Transition towards Sustainable Mobility – Perspectives Derived from a Temporal Framework

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Abstract: Transition towards sustainable mobility is analyzed in a temporal perspective. Temporal framework for analysis is outlined and a case study focused on automakers as one of the major players in the overall field of relevant players for transition is presented and discussed. We made in-depth interviews with 6 out of the TOP 10 major automakers plus one further corporation as an example for a subsidiary of a major. Results of the case study demonstrate that transition towards sustainable mobility (TRANS) has different features compared to UnSustainable Mobility (USM) and to Sustainable Mobility (SM) as well. It can be concluded that the still dominant framing within USM should be changed and all players should actively step forward to the next stage and shape TRANS as time frame.

"We earn money for research and marketing of our sustainable products from unsustainable business."
(Director of one of the global players in chemical industries; private communication Spring 2005)

1. Introduction: Transition towards sustainable mobility

Western way of living and economy is overwhelmingly successful. At the same time people all over the world are learning that this type of economy is unsustainable. The World Commission on Environment and Development (1987) summarized that understanding in its report *Our Common Future*. At the World Summit on Environment and Development, which took place at Rio 1992, the Agenda 21 was decided on by all nation states (parties) of the world. Ever since sustainable development is a hot debated issue, giving headway for raising awareness and first actions on major challenges like climate change as well as being used as a misnomer for all sorts of interests. After all, it is still not just a shallow label as often claimed but a signpost for the overall direction of change in the 21rst century: we have to change into the direction of sustainable development.

Economy, society, life-styles and alike have to be transformed to become sustainable. This *transition* is not a minor undertaking but the scope of the task is in the order of the transformation of regulated economies shaped in former Soviet-style to market-economies and pluralistic and democratic societies (see classic on the issue Polanyi 1944).

Transformation to a society and economy based on principles of sustainable development (Enquete-Commission 1998: 27-54; summarized Federal Environmental Agency 1998: 11) is a deep-rooted change. Time research reveals that time is not just one-dimensional clock time but a broad range of temporalities like rhythms, time scales, synchroniziation and desynchronization to analyze processes of change. We propose to utilize the knowledge of time

research to improve the understanding of this challenge: transforming a basically unsustainable economy | society towards a sustainable one. Transition is the relevant category being one of the *modes of time*.

We take *sustainable mobility* as an example for the general topic to have a comprehensible object for our temporal analysis. This is not just an illustrative, interesting case but it is at the core of transition towards sustainable development in general:

- transport is still nearly totally dependent on non-renewable fossil fuels (crude oil and its derivates);
- it is heavily contributing to climate change;
- transport is basic to lifestyles and well-being; and
- transport is a key sector in the economy and playing a decisive role in the division of labour;
- we may not just wait-and-see for smooth change towards sustainable mobility but the attractiveness of fossil-based mobility is clearly demonstrated in rising economies like China and India.

Within the broader issue of sustainable mobility and relevant players we choose *automakers* as a *case study*. They are one of the major players in the field needed to play their role in the transition. The overall challenge of transition towards sustainable development may be specified for mobility: transform unsustainable mobility towards sustainable mobility. Our *working hypothesis* is:

> *Time research focussing on transition as a time mode will give valuable insights for an improved understanding of the transformation process from unsustainable mobility towards sustainable mobility.*

It is the objective of the paper to demonstrate the validity of this hypothesis and thereby to demonstrate the analytical power of time-research for transition towards sustainable mobility in particular and therewith its significance for transition towards sustainable development in general. Time-research as well as results on sustainable development, sustainable mobility and related issues like energy and natural capital are included into the analysis. The basic structure of our analysis is depicted in Figure 1.

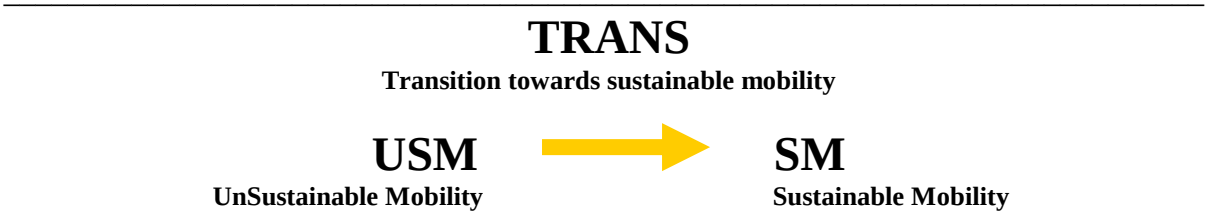

Figure 1: Basic structure of analysis – transition from unsustainable mobility towards sustainable mobility

In the second chapter, the temporal framework for the analysis is presented. In the following chapter sustainable mobility and the role of automakers to be used in the case study are briefly introduced. In the fourth chapter, the method of in-depth interview is presented. In the fifth chapter, results are presented with a special emphasis on the temporal focus. In the sixth chapter, results of interviews are discussed, again with a special emphasis on the temporal analysis to understand transition towards sustainable mobility. Finally, perspectives are derived for an active shaping of transition as a dynamic process towards sustainable mobility.

2. Temporal framework

There is a broad range of temporal categories (on temporal diversity see Geißler 2002) and interesting approaches in time research (for introduction see Adam 1990, 2004a; Held & Geißler 2000) which may be useful for the analysis of transition to sustainable development. We selected a specific sample out of this research which we thought to be specifically useful for our analysis. The temporal framework is designed to be useful to analyze the transition towards sustainable development in general but having in mind specifics of transition from unsustainable towards sustainable mobility as the example we have chosen for our case study.

(1) Temporal categories prima facie

Our Common Future was the starting point for the rising public awareness on the topic. This report of Brundtland-Commission was already focused on *future* as a basic temporal category. Future has become a major aspect in its own right in modern times being part of economic calculus as well as of efforts to develop instruments to understand and model potential futures like scenarios (for time research on future see Adam 2004b) and to improve planning methods and time management (see e.g. Covey et al. 1994). In German spoken debates this inherent feature of sustainable development is often explicitly underlined with the use of terms like *zukunftsverträglich* or *zukunftsfähig* which literally means "suitable for the future", "to be sustained in the future for long". Take the example of a German parliamentary Enquete-Commission on the subject which describes sustainable development as *"Leitbild einer nachhaltig zukunftsverträglichen Entwicklung"* (Enquete-Kommission 1998: 27). This future-specific German term is simply missing in English by translating it into "The Model Sustainable Development" (Enquete Commission 1998: 27). Inherent inter-temporal qualities of sustainable development are debated with respect to its normative underpinnings of intragenerational and intergenerational justice (for temporal dimensions of sustainable development see Held 2001). Using time research as a conceptual tool box for analysis it is specifically important to understand the difference between *future* and *futures* as potential paths ahead (Adam 2004b; Schomberg, Pereira & Funtowicz 2005).

Speed | acceleration are other *prima facie* candidates for relevant temporal categories. Pacing up the way of life, speeding up economic processes and overall rate of change is to some degree an obsession in public debates and media (see e.g. Gleick 1999; Borscheid 2004). This is an indicator for the underlying far-reaching changes which have attractive features on the one hand but also disturbing accustomed structures and habits on the other hand. Speed and accelereation are also specifically important in the field of sustainable mobility. Given laws of nature, energy spent increases for a given weight to be transported with pacing up speed. Trend for up-sizing and increasing power of engines is the imprint of unsustainable mobility. This has evidently to be reversed in the years to come in a world heading towards transition to sustainable mobility.

(2) Transition and related temporal categories

Transition. Speed and acceleration are relevant, but for the objective of our analysis we have to start with another temporal category, transition. Transition is not just a simple *between*: between a state *before* and a state *afterwards* (for an introduction into philosophical background see Adam 1990, 2004a). Transition is a *mode of time* (see Sabelis 2002: 19; Held 2004). Its qualities may be understood in their own right. In ecology as well as in cultural terms transition is basic for diversity (Hofmeister 2002).

Time scale. This is another temporal category basically needed to analyze processes (Kümmerer 1994, 1995, 1996). Transition may be a process in a short period of time on a

time scale of hours in everyday life but it also may cover years, decades or "much longer" according to the relevant time scales in case. Or in general terms: it may be in the order of micro cosmos processes within fractions of seconds up to geological time scales. Time scales are relevant for economics and automakers such as time scales of natural resources, transportation, production, waste, interest rates, development of new ideas and specific innovations, implementation of a new technology, market penetration and so on. Time scales of relevant processes are not separated but, on the contrary, there are interdependencies, interplays and interconnectedness.

Inherent system time. What is the time scale of transition to sustainable mobility? What are time scales of relevant processes within transitional period? What determines their relevant system times? To answer these questions a related temporal category is useful: inherent system time (Kümmerer 1996). On a certain level there is some variation of the adjunct time scales. The average time period which is typical not just for the individual system or process but for similar ones is called the inherent system time.

Uncertainty. There is a broad range of different types of transition. For example, some transitions are experienced regularly so that the future state after transition is not inherently uncertain. On the other hand, there may be transitions into an *open future* and | or transitions on a grand scale in which players in the field will experience all sorts of uncertainties: for example, time scale of changes, direction of transition, specific "end-point" after transition in the next stage of development and alike.

Path dependency. There is a specific type of uncertainty in dynamic processes which is characteristic for the transition of whole economies and societies. Will processes end up "in the long run" necessarily at a specific "endpoint" which in turn will be then the starting point for the next stage? To put it in terms of our specific case: will there be just one final "outcome" as sustainable mobility? Or are actors faced with path-dependent processes (see Clark 2003) in which accidental exogeneous shocks, timing effects, sequential effects and alike may influence the process and, therefore, the outcome of transition? Are there criteria to judge what to be expected on that?

Short-term – long-term. Differentiation of short-term | long-term interests is relevant as well for analysis of transition to sustainable development. Sustainability necessarily implies to integrate a long-term perspective. What is the scope of future orientation from players in fields like transition to sustainable mobility?

Smooth change – discontinuity. There may be a more or less clear break at the end of the old dominating system states (in this case: unsustainability) to a transitional period or a smoothly, gradual process of beginning transition. There may be also gradual processes dominating within the transition period or there may be one or a multitude of thresholds, shocks and hard-landings.

Phasing in | phasing out. To understand more or less gradual | discontinuous processes within transition *phasing out* of the imprint of the driving forces of the old system has to be understood in its relevance for ongoing processes. New processes come into play, its determinants becoming stronger and *phasing in* is coming into play.

Simultaneity. In a temporal perspective we may put that into another perspective: simultaneity (see e.g. Adam 1990: 165 ff; Clark & Maielli 2005). This aspect is at the very basics of economy being ruled by relative prices, time needed for adaptations (time scale) and smooth changes.

Simultaneity is intertwined with phasing in | phasing out as well as smooth-change | discontinuities: Will there be a long period of simultaneity? Have the players in the field to be aware of a slow and gradual process of phasing-in alternatives and slowly diminishing shares of fossil powered transport? Or are breaks to be expected when some thresholds will be reached? Have such bottlenecks | thresholds a high likelihood or are players faced with at least some potential for a discontinuous transition?

(3) Subjective awareness of temporal categories and their relevance for action

We use these categories for our temporal analysis of transition to sustainable development | sustainable mobility. But: do actors have in mind those very categories? Are they thinking in terms of time scales, inherent system times? Is transition to sustainable mobility a relevant category for them, shaping their awareness in the field, their attitudes, evaluations of settings and their decision-making? We introduce two additional temporal categories for a better understanding of these questions and accordingly for a differentiated analysis.

Time frame. First we introduce time frame as a new category for analysis. This category is based on the model of frame selection (Esser 2005; Kroneberg in preparation) and applied for temporal analysis. This model is taken from sociological and social psychological theories of action. Actors rationally have specific frames in mind

- to cope with information,
- forming a relevant "frame" of the overall setting,
- giving order for interpretation of relevant states and processes
- as well as a normative foundation for decision making and habitual behaviour.

Clark (1985) introduced the term time frame, too, also as a temporal catogory relevant for the orientation of actors. But he specified it somewhat differently as an orientation "to the past | present | future, including an image of the future" (Clark& Maielli 2005: 5).

Shared time frames. Using time frame as a category of analysis allows to ask if players in the automotive industry have a time frame "transition towards sustainable mobility" or if they are acting in a mind-set "business-as-usual within unsustainable mobility with minor modifications". Time frame is also a helpful category to differentiate between shared time frames and differences in basic time frames of relevant actors playing in the same field of action like research community on the topics in question, carmakers et cetera. *Reframing* of existing time frames is another relevant aspect for our subject. Persons interested into the theoretical background of shared time frames may find the closely related concept of mental models which was introduced by Denzau & North (1994) into dynamic economic analysis, stressing the heuristic value of shared mental models.

In Figure 2 the overall temporal framework for analyzing the transition to sustainable development is depictured.

3. Sustainable mobility and automakers

Transport played an essential role in industrialization and the increasing division of labour. Transport of persons and goods, short-distance travel in everyday activities as well as long-distance travel are closely related to the increasing material wealth and made its imprint on urban areas and landscapes. While railways were essential for the initial take-off increasing speed and distances first hand in the 19th and first part of 20th century, automobile and, later on, air travel developed a high *attractiveness* for personal mobility which spread globally.

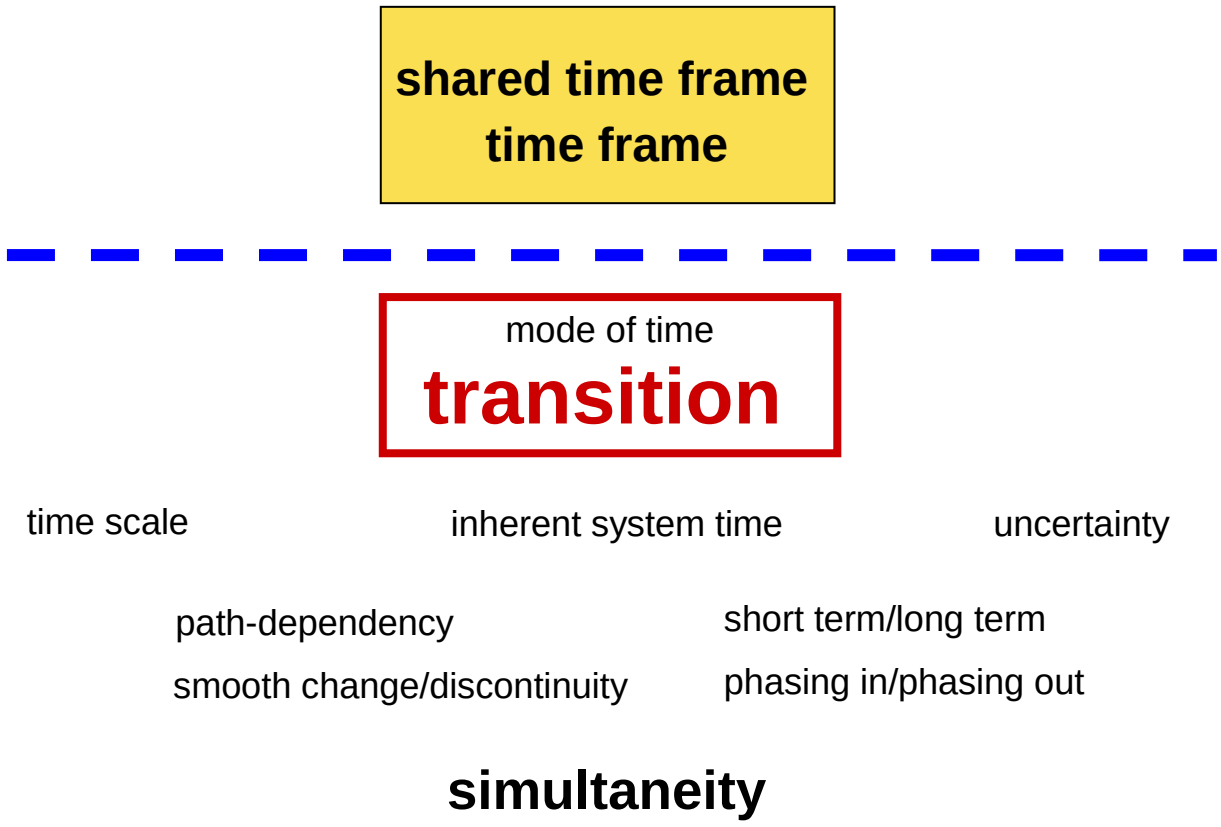

Figure 2: Temporal framework for analysis of transition towards sustainable development | sustainable mobility

Quality of life was enhanced by the increasing potential to be mobile. On the other side of the coin there had been negative impacts early on. Environmental issues became an issue due to the emissions of transport. Oil price shock in the 1970s and beginning 1980s was an early warning of more to come (Brook et al. 2004). Automakers responded with efforts to improve energy efficiency. Political measures gave incentives for innovations to tackle problems caused by vehicle emissions. While reducing emissions and improving energy efficiency per specific transport unit, this was compensated by the higher increase in absolute, aggregated terms. Thus, transport became the main important exception in energy consumption not being successful to decouple its development and economic growth.

Brundtland-Commission and the Rio Agenda 21 did not only make a breakthrough for sustainable development in general but also broadened debate on transport policy to the arena of sustainable mobility (Federal Environmental Agency 1998; OECD 2002). Clean air debate heated on in the 1990s in urban agglomerations. Greenhouse gases and climate change became an issue on the public agenda. Public awareness of energy issues rebound after a long-time low for oil prices alongside increasing oil prices.

Focus on sustainability stimulated debate to proceed from addressing *transport* basically with a technological-infrastructure approach to a braoder understanding of *mobility*. This is not just a new term for the good old *transport*. Instead of narrowing the task to bring persons and goods from A to B, mobility is changing the view, starting from the persons and their needs including emotions. Mobility includes options to be mobile, i.e. having the potential to be

flexible and agile (see Federal Environmental Agency 1998; Becker 2003). The very success of increasing mobility in industrialized countries, even shaping identity as part of the American way of life – not just in the US – made its impact. This is even getting stronger today with the beginning take-off in newly industrializing countries like China, India and others. Unsustainability of the dominating type of transport system with an ever-increasing level of mobility came to mind of decision-makers in politics, business-world and the media. Summarizing very briefly: some major issues emerged to be on top of the agenda (see Box 1). Dependency on non-renewable fossil fuel, climate change and energy security are closely linked.

Box 1: Major issues of unsustainable transport

Dependency on fossil fuel

Transport is nearly totally dependent on crude oil and its derivates (IEA 2005a: p 23) being inherently unsustainable. EU-Commission is addressing this under the heading Held Hostage by Oil: "Transport certainly represents the great unknown for the future of energy. With a market entirely dependent upon on oil (98% of transport consumption […])" (CEC 2000: 15).

Climate change

- powered by fossil fuels transport sector is one of the major driving forces for the increasing emissions of greenhouse gases (Enquete-Kommission 1994; CEC 2000; IPCC 2001; IEA 2004, 2005a, b).
- every single hurricane season is a potential threat heating on public debate on the issue

Energy security

- nearly all industrialized countries and most other countries are heavily dependent on oil imports
- increasing demand, fuelled by still-rising demand in countries like US plus the additional steep increase in Chinese et al. demand, is no longer met by a supply of oil having ample spare capacities (CEC 2000)
- uneven regional distribution of oil resources is adding to concerns (see e.g. IEA 2005a, b)
- easy oil is quickly on the decline, causing a strong pressure for new reserves to substitute existing oil fields (IEA 2005a: 41, fig. 2.1.)

Other issues

- noise emissions
- resources including specific rare metals, etc.
- safety and health
- land use and related problems are on the agenda, too (see RSU 2005)

While the debate on sustainable mobility is beginning to gain ground, at the very same time a long-standing trend is still alive: Up-sizing of cars and the rise of the then new born star called SUVs compensated the technical progress (SUVs are *automobiles* in an everyday-understanding, however, they are by definition not *cars* but *light-trucks*). Not to forget the steep increase of air traffic since the beginning of the public debate after the Rio Conference 1992, only shortly interrupted in the aftermath of 9/11.

All players are needed to play their role in an attempt to end with unsustainability of transport and to start real transition towards sustainable mobility. Automakers play a key role in this transitional process. For a long time, automotive industry was dominated by a combination of two approaches: on the one hand being active for technology-driven innovations and on the other hand being dominated by an attitude just to react to political measures (see e.g. autobiographical notes by a former head of research of Volkswagen, Barske 1994). Now automakers have to play a pro-active role which is by no means an easy task in a competitive business

environment with a short-termism setting. But demanding as it is, we all depend on their share for transition.

Our case study is part of a much broader setting of transition including mobility styles (Götz et al. 2003; Schubert 2004), development of settlements and overall spatial planning, mobility services, new types of combining modes of transportation, giving human-powered mobility its relevant share, innovative forms of mobility including the combinations of the potential of mobile telecommunication technologies with other forms of mobility (see Buhr et al. 1999; Canzler & Knie 2000; Politische Ökologie 2003).

4. In-depth interviews – method

We decided to make in-depth interviews with representatives from the automotive industry to test our thesis and the analytical power of our temporal framework. This method allows to combine characteristics of qualitative research with some semi-quantitative estimates. It is specifically suited to understand if and what time frames are relevant for representatives of automakers. We elaborated a draft guideline for the interview which we tested twice with an expert of one of the major corporations and a consultant in the field. The draft was revised according to comments of those experts. With the exception of two minor details guideline for in-depth interview proved to be understandable by and made sense for respondents. All of them confirmed that to be the case at the end of the interview.

We were successful to have the chance for interviews with seven major corporations of the automotive industry each between one and a half to two hours.[1] In Box 2 detailed information on interviews is given.

Box 2: Characteristics of interviews

N	7 companies, 9 representatives
Sample	6 out of the TOP 10 of automakers (majors) + 1 example for a subsidiary of a major
Functions	heads of environmental affairs, experts in R&D and in sustainable development
Professional background	natural scientists, engineers, financial affairs expert
When	August 16th to October 10th, 2005
Where	European headquarters of corporations and Tutzing (DE)
Method	in-depth interview with a pretested interview guideline
Type of questions	(a) open questions with additional subquestions according to specific first reaction; (b) questions with given items; (c) checklists with a given temporal sequence to be rated; (d) time scales | points in time to be assessed.

Four interviews were pre- and three post-Katrina. There was no evident impact of that exogeneous event to be seen in answers. Main bulk of questions were addressed at the level of corporations. Respondents could, if necessary, differentiate according to differences between regions, divisions, brands and alike. Some questions were explicitly differentiated to address:

- understanding of corporate's position,
- personal view of respondent and

[1] We thank all experts of corporations that they took their time to answer our questions.

- view in the broader community of automotive industry | car makers.

Respondents did know the objective of our interview in general terms and also its overall structure (see box 3). However, they were not told detailed questions in advance. Questions were put into a specific sequence not to frame awareness of respondents first hand on our thesis and related temporal aspects but to learn *on their understanding* of the topic.

Summarizing. The case study is not representative but covers a broad range of corporations and a relevant share of world market.

That can be validated by comparing our results with a study of SAM sustainable asset management & World Resources Institute on the Automotive Industry including all TOP 10 majors with a special emphasis on their competetiveness on climate change impact (Austin et al. 2003). Our study covers the whole range of their ratings and assessments as well.

Box 3: Structure of in-depth interview

First Part	Corporation: some general indicators and basic understanding of topic
Second Part	Fossil mobility: cheap crude oil as starting point
Third Part	From fossil mobility towards sustainable mobility: alternatives to crude oil
Fourth Part	Post-fossil mobility: strategic orientation and long-term prospects

5. In-depth interviews – results

We got relevant answers in all interviews. Quotes are not used to be attributed to specific persons/corporations. We are only interested to improve the understanding of the topic in case and test the analytical power of temporal research for that objective. Comparison of results are also *not taken as representative* for the community of carmakers. However, they are *characterizing the whole range of the matter* within the community with respect to our subject: transition to sustainable mobility. Interviews are also not used to specify positions of one corporation or the other. For the purpose of this paper we select some main results from a much more differentiated tableau we got as results from the interviews.

(1) Corporation: some general indicators and basic understanding of topic

In the first part of the interview questions were raised as a starter on:

- respondent,
- corporation,
- understanding of sustainability in the corporation | personal and
- understanding of mobility in the corporation | personal.

Sustainability is relevant for all corporations and respondents personally but some cultural differences are revealed: understanding of sustainability and mobility may be focused on core competence of individual automobility or on broader approaches of sustainable mobility including mobility services to name but one example.

(2) Fossil mobility: cheap crude oil as starting point

Questions on fossil mobility based on cheap crude oil formed the next part of the interview. This is the starting point at the core of *unsustainable mobility (USM)* with its nearly total dependency on fossil, non-renewable crude oil and its derivates. Oil fields were formed in geo-

logical time scales (millions of years) but consumed at a time scale of some 10 generations. For our subject transition it is important to analyze the understanding of this starting point from respondents.

Availability of (cheap) crude oil is an issue for all corporations. Attribution when it did become an issue differs widely (see Box 4). Impact of the main setting (home market) of corporations is to be seen. That is specifically distinct in the case of corporations with close to equal footing in Europe and the US or at least having very strong brands in both regions. Japan is described as another distinct market by some respondents who had lived there for some years.

Box 4: At what time did availability of crude oil become a topic in the corporation?

Range of answers
N = 2 beginning of 1970s at the time when oil price crisis started
N = 2 beginning of the 1990s
N = 1 six years ago
N = 1 difficult to answer | a slow gradual process
N = 1 last year | since beginning of 2005

Peak oil is used to describe time when oil production for a country, region or worldwide has reached its peak and production will decline afterwards (see IEA 2005a: 38 f; see also the classic by Campbell 1988). There is a related term depletion mid-point which is focused on the time when half of oil potentially to be taken out of the ground is exploited (see BGR 2005: 35). In fact, both indicators are quite often used interchangeably. According to specific temporal profile of extraction peak-oil and depletion mid point can coincide or vary somewhat.

Estimates differ when peak oil has to be expected: there are expectations within a range from 2010 | 2015 to 2030plus and one answer "too uncertain to estimate at all" (see Figure 3).

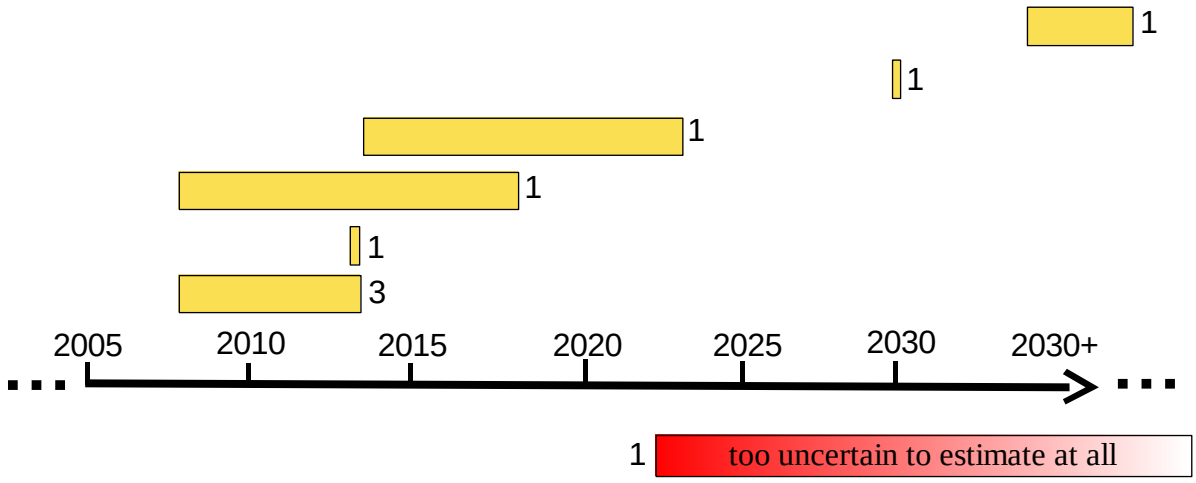

Figure 3: Fossil mobility: Personal Expectation on time scale of peak oil according to time line (9 respondents from 7 corporations; numbers right from bar: number of respondents with same time scale of expectation on peak oil)

That is just one example for the fundamental uncertainty automakers are faced with. This is also to be seen in the detailed answers on questions to evaluate oil markets, expectations on oil prices – which are relevant as relative prices for alternatives – and specifically their under-

standing on demand side, supply side and issues like peak oil. Role of estimates on future price dynamics on the basic energy of automobility – crude oil – is different in corporations. The general increasing trend is to be taken-into account in all corporations but not detailed forecasts of oil prices which are too uncertain to estimate.

Summarizing:

- Differentiating time scales is basic to all respondents on many items in this part of the interview. This was confirmed also in the third and fourth part.
- Respondents | carmakers have to operate in a setting with fundamental uncertainties. This effect is even more pronounced in settings where unsustainable trends on the markets like up-sizing were taken as given | taken for granted to go on for long.

(3) From fossil-based mobility towards sustainable mobility: alternatives to crude oil

In the third part of the interview questions were raised on the understanding of alternatives to crude oil which may be formative for *transition (TRANS).* First, we asked in detail if sustainable mobility is an issue in the corporation. It is relevant in all corporations with some differences in operationalization. Specifically, translating general understanding into strategies and products is seen as the core challenge in this case. Answers differed in a broad range *when* it became an issue in the corporation (see Box 5). Again, critical incidents played a role in the path-dependent process of integrating sustainable mobility into the business of corporation which is a much broader approach compared to handling specific environmental issues as was the main focus in the previous stage.

Box 5: When did sustainable mobility become an issue at all in the corporation?

Range of answers (each N = 1)

- laid down in companies' founding principles many decades ago (in other terms but essentially same meaning)
- oil price crisis beginning of 1970s
- gradually beginning in the 1980s
- at the beginning of the 1990s with establishing environmental guidelines, Rio 1992
- gradually after the midst of 1990s
- gradually with an important decision in 1997
- 1999 | 2000 at a specific critical incident

The range of answers underlined the corresponding broad range of answers when availibility of cheap crude oil has become an issue in the corporation (see box 4 above). Climate change and oil dependency | energy security were major driving forces in all corporations that sustainable mobility became an issue. Long term survival of corporation and other determinants like political decisions on framework conditions are also mentioned by some of the respondents.

Alternatives are clustered by respondents | companies according to time scales. Taken as examples:

- improving efficiency of conventional Internal Combustion Engines (ICEs; Otto and diesel engines) is everyday business for all;
- hydrogen-powered fuel cell is seen as a long term alternative with estimates on time scale for market introduction widely differing (all but one exception).

Comparing answers reveals that there is no consensus which alternatives will be relevant as transitional strategies only. There is a fundamental uncertainty for most of the respondents

what the ultimate alternative will be for sustainable automobility as part of an overall sustainable economy. Time frames of respondents are basically different according to that. Even the understanding of the setting of the automotive community is divergent, i.e. assessment of carmakers dominant | mainstream understanding on the issue differs (two illustrative quotes):

- "We guess that the final goal – fuel cells powered by hydrogen – is essentially the same for all."
- "Hydrogen technologies you may find big differences in evaluation of costs and environmental effects. – Yes, you may characterize that as a deep rift. There are basic differences on the evaluation of energy sources like hydrogen."

Varying intensity of uncertainties combined with a different understanding of urgency of transition is associated with very diverging time scales. Time frame on transition is different which is reflected in the evaluation of alternatives to crude oil. A range of alternatives are in the focus. There are specific markets with respect to alternatives like alcohol fuels in Brazil etc. That in turn demonstrates that political framework conditions are relevant for phasing in alternative fuels. Answers are summarized in Box 6.

Box 6: Summarizing understanding features of USM and TRANS

- USM is characterized by just 1 fossil fuel which is close to totally dominating the field.
- Alternatives to crude oil are diverse in TRANS.
- The challenge of TRANS is on the horizon which all respondents are aware of.
- Priorities on alternatives differ with biomass fuels being the priority for one corporation while others have a broader portefeuille.
- Renewable hydrogen is basic to all in the long term.
- All corporations but one are favouring fuel cell as long term alternative for SM; the one has conventional ICE powered by renewable hydrogen as its vision.
- Improving energy efficiency of engines | powertrain is relevant to all.
- Corporations are divided on the issue to include the potential of down-sizing (less weight of vehicle, less volume of engine etc.). Premium/mass market position of corporations is basic to understand that difference.
- Hybrid cars are the new star in town being a challenge for most companies but one of our sample is a front-runner with first mover advantage.

We asked in detail what alternatives are relevant for the corporation and the priorities they have on alternatives (see box 7). An overall tableau of alternatives was presented to respondents which was pre-tested in tests of the draft interview guideline. The tableau was useful and close to embracing the overall existing set of alternatives which is seen as relevant right now but compressed natural gas (CNG) had to be added. The main types of alternatives were structured according to the following criteria:

- engines: conventional engines – new engines (fuel cell, electrical traction);
- efficiency | fuel: energy efficiency – fuels;
- non-renewable | renewable: fossil-based alternatives – renewable alternatives;
- infrastructure: given infrastructure – new infrastructure (hydrogen).

(4) Postfossil mobility: strategic orientation and longer-term prospects

The understanding of postfossil *sustainable mobility (SM)* and the *transition (TRANS)* towards SM was the final part of the interview to learn more into-depth on expectations on the stage of sustainable mobility and on their understanding and strategies of transition.

Box 7: Relevant alternatives to crude oil for corporation and priorities

(1) Improving energy efficiency for existing engines

- *improving energy efficiency conventional ICEs*. "relevant potential" for all
- *down-sizing*. diverging due to position in market segment (main determinant: acceptance of customers)
- *hybrids*. "relevant potential" for all (consensus: driving forces on markets are getting stronger)

(2) Alternatives to crude oil with conventional energy

- *liquified natural gas (LNG)* | *compressed natural gas (CNG)*. market specific, "relevant" for all global players
- *gas to liquids*. ranging from "very high potential | high priority" to "not relevant"
- *fossil produced hydrogen*. "not relevant" for most; but some see it as "relevant for phasing in hydrogen later on"
- *electrical cars.* mainly "not relevant"; some qualifying: "not relevant today but a surprising breakthrough on batteries would change that"; "relevant without priority" (N = 1)

(3) Renewables with conventional engines (given infrastructure | technologies)

- *biomass used as blending*. "relevant potential" (N = 6); "high potential | high priority" (N = 1); political framework relevant
- *biomass using parts of plant*. "relevant potential" to most corporations; but second to using whole plant
- *biomass using the whole plant*. "high potential | high priority" (N = 1); "important" (N = 1); "relevant but no priority" (N = 5)
- *conventional ICEs powered by hydrogen*. "long-term objective | high potential/high priority" (N = 1); "working on it" (N = 1); "not relevant" (N = 5)

(4) Renewables with new technologies and new infrastructure

- *electrical cars based on renewables*. "not relevant right now" for most; others stressing new batteries key
- *fuel cell powered by methanol*. "yes, may be a transitional step to the final use of hydrogen/but no R&D right now" (N = 1); "not relevant but if progress on transformer that may change" (N = 1); "not relevant, stopped R&D" (N = 1); "not relevant" (N = 4)
- *fuel cell powered by renewable hydrogen*. "top priority as long-term alternative" (N = 6); "relevant only for additional functions" (N = 1)

All respondents have a clear understanding of transition from unsustainable mobility which is fossil-fuelled transportation to postfossil sustainable mobility. For all of them that is relevant and a challenge in general (see figure 4 upper part). But the underlying, more basic personal orientiation on transition differs widely (see figure 4, part below). Differences arise because for some respondent genuine uncertainties make a stronger impact compared to others and on variations in the estimates of time scales like the one related to peak oil, expectations on development of oil prices to name but a few items. Three of the respondents are already actively in a *time frame transition*. Others are close to it with some reservations due to uncertainties but one is even more undetermined on the issue. In one case there is an interesting difference between the personal time frame on the issue and the one the respondent reported to be relevant for the corporation.

Fuel cell powered by renewable hydrogen is dominating long-term perspective for sustainable personal mobility. However, one corporation is not just focused on the engine | fuel but has an overall long-term vision called eco-car.

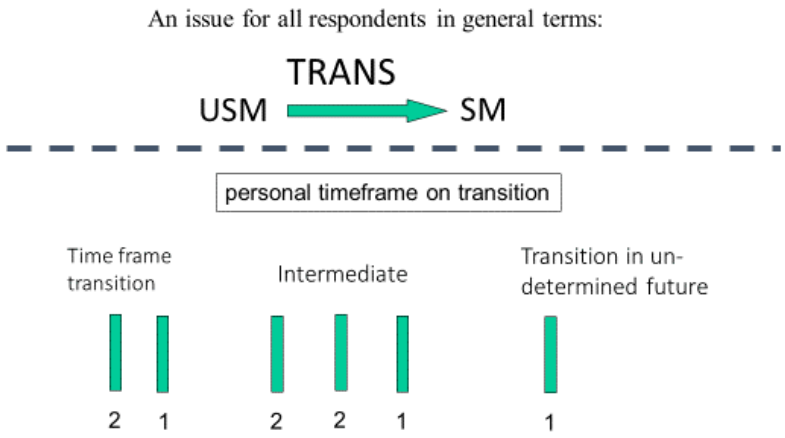

Figure 4: Personal time frame on transition (9 respondents from 7 corporations)

Some respondents stressed specifically the diversity of sources of hydrogen which is not a primary energy itself but a secondary energy carrier which may be produced from all sorts of fossil and renewable fuels (comparable to electricity). The issue of diversity of fuels vs. domination of one fuel in the long run is judged differently. Judgement on time scales varies with respect to many determinants like:

- availability of crude oil and long-term development of its price,
- market introduction of new fuels and type of engines,
- dependency on a new infrastructure for hydrogen (labelled as an chicken-and-egg problem by some),
- certainty of success of fuel cell, and to be more specific, on the chances to bring costs down to be competitive at all.

Critical incidents of the past are influencing expectations of today and overall confidence on the success of fuel cells. For example: disappointment of high-flying expectations in the 1990s on electrical cars is still alive. It is influencing context and agenda of debate in some corporations while others tend to see it as part of an overall trial and error process.

Inherent system times are again in this part of the interview a basic issue for all respondents. It is not just money spend on R&D for fuel cells and renewable hydrogen, to take a prominent example in case; and it is also not just relative prices of alternatives compared to changes of oil prices; however, time is needed for basic research, to work on development, to prepare production on a big scale for market introduction et cetera. Summarizing the argument: you may not just put either

(a) a given amount of money and humanpower in let's say a period of 5 years on R&D for innovation of technology T_1 or
(b) the same amount of money | human power in 1 year

to come to the same result. On the contrary, respondents made strong claims that there are inherent system times (endogeneous) which are flexible only to some degree.

Phasing in alternative fuels while *phasing out* fossil fuel was understood by all respondents as a fundamental feature of transition: "It is a constant task of overlapping development and marketization." Strategies seen as relevant for the start of transition like biomass and syn fuels are dependent on political decisions for the general framework. The case of hydrogen | fuel cell is seen different because this is not just changing some characteristics within an established framework. Instead technology-path on ICEs, developed and improved over a period of more than 100 years, is challenged by a new technology path – fuel cell – which is a newcomer in transportation. Therefore, transitional strategies and the the long-term alternative to be successful "at the end of the day" are different compared to biomass and other alternatives which may be more easily phased in. Blending petrol with biomass is one point in case, development of flexi fuels which allow a broad range of different shares of fuels is the more general example (e.g. complementing petrol | diesel with biomass fuel in a range from 15% to 85%).

Expectations are differing on *simultaneity* in phasing in the new path and phasing out the former. Hybrid cars, combining a conventional ICE with an electrical engine, play a prominent role in the setting of alternatives being at the centre of interest right now in public and within the automotive industry as well respondents claimed.

Most companies seem to be higly dependent on *triggering events*. The case of zero emission (California) as a legal framework condition was mentioned as an example. However, one corporation of our sample seems to be on a path which may be labeled as *endogeneous transition*.

Our direct question on path dependencies with pre-selected items stimulated an interesting result: It revealed that the overall time frame "transition" (see figure 4) is strongly influenced by the understanding if there will be just one final solution "in the end" to be competitive or if this may be *path dependent*. Respondents who answered "no" to one path argued with a multi-path perspective revealing that diversity is an issue to come.

We also asked respondents to assess the position of their corporation on four items on a given sequence of stages from basic research to mass market beginning with "(1) basic research" and ending with "(12) mass marketing, significant increase in market share due to life cycle of vehicle cohorts in the market". In figure 5 estimates are summarized for those four items being examples for the full set of alternatives (see Box 7). Again, inherent system times for research, development, preparing mass production and market introduction itself were stressed by all respondents.

We also asked for the relative position of corporation on the four items – hybrids, hydrogen | ICE, biomass | ICE and fuel cell | hydrogen – within the automaker community. Results on relative positions of corporations are summarized in Table 1. Different biomass fuels were included by respondents so that there are relatively many first movers on that alternative (or to be more precise: early movers). In some cases, corporations started early on with R&D but did not put as much effort into the line of innovation as competitors did, so a first-mover rating may be associated with a rating on stages of sequence not as a leader.

With respect to fuel cell one respondent made a comment on stages of research and early development: rating indicates that the company did in fact start quite early but did not keep pace later on compared to other companies. Cooperation on R&D on some of the alternatives has to be taken-into account as well for the interpretation of the ratings. But anyway, a clear cluster emerges on the understanding of relative positions within the community differentiated according to alternatives in question:

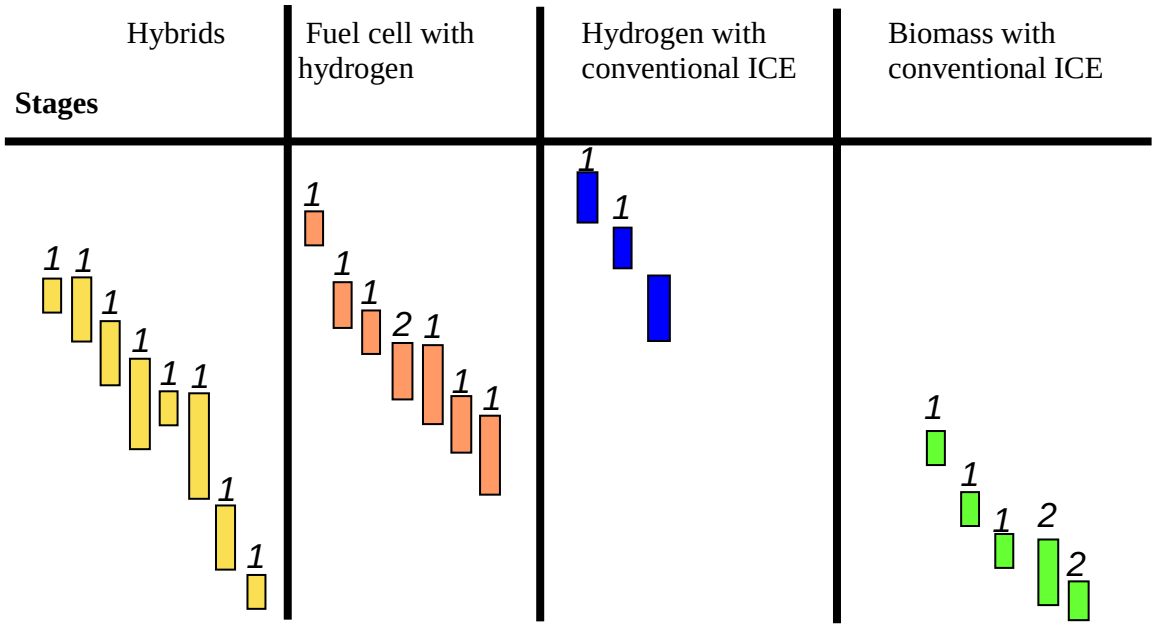

Figure 5: Sequence of stages from basic research to mass market for selected alternatives to crude oil

Numbers on Y-axis: 0 not relevant to corporation | 1 basic research | 2 applied research – laboratory scale | 3 development – beginning field tests | 4 development – preliminary specifying mass production parameters | 5 development – production pre series & field tests at a bigger scale (testing on the road in all conditions) | 6 decision on mass production | 7 specifying mass production parameters | 8 construction of production facilities | 9 lead-time to beginning mass production / marketing concept et cetera | 10 start of mass production | 11 increasing economies of scale / break-even | 12 significant increase in market share due to life cycle of vehicle cohorts in the market

Italic numbers on top of bars: number of respondents

- *(a) hybrids*. cluster emerges on relative positions which correlates not close to 1 but is more or less in agreement on the general position of the corporation in the setting of the community;
- *(b) hydrogen | conventional ICE*. there is a close to complete agreement on the setting of relative positions of companies;
- *(c) biomass | conventional ICE*. this reveals a differentiated setting because there are various types of bio-fuels;
- *(d) fuel cell | hydrogen*. there are basically two groups of respondents; one clearly identified as being part of lead-group and the other one with some differences on ratings of relative positions within the lead group.

Long term issues play an important role in all enterprises, specifically for R&D. But short-term orientation is still strong in some corporations while others already tries to have a balanced approach of *short term* calculation and *long term* economic rational (see Box 8).

	Hybrids	**hydrogen | ICE**	**biomass | ICE**	**fuel cell | hydrogen**
first mover	N = 2	N = 1	N = 4	N = 4
fast follower in broad field	N = 4	N = 1	N = 2	N = 2
not active		N = 1		
not relevant		N = 3	N = 1	N = 1
don't know	N = 1	N = 1		

Table 1: Relative positions of corporation in the community of automakers on four alternatives

A closer look on ratings is revealing differentiations: One answer was split into European and US part of the company. One respondent differentiated between corporation and R&D, another one between corporation and research; R and R&D having a more balanced orientation. In one case, item 3 was interpreted in broader terms, including not only long term economic rationale but also including social rationale. These types of differentiation are relevant throughout the interview: cultural differences and differences between divisions in the company with various functions were explicitly stressed by respondents all along the interview.

Box 8: Basic temporal orientation of corporation

N = 1 item 1: taken together, short termism is dominating on the ground in the corporation
N = 5 item 2: short termism is still dominating but there are also some bits of longer term strategic planning
N = 2 item 3: short term calculation and long-term economy rational are balanced

8 ratings, 1 interview differentiating US – Europe

It is interesting to note that not all respondents did intensively answer on our question related to *simultaneity*. To some degree that low profile answer is due to the very long time-scale and uncertainties some respondents associate with the basic change to a new type of engine/fuel infrastructure. But taken together answers from the whole interview it is evident: transition is demanding when you have to depart from a system with just one fuel to a diversity of fuels. This is underpinned by a subjectively uncertain future what will really emerge in the long run but with the necessity to decide already today on priorities of investment in R&D. And even more so: simultaneity is on the horizon of an established type of engine and at least one basic newcomer. You have to be profitable with conventional business and at the same time successfully introducing alternatives. Representatives from 4 of the 7 companies stressed that very basic problem of simultaneity in different parts of interview which we had not asked for in any specific question. To put it in the words of two respondents:

> "You have only the potential to invest in environmental technologies if you make profit in other terms."

> "You have to be successful right now on markets as well as have a long-term perspective. You have to make good business and profit right now and to have adequate solutions for the future. It will not work the one without the other."

6. Discussion

(1) Transition, time frame and shared time frame

Results of interviews tell us that it is revealing to focus explicitely on *transition* as a *mode of time* to improve understanding of the challenge: to transform from unsustainable mobility to sustainable mobility. It is not just to put capital letters like USM – TRANS – SM on the issue but to learn on differences within the communities of relevant players and to derive consequences for basic orientation and actions. Maybe, the years 2005+ will be seen *ex post* in the years ahead as a time when awareness of *TRANS as a period of its own* was at its very beginning. At least, majors of automotive industry as one of the relevant players in the overall field of players in TRANS seems to be aware of the challenge ahead.

Time frame is a basic temporal category to understand that in more detail. Some carmaker companies are already in a time frame TRANS or close to it, while others have their reasons to be somewhat cautious: uncertainty on various levels and on many relevant issues makes its impact. There seems to be a *shared* time frame in one of the corporations that the company should actively follow TRANS. There are other respondents who personally are close to that time frame but report that the company is still "somewhere in between": still in a world mentally framed by USM and to some degree at the beginning of TRANS. There is not (yet) a shared time frame on TRANS in carmaker's community but at the same time different frames at work. They know each other, they meet each other in groups on the subject organized by business associations, at the national level in groups organized by ministries as well as at the European level at Brussels including all majors and many other companies. The European Hydrogen and Fuel Cell Technology Platform (HFP; www.hfpeurope.org) is an example in case which integrates all business sectors including carmakers as well as experts and EU representatives and was initiated by the European Commission (2003). Taken together, our case study was undertaken at a time when TRANS is around the corner but not yet mainstream.

Of course, it is not just a matter of a shared time frame within the automakers' community because they are part of a broader setting in societies and politics, as was stressed by all our respondents. At the moment, they are faced with an overall setting worldwide which is *mixed*: literally spoken with one leg still in the fossil age and hence USM; and with the other leg at the beginning of TRANS (image of two legs is taken out of Hicks 1976).

On the one hand, time frame is still dominated by an orientation to USM with regard to oil as *the* basic fossil fuel for cars. Addressing increasing oil prices as the major problem is just one outstanding indicator for that time frame. Players at all levels – like World-Bank, IEA, OECD, G-7, economic advisers at national level et cetera – are arguing that high oil prices are the problem which may be solved with additional investment in fossil fuel bringing in turn prices down (detailed argument on underlying economic rationale see e.g. Brook et al. 2004). True: if prices increase *too quick a pace* (as a consequence of speeding up demand missing strong pro-active measures) then people all over the world and firms have not time needed to adapt (inherent system time). That may be understood in analogy to ecosystems resilience to impacts of climate change: they have the potential to adapt up to a specific increase of temperature in a given period of time. A temporal analysis reveals: given an adequate pace increasing prices are a pre-requisite to phase in increasing energy efficiency combined with an increasing share of renewables. Higher prices are not just the problem but part of the solution. There are weak signals for a change: for example, an OECD paper argues that fiscal policy should not try to reduce impacts of increased oil prices because that would counteract the long run goal to reduce oil intensity (Brook et al. 2004: 42f).

On the other hand, there are players like European Union which are getting closer to TRANS: EU-Commission and other bodies of the EU are actively addressing the issues starting basi-

cally in 2000 with a Geen Paper on security of energy supply (CEC 2000), going along with a White Paper on transport (CEC 2001), issuing a directive on bio-fuels and having invited experts and stakeholders to the Platform on Hydrogen and Fuell Cell Technologies, already mentioned above. At the moment EU-Commission is working on an additional Energy Services Directive.

Summarizing:

- On the one hand we are faced with a time frame USM focusing on business-as-usual with as minor changes as possible.
- On the other hand, steps to TRANS are underway at the very same time, actively focusing on pro-acitive measures.

Going back to players of our case study, we understand that time frames have a strong impact. If a person | group | division | company is already in a time frame TRANS they tend to be pro-active and no longer basically reactive as a main type of action. Of course, those companies | entities also do take-into account changes in political framework condition and react to those changes, they also follow the changes of oil prices etc. But they try to have a strategy on their own to become less dependent on fossil fuel and find bridges to SM (see below in more detail). There is an illustrative example on the influence of time frame: hydrogen is a secondary energy carrier which may be produced by all sorts of primary energies (see Dunn 2001; IEA 2005c):

- Some respondents argued that this diversity is a source of uncertainty. Therefore, they are cautious with an explicit switch from USM to TRANS today.
- Others, already living in or close to a time frame TRANS interpreted diversity as a basic feature of SM. Therefore, diversity of renewable primary energy resources is not just a problem but an inherent, positively valued characteristic of TRANS on the way to SM.

We conclude this paragraph on the influence of time frame specifically orientated to TRANS or still oriented to USM with an example: According to the relevant time frame energy efficiency measures have quite a different role to play (see Box 9). We may learn that including down-sizing into efficiency stragegy is essential (Henseling 2005) because otherwise we will continue to compensate success per transport unit with growing energy demand. *Speed* and *acceleration* are relevant temporal categories for a detailed analysis of this example (given level of active and passive safety):

- *speed limit*. take a general speed limit world-wide X km/h combined with a mandatory standard, technically to limit power to engine at a given speed (let's say X + 50 km); this would allow to reduce weight of all car components thus reducing energy needed and costs;
- *acceleration*. adding a rebound in the trend on further acceleration of cars would further lower needed energy (from acceleration 0 to 100 km/h in x sec to x + 1 sec, x + 2 sec etc.).

Box 9: Differentiating rationales in time frames USM and TRANS – the example of energy efficiency (EE)

USM at a mature stage	EE is a competitor, decreasing oil demand
USM closer to the end	EE is helping to make better use of oil reserves and reducing greenhouse emissions, thereby postponing end of USM
USM close to TRANS	increasing EE on conventional ICEs give time to start with TRANS; example: increasing EE on diesel | Otto ICE reduce demand per transport unit

TRANS	down-sizing is integrated into EE strategy to allow for introduction of renewables which are more expensive per transport unit
TRANS	actively seeking steps which build momentum to SM; example: hybrids increase EE + add relevant experience on electric power-train management which is needed for fuel cell cars
TRANS close to SM	EE inherently linked to renewable fuels

(2) Path dependency

This example displays a *path dependency* which is normally not seen because it is not caused by direct impacts but hidden in the underlayer. As long as there is enough "cheap" oil in the ground ("cheap" is a loosely used term) and oil supply is fine and if there are no fundamental troubles like greenhouse gas emissions, USM is very attractive. At the very moment, we can experience the emotional touch and attractiveness of the automobile in countries like China and India where the take-off of automobility in the existing form is taking place right now.

Crude oil may not be reduced to be fossil and non-renewable. It has a high energy density which is fine for storage. It is but one primary energy to fuel automobility; this feature is seen as positive due to handling qualities. Therefore, thinking is framed in those terms: one fuel powering one type of engine (ICE). Diversity of energy sources and simultaneity of engines are different. Therefore, there is an attractive promise around shaped by the experiences of USM period:

- from 1 engine (ICE) to 1 other engine (fuel cell) and
- from 1 fuel (oil) to 1 other fuel (hydrogen).

The relevance of this example may be easily understood also by non-experts on mobility and automotive sector when one takes-into account impacts of small differences even within the fossil fuel world right now: differences within qualities of oil derivates (petrol, diesel) and ICE (Otto, diesel). In the US energy efficiency did fade away as a big topic in the late 1980s and 1990s, diesel cars are nearly not on the roads. In Europe diesel were developed at the very same time from a fuel secondary to petrol to become a relevant competitor even in the premium market with higher energy efficiency (but with a need for a particle filter). These differences made a strong impact on global carmakers because they are still influenced by the setting of their home markets; a fact, respondents of our interviews were stressing again and again.

Therefore, we are not just faced with direct path dependencies only but some are more deeply routed *indirect* path dependencies as well. The way of thinking on diversity | advantage of one fuel | 1 type of engine in USM itself is still framing perspectives at the beginning of TRANS. *We have to learn on diversity*: It's not just about additional costs (infrastructure et cetera) and it is not just to be faced with increasing uncertainty. The very problem of 1 dominant fuel is total dependency. Energy security is not just in doubt by accident but that's the cost of a core feature of USM with one fossil fuel ("there is nothing like a free lunch", John Maynard Keynes). TRANS is not an easy task at all but changing setting of economic rationale for players. There is a potential for a mixture of fuels with a whole array of decentralized, regional markets (see e.g. European Commission 2003). Diversity is a story on *potentials*, like potential to have a balance of centralized – decentralized features of markets, to have *options* and not giving all eggs in one basket: diversity of possibilities is a feature of transition (Hofmeister 2002: 114; see also Spehl & Held 2001). And it is a characteristic of SM as well as a

frame for an open future, stressing potential of different paths ahead embedded in an overall sustainable development (see on futures Adam 2004, Schomberg et al. 2005).

Direct path dependencies are also relevant for the beginning of TRANS. Hybrid car was confirmed in interviews as a basic element within overall TRANS which displays the strongest pressure towards TRANS right now (see Box 10).

Box 10: Market introduction of hybrids

- *Market introduction.* 1997 in Japan by Toyota and Honda
- *Inherent system time.* 2 to 3 years between "decision on mass production" (stage/point in time 6) to "start of mass production | beginning market introduction" (stage 10; Fig. 5),
- *Decision on mass production.* Probably in 1994
- *Critical incident | triggering event.* early 1990s specific situation in California, debate on Clear Air Act | Zero Emission cars
- *Relative prices.* Low oil prices, no debate of experts on an imminent steep rise of prices
- *Specifics of settings.* Germany | Europe diesel gaining ground on energy efficiency; diesel not relevant in Japan; know-how on hybrids at that time in German corporations (Daimler, BMW, VW) comparable to Japanese companies
- *Alternatives.* Electrical cars, hybrids, fuel cell – with different expectations on time scales, competitiveness, compatability of solution to technological-styles

Sources: Interviews; private communications with former head of research Volkswagen at beginning of 1990s, ex-manager R&D of Daimler and an energy expert, November 2005; Barske 1994

It is an interesting example for path dependency: driving force for development at the early 1990s had not been debates on TRANS (Rio conference just happened) but the impacts of success of the automotive society in California: car emissions and their impacts caused a public debate on air quality in urban agglomerations. That triggered increased R&D activities of carmakers on solutions to that problem (to qualify for credit points under Zero emission car regime). Technical competence was there in many companies but just two of them (two out of four Japanese corporations) decided to start mass production and to bring hybrids onto the roads and streets. At the same time high expectations on a breakthrough on batteries fuelled hopes for electrical cars. And fuel cells began to attract attention with expectation on time scales needed for market introduction much shorter compared to the development since then. In one company projections had been to start with fuel cell production for market in 2005. As respondents and other experts told us, there was a difference in technology orientation at the time of decision (mid 1990s) which also may have had its share in the unfolding story. Hybrids are combining an ICE with features of an electrical car:

- some decision makers in companies interpreted hybrids literally as a strange mix, not an all-electrical car and not an improvement of an ICE;
- while others saw the potential of learning on electrical powertrain, i.e. to see the "disadvantage" as a potential.

Ex post we may see that hopes for a breakthrough on batteries failed (e.g. compare Barske 1994 to todays assessment). Fuel cell is a promising alternative but time scales are longer then optimistic expectations some ten years ago (European Union 2003). Improvement of energy efficiency on the European diesel track made their way, too, but that did not stop hybrids going global: from Japan to California and then Europe and the whole of Northern America. If

no debate and later on legislation in a specific region on Zero emission car would have taken place time scale for TRANS would be even longer today. *That is path dependency at work.*

We suggest to research this specific case of shaping hybrid cars in more detail to learn on the interplay of actors in path dependent processes (on the method see Dierkes 1997, including examples of automotive industry; see also previous work on Rover and Fiat Clark & Maielli 2005). Or to put it in more general terms: There is a need to add understanding of *dynamics* of processes to more *comparativ-statical* models used in scenarios (see Held & Kümmerer 2004).

(3) Smooth | gradual change and discontinuities

That is another important point in case: there are a lot of debates on the future of mobility, automobility, energy sources powering mobility and alike. Scenarios play a prominent role in that debate. TRANS is typcially not understood in its own right in most of those scenarios since they are modelled in a static or comparative-static framework. A temporal analysis focusing on the dynamics as well has to complement scenarios (see specifically on transition towards hydrogen fuel cell vehicles, e.g. European Union 2003).

In such an analysis an interesting topic arises: Will TRANS be a *smooth path* with *gradual changes* from USM to SM? Or will we face bottlenecks, thresholds and breaks of trends so that there is a potential for *discontinuities*? Respondents in our interviews mainly resumed to expect a smooth path ahead answering our direct question on the topic. But within the interview some bits and pieces are to be found which reveal a somewhat different picture: Uncertainties again are key to understand that, uncertainties which make sense due to experiences like the failing of hopes for electrical cars to take just one example. There is a strong tendency to see fuel cells powered by renewable hydrogen as the long-term alternative but questions are still there like: will obstacles be overcome in due time? On the other hand: as long as oil prices are still competitive relative to renewable alternatives even in a changing world with increasing oil prices, alternatives may be phased in only at the margin for quite a while. When alternatives like hydrogen may come close to be competitive, a change in main energy source fueling automobiles may come not gradually but with a “big bang”.

As one of the respondents has literally answered in the interview: we can be aware that “the Unexpected Happens” (Ifmo 2002: 48). To be more accurate: we should not be surprised but preparing ourselves for potential lines of developments and events influencing those lines at the end of USM and beginning TRANS. In terms of the good old scout motto: Be prepared! Canzler et al. (Science Centre Berlin) have proposed to add a further step to conventional scenarios (Ifmo 2002: 48 ff):

- analyse feasibility of gradual change with respect to potential of triggering events which may break trends.

This extension of methodology is not just relevant for automakers within the field of our case-study but for the whole setting of TRANS from USM towards SM: typically reference scenarios are presented on the future of mobility (energy, climate change impacts) drawing existing trends into a long-term future like points in time as 2030 (see e.g. OECD 2002; for energy and transport see IEA 2004, 2005b) and even further ahead to 2100 (IPCC 2001). Those reference scenarios are correctly labeled as *business-as-usual (BAU) projections*. But: is it *feasible* to go on without real changes? For example: is cheap oil really in the ground which is assumend in BAU-scenarios for 2030 or even 2100? Such a labeling is still dominant, but is it sound? BAU-scenarios suggest: we can decide to change | go really into TRANS *or not to do so*. Indefinitly? (Which would be a contradiction in itself – to sustain the unsustainable.) What will be the consequences? Is that a real option: may we assume today that societies like in the US

may stand further hurricane seasons ahead? Or have we to be aware of a potential, that just going on with minor adaptations increases the probability of discontinuities? Even the International Energy Agency is suggesting to re-examine assumptions on projected fossil fuels oil and gas supply: "There is no guarantee that required key technologies will actually emerge in time to make new supplies available in the way that the models project." (IEA 2005a: 19)

There is an ongoing debate in economics on the issue of substitution of natural capital by produced capital which is interesting for these questions (Daly 1997). Economists like Solow and Stiglitz had to confess that their argument that natural resources may be substituted by other factors (capital, labour, technological progress etc.) is not really valid, an argument they had used to argue against the report of the Club of Rome *Limits to Growth* in various papers in 1974: "*for the intermediate run – for the next 50-60 years*" (Stiglitz 1997: 269, italics there) or "for a long time" (Solow 1997: 267 f; Held & Nutzinger 2001).

We may generalize the argument:

- BAU may not just be taken as given but its feasibility has to be validated;
- easy oil is close to or maybe already at its peak; therefore, we may not just go along as usual but there has to be an active strategy to postpone the end of the fossil age in general and oil as the fuel for transport in USM in particular (see IEA 2005a on that issue);
- climate change and energy security are closely intertwined; we are *now* faced with decision actively to step forward to TRANS or to actively postpone end of USM; that is associated with the risk to be taken-into account that *then* later on time for TRANS may be too short. Inherent system times for needed changes in technologies, infrastructure, division of labour, spatial structures of settlements, habits, lifestyles, etc. are key for that;
- or to put it in other terms: trying to go on as long as possible within fossil age of USM with as minor adapatations as possible may face the problem, that the "minor adapatations" have to be increased without really solving vulnerability; volatility may increase further on. Measures may be increasingly *too less, too late*.

As was pointed out, our proposal to include gradual changes and potential for discontinuities into analysis are strongly related to *time scales* and *inherent system* times: reaction time of societies to changing conditions like impacts of climate change and energy sources have inherent system times of their own (Holling 1986; Kümmerer 1996). Time needed for R&D as well as their commercialization and the lifestyles as well have their own inherent system times, as all respondents stressed in their answers. It is not by accident that the reactive business-as-usual approach is already causing trouble and a rough time for some of the oil majors.

To give just one illustrative example: Setting in the US favoured customers of automakers to live in a specific world in which USM, fossil non-renewable fuels, climate change, TRANS and alike were far away and alien. That in turn gave incentives to the major American carmakers to make the main bulk of their profits with up-sizing: SUVs were their business. What was part of success for many years became a problem within a very short period of time. Even American customers are reacting to the steep and quick increase of oil prices. Taking inherent system times of a new car generation into account it is no surprise that global players perform differently in such a changing environment. Some has to re-act because they had not the incentives in their setting to be pro-active before.

(4) Short term | long term and phasing in | phasing out

Companies of the automotive industry are active in a business world like all big players which is dominated by short-termism: quarterly reports indicate the relevant temporal unit in this realm. On the other hand, all respondents agree that TRANS and SM has a need to balance *short-term* rationale with *long-term* strategic planning and activities. In all companies of our

sample at least research activities are trying to follow a balanced approach. That is not an easy task if the overall setting is taken-into account they are active in.

Respondents also stressed that *phasing in* alternatives and *phasing out* crude oil is a challenging task. Relative prices are important because at the very beginning of a technology, a new type of fuel, etc. economies of scale are just at its beginning to work. Estimates on learning curves, economies of scale and alike are important to be realistic on the development of the return-on-investment and break-even point of profitability. Therefore, it is not that easy as conventional wisdom tells us with talk on first mover advantage. A decision to start first/early may be too early, so that there is nothing like a first mover advantage but a premature start disadvantage. *Timing*, or in other terms, *kairos*, is relevant.

On the other hand, an actor may be too late, as was pointed out. If relative prices are changing more quickly than expected it can be key to sustain business to have other options in store. If a player is still in the time frame of USM but in real life and business TRANS is at its very beginnings and is getting momentum that may play against him | her: forced to react and with diminishing potential to lead and influence the paths ahead.

(5) Simultaneity

Simultaneity is a feature very much differentiating TRANS from the former period of USM. Phasing in renewable alternatives like biofuels into a market which is dominated by fossil fuel is a new type of setting. If political framework conditions change – like time scale on tax reduction – then players may be confronted with tough choices. But biomass allows to have phasing in strategies like mandating blending (a given share like 5% biomass fuel has to be added, etc.) without fundamental changes in technologies, infrastructure and habits of end-users. That's why European Union started on the issue of renewable fuels in transport with a Directive on Biofuels and that countries like Germany decided on mandatory blending of biofuel in autumn 2005.

Hydrogen is different as it was stressed in interviews by respondents. A new infrastructure has to be put in place which then needs demand to have a return-on-investment in due time.

Adding to that simultaneity is specifically demanding since, as was pointed out, USM was shaped by the rise of just one fossil fuel with basically one type of engine. Therefore, as was outlined on path dependency, simultaneity of different fuels and different powertrains of cars is something new in TRANS. We propose to see hybrids as the first step to learn that lesson (see also above on path-dependency). Absolute figures sold in the market and market share are still low (for example in the order of 200.000 units by the market leader, Toyota, in 2005). But it has opened the door to have not just one aggregate but a combination. All players have to follow suit. Experience with electrical traction is accumulating with hybrids on the roads and streets (for example: re-use of brake-energy) which helps to add fuel cells as a basically new line in the future.

In Table 2 we have summarized features of USM, TRANS and SM in comparison, to better understand the *overall result* of our case study:

> TRANS has different features compared to USM and SM. Being in a time frame of USM has consequences different to a time frame of TRANS.

Table 2: USM, TRANS and SM – features in comparison

Characteristic features	USM	TRANS	SM
Fuel	1 dominant fossil, non-renewable fuel (crude oil) as primary source	simultaneity of different fuels	hydrogen basic secondary energy, diversity of primary renewable energies, fossil fuels phasing out finally
fossil fuel	crude oil seen as practically "unlimited resource"/low value taken as given	oil highly valued to subsidize TRANS in energy terms, beginning phasing out later on	still high value per unit, but segment further decreasing, phasing out air traffic later on
renewable fuel	marginal	increasing segment, highly valued, phasing in	primary sources of energy for secondary energy hydrogen and electricity/ not unlimited
energy efficiency	specific increases of energy efficiency but up-sizing and growth compensating that; later on, trying to prolong USM	increasing emphasis including down-sizing	inherently linked to renewables including downsizing
Engine	1 dominant type of engine/ICE (2 sorts: Otto, diesel)	simultaneity of engines (ICEs, hybrids, fuel cell)	diversity (ICE; hybrids; new lines like fuel cell and electrical car; may be others)
Future orientation	short-term orientation dominating; more of the same | similar, i.e. refinements and adaptations within	trying to balance short term with longer term economical and social interests	balance short-term with long-term economic and social interests
time scale	seen as unlimited for a long time; closer to the end trying to postpone TRANS	no defined time scale but a long period of its own (> 1 generation)	Unfolding
uncertainty	as normal to all business	strong at the beginning	open future; uncertainty seen as part of SM
differentiation within	rise of USM; mature stage; coming closer to the end trying to postpone end of NSM with minor adaptations	no clear defined outset; beginning of TRANS different to stages later on (USM still strong) – close to the end of TRANS overall setting is changing (features of SM getting stronger)	Path dependencies of USM and TRANS relevant at beginning of SM; later on, diversity, open future
type of action	reactive to exogeneous shocks, changes in political framework conditions etc.	trying to be proactive, steps to SM are actively followed (like e.g. hybrids)	Proactive
paradigm of persons' mobility	automobile centred (long distance: air carrier)	oriented to improve diversity	diversity including different types of cars and other innovative modes of mobility, mobility services, electronic mobility combined with personal mobiliy

7. Conclusion and perspectives

In this paper we have presented a case study of automakers on the issue transition towards sustainable mobility. The temporal analysis reveals:

- TRANS is different to USM and different to SM;
- TRANS has to be understood in its own right;
- temporal framework (time scale, inherent system time etc. see Figure 2): all categories are useful for an improved understanding of TRANS;
- further temporal categories may be added in a more differentiated analysis like beginning | ending, timing | *kairos* and rhythm*;*
- time frame is basic to understand specifics of TRANS as is simultaneity;
- time scale, inherent system time and uncertainty are important as well throughout.

The validity of our thesis is thus demonstrated.

From our analysis we may derive a *more general perspective*: Today many isolated steps performed by different players in the field can be seen. If active steps by many players to TRANS would be made isolated measures could add up and TRANS would gain momentum. Politicians as well as all other players in the field can win if they proceed to change their time frame explicitly on TRANS. In other words: actors still in a time frame of USM should *reframe* to the time frame TRANS. Otherwise, activities to postpone the end of fossil-based, unsustainable mobility will increase probability of higher volatiliy of oil prices and disruptions. Time needed – see inherent system times – for change will then be running out.

> *General perspective on TRANS:* All players should actively step forward to the next stage actively shaping TRANS as a new stage and a shared time frame.

Then, it has to be stressed again, fossil fuel will even have higher value because it is not just wasted but needed for the transition to SM. It's no accident that this is exactly according to one of the basic requirements of sustainable development in general:

> "[…] use of non-renewable resources below the rates of development of renewable substitutes." (OECD 2002: 16; see also Federal Environmental Agency 1998: 11).

On this road to TRANS we should have in mind:

Oil is still dominating at the beginning of TRANS. Automakers have to earn actually money right now in the short term with conventional business to finance R&D as well as marketing efforts for their TRANS-strategies on improving energy efficiency and phasing in renewable alternatives.

Our case study did cover only part of the overall field of TRANS: the whole of mobility including air-traffic, human powered mobility (which is basic for health reasons), new forms of mobility, introducing mobility services, improving combinations of modes of transport, restructure settlements and spatial planning accordingly, and, last but not least, to use the potential of electronical mobility in combination with real movements in time and space. *Paradigm of mobility diversity* may be a guide for this broader setting (Mobilitätsinitiative et al. 2004).

Fuels for sustainble mobility is but one part of transition to overall *sustainable energy*. Temporal analysis on diversity, simultaneity and alike is relevant as well to other parts of energy system.

Transition to sustainable mobility is one segment of the overall transition to a *sustainable economy and society in general*. We suggest that temporal analysis may be helpful for other sectors as well. For example, analyzing sustainable or green chemistry would be a case to start with (introduction see Anastas & Warner 1998; Kümmerer & Hofmeister under review). Take the quote at the beginning of our paper: simultaneity is characteristic there too in chemical

industry for transition. We may end to suggest simultaneity being characteristic for transition in general.

In one of our questions we have used an item on the issue of transition according to the still dominating understanding of business-as-usual: Item "no, business-as-usual with some minor adaptations is the order of the day". One of our respondents exactly pointed out the difference if players change to a time frame of transition:

> "It is difficult to answer because our 'business-as-usual' is differerent from other people's 'business-as-usual'."

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