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Sticky Transformation
How path dependencies in socio-technical regimes are impeding the transformation to a Green Economy

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Abstract. Many works in innovation research use path dependencies to explain the fact that change is often difficult to achieve. With regard to a transition to a Green Economy, this paper identifies specific path dependencies in 15 areas of transformation in the sectors of mobility, food, housing and raw material in Germany. In total, 30 subtypes of technological, economical, organizational, user-specific and legal path dependencies were identified and included in the analysis. One of the overarching observations is that for a successful transition to a Green Economy, the role of the state seems to be central. In many areas of transition, supposedly transformative regulation is full of loopholes and does not work, as special interest lobbying prevents the democratic implementation of effective, path-changing regulation.

Keywords. Evolutionary economics, path-dependency, transformation, transition, Green Economy.

1 Introduction

Many works in innovation research use path dependencies to explain the fact that change is often difficult to achieve, especially with regards to transformation to a Green Economy. The vast majority of contributions explain path dependencies as a primarily technical phenomenon. The historical typewriters QWERTY keyboard (Paul A. David, 1985; Liebowitz, 1995) and the video cassette systems Betamax and VHS (Vergne & Durand, 2010) are often taken as examples. However, path dependencies go far beyond technical lock-ins. The project "Evolution2Green" has the interim target to analyze essential obstacles to transformation with a particular emphasis on socio-technical path-dependencies in 15 diverse areas of transformation in Germany.
The ultimate aim of the project is to identify essential prerequisites for successful path changes and to compile best practices for the transformation to a Green Economy. The main objective of this paper is to identify concrete manifestations of path dependencies with a focus on fields of transformation towards the political objective of a Green Economy (BMU & UBA, 2012; UNEP, 2011).

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2 Theoretical Background

In a routine path, considerable ties are generally at work that stabilize it over long periods of time and can make it highly resistant to changes of any kind. A deviation from the path becomes highly difficult and competing paths can be locked out. Evolutionary economics applies the concept of path dependencies to analyze and explain both the ties and the forces locking out alternatives (Nelson, 1987; Nelson & Winter, 1982). In this context, Gavetti and Levinthal (2000) differentiate between dynamics directed backward and building on experiences on the one hand and dynamics directed forward and supported by cognitive assumptions on the other (Gardini, Hommes, Tramontana, & de Vilder, 2009; Gavetti & Levinthal, 2000).

Nill (Nill, 2009; Nill, Sartorius, & Zundel, 2005) clearly distinguishes between lock-in in the case of competition between an incumbent technology and a new solution ("old/new competition") on the one hand and competition between two new technologies ("new/new competition") on the other. Path dependencies in the case of competing new technologies have been analyzed to explain lock-in, which may be driven by increasing returns and even happen in the case of not necessarily superior alternatives (Arthur, 1989). Through contingent events, one of the alternatives may get an initial advantage and later on dominate the market. Others study path dependencies with regard to competing new technologies in the phase of niche formation (Nill, 2009) and niche management (Kemp, 1994).

David (2000) intensively works on definitions of path dependency. Vergne and Durand also introduce a formal definition of path dependence distinguishing between path dependence and other 'history matters' kinds of mechanisms, linking cases of path dependence to stochastic processes, contingency events, self-reinforcing mechanisms and lock-in (Vergne & Durand, 2010, p. 741). Garud et al. (2010) systematically discuss and reject Vergne and Durand, opening the space for a discussion of path creation mechanisms. It must be admitted that the process they describe as path creation (Garud et al., 2010; Karnøe & Garud, 2012) very much overlaps with entrepreneurship research (Casson, 1982; Schumpeter, 1983) and works on the social networks of entrepreneurs (Aldrich & Zimmer, 1986; Jarillo, 1988) as well as the idea of cluster formation (Kärcher-Vital, 2002; Porter, 1998), which Ketels and Protsiv (Ketels & Protsiv, 2013) empirically apply to sustainable development.

In order to maintain the operability and policy relevance of the concept, in this paper, path dependency is very broadly defined as follows:

> *The term "path dependency" describes that an event is dependent upon previous events and patterns of activity. The concept of path dependency states in general that earlier events in the chain of events A, B, C, D, E ... have a causal effect on later ones.*

This definition was chosen while keeping in mind that the analysis based on this definition shall identify path dependencies with a focus on cases of "old/new competition", where generally speaking, an old non-sustainable technology or solution competes with a new, more sustainable technology or solution. The definition is much broader than that used e.g. by Vergne and Durand and might include effects which others may label more generally as obstacles.

In the literature that deals with path dependencies, different kinds of feedback-loops and self-reinforcing effects are discussed (Lehmann-Waffenschmidt & Reichel, 2000, p. 349)—yet in many cases, no systematic distinction between different types of path dependencies is made. This would be important to better understand opportunities for deliberate change and innovation. An interesting example of a more differentiated, systematic approach is found in Nill (2009, p. 138), who distinguishes six types of lock-in amplifiers (translated by the authors):

1. "Irreversible investments in the established technology,
2. switching costs due to technological complementarities,
3. uncertainty about the quality of the new technologies,
4. set-up costs of the new technology,
5. coordination problems among the actors promoting the new technologies, and
6. institutional barriers to change."

Unruh (2000) puts path dependency in the context of technological systems. Lock-in arises when inter-related components of a system develop a high value for the users as well as for producers and express themselves in specific and often very stable production and consumption patterns. As an example for a technological system Unruh (2000, p. 822) mentions cars and personal transport, including supply industries, petroleum production and distribution, rubber manufacturers and road builders into a broader system, which is bigger, has more power and is harder to change than an individual technology. The long-term stability of such a system is reinforced by the fact that firms are bound to the dominant design trajectory focusing on small-scale innovation to optimize their products and are rarely the source of radical innovation. Since incumbent firms usually generate higher profits and cash flows than possible competitors with new (sustainable) products, they have better access to capital to fund their investments, thus further exacerbating the lock-in conditions. Besides the resulting differences in available endogenous capital, the availability of external funding follows the same dynamic. Financial institutions are risk averse in their lending practices and more prone to invest in the established path than in competitors with new and less proven products (Unruh, 2000, p. 823). This dynamics has an important impact on basic sustainability innovations sincs Fichter and Clausen (2013, p. 275) found, that the majority of basic innovations are generated by new companies, whereas established companies develop the majority of incremental innovations and use them to extend the paths of their existing products.

When the system grows in size, industry associations and unions form and eventually merge their interest. Users are also bound to the system, since the high practical value of the systems services evolves in behavioral institutions and social norms. The main types of path dependencies to be drawn from Unruh are:

- A successful technical system which has evolved over time and includes physical, social and informational elements,
- producers of the dominant design owning their production facilities and making profit, with the long term effect of thinking only in the dominant design trajectory,
- industry associations and trade unions profiting from the established path and lobbying for their interest,

- users of the dominant design, owning the respective products and bound in the daily routines and cultures of using them.

Unruh uses the case of electric power networks to give an overview of underlying system dynamics. Public institutions play a specific role in the view of Unruh. While the above mentioned path dependencies are all elements of a market logic (similarily described by Kirchner (2008)), in which a stable interplay of actors are profiting from specific production and consumption patterns, public institutional policy may override the market logic (Unruh, 2000, p. 324). When such institutions are established, they tend to persist for long periods of time. Lobbying efforts by incumbent regime actors often make use of this dynamic to protect and prolong established paths from changing market conditions. However, for certain reasons government might choose to use its regulatory power to change a path. Such reasons might be national security or public safety, the provision of a universal service to everybody or cases of so called natural monopolies (Unruh, 2000, p. 325). Even in cases of a very successful technological system, detrimental effects on the environment might be a reason for government to change policy in a path changing way. It might be hypothesized that the actors of the established path would try to prevent government from doing so and if they do not succeed, to at least prevent it from implementing regulation which would really be effective in changing the path. Consequently, Nill (2009, p. 471) uses the notion of "path-effectiveness" to evaluate path changing policy approaches.

In this paper a first rough delineation of different types of path dependencies will be used, mainly building on the work of Unruh (2000) and a contribution by Fichter and Clausen (K. Fichter & Clausen, 2016; 2013, p. 90). The following main types of path dependencies will be distinguished:

- Technological path dependencies generated by a lack of complementary or alternative products or infrastructures,
- Economic path dependencies resulting from economies of scale and associated fixed capital investments,
- Organizational path dependencies resulting from process routines, procedural requirements, or corporate culture,
- User-specific path dependencies based on perceptions of uncertainty, behavioral routines, and cultural norms,
- Legal path dependencies based on laws, subsidies, technical norms, and approval requirements with a focus not only on the legal basis of the stability of the dominant path but also examining existing policy activities aiming at a path change.

3 Scope and Method

Based on focal areas of the Federal German Sustainabilitry Strategy (Die Bundesregierung, 2016) the analysis presented in this paper is carried out with a focus on the transformation areas of mobility, food and agriculture, energy and housing as well as raw materials. We choose areas in which progress towords sustainability is so far limited. The regional focus is Germany.

The paper strives to analyze essential constraints to the transformation processes

towards a Green Economy with particular attention to path dependencies in a broad spectrum of 15 transformation fields, which have been determined on the basis of a pre-study and a discussion in an expert workshop.

For each of the 15 fields of transformation a concise paper has been written wich is based on a literature analysis as well as four to six expert interviews. These areas are car drive systems (Clausen, 2017a), streets (Clausen, 2017b), alternative modes of individual transport (Korte, Göll, & Behrendt, 2017) and end-of-life vehicle recycling (Tappeser & Chichowitz, 2017c) in the area of mobility, meat consumption (Clausen & Mathes, 2017), nitrogen use (Tappeser & Chichowitz, 2017b), pesticides (Tappeser & Chichowitz, 2017a) and green infrastuctures (Tappeser, Kohlmorgen, & Marden, 2017) in agriculture and food, district heating (Clausen, 2017d), heating based on renewables (Clausen, 2017c) and heat insulation of buildings (Tappeser & Chichowitz, 2017d) in energy and housing and feedstock-change in the chemical industry (Behrendt, 2017a), recycling of technology metals (Behrendt, 2017c), persistent substances (Behrendt, 2017b) and decentralised production (Odenbach, Göll, & Behrendt, 2017) in the area of raw materials. The results of theses papers were subjected to a cross-sectional analysis, on the basis of which conclusions were drawn and discussed in an expert workshop (Clausen & Fichter, 2017).

This paper provides an overview of typical path dependencies impeding the transition to a Green Economy in Germany following the typology of path dependencies mentioned above. In the conclusion, some interdependencies of path dependencies are shown and first managerial consequences are described.

Limitations of the work arise from the high complextiy of the subject and the broad spectrum of transformation areas studied. Overall, we see the paper as exploratory study, shedding at least some light on the importance of path dependencies in the transition to a Green Economy.

4 Types of path dependencies

4.1 Technological path dependencies

Technological path dependencies have been described around the problem of switching, e.g., the historical typewriters QWERTY-keyboard (Paul A. David, 1985; Vergne & Durand, 2010). But it is not only a matter of technologies or artifacts, it is also the fact that many people, producers and users alike, are used to old designs. Changing a technological path might therefore be a long-term project.

The first example for technolgical path-dependencies impeding the transition to a Green Economy highlights a case of technical knowledge being concentrated in two countries leaving other countries with a strong disadvantage to enter the new path (Clausen, 2017a). The second example highlights plant and animal breeding and the danger of dependency of a new high-tech breeding path because of extinction of a wide range of agricultural plants and lifestock breeds (Clausen & Mathes, 2017).

For example, analyses by the Fraunhofer ISI (e-mobil bw (Hrsg.), 2015; Zanker, 2015) demonstrate how large the danger is that the German automobile sector will be outpaced internationally because of the change of technical path from the internal

combustion engine to the electric drive. Hybrid electric vehicles (HEV), plug-in-hybrid vehicles (PHEV), battery electric vehicles (BEV) (all together called xEV), and fuel cell vehicles (FCV) were examined in this study. The number of international patents in the individual countries was used as a measure of mastery of propulsion technologies. The analysis of patent applications is based on international patent applications in the years 2009 through 2011 (e-mobil bw (Hrsg.), 2015, p. 19). In the country comparison, Japan and Korea submitted between 40% (electric motors) and 60% (power electronics and batteries) of the international patents from 2009 through 2011. Germany matches Japan in just one category: the internal combustion engine. The real production figures of electric vehicles in the regions compared show a similarly unambiguous picture in 2013 (Zanker, 2015, p. 9).

However, technological path dependencies can also be consolidated long-term if necessary factors for taking an alternative path have not been maintained and at some point have ceased to exist. Such a finding emerges, e.g., from the analysis of the path taken in the early 1950s to breed hybrids of broiler chickens (IÖW et al., 2004, pp. 3–61), which resulted in economic success so vast and economic concentration so great that some of the broiler chicken breeds used before this path was taken have become extinct or are in danger of extinction. As a result, the option to take the previous path is practically no longer available today. This effect can be observed in the case of many animal and plant species used by the agricultural production system. In the area of breeding broiler chickens, the effect is intensified by the fact that the number of major companies anywhere in the world still active in this area has dropped to just three (Elfick, 2011).

Technical path dependencies as described above can be one of the most important reasons for an inability to transform. A long-term vision and clear plans may be important for driving R&D as well as resource conservation. Both of these aspects are necessary to prepare a transformation whose trajectory cannot be foreseen at the beginning of the process. What we need in firms as well as in policy is a kind of precautionary principle in the technology arena. Even if there is a dominant technology in a dominant path, alternative technologies and alternative paths should be kept open in case we have to make use of alternative options.

4.2 Economic path dependencies

Transformation will in many cases create or destroy value. Schumpeter (1983) coined the term “creative destruction,” which highlights both sides of change: the coming of the new and the termination of the old.

Economic path dependencies cover the potential lock-in effects of existing values (production plants as well as goods used by households as houses, cars and appliances), but also economies of scale. Valuable investments might become sunk costs if they cannot be used for the intended period of time. New investments have to be made (and financed) to achieve change. Economies of scale require careful observation since they tend to have a tipping point after which the innovation gains market share.

Investments. The transformation toward sustainability requires changing infrastructures, buildings, and facilities that represent substantial value. For example, significant investments in the housing stock are necessary to bring it up to an up-to-

date energy standard. The German Federal Ministry for Economic Affairs (BMWi) (2014, p. 13) assumes that approx. 350 euros/m^2 will be necessary to cut energy consumption in half[1]. Assuming approx. 45 m^2 living space per person[2], a population of approx. 80 million, and the need to refurbish approx. 60% of the buildings or living space, investment needs (i.e., costs of switching paths) will amount to roughly 750 billion euros in the period from 2015 to 2050. In the case that district heating is extended to about half of all buildings, further money will need to be invested (Clausen, 2017d).

While renovated buildings usually increase in value, some other investments can be expected to lose value. This might be the case for central heating systems based on natural gas or oil if they are no longer used because of climate policy. Denmark has already started a long process of phasing out such systems. To achieve the target of climate neutrality by 2050, Denmark has decided to ban gas and oil heating systems from use in new buildings since 2013 and oil heating systems in the case of replacement in old buildings if a district heating system is available since 2016. There is an ongoing discussion in Norway about a regulation to stop sales of gas and diesel cars by 2025 in order to achieve a climate neutral car fleet by 2040 (Regjeringen Norge, 2016). The activities show that in order to limit lost investment, it is necessary to draw up long-term plans which take into account the long service life of the products in question and the long time it takes society and business to build and install new systems. The German "Atomausstieg" (phasing out of nuclear power) is a prime example of such an exnovation strategy. While the original plan was drawn up in 2002, the last plant will be shut down in 2022.

Economies of scale. Another type of economic path dependency has to do with economies of scale. As a result of economies of scale, established products produced in large quantities can often be marketed very efficiently and at low cost. For this reason, it is initially difficult, but not impossible, for new products to enter the market if they are based on a fundamentally more efficient or attractive principle. One example of this was the highly energy-efficient LCD monitors introduced to the market in the late 1990s, which were at first significantly more expensive than the cathode ray tube (CRT) monitors dominating the market at the time. Around 2004, the prices of the two technologies converged, resulting in LCD monitors replacing CRT monitors within a brief period of just three years (see Figure 1).

[1] The fact that specifically the single-person households of older people between 65 and 75 years of age have especially large living spaces averaging 103 m^2 (cf. chapter 0) is a particular challenge here.
[2] Cf. press release of the German Federal Institute for Population Research (Bundesinstitut für Bevölkerungsforschung, BiB) of 24 July 2013, http://www.bib-demografie.de/SharedDocs/Publikationen/DE/Download/Grafik_des_Monats/2013_07_pro_kopf_wohnflaeche.pdf?__blob=publicationFile&v=3 last accessed 8 July 2015.

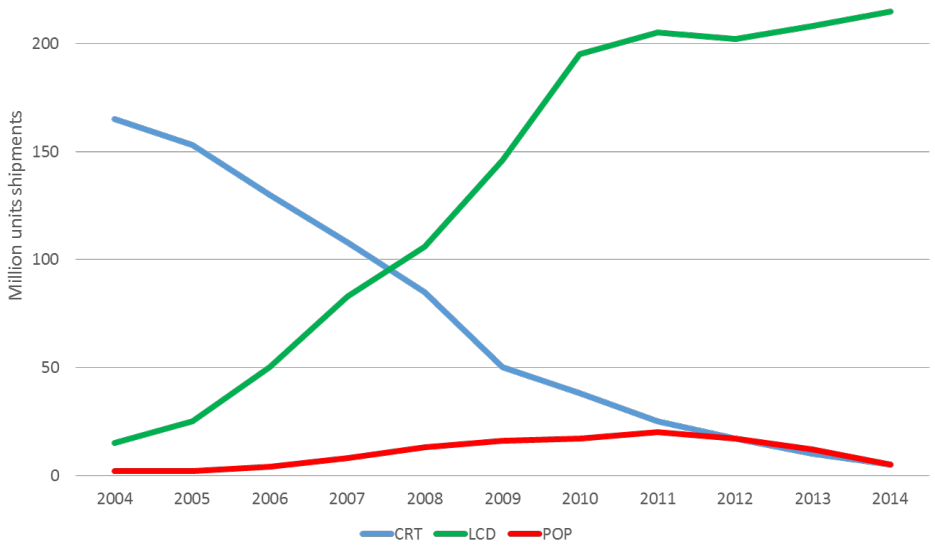

Fig. 1. Sales figures of cathode ray tube (CRT), LCD, and plasma (PDP) monitors Source: http://www.prweb.com/releases/2014/04/prweb11768569.htm of 18 July 2017.

In other words, the factor economies of scale has a dual character with respect to path dependencies. It first stabilizes the position of the established solution until a tipping point is reached; then the advantages arising from the economies of scale shift to the new product, and may do so very quickly, so that they then become a hindrance for the established product.

This tipping point in the energy market is in sight. Photovoltaics have already reached cost parity for consumer-produced household electricity[3]. Off-grid systems have apparently also reached the point where states such as Kenya are tending to opt for a decentralized solar-based energy system rather than for centralized power plants and grids (Mbithi, 2014). The German Advisory Council on Global Change (WBGU)(2011, p. 168) expects further progress in cost development dependent on growth in volume (see Figure 2).

[3] However, the cost parity that had been achieved and further expansion then became the starting point for the consideration that the EEG, which was amended in 2014, was to slow an additional rapid expansion of photovoltaics for consumers' own use by introducing the obligation to pay a portion of the EEG fee for solar electricity produced by consumers themselves (as well as for other kinds of electricity from renewables). This provision in the new EEG, too, can ultimately be understood as a path-extending measure for the centralized structure of the power grid with its fossil fuel-fired power plants.

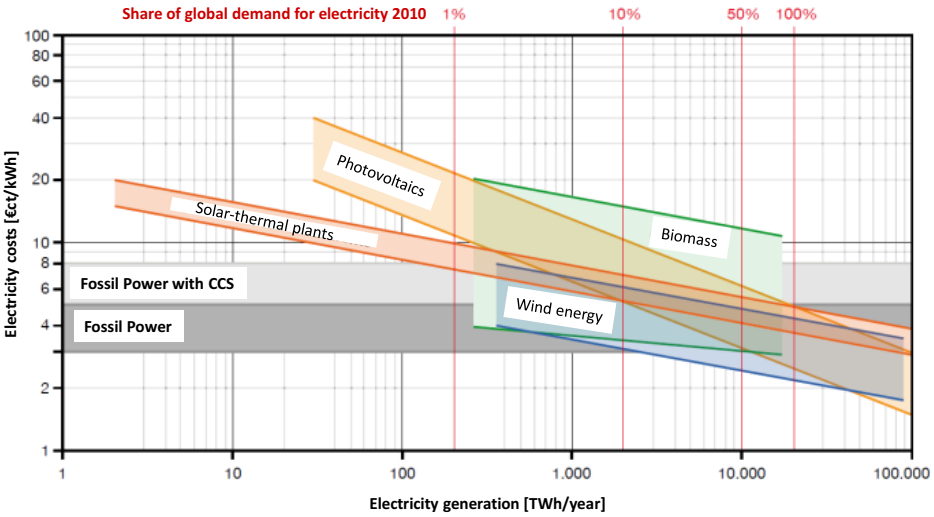

Fig. 2. Development potential of the costs of electricity from renewables Source: WBGU ((2011, p. 168)

Foreseeable changes in relative prices because of economies of scale are also relevant for the development of electromobility. For example, in its National Development Plan Electromobility (Die Bundesregierung, 2009, p. 10), the German federal government hoped that battery costs would drop from 1,000 to 1,200 euros per kWh to 300 to 500 euros, which would enable their entry into the mass market. A price of 300 euros per kWh has already been achieved, and additional reductions to approx. 150 euros per kWh are expected by 2018 (Hackmann, Pyschny, & Stanek, 2015).

If electric vehicles become more affordable and convenient than conventional alternatives by 2022 (OECD / IEA, 2013; Randall, 2016), this might be of importance for the German automotive industry, which is still not particularly busy developing and scaling up technologies beyond gas and diesel. A parallel increase in range, from 120 to 150 km today to then 200 to 250 km, could also reduce consumers' reluctance to purchase electric vehicles (Clausen, 2017a).

Economies of scale are important for all actors in a transformation process. While businesses have to monitor carefully how long their innovative competitors will need to achieve cost parity, policies may provide subsidies until parity is achieved to boost innovative markets. If a firm ignores innovative competitors' economies of scale, its market shares might shrink.

4.3 Organizational path dependencies

Organizational path dependencies are understood here as those in which ties develop because of process routines, procedural specifications, or corporate culture. The organized representation of interests, which is also often directed toward stabilizing a path, will be analyzed here as well.

Organizational routines and corporate culture. Process routines, procedural

specifications, and behavioral routines in keeping with corporate culture are special forms of routines in companies and organizations. They are embedded in a more or less firmly enshrined corporate culture. Schein (1995) differentiates three levels of corporate culture:

- artifacts as obvious elements of corporate culture (organizational structure, rituals, figures of speech, architecture of the company buildings, or visible patterns of behavior),
- the organization's values (what is important to the organization),
- basic assumptions (assumptions that are not questioned and not consciously reflected concerning human nature, the environment, time, or reality in general).

While the artifacts, which also include behavioral routines, are relatively simple to change, transforming the underlying values and basic assumptions takes considerable effort and time.

The Competence Center for Innovation and Sustainable Management studied the attitudes toward climate change of 159 decision-makers in industrial, service, and wholesaling and retailing companies (Tachkov, 2015). Tachkov finds that differences exist especially between explicit and implicit attitudes.[4] In other words, if the question is asked openly and directly, then a very strong majority of 85% expresses moderate to strong agreement with the responsibility of businesses for climate mitigation. Interestingly, in an implicit association test concerning implicit relative preferences for "growth" or "climate mitigation," approx. 50% of the sample are on each side of the distribution. Tachkov (2015, p. 18) concludes "that it is not enough to implement sustainability goals and visions and to demand that executives take them on and share them, or to survey their agreement with such goals." In other words, the dissonance between explicit and implicit attitudes would imply that when appropriate opportunities arise, executives confirm that they consider climate mitigation important. Yet they would make really important decisions without regard to the goal of climate mitigation.

One of the main reasons for the emergence of organizational path dependencies are false or no longer up-to-date basic assumptions, on the basis of which decisions are made. A number of examples have been found:

- Low prices for food and heating energy are implicitly part of the basic supply of the population and are seen as part of social care. Responding to the latest proposal by the environmental authorities to increase the value added tax on meat to the standard rate for non-food consumer products of 19%, the Minister of Agriculture commented that he did not want to prescribe what people should eat. Ultimately, government follows the Roman rule of "panem et circensis", which today might be fast food and television.
- Another basic assumption refuted by numerous studies (Rheinisch-Westfälisches Institut für Wirtschaftsforschung (Hrsg.), 2010; Umweltbundesamt (Hrsg.), 2005, 2008, p. 92) is the implied link between ever-increasing road construction and economic growth (Clausen, 2017b).
- In politics it is also taken for granted that – as a function of its historically

[4] Kora Kristof found similar assessments in relation to attitudes toward the environment and sustainability and therefore differentiates between "implicit theories" and "explicit theories"(Kristof, 2010).

> aquired status in environmental law - agriculture should be exempted from the majority of existing environmental regulation because it contributes decisively to the basic supply of the population with food. The fact that this exception - as demonstrated by the examples of water pollution and biodiversity loss due to the high use of nitrogen fertilizers and pesticides - obviously leads to the fact that in the foreseeable future agriculture will no longer be able to fulfill this function hardly irritates anybody in politics.

Corporate lobbying. Interest groups are established both by businesses and by civil-society groups. From the perspective of analyzing path dependencies, trade associations are very important; their interest is often linked to continuing existing business models. Yet it is difficult to determine the extent of lobbying in Germany due to a lack of data. In any case, the costs of these structures should be significant, but are not known for Germany (Lobby Control, 2013, p. 13). In the US, the business community spends approx. 3.3 billion dollars per year for this purpose (loc. cit.).

Again, lobbying to prolong existing paths is a strategy employed by management. Since many others in an industry association are also opting for certain activities, this confirms to individual managers that they are right. But successful lobbying might in the long run turn out to be a bad strategy for some actors. If change comes nevertheless, it might be too late to change firms that lobby for and stick to the old path.

Trade unions. The German Trade Union Confederation (DGB) with its member unions and its more than 6 million members in 2014 is also an interest group that cannot be viewed separately from economically successful industries. As the frantic actions of the political community in crisis situations make clear time and again, securing these jobs and grandfathering the rights of these workers are often highly important in the short term. But structural transformation often also generates losers. Exnovation explicitly results in certain products or technologies being phased out of the economic process, generally resulting in the loss of certain jobs and the necessity of creating alternative job opportunities.

For example, the number of jobs in the sector "mining/crude and manufactured minerals" in Germany declined from 317,000 in 1991 to 130,000 in 2000 and just 76,000 in 2010; in the sector "energy supply" from 382,000 in 1991 to 267,000 in 2000, and just 254,000 in 2010 (Statistisches Bundesamt, 2014, p. 349). 302,000 jobs were eliminated in the two sectors by 2000, and another 67,000 by 2010. The reasons for this are diverse. For example, German mining was highly dependent on subsidies and no longer internationally competitive as early as the 1990s. In the late 1990s, the energy sector took great efforts to increase efficiency in the course of market liberalization. Nonetheless, it is doubtless true that the beginning transformation of the energy system and in particular of electricity supply involved cutting jobs in conventional businesses since the year 2000.

But it is also important to note that a considerable number of new jobs is being created in the course of the structural transformation. For example, the 67,000 jobs lost in the conventional energy system between 2000 and 2010 are contrasted by an increase in employment in the renewables sector from 106,000 in 2002 to 360,000 in 2010 (Umweltbundesamt, 2014, p. 4). This amounts to a net increase of just under 200,000 new jobs in the energy sector.

Like management, trade union leaders bear responsibility for choosing the right option. If they collaborate with management and cooperate in activities prolonging existing paths, they might succeed in securing the jobs of their constituencies for a certain period of time. But if change comes nevertheless, it might be too late to change firms that stick to the old path, hence decreasing job security in the long run.

4.4 User-specific path dependencies

Innovations, and in this context in particular basic innovations, often involve uncertainties for suppliers as well as customers. Studies in the field of ecological consumption see uncertainties as an important reason for the more sluggish diffusion of innovations in the end consumer market. Antoni-Komar and Pfriem mention reservations about unfamiliar places to shop in the organic products segment as well as concerns about the security of supply when switching from fossil fuels to renewable heating energy sources (Antoni-Komar & Pfriem, 2010, p. 231).
Uncertainties are one, but not the only, reason for routines. Blättel-Mink et al. (2013, p. 95) also emphasize the simplifying effect of routines in everyday life. *"In light of the complexity of the circumstances of life described above, routines enable us not to have to think about, weigh, discuss, and decide anew every day which action is suitable for which situation"* (Blättel-Mink et al., 2013, p. 95). In other words, the tendency to simplify one's life by using routines also results in locking in certain patterns of behavior and consumption.
What is more, individual consumption is embedded in the context of the system of consumption and production of the culture in question, in other words, in what we have learned from others and are accustomed to recognizing as "normal".
A main fact is, that consumers are often satisfied with the function and price of conventional solutions.

- Large sections of the population are simply satisfied with the established regime and its products and services. Inexpensive meat, large, poorly renovated but cheap apartments to be heated cheaply due to low energy prices, high-priced, big and fast cars with a lot of comfort: many of us see the price-performance ratio of these offers to be very reasonable.
- Existing alternatives are often not able to arouse a desire for change because they do not provide added functionality at a comparable price. The renewable heating systems for houses, car-sharing services as well as electric cars all show that market dynamics alone do not lead to fast diffusion.

The maintenance of the usual forms of consumption is stabilized by lack of knowledge and uncertainties regarding alternatives.

- Consumers and, in some cases, farmers have such low awareness of the environmental impacts of conventional farming and the benefits of organic farming that consumer choices and production patterns do not change.
- Beyond the problem of high costs, uncertainties regarding function, range and charging systems cause a very slow development of the market for electric vehicles.
- Incorrect notions about the costs of refurbishment and ignorance of the advantages in terms of housing comfort result in a low number of homeowners investing in comprehensive energy refurbishment.

4.5 Legal path dependencies

Path dependencies originating from laws and regulations seem to have primarily indirect effects. In most markets, use of the dominant product in the market is not obligatory, and use of alternatives is not banned. As long as there is no major alternative, specific aspects of products, e.g., safety, may be subjected to certain standards or norms, but why should regulating bodies make a product obligatory or ban it from the market?

This situation changes if there is a convincing political reason for product regulation. If a product leads to severe negative externalities in the environmental or social domains, there may be a reason for the state to regulate. Such regulation only makes sense if the market can provide alternatives not producing said externalities ("functional equivalent"). Provided such alternatives exist, the government may plan to formulate regulation to achieve a market in which products without negative externalities dominate. Facing potential losses in market share, the various actors having an interest in the ongoing success of the current dominant product tend to make attempts at altering or influencing the envisioned regulation in order to make it less successful. As the following examples illustrate, this dynamic frequently leads to prolonged paths of socially and environmentally questionable products.

Laws and regulation. A first example is energy policy. Besides the Renewable Energy Sources Act (EEG), regulation of the electricity market in particular is of considerable economic relevance for the German energy market. Electricity market regulation has been criticized since the 1980s because it does not, or only to too small a degree, internalize the external costs of fossil and nuclear energy and has thus prevented competition with other forms of energy from occurring in the first place (Hohmeyer, 1988). Although the coalition government of the Green Party (Bündnis 90/Die Grünen) and the Social Democrats in Germany (1998-2005) took initial steps toward an ecological tax reform in 1999, its absolute increase of energy prices was modest. In a study for the German Federal Ministry for the Environment, the external costs of the various fossil fuels on the market were estimated at 6 to 8 cents/kWh on average (DLR & Fraunhofer ISI, 2007, p. 2). If these costs were internalized, this would more than double the price of electricity generated from fossil fuels and thus turn market conditions on their head. A similar situation can be found in the markets of natural gas and oil for heating (Clausen, 2017c) as well as for gas and diesel for cars (Clausen, 2017a) with low prices in both markets.

In other words, an important component of institutional safeguarding of the fossil energy sector is not the existence, but the lack of existence of a truly effective arrangement for internalizing costs. For this reason, the internalization of external costs continued to be high on the political agenda of the proponents of renewables in order to improve their market opportunities. The decision to introduce the EU emissions trading system in 2003 was an interim success. The price of certificates from their introduction in 2005 to 2007 was approximately €25, but it then declined steadily, with the exception of a peak at the beginning of the second trading period in 2008. This development was caused by details of emissions trading law, which resulted in a long-term oversupply of certificates, thus driving down the price in the absence of scarcity. The oversupply is considered to have two equally important causes: the number of

certificates issued, which was too large in any case, and the generation of additional certificates through Joint Implementation and the Clean Development Mechanism (Agora Energiewende, 2015, p. 7). Over the last six years, the surpluses have grown to roughly 1.3 times the number of certificates issued annually (cf. Figure 3).

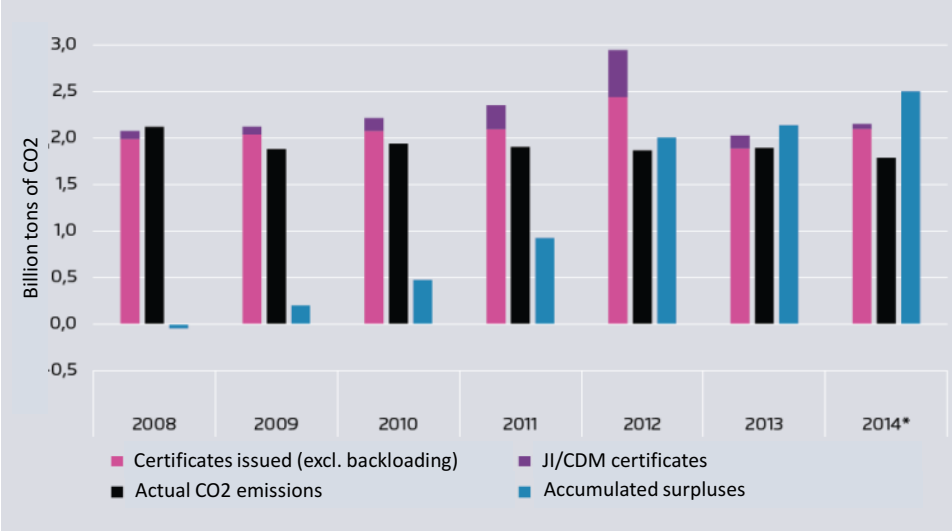

Fig. 3. Development of emissions and surpluses 2008 to 2014 Source: (Agora Energiewende, 2015, p. 10).

The deterioration of the price of emissions certificates is central to the failure of the market mechanism introduced to promote the energy transition. Nitsch makes this clear in a scenario study on the EEG (Nitsch, 2013) in which he demonstrates that the EEG causes persistent, high additional costs for electricity consumers in the absence of active climate policy that increases the price of certificates. But if the external costs of fossil fuels were included in the price of certificates and thus also in consumers' costs, then by 2050, the EEG would either result in significantly lower costs overall or even lessen the long-term burden on the economy by up to 450 billion euros cumulatively, depending on the scenario (Nitsch, 2013, p. 8). According to Nitsch (loc. cit. 9), the EEG has already reached its goal of cost degression and its effect of promoting innovation. However, it will not be possible to get on the path to further decarbonization as agreed at the 2015 G7 summit and in the Paris Climate Agreement by continuing to promote innovations, but only by implementing additional policy tools for internalizing costs and thus ultimately also exnovation, i.e., phase-out of problematic or harmful energy sources.

Two prominent examples of exnovation regulations are to be found in the energy sector, namely the German nuclear phase-outs of 2002 and 2011 (following the 2010 resumption) and the 2009 ban on incandescent light bulbs[5]. The advantage of a market ban is that it is simple and effective. At least the light bulb ban seems to work, classic

[5] Numerous other exnovation regulations exist in particular in the chemicals sector, e.g., in the ban on the "dirty dozen" in the German Foodstuffs and Consumer Goods Law and in the REACH regulations.

light bulbs are no longer for sale in Germany.

A second example is regulation concerning the fuel consumption of cars (Clausen, 2017a). As a first step, a 1998 voluntary agreement with the automobile industry attempted to reduce CO_2 emissions to 140 g/km by 2008. But that target was not met. In December 2008, the EU Council and Parliament agreed on a regulation to reduce the CO_2 emissions of new automobiles. The new goal for 2015 was now 130 g/km. The EU Commission[6] states that the average emissions of a vehicle sold in 2014 were 123.4 g CO_2/km, so the goal for 2015 has been reached. This corresponds to a reduction by 17g or 12% since monitoring began in 2010.

Here, too, a closer look reveals that the issue of safeguarding interests by shaping the legal framework appears even more complex. A more differentiated image of the attainment of the goal, which is encouraging as such, emerges if we also view the increasing difference between the figures given by manufacturers and the CO_2 emissions calculated on that basis on the one hand and real fuel consumption figures on the other. According to a study by the US International Council on Clean Transportation (ICCT, TNO, IFEU, & Sidekick, 2013), this difference averaged 23 percent for new vehicles delivered by German manufacturers in 2011. This discrepancy has displayed an upward trend since the beginning of the millennium: "… the average discrepancy between fuel consumption (and, by extension, CO_2 emission) values reported in spritmonitor.de and manufacturers' type-approval values increased from 7 percent in 2001 to 13 percent in 2007 and then jumped to 23 percent by 2011" (ICCT et al., 2013, p. 6). The German environmental organization Deutsche Umwelthilfe (2013) carefully lists 20 ways to tweak consumption figures by changing or optimizing the vehicle, the engine, and the testing facility. The successes achieved in this way seem to explain a large part of the EU's reduction requirements. In other words, the 21% reduction of CO_2 emissions from 2008 to 2014 (from 157 g/km to 123.4 g/km) is contrasted by additional measurement errors of approx. 10% from 2007 to 2011 alone, which account for half of the effect achieved.

The regulation of successful transformation requires politicians with courage. If a transformation is needed, then it is simply a sign of inconsistent policies or corruption if the necessary regulatory instruments are not watertight.

Subsidies. Subsidies are used for the most diverse purposes. In some cases, it is clearly recognizable that they serve to stabilize a path. The largest individual subsidy detrimental to the environment is the allocation of CO_2 emission certificates free of charge. At prices of CO_2 certificates averaging 15.40 euros per ton in 2010, the theoretical volume of subsidies was 6,098 million euros that year (Umweltbundesamt (Hrsg.), 2014, p. 24).

Path stabilization is also apparent in the case of subsidies for coal. For example, subsidies for hard coal amounted to 1,917 million euros, for the lignite sector at least 279 million euros, and energy tax relief for coal was 190 million euros in 2010 (Umweltbundesamt (Hrsg.), 2014, p. 62).

[6] cf. http://ec.europa.eu/clima/policies/transport/vehicles/cars/index_en.htm last accessed 30 August 2015.

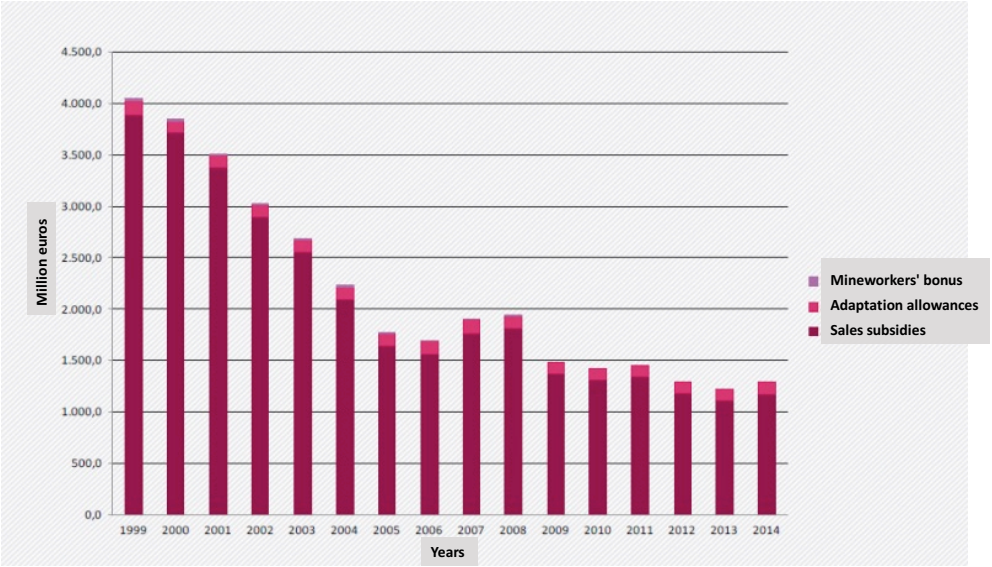

Fig. 4. Government funding for hard coal from 1999 to 2014. Source: German Federal Environment Agency (ed.) 2014, 20.

In the 16 years from 1999 to 2014, a total of approx. 33 billion euros of subsidies was paid to the coal sector and contributed to keeping the increasingly uneconomical sector alive longer. At least the subsidies for hard coal have been on a downward trend since the turn of the millennium. Support is scheduled to end in 2018, and the mines are to be closed then (Umweltbundesamt (Hrsg.), 2014, p. 19).

Further energy subsidies will not necessarily impact the energy mix, but should have an effect on the pressure to increase efficiency. They prevent prices from telling the ecological truth. Examples of such subsidies include (Umweltbundesamt (Hrsg.), 2014, p. 62):

- Reduced concession fees for electricity, or exemption from concession fees, for special-rate (i.e., energy-intensive) customers, equivalent to 3,500 million euros
- Reductions of electricity and energy taxes for the manufacturing sector, agriculture, and forestry, equivalent to 2,518 million euros
- Ecotax capping for the manufacturing sector, equivalent to 1,939 million euros
- Tax relief for certain energy-intensive processes and procedures, equivalent to 983 million euros
- The special compensation provision of the EEG for electricity-intensive businesses and railways, equivalent to 1,455 million euros
- Reduced cogeneration charge rates for energy-intensive businesses, equivalent to 103 million euros
- Favorable electricity grid charge rates for energy-intensive industries, equivalent to 33 million euros.

The reason given for these subsidies lies in maintaining the international

competitiveness of the companies in the relevant sectors, whereby their damage to the climate is not taken into account. The subsidies in the energy sector as calculated by the Federal Environment Agency amount to 21,649 million euros per year overall, or more than 200 billion euros over 10 years.

Additional subsidies relevant for the transformation toward a Green Economy are granted to the transportation sector and total 24,168 million euros (Umweltbundesamt (Hrsg.), 2014, p. 63). The largest items here are the reduced energy tax rate for diesel fuel, equivalent to 7,050 million euros; the distance-based commuting allowance in income tax law, equivalent to 5,000 million euros; the exemption of kerosene from the energy tax, equivalent to 6,915 million euros; and the exemption of international flights from value-added tax, equivalent to 3,490 million euros. Flat-rate taxation of privately used company cars, equivalent to at least 500 million euros, must also be mentioned. These subsidies have influence on the choice of the car as primary form of mobility and impede change in the mobility system (Clausen, 2017a).

Subsidies are an important means for policies to influence transformation processes. They can either speed up transformation or slow down change. Intelligent use of subsidies of both types might actually lower the burden society has to bear during transformation because transformation is too expensive if it is driven too fast (loss of value) or too slowly (not achieving targets). Corrupt use of subsidies might prolong an unsuccessful path and lead to a loss in national competitiveness.

Norms and standards. Norms and standards are also considered to be "secondary body of rules," a fitting description. At the end of the millennium, laws included references to approx. 20 % of all DIN standards (DIN Deutsches Institut für Normung e. V. (Hrsg.), 2000, p. 20).

Companies see the positive effects of industry-wide standardization on manufacturing and transaction costs (DIN Deutsches Institut für Normung e. V. (Hrsg.), 2000, p. 14). They also see its effect on market power over suppliers and—to a smaller extent—customers (DIN Deutsches Institut für Normung e. V. (Hrsg.), 2000, p. 16). A survey of companies by the Deutsches Institut für Normung (DIN) also reveals that standards inhibit innovation projects only to a small degree and that companies think that participation in the preparation of standards reduces the risk of misguided R&D.

Since the preparation of standards is a kind of technology transfer between businesses, it supports efficient diffusion of innovations (DIN Deutsches Institut für Normung e. V. (Hrsg.), 2000, p. 25). If both innovators and manufacturers who enter a market later on are included in the process of preparing standards, then ultimately many companies will benefit from participation in industry-wide standardization when they develop technologies. They gain know-how through the standards.

Since norms usually standardize the details of certain artifacts, but do not impact alternative artifacts (e.g., basic innovations with similar functions), it appears likely that standards indeed tend to be smaller barriers to innovation, but may be all the more important for the later diffusion of new technical solutions.

5 Outcome

Market capitalization as well as the value of real estate are of enormous importance for decision-making. However, they are not path dependent. Stock-exchanges value firms mainly because of expectations of future performance, which can hardly be called a "previous event".

Market capitalization can be better described as an outcome of a management process creating the foundation for expected future performance. Paths as well as expectations about coming path changes are of importance for market capitalization. This can be shown by the following example of energy industry, which after Fukushima and the German Energiewende obviously is stuck to a path with is expected to be terminated within the next thirty years.

5.1 Market capitalization

Capital markets and the values generated and disappearing there matter in the context of sustainability-relevant sectors. This notion suggests itself on the basis of the market capitalization of the 100 largest European companies in eight sectors calculated by PricewaterhouseCoopers. For example, the market capitalization of the 16 most valuable companies in the European energy sector dropped from approx. 1.6 trillion euros in 2008 to just approx. 980 billion euros in 2013 and bounced back to approx. 1.1 trillion euros in 2014 (PricewaterhouseCoopers, 2014, p. 14). By June 2016, the value declined to approx. 860 billion euros (Bloomberg, 2016). In other words, the 16 most valuable European energy companies lost approx. 47% of their market capitalization between 2008 and 2016. The corresponding values for Germany dropped from 140 billion euros in 2008 (PricewaterhouseCoopers, 2014, p. 14) to 39 billion euros in 2016, or approx. by 72% (Bloomberg, 2016).

No less than 750 billion euros of company value in the European energy sector were wiped out in eight years. That is almost four times the amount that disappeared in Germany's Neuer Markt of dotcom-firms around the turn of the millennium[7] (at the time approx. 200 billion euros) and is far more in total than the German bank bailouts following the subprime crisis in 2008.

The magnitude alone of the sums in question in the energy sector is reason enough for the most intense efforts on the part of the companies and their owners or shareholders to maintain their company value and to do everything possible to maintain the business model. In addition, there is an interesting constellation of interests because approx. 24% of the equity of RWE[8] and of many municipal utility companies are owned by municipalities. As a result, municipalities are in the dilemma that they diminish the value of their own holdings if they pursue systematic climate mitigation policy.

In the end, market capitalization is the responsibility of management. If firms ignore change, their market value will suffer, as the European energy industry is currently experiencing. The European automotive industry might see the same effects if it does not rapidly develop and produce the cars that the sustainable society of the future already wants to buy today. Auto Scout 24 (2015, p. 18) finds that only 6.3% of

[7] A temporary IT and dotcom segment of the German stock exchange that crashed in 2000.
[8] cf. Hannoversche Allgemeine Zeitung of 3 September 2015, 11.

Europeans expect to drive gas or diesel cars by 2040. In other words: it would be a good idea to phase them out now.

5.2 Real estate

The value of real estate outside the major urban centers with their partly astronomical prices has hardly been made a topic of discussion recently, and certainly not in the business press. Nonetheless, it should be mentioned here, quasi in parallel to the market capitalization of the energy companies. Real estate is relevant for the opportunities to shape the energy system, and not only within cities; the generation of bioenergy as well as wind energy or groundmounted PV facilities need space—the topic of competition for real estate has been addressed time and again, especially in the global context. It stands to reason that real estate prices could have increased and thus impacted opportunities to switch paths.

German federal statistics (Statistisches Bundesamt, 2013, p. 14) show that the average purchase value per hectare of agricultural land sold has increased significantly: from 8,692 euros per ha in 2005 to 16,381 euros per ha in 2013. The total value of agricultural land in Germany calculated from this figure thus increased theoretically from approx. 162 billion euros by 143 billion euros to 305 billion euros; agricultural land accounts for no less than 52.3% of the 357,000 km^2 of Germany's total land area. The increase in value of agricultural land during this period corresponds to a return of approx. 8% per annum. So while approx. 100 billion euros disappeared from the market capitalization of the German energy corporations between 2008 and 2016, even more than this amount is to be found in agricultural (energy) land. Besides investments in material assets and market capitalization, the value of real estate could also become established as a starting point of a new economic dynamics, since the land owners could form new constellations of interests for the purpose of further increasing value, which could potentially impact energy policy.

The change in value of real estate is not a means that policies can use to speed up or slow down change. But it might have social effects, e.g., on small farms. Rapid changes of real estate prices also encourage speculation, with potential risks for national wealth.

6 Conclusion

The analysis of path dependencies seems to be a fruitful task for transformation research. The systematic analysis of path dependencies generates a good overview of different group interests, possible values that might vanish during the transition towards a Green Economy, the legal positions of actors, and the legal framework which makes transformation easy or hard to achieve. An important fact is that existing sectors selling products in large quantities employ more people and have a greater lobbying capacity than emergent sectors with just a few innovative products.

The analysis of the five types of different path dependencies reveals some interesting insights. Some of these are:

- The basis of some legal as well as organizational path dependencies are false or no longer up-to-date basic assumptions regarding the appropriateness of existing arrangements, on the basis of which political decisions are made or

organizations are led. Such decision-making bases, which are characterized by Schein (1985, p. 14) as an "unquestioned basic assumption", can very effectively and over long-terms inhibit changes.

- At the center of environmental law, which is currently not very effective in many places, we found laws and regulations with gaps or other elements that limit their effectiveness. The case of such "incomplete environmental law", appears not only to be a matter of individual cases, but rather of a general principle that requires an in-depth investigation.
- Cost pressure and high path change costs impede change as well as missing technologies and infrastructures, the development and / or provision of which is connected with additonal costs. The minimization of path exchange costs should receive much more attention.
- The satisfaction of many users with the characteristics and costs of common, but environmentally problematic products is a fact that is often underestimated by environmental policy.

Additionally, these path dependencies are showing a number of self-reinforcing interdependencies (cf. Figure 5).

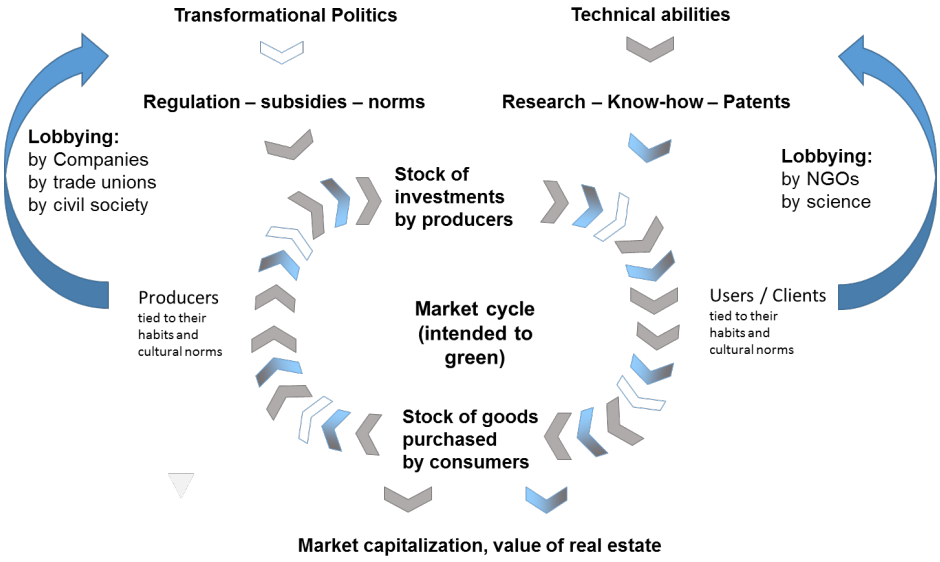

Fig. 5. Interdependencies of path dependencies. Source: Borderstep Institute

At the center of the transformation-dynamics there are a huge number of markets in which goods are sold and bought. Many of the goods or technologies are part of larger technological systems and regimes (Kemp, 1994) and the transformation of such markets is heavily interrelated. These goods or technological systems may or may not be sustainable, and suppliers as well as users are locked in habits, organizational structures, or simply in investments and infrastructures which make it easy to follow the old path.

A central external factor for change is technical ability. For instance, as long as only Japan and the US possess sufficient know-how (measured in patents as well as the number of cars actually sold) to build high-quality electric cars, the European auto industry will slow down change at any cost. Politics, influenced by the strong car lobby associations, supports them in prolonging the historic path of gas and diesel drives. R&D, if necessary with public funding, will be a central means for lock-out.

In addition, in terms of the production of food, Europe is about to hand over more and more genetic stock (of animal breeds as well as plants) to private companies, which may or may not preserve it. Potential paths back to sustainable agriculture based on regional and climate-resistant livestock and crops could thus be permanently locked out.

The real value of firms measured in market capitalization is in fact an outcome of the process. The energy sector shows that a non-transformative strategy, supported by strong lobbying by companies as well as trade unions, has not been successful. About 50% of market capitalization was lost in the years 2008 to 2016. It is in fact the job of top management to look ahead and invest in the solutions of the future, not in those of the past. This is the only way to secure the wealth of shareholders of incumbent firms in the long run.

A reason why incumbent firms are nevertheless important actors in transformation is that their possible influence on the diffusion of new solutions is high (K. Fichter & Clausen, 2016; Klaus Fichter & Clausen, 2013). It might therefore be a central task within transformation to pave the way for future success of incumbent firms. But our analysis also revealed that important path dependencies exist at the cultural level of exactly those incumbents. Not every manager in business or politician shares, e.g., the vision of 100% renewable energy, and some of them are not even able to imagine that the Paris Agreement will ever become effective. They simply cannot imagine a world without gasoline and diesel cars, without gas- and oil-fired central heating, or without the habit of building new roads. Even if they agree to rigorous climate protection targets, they are convinced that we will still need fossil-fueled artifacts in the future.

We are convinced that careful analysis of path dependencies makes it easier to have a realistic view of the transformation project in the various sectors. It enables us to identify winners and losers (there is no field of transformation with win-win situations only) and makes it easier to develop a policy integrating as many actors and groups as possible in the transformation project and to plan for those negatively affected. Historical examples might be the Dutch environmental covenants (Biekart, 1995) or the Japanese practice of negotiating policies between government and business and then jointly working on their realization (Jänicke, Mönch, Binder, Carius, & Forschungsstelle für Umweltpolitik, 1993). A promising strategy for effective transformation may consist of establishing transparency regarding the pace of the envisioned transformation. If the chosen speed allows for old, unsustainable investments to amortize while new and sustainable investments are made at the same time, then consensus-building will be easier.

But consensus must not result in inactivity. Our analysis also identified numerous regulations which seem to support change, while in fact they transfer old practices into the future through a variety of loopholes. Actually, some of these regulations do not support change at all. This “regulation without effect” serves as a political means to

pacify critical groups and change agents, while on the other hand it sheds light on politicians who themselves do not believe in or strive for real change. Again, the central actors enabling successful transformation seem to be politicians who believe in their own targets, e.g., those set in the Paris Agreement, and put them into practice, as well as a civil society, including the sciences, forcing them to do so.

But the link between actors of the established regimes and politics seems to be too close. Unruh asks in his article on the escape from carbon lock-in: "Is a major catastrophe required?" (Unruh, 2002, p. 323). Our analysis might show an alternative: Optimists might argue, that a consequent politics will establish a co-operative process to find a way out of non-sustainabiliy and will face opponents on this way in a target oriented and upright manner. Pessimists like Harich (2012) or ultimately Unruh might be convinced that the influence of established regimes on politics is too high and only the mentioned major catastrophe will ultimately lead to path change.

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