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SUSTAINING CLIMATE CHANGE MITIGATION – POLICY, TECHNOLOGY, AND SOCIETY

ABSTRACT

In a world that is becoming more and more exposed and vulnerable to the effects of global climate change, combining integrated risk assessment tools with effective strategies for both mitigation and adaptation is a key prerogative for policy-making. With the focus of both researchers and decision-makers gradually shifting from observing and assessing the bio-physical aspects of climate change to a more human and society centered understanding of the nature of the problem, the social, behavioral, economic and technological aspects have entered center stage of the public discourse. Responses to the climate change challenge have to establish an optimal interplay between mitigation, adaptation and socio-economic instruments. Yet, given the band-width and scale of the climate problematique and its projected impacts, very ambitious mitigation measures have to be undertaken without delays, a fact that is particularly true for emerging economies with their very rapid and unprecedented growth rates, both in GDP and GHG emissions terms.

The challenge for the next years is to harmonize poverty eradication and attaining the Millenium Development Goals through stable economic growth with mitigating the effects of climate change. Therefore, "inclusive green growth" has become the motto of the day. But how can this goal be achieved? Obviously, quite fundamental changes have to be introduced that affect both the production and the consumption sectors and allow for real innovation in technologies and energy, in urban mobility, infrastructure and transportation grids. This paper illustrates the deep social and societal nature of climate change response strategies, especially in the area of mitigation, and shows that transitions to green and low-carbon economies will have to embed policies, incentive schemes and economic instruments in a larger societal context of social learning and behavioral change.

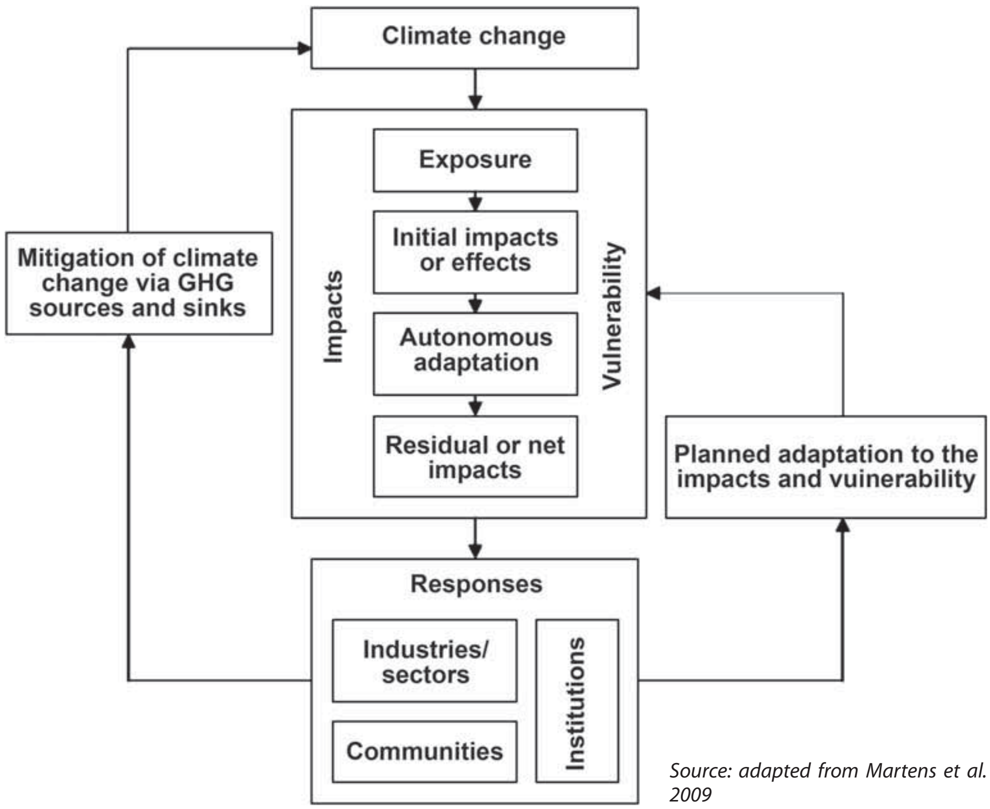
KEY WORDS: climate change, mitigation strategies, Millenium Development Goals, inclusive green growth, social learning, innovations

INTRODUCTION[1]

Intelligently designed processes of linking state-of-the-art vulnerability assessments with highly effective adaptation and mitigation measures at very large scales will become a key challenge for societies and policy-makers in the years to come, and will require the art of combining integrated risk assessment tools with an advanced approach to adaptive governance and policy-making processes. Ultimately, climate change and its adverse effects on people is becoming more and more a social and societal paradigm rather than just a "natural" or biophysical one. Indeed, the social and behavioral aspects of climate change and its societal dimensions have entered center stage in the public discourse [Martens and Chang, 2010].

The chart (after Martens and Chang [2010]) represents the classic conceptual matrix

[1] This paper represents a modified and abbreviated version of a study that was prepared for the Asian Development Bank (ADB). While the ADB study focuses on policy and development financing practice aspects in an Asian context, this version can be considered more generic and academic in its focus.



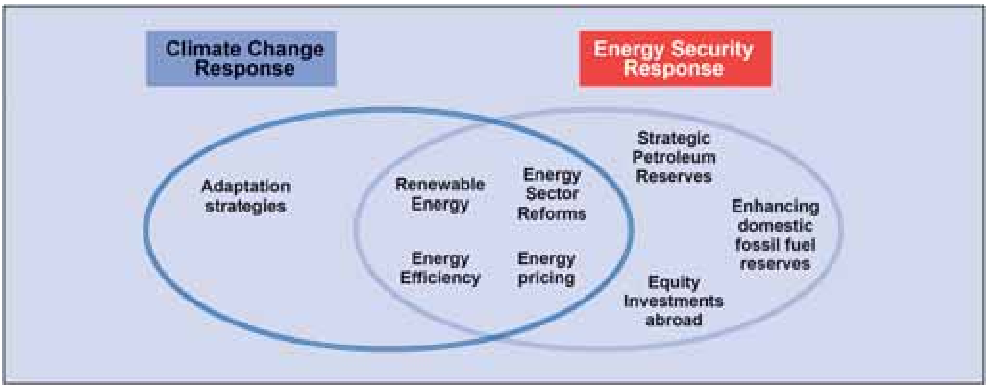
Source: adapted from Martens et al. 2009

Figure 1. The analytical framework for vulnerability–adaptation–mitigation research in the context of climate change

of the vulnerability-adaptation-mitigation nexus and illustrates the predominantly social and societal nature of this set of phenomena and their interaction. Social and societal dynamics constitute the climate change problematique and also hold vulnerability, adaptation and mitigation together.

The Intergovernmental Panel on Climate Change (IPCC) in its Third Assessment Report (TAR) in 2001 defined vulnerability as 'the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes'. IPCC lead authors have coined our understanding of vulnerability as being composed of exposure, sensitivity and adaptive capacity. Our societies' policy responses aiming to reduce vulnerability to climate change usually target one of these three. Martens and Chang [2010] write: "Exposure can be reduced (e.g. by changing the sectoral composition of the economy), sensitivity can be reduced (e.g. by making operational adjustments), and the adaptive capacity can be increased (e.g. by making contingency plans)."

However, the adaptive capacity of a social-ecological system depends on the effective interplay between mitigation and adaptation dynamics mostly expressed by devising such factors as economy, technology, human and social capital, and governance tools [Martens and Chang, 2010]. Therefore, effective policy responses to climate change always have to strive a balance and a harmonious interplay between mitigation and adaptation strategies, essentially using the same toolkit for both. Technological innovation, greening economies and businesses, and ultimately the dynamics of inclusive green growth are playing a key role in any climate regime, including in adaptation regimes. They are as good and effective as much as they operate



Source: ADB

on the system-inherent dynamic of the social and societal sphere. Negligence of the societal roots of any of the climate change cluster related factors, whether in terms of impacts, policy or technology is likely to lead into the wrong direction, i.e. on presumably less effective trajectories. Martens and Chang write: "The willingness and capacity of society to change is critical. Information and awareness-raising can be useful tools to stimulate individual and collective climate action... Mitigation, being an action targeting the long term, means attaching value to the interests of future generations and ... can be considered an altruistic response by society".

Such findings illustrate and underline the deep social and societal nature of climate change response strategies. If these assumptions are correct, paying due attention to the social and societal factors will be of critical importance when identifying ambitious strategies toward sustainable changes in the technology and energy sectors, low carbon intensity and green growth, especially in the rapidly emerging and developing Asian countries. The challenge in the years to come, given the very particular nature and dynamic of development trajectories particularly in emerging countries, is to balance poverty eradication and progress toward achieving the MDGs through economic growth with mitigating the effects of climate change, which is still largely coupled with precisely this trajectory of growth. "Green growth" and "inclusive growth" are the buzzwords of the day, but how are these concepts at all to become real? Clearly, there is no simple answer to this question. However, it is obvious that integration is key: integrating policy with vulnerability and risk assessment, mitigation and adaptation. Without paying due attention to the underlying human, social and societal factors those goals will not be reached.

The dynamics at play in this matrix largely build on convergence between policy frameworks, economic incentives, technological innovation and efficiency, all of which have societal connotations and draw upon the ability of humans and societies to change cultural constructs, attitudes and behavior through social learning. These dynamics and their inter-linkages are the focus of this article, which aims to shed light on the sometimes hidden or unseen human and social forces behind phenomena that we often enough consider as merely technical in nature.

THE GOVERNANCE CHALLENGE

As the Kyoto Protocol, which governs global emission reduction goals and policies, runs out, the UNFCCC process is expected to provide guidance for the future. However, it so far has not resulted in a new legally-binding protocol. The recent climate summit in Cancun, Mexico (UNFCCC COP 16) finally endorsed the 2 °C goal. However, it does not foresee any peak year or any collective target for cutting emissions. As a result, the concept and vision that global sustainable development affairs should be addressed primordially on a collective and truly international basis is still under threat. It seems unclear whether the approach of consensus driven inter-governmental decision-making has a meaningful future in global climate politics, or whether nation states will decide on their own, or in small groups, by how much they are willing to cut emissions. The concept and notion of Global Governance could well face a new paradigm shift and gradually be replaced by a "Club Governance" mode, i.e. world politics in smaller, exclusive circles.

At this juncture, the following questions seem prudent, and effective mitigation and adaptation policies will largely depend on answering them in a satisfying manner: How can global climate change, its manifold threats and adverse impacts still be met and tackled? What are promising strategies well outside the routines and path-dependencies of global climate negotiations? What are the potential and roles for technical and technological solutions and their social and societal acceptance? In the absence of a global breakthrough, additional negotiations in smaller circles, for instance within the G-20, or between developed and developing countries, and the formation of so-called "coalitions of the willing" could lead to partial results and should therefore not be generally dismissed. Especially at regional scale, intense talks between policy makers and a variety of stakeholders are necessary and have potential to advance solution-oriented efforts world-wide. By the same token, it is important to realize that the global climate change agenda is quite convoluted and has reached a state of almost incomprehensible complexity. It may therefore be fruitful to disentangle some of the most controversial issues and, for instance, yield to strive global agreements on questions of financial subsidies or compensation, on the harmonization of national adaptation policies, on technology transfer, or on the creation of new carbon markets, in separate fora.

We will have to "re-marry" the climate change agenda with those on development and human security. Climate change is, of course, not only about the environment. For instance, it results in the degradation of ecosystem services with direct impact on human wellbeing, and in growing human and social vulnerability, particularly in developing countries. This means costs for prosperity, economic development and human security. Climate change thus severely undermines the achievement of the Millennium Development Goals (MDGs). Moreover, we risk derailment of the MDGs if we fail to mitigate and adapt to climate change effectively. Therefore, an integral approach is much needed at the level of global and regional governance systems and collective political action. In the absence of a truly functional global approach to effective management of the climate change crisis, particular in terms of mitigation regimes, the geographical regions are carrying responsibility, Asia in particular given its unique growth rates and carbon related dynamics on the one hand side, and rapid development of key technological skills and resources on the other.

Recent leading-edge science suggests that even if global green house gas (GHG) concentrations can be stabilized at the level of 450 ppm CO_2 equivalents (CO_2e) by means of very ambitous mitigation efforts, we will still have to deal with a ca. 50% chance of surpassing the globally recognized 2 °C target. If such probability is to be decreased to less than 30%, stabilization at 400 ppm CO_2e will be required. The Wuppertal Institute concludes: "However, for the 400 ppm CO_2e scenario to be feasible, most probably negative emissions would be required by the end of the century, which could be achieved by combining the use of bio-energy and carbon capture and storage (CCS)" [Sterk, 2009]. What both the 450 ppm and the 400 ppm CO_2e scenarios have in common is a peak in global GHG emissions around 2020. This means that all the countries with significant GHG emissions will have to reduce their emissions by that time. To make this scenario a reality, a global and binding deal implying reliable collective action by basically all net emitters is a key. The fact that this deal would have to become effective in less than a decade poses an enormous challenge for policy makers but also society at large. It appears almost self-evident that ambitious targets will most likely not be achieved by governmental and inter-governmental policy-making and regulation alone. Even a very ambitious and legally binding UN treaty of the Kyoto kind will most likely not lead to the level of changes and reductions described above without the mobilization of a drastic change in the production-consumption nexus of GHG emitting countries. Success in this context certainly means to be able to surpass certain societal tipping points to trigger genuine green growth and large-scale behavioral changes.

It seems impossible to meet ambitious targets without drastic and transformative changes in policy, society, technology, economy and human behavior. Also, it will be necessary to develop a variety of different scenarios and trajectories for change, depending on the geographical regions, as it will hardly make sense to simply apply a German or European model to, say, Asian countries and subregions. Martens and Chang conclude: "The impacts of climate change are felt more immediately by individuals in society and adaptation is typically viewed as obeying the everyday 'self-interests' of individuals. As such, studies on risk perception by individuals, industries and organizations will be critical to understand its influence on the acceptability and ultimate effectiveness of different responses. Mitigation policy is primarily focused on decarbonization and involves interaction among the large emitting sectors such as energy and transport, or else targets efficiency improvements according to specific end-users, commercial and residential" (p. 7).

FROM POLICY TO BEHAVIORAL CHANGE AND SOCIAL LEARNING

The Centre for European Policy Studies (CEPS) states: "All public policy seeks to influence behavior – investment, innovation, consumption – to achieve some socially-desired outcome. If policy is very successful it becomes embedded in social and economic norms and behavior. But it is also important to remember that policy is always acting in a broader economic and social context. This makes it hard to measure the impact of policy because the phenomenon that policy is seeking to influence – in this case GHG emissions – is also affected by many other factors. A more specific reason why measuring *policy effectiveness* is difficult is our still incomplete knowledge about how policy signals affect the behavior of economic actors, not only through prices, but through the relative incentives and penalties they generate, and the expectations they shape over the longer term" [CEPS, 2009]. It appears difficult to measure policy effectiveness – whether that of an individual or a clustered nature – especially if innovative policies are analyzed. It is even harder to project the impact and effectiveness of future policies, for instance in the context of climate change mitigation. Policy analysts usually tend to apply a larger theoretical and analytical framework than economic modelers, to include such variables as power, interest, rules of the game, or normative considerations. It is conceivable that these factors can indeed influence the creation of markets and opportunities, for instance for sustainable investments in new technologies, or energy. While projections or predictions regarding the effectiveness of policies are difficult, no one would challenge the fact that pro-active climate policies are a critical component of larger incentivizing schemes and frameworks. Other important components of such schemes are, inter alia, "high energy prices, investment in greener infrastructures, increasing competitiveness of renewable energy technologies ... as world markets expand, [or] growing concern about energy security" [CEPS, 2009]. Neither policy frameworks nor economic measures alone are likely to create enough potential to trigger significant change in the respective areas of both technological and behavioral patterns, but together can form a strong regime of authoritative forces that indeed do influence the behavior of individuals and societies, and the emergence and diffusion of powerful technological alternatives and green growth, both leading to significant emission reductions.

Given the nature, magnitude and scale of the climate change problematique, large-scale behavioral change is required from the individual to the societal and supra-societal levels across all geographical regions. In this context it is prerequisite to take into account that changes arising from new behaviors are often multifaceted and need the right institutional arrangements and incentive schemes to make them effective and sustainable. This is the point where both pro-active policy making and good incentives for innovative investments have to come in and play out their strength. Integrative approaches, triggered by the right set of policies and economic and financial incentives, can link technological innovation and behavioral solutions and thereby simultaneously address the changes needed to initiate effective mitigation measures. For public policy makers, entrepreneurs and investors alike, the key question in this regard is: How can we avoid the disruption of the economy and turn the desired and necessary changes into a competitive advantage?[2] If the assumption is correct that the root cause of anthropogenic climate change lies in the implications of the unsustainable trajectory of industrial revolutions in the 19th and 20th centuries, and therefore in the so-called "Western economic paradigm", climate change is ultimately a deeply societal and behavioral issue, which means that any solution will have to fully imbibe societal and behavioral factors, and their relation to energy, technology, and production and consumption. Geologists call our time the Holocene but Nobel Laureate Paul Crutzen noted that the last two hundred years have been a really unique era, not only in human history but in the Earth's physical history as well. He coined the term *Anthropocene* to signify the fact that human beings for the first time have taken hold not only of the economy and of population dynamics but of all the planet's physical systems as well: "The Anthropocene is the period when human activity has overtaken vast parts of the natural cycles on the planet, and has done so in ways that disrupt those cycles and fundamentally threaten us in the years ahead" [Sachs, 2007].

Inter-disciplinary research shows that behavioral changes can be catalyzed through processes of social learning. Social learning theory focuses on the learning that occurs within a social (or societal) context. It assumes that human beings learn from one another through observational learning, imitation, and modeling. Albert Bandura is considered the leading proponent of this theory. As it comprises attention, memory and motivation, social learning theory combines both cognitive as well as behavioral frameworks. Social learning theorists say that both awareness on the one side but also expectations of future reinforcements or punishments on the other influence the behaviors that people exhibit [Ormrod, 1999]. In social learning theory, modeling is a powerful means to generate new behavior and influence the frequency of previously learned behaviors. People are more likely to engage in new behaviors when they have high self-efficacy, i.e. when they feel that

Box 1

Necessary conditions for effective modeling:

– **Attention**: Various factors increase or decrease the amount of attention paid, e.g. distinctiveness, affective valence, prevalence, complexity, functional value.
– **Retention**: Remembering what you paid attention to. Includes symbolic coding, mental images, cognitive organization, symbolic rehearsal, motor rehearsal.
– **Reproduction**: Reproducing the image. Including physical capabilities, and self-observation of reproduction.
– **Motivation**: Having a good reason to imitate. Includes motives such as past (i.e. traditional behaviorism), promised (imagined incentives) and vicarious (seeing and recalling the reinforced model).

[2] For more information please refer to the work and findings of the ***Industrial Transformation (IT) project*** of the International Human Dimensions Programme on Global Environmental Change (IHDP), at website: www.ihdp-it.org.

they will be successful in performing them. The box below shows the necessary conditions for successful i.e. effective modeling in social contexts [Ormrod, 1999].

In *Learning to Manage Global Environmental Risks,* the Harvard University-based "Social Learning Group" provided a functional analysis of social responses to climate change, ozone depletion, and acid rain, and analyzed a variety of empirical case studies. The authors examined how the interplay of ideas and actions applied to major environmental problems, by means of social learning, laid the foundations for effective global environmental governance and successful risk management. Their study has great potential and significance for the question of how policy innovation and major technological shifts can lead to effective climate change mitigation through social learning [The Social Learning Group, 2001]. Moreover, Howard Gardner's research suggests that social learning and behavioral change can be achieved through what he calls *representational redescriptions:* "Get the message out in lots and lots of different ways, lots of different symbol systems, lots of different intelligences and lots of different embodiments. The notion that you say it once and it gets through is just wrong. You have to be extremely resourceful in finding diverse ways to get the same desired mind-change across" (please refer to www.cio.com, Issue of 1 April 2004, p. 73 ff). It is self-evident that social learning and large-scale behavioral changes have to be embedded in specific socio-economic landscapes and the larger societal changes of which they are part. This means that different approaches will have to be identified for poor or extremely poor countries, for emerging economies, and for developed countries, respectively.

A rich body of experience is health where social learning and behavioral change have been studied extensively. From health related behavioral issues we know that factors such as perceived threats and benefits or self-efficacy can be strong an lasting drivers for behavioral changes. Major studies in the areas of changed attitudes towards smoking or sexual behavior in connection with HIV prevention, for example, have impressively demonstrated that en masse changes in attitude, lifestyle and behavior can occur relatively rapidly and in a non-linear fashion. The famous *Health Belief Model* (HBM, see box below) highlights some of the most important drivers for change and learning. It is fully conceivable that the mechanics at play during such change processes can be of equal or similar value and function for changes that need to occur with regard to climate change mitigation, adaptation and energy efficiency, although long-term studies with similar epistemological value as is the case in the health sector do not yet exist due to the fact that climate change related behavioral change is a relatively recent phenomenon [Rosenstock et al., 1994].

Box 2

Health Belief Model (HBM)

[Rosenstock, Strecher and Becker, 1994]

– **Perceived Threat:** Consists of two parts: perceived susceptibility and perceived severity of a health condition.
– **Perceived Benefits:** The believed effectiveness of strategies designed to reduce the threat of illness.
– **Perceived Barriers:** The potential negative consequences that may result from taking particular health actions, including physical, psychological, and financial demands.
– **Cues to Action:** Events, either bodily (e.g., physical symptoms of a health condition) or environmental (e.g., media publicity) that motivate people to take action.
– **Other Variables:** Diverse demographic, sociopsychological, and structural variables that affect an individual's perceptions and thus indirectly influence health-related behavior.
– **Self-Efficacy:** The belief in being able to successfully execute the behavior required to produce the desired outcomes. [Bandura, 1977].

A "translation" of the Health Belief Model into a climate change context could look as follows: ***Perceived Threats***: This could be developed societies perceiving scrutiny for their lifestyles' contribution to climate change or developing societies that perceive exploitation by affluent nations; could also be the threat felt by more vulnerable nations to the effects of climate change (i.e. coastal zones). *Perceived Benefits:* One potentially all-inclusive benefit of the climate change crisis could be the global governance system, which requires all countries to work together to reach a common goal. Climate conferences can help to set a precedent, making future global discussions and goal setting run more smoothly. Huge potential benefits lie in the development and application of carbon efficient technologies and related economic benefits and return on investments. *Perceived Barriers:* Perceived barriers with regards to climate change, like in the health sector, include economic demand. Aside from this, the perceived barriers having to do with climate change are not as easily penetrated as in the HBM model. Climate change problems require a lot more effort and commitment. A great barrier of climate change is that it mandates global citizens to not only recognize the faults of their lifestyles, but also the dedication to change. *Cues to Action:* Can be physical or social. Physical cues include the consequences of climate change (i.e. sea-level). Since physical cues are not easily observed by all, social cues like the media publicity observed in Copenhagen are necessary to spread awareness. *Other Variables:* Another variable could be the fact that many people cannot directly observe the effects of climate change. *Self-Efficacy:* "The belief in being able to successfully execute the behaviour required to produce the desired outcomes." [Bandura, 1977] The MDGs could be an example of this; a plan of action that individuals can depend on and institutions can strive to achieve.[3]

In conclusion, we understand that effective innovation in the area of technology and energy requires social learning and the right governance (or policy) environment in order to become effective and sustainable. Especially the social and behavioral aspect is often neglected or underestimated, which is a mistake. Technological innovation works through imagination, niches and novelties. Societies can develop diverse pathways of technological and economic development and adapt within certain conditions. Social learning plays a key role in this context as it allows establishing and maintaining a collective memory of previous adaptive responses. This often happens through institutions, norms and values, and social traditions. Various social groups have introduced changes and new behavioral patterns to resource use and environmental protection. These actions, by means of social learning processes as described above, have no doubt created a different level of public awareness, which can be replicated in other contexts.

SOCIO-TECHNICAL REGIMES AND INNOVATION

The role of knowledge co-production and dissemination, and the mechanisms and mechanics of social learning require more attention, as the foregoing chapter has shown. Yet the emergence of so-called "socio-technical regimes" for sustainability and low carbon economies, and a truly dramatic increase of energy efficiency and productivity around the globe, but especially in Asia, seem critical. New and smart green technologies, energy forms and production means are performing effectively and achieve their best results once they are embedded in a well-educated and sustainability oriented societal framework. Yet this poses some challenges to our governance systems. Our political, legal and economic institutions have to [4]feature a certain amount of adaptive capacity paired with provisions that foster knowledge production and diffusion and technological innovation on the one hand side, and individual and collective learning and behavioral adaptability on the other.

[3] Special thanks to Ms. Kyr Hudson, University of Michigan, for her input.

[4] This paragraphs draws on the work and findings of the Industrial Transformation project (IHDP-IT), at website: www.ihdp-it.org.

Box 3
A larger governance context
Institutions and global governance:
– Changes in institutional and environmental governance frameworks for effective management of ecosystems.
Economics and incentives:
– Economic and financial interventions as instruments to regulate the use of ecosystem goods and services.
Knowledge responses:
– Effective management of ecosystems is constrained by a lack of knowledge and information.
Technological responses:
– Development of technologies designed to increase the efficiency of resource use and reduce impacts of drivers of environmental change.
Social and behavioural responses:
– Public education, civil society action and empowerment of communities can be instrumental in responding to ecosystem degradation.

Source: IHDP

This requires a balance between policy making, economy, technology, and social learning and acceptance. A key question in this context is the one on how societies can effectively link human, economic and social development with environmental sustainability and bold climate change mitigation efforts. The research agenda of the "Industrial Transformation Project" of the International Human Dimensions Programme on Global Environmental Change (IHDP-IT), has triggered remarkable work in the fields of energy and material flows, food, cities with focus of water and transportation, information and communication, governance and transformation processes [IT 1999]. IHDP-IT defines the foundation of industrial transformation research, particularly in Asia, as follows: "Industrial Transformation research starts with the notion that changes in technologies, put differently, changes in the ways in which humans use environmental resources and services, are embedded in the socio-economic realm and modify the natural environment. This embraces processes and products, production and consumption chains and distribution and disposal activities. IT research is also interested in the institutions and incentives that shape these systems (i.e. property, liability, regulations), and how these situate and influence social actors (government, producers, and consumers)" [Asian Transitions and Globalization, 2006]. It is critical to understand how these systems might be able to change without producing significant additional GHG emissions and ecosystem failure. In other words, the interaction of economy driven innovation with change processes in provisional systems influenced by societal development (e.g. energy, mobility, food) is at the heart of these questions [Olsthoorn and Wieczorek, 2006].

Industrial transformation and sustainability transitions have been an important focus of the research and policy communities in a number of European countries already for some time, especially regarding the aspect of large-scale innovation in production and consumption. Such research and policy debates have not only included technological aspects, but also the roles of institutions and behavior. However, "there is a need to connect these 'western' debates about transitions and sustainability with current understandings of processes of social, political and economic development in other parts of the world. Given the transformative changes are most manifested in the rapidly urbanizing and developing Asia, this part of the world appeared particularly challenging. A characteristic feature of much of the current Asian policies and research linked to technology, industry and sustainability relates to product-process innovation and to the question of how to achieve near-term improvements in energy-, resource- and pollution-intensities through the adoption of best available technologies. The achievement of higher-level environmental and sustainability targets – including low-carbon or less resource-intensive development pathways – has [so far] attracted less attention, partly because these economies are still relatively less resource-intensive per capita than most industrialized economies" [Olsthoorn and Wieczorek, 2006].

The term "transitions" usually refers to long-term and large-scale changes in human environment-interactions. Transitions touch upon deeply cultural, social, behavioral and institutional aspects in building upon or bringing about novelty and innovation, especially in the areas of energy, technology, infrastructure and transport. Their co-efficient can be measured in a variety of ways, but in the context of climate change energy and resource intensity are a key. Asia matters because of the sheer scale and rate of urban and industrial growth and "their profound implications for environmental quality and resources locally, regionally and globally, which make Asia central to sustainable development on a global scale. Asia is in the midst of a massive urban-industrial transition that in absolute terms of urban population growth and scale of economic activity is historically unprecedented". Can this period of industrial transformation in Asia be useful for sustainable development world-wide? From research in East Asia we know that pro-poor economic growth and technological capability development have worked if and where the right institutional set-up was provided. "The relevant institutional conditions range from fundamental starting conditions for industrial-environmental capabilities building (such as political stability, rule of law, and control of corruption), effectiveness of government institutions in carrying out policies, availability of information around technology choices..., to the degree to which development options are structured by international agreements" [Olsthoorn and Wieczorek, 2006].

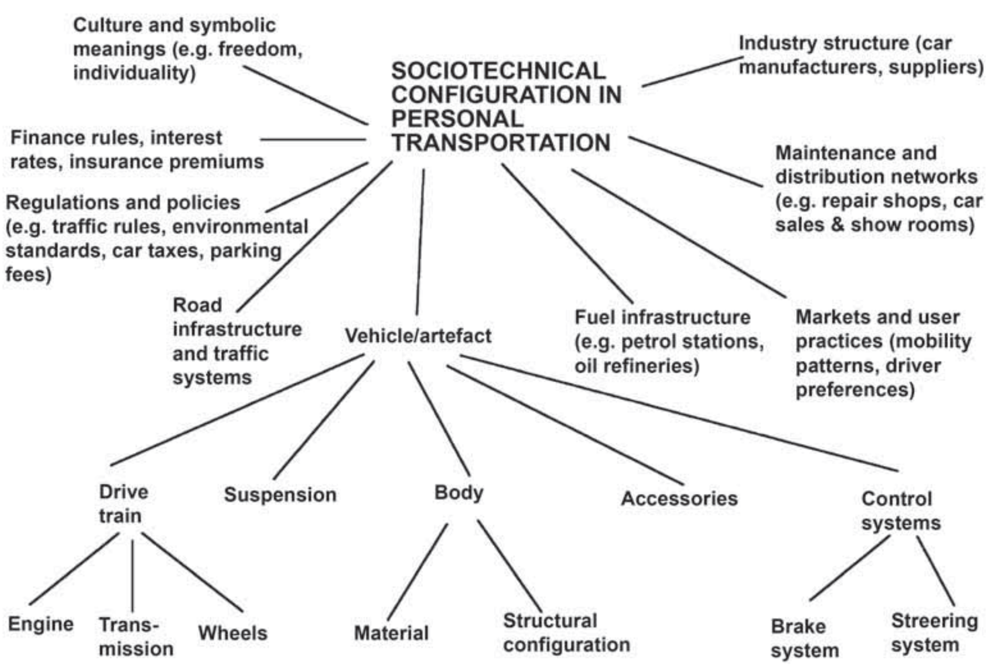
Taking the sustainability dimension to both consumption and production as well as to both social and technical change must be the overarching goal of every low-carbon development approach. What is needed is a long-term perspective of big change however occurring in a relatively short run. The history of technological change and innovation is quite promising in this regard as it shows in a number of cases that even radical and relatively abrupt changes are possible, e.g. the transitions from sail based to steam based intercontinental transport, from horse based to automobile based mobility, from home based to city grid based sanitation, or from note-pad based to PC based information systems. According to Fred Steward, "we can look at these examples and can get hold of some patterns such as e.g. the dynamics of transformative innovation and search guidance as to a possible point of intervention. We see that radical change is systemic in nature, takes time, embraces technological and social innovation, involves diversity of actors – on both the production and the consumption side – and disrupts certain social arrangements." Steward states that the merit of this approach to transitions is that it conceptualizes innovation in relation to a prevailing domain of socio-technical practice in contrast to a more traditional perspective on single technologies or sectors, which is far too narrow a vision. The transitions approach takes note of the complexity of systems and the huge diversity of involved actors. Applying this approach to the question of climate-resilient and inclusive economic growth and innovation seems promising. It is about purposive, not merely emergent change as such change has to be induced.[5]

The transitions approach thus suggests that any technical innovation is embedded in a larger frame of socio-economic conditions and the dynamics of social change. In other words, social change and technological change usually go hand in hand, as the cases from technological history have shown. Important in this connection is the concept "socio-technical regime" which refers to a relatively stable configuration of institutions, technologies, rules, practices and networks of cooperation that determine the evolution

[5] The Steward quotes are taken from the report Asian Transitions and Globalisation: Towards an Analytical Framework. Workshop report (6–7 July 2006, Chiang Mai, Thailand), ed. by Anna J. Wieczorek.

and use of technology [Kemp et al., 1998]. In its entirety a socio-technical regime includes production, diffusion and use of technology [Geels, 2002 and 2004]. Please refer to Stamboulis Y. and Papachristos G. [2008]: Investigation and modelling framework of biofuels as a new socio-technical regime, the 2008 Conference of the System Dynamics Society (conference paper). To illustrate how such regimes work, the example of a typical configuration (or "regime") in the car-manufacturing sector is given below.

The picture shows the wider "landscape" in which the development, production and diffusion of a car is typically embedded. This scheme can be applied to any (new) technology. The purposive selection and development of new technologies has to take into account and model a variety of non-tech factors, incuding such things as culture and symbolic meanings, user practices and policies alongside finance rules and markets etc. Such a configuration around an artefact or technology hence can be called a socio-rechnical regime. Regimes tend to be stable and sometimes even "sticky". Replacing existing regimes by new ones – in the given case more climate-friendly ones – is essentially like initiating paradigm shifts. To yield real green and low-carbon growth in rapidly emerging countries, the wider production-consumption field will have to undergo a number of such paradigm shifts, i.e. regime changes. Smith et al. write: "We understand regime change to be a function of two processes: (1.) Shifting selection pressures bearing on the regime; and (2.) The coordination of resources available inside and outside the regime to adapt to these pressures. Conventional economic analysis of technical change tends to focus on pressures that operate visibly at the level of the firm (such as pricing, competition, contracts, taxes and charges, regulations, standards, lia- bility, profitability, skills and knowledge). Analysis at the level of the socio-technical regime, on the other hand, includes such factors, but goes beyond them to consider less economically visible pressures emanating from institutional structures and conventions, including changes in broad political economic 'landscapes', or wider socio-cultural attitudes and trends [Geels, 2004]. These can be directed at specific regimes, like the activities of the anti-nuclear



Source: Geels, 2004

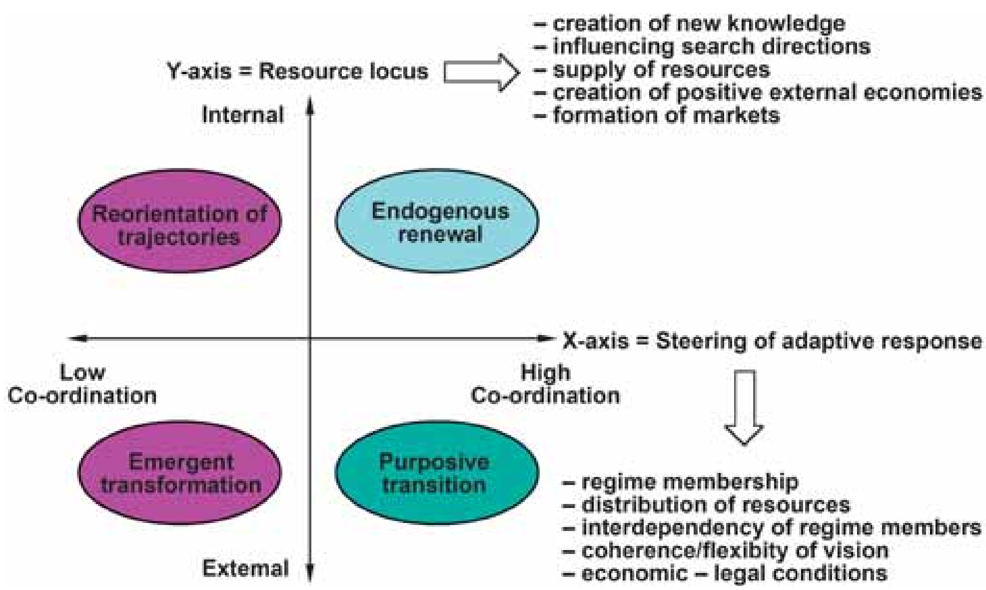
movement. Or they can be more general, like the ebb and flow of environmental attitudes in society" [Smith et al., 2005].

Smith et al. continue: "All regimes have some capacity and resources to respond to the selection pressures bearing on them. We refer to this feature as the ***adaptive capacity of a regime.*** In developing Asian economies we observe the rapid growth [...] of socio-technical systems... The specific nature of these socio-technical systems, the technologies they are based on, and the patterns of economic growth and consumption they foster, will have a profound influence on the resources and energy profile of the developing economy." Economic development in Asia has been analyzed as a process of systems innovation featuring the emergence of "new socio-technical systems, replacing or radically altering traditional and early-modern systems in key sectors, including energy, transport, agriculture and food, water and urban development" [Berkhout et al., 2008]. New knowledge comes to bear on changing policy settings and institutions as well as a changing social or societal context. "The central elements of these systems – socio-technical regimes – are the embedded outcomes of processes occurring at different levels of the system, including innovation in niches and adjustment of landscapes (systems of innovation)" [Berkhout et al., 2008].

CONCLUSION

The systems innovation approach helps us understand economic development as an ongoing and iterative process of formation and/or reconfiguration of so-called socio-technical regimes. The below chart by Smith et al. [2005] maps out four types of transitional development trajectories. It appears that "purposive transition", which requires a ligh level of coordination between regime members (e.g. from public authorities via technological communities, the finance sector to consumers), and a relatively high level of external resources, is the most promising one.

According to Jacobsson and Johnson [2000], innovation is supported by the following functions: Creation of new knowledge; Influence over search processes among consumers and producers; Supply of resources; Creation of positive external economies; and Formation of new markets. It is quite essential to work across all of these functions to establish a framework of policy,



investment and targeted action to stimulate technological change. Berkhout et al. [2008] conclude: "It becomes possible to envisage the emergence of new, more resource-efficient socio- technical systems as the basis of more sustainable development pathways in developing Asia. Such sustainable socio-technical systems will emerge in the context of interaction between domestic and globalized markets, knowledge flows and governance". Emerging socio-technical regimes and transition contexts will vary significantly. It is remarkable that precisely this context of variation has given rise to numerous "sustainability experiments", such as eco-cities, biofuel initiatives and sustainable forestry projects [Berkhout et al., 2008] that not only demonstrate what is possible in terms of transitions and regime change, but also how policy frameworks, investment schemes and assistance will have to vary.

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