustable enough. Corporate Social Responsibility is one example of a bottom up regime that uses the market forces. More emphasis have to be put on regulatory techniques together with the surrounding normative structure [47]. It is important to se regulation from a new, normative perspective and LUCID will critically rethink contemporary regulative processes.

- Democratisation through deliberation

The strong deliberative turn in democratic theory during recent decades speaks to an emerging concern with the distance between the interests and motives of citizens and the decisions made in their name [48]. A growing scholarship today questions liberal democratic institutions by pointing at the lack of voice of citizens and the poor representation of ecological values in decision-making processes [10, 49]. Deliberative democratic theory has evolved as a response to this perceived weakness of liberal democracy. It seeks to both democratise and green policy discourse by increasing the opportunities for citizens to engage in decisions that affect their lives and surrounding environment. This deliberative project also extends to the international arena and has been approached as a strategy that may bridge the democracy deficit in governance arrangements beyond the state [50] and foster a trans-national green public sphere [10]. In this sub-theme we seek to examine how 'democratisation through deliberation' plays out in the environmental domain. We are particularly concerned with the potential synergies and tensions between the substantive and procedural aspects built into this deliberative project. As famously claimed by Goodin [51] "(t)o advocate democracy is to advocate procedures, to advocate environmentalism is to advocate substantive outcomes." Hence, how and to what extent can a deliberative model of democracy represent a pathway towards sustainability?

4.4 Two cross-cutting themes: problem solving and critical theories

In 1981 Robert Cox [8] made a seminal distinction between theories that seek to solve the problems posed within a particular perspective, and critical theories that are more reflective upon the process of theorising itself. The first category of problem-solving theories takes the world as it finds it, with prevailing social and power relationships and the institutions into which they are organised as the given framework for action. The general aim within this school of thought is, according to Cox, to reduce a particular problem into a limited number of variables that can be studied with such precision that regularities of general validity can be identified. While problem-solving theories hereby seek to guide tactical actions and increase the efficiency of the existing institutional framework, the latter category of critical theories stands apart from the prevailing order of the world and asks how it came about. Unlike problem-solving theory, critical theory calls contemporary institutions and power relations into question and allows for a normative choice in favour of alternative social and political orders. While acknowledging that each school of thought has its strength and weaknesses, Cox [8] affirmed that there is no such thing as a theory in itself divorced from a standpoint in time and space. Theory is always *for* someone and *for* some purpose. This epistemological claim functions as a central organising principle for LUCID. While our different disciplinary perspectives are grounded in both problem-solving and critical research traditions, we see epistemological reflexivity as a necessary prerequisite for successful interdisciplinary dialogue and integration.

4.5 Synthesis: Towards a Sustainability Science

Based on our critical analysis of scientific understandings, sustainability goals and sustainability pathways, the aim is to build and synthesize much needed theories and methods for sustainability science that have the potential to transcend two crucial interfaces:

- Nature and society. There is an urgent need to develop theories that can capture the dynamics of the linkages between natural and social systems. Integration efforts in sustainability science have most often been based on systems thinking and modelling, scenario construction, and regional/spatial integration. Combinations of these approaches have dominated efforts to assess sustainability, and integrate science in policy or planning processes at different levels. The challenge is to transcend earlier studies by focussing more on social, economic and political aspects of sustainability in order to integrate formal and informal institutions [52] in various

systems such as norms, regulation, decisions, conduct and behaviour. The integration of social and natural cycles is one concrete example that will be pursued in LUCID.

Modern society is heavily dependant on manipulating a number of bio-geo-chemical cycles such as: the carbon cycle for provision of energy; the nitrogen and phosphorous cycles for provision of food; and the water cycle for provision of water, food, energy and transport. In natural science, the study of such cycles has resulted in biogeochemistry, an area of scientific inquiry that integrates the disciplines of biology, geosciences and chemistry. [53, 54]. A similar development in the social sciences, but still very much in its infancy, is Material Flow Analysis, MFA, briefly introduced in 4.1. To some extent, MFA resembles macro-economic modelling, with the difference that MFA deals with physical units of materials rather than monetary units. The challenge to integrate the complete cycles, both the natural and the social components of these cycles, is at the very heart of sustainability science. Such a development requires a rethinking of the ontology and epistemology of disciplines. For example, the natural science ontology of the carbon cycle is based on carbon as a bio-physical entity that can be studied objectively using quantitative methods. If the ontology is reformulated to incorporate also carbon used in the manufacturing, transporting and consumption of goods, then the cycling of carbon becomes as much a social as a natural cycle. Analogous reasoning of integration can be applied to the water and the nutrient cycles. In LUCID we will use broad scientific expertise to develop and refine a much needed integrated approach to these important cycles. Such understanding is vital for finding remedies to climate change and food insecurity.

- Science and society. The idea here is to explore how scientific understandings of socio-ecological systems can contribute to governance for sustainable development. LUCID will explore how scientists can navigate between the demand to provide effective policy advice on the planetary life-support system, and the calls for socially robust knowledge and legitimate expertise that is open for plural viewpoints and public deliberation [31]. This can probably only be done via development of participatory interactive processes such as Integrated Sustainability Assessment (ISA) [55]. Efforts will also be made to develop and refine methods for stakeholder interaction in combination with scenario construction, systems thinking, systems analysis and systems dynamics.

5. Modes of research, supervision and training

Research on complex issues is usually best pursued in groups where researchers with different but related expertise investigate different aspects of a joint problem. LUCID will offer scientific training and a fruitful learning environment where the exchange of knowledge between younger and more experienced researchers is emphasised. The core of LUCID is therefore a research school where PhD candidates from different disciplinary backgrounds and Post-docs work closely together and where research students are supervised in interdisciplinary groups. Professional scientific leadership is here of utmost importance. And in addition to research, training of researchers is therefore a crucial component. Some of the most important topics for LUCID are:

- Ontology and epistemology in different sciences, perspectives and main approaches
- Natural science for social scientists and social science for natural scientists,
- Research design, academic writing and publication skills,
- Scientific leadership.

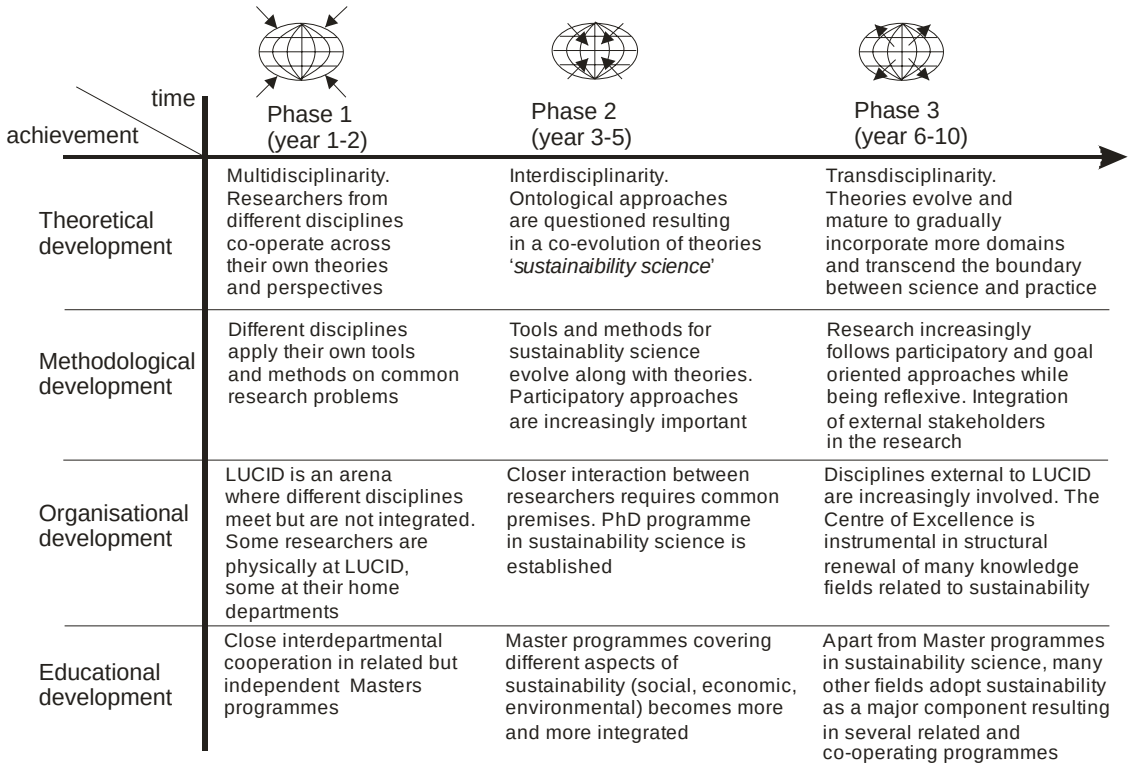
LUCID will actively contribute to the international research arena on sustainability by:

- Arranging scientific events, ranging from large conferences to small targeted workshops,

- Participating in international conferences, both as scientists and as co-organisers,
- Participating in international scientific assessment processes, such as IPCC.
- Actively promoting secondment of researchers in the international networks (Appendix U)

6. Expected achievements and milestones

LUCID is seen over a ten year period of research with mutual links to graduate education. In the scheme below, including indicators for evaluating our progress, development in several crucial domains are described: theoretical, methodological, organisational and educational.



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