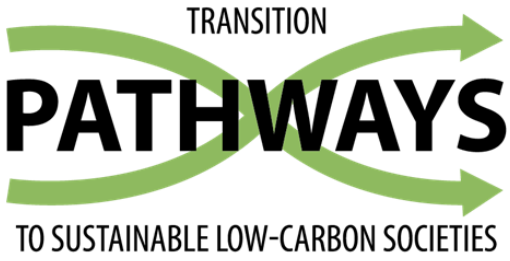


PATHWAYS project

Exploring transition pathways to sustainable, low carbon societies

Grant Agreement number 603942

Deliverable D2.2: 'Analysis of stability and tensions in incumbent socio-technical regimes'

Main report: Introduction and findings from 11 country studies

Edited by: Frank W. Geels
Sustainable Consumption Institute
University of Manchester

29 May, 2015

Preface

This report presents the findings from task 2.2 in WP-2 of the PATHWAYS project, which aims to make an analysis of socio-technical regimes, and provides an assessment of the degree of stability and tensions, in five empirical domains (electricity, heat/buildings, mobility, agro-food, land-use) for several European countries.

The PATHWAYS project aims to 'Explore transition pathways to sustainable, low carbon societies'. Work Package 2 aims to provide a socio-technical analysis of the *dynamics of transition pathways* in five empirical domains for several European countries. This socio-technical analysis uses the Multi-Level Perspective (MLP) as its conceptual framework, which focuses on interactions between radical niche-innovations, incumbent regimes, and exogenous secular 'landscape' developments. The basic idea is that transitions come about through the alignment of processes at three levels: a) green niche-innovations build up internal momentum (e.g. through learning processes, price/performance improvements, and support from powerful groups), b) changes at the landscape level create pressure on the regime, c) destabilisation of the regime creates windows of opportunity for the diffusion of niche-innovations.

The analysis of future transition pathways in WP-2 is operationalised through five analytical tasks which subsequently address the following topics:
Task 2.1: Green niche-innovations and their momentum in the two pathways (deliverable due in Month 12).
Task 2.2: Stability and tensions of incumbent socio-technical regimes in five empirical domains (deliverable due in Month 18).
Task 2.3: Integrated analysis of D2.1 and D2.2 to asses feasibility of different transition pathways (deliverable due in Month 22).
Task 2.4: Comparison of transition pathways in both countries (deliverable due in Month 28).
Task 2.5: Forward-looking analysis of transition pathways (deliverable due in Month 32).

This main report provides an introduction to Task 2.2 (describing the conceptual framework and research template that all researchers shared) and its results, based on findings in 11 country sub-reports that underlie this main report. These 11 reports analyse the degree of stability and tensions in existing regimes in five empirical domains and different countries:
Electricity: Germany and the UK
Heat/buildings: Sweden, Germany, and the UK:
Mobility: The UK and the Netherlands
Agro-food: The Netherlands, Hungary
Land use and bio-diversity: Portugal and the Netherlands.

For more information, the reader can consult the individual country/domain reports, which are available at the website of the PATHWAYS project (http://www.pathways-project.eu/).

Throughout the research process, there have been various interactions between the WP-2 coordinators and the different research teams (e.g. conference calls and a workshop on 23-25 February 2015 to discuss progress reports). We also organised an internal review of each of the eleven country reports, including executive summaries, and an internal review of the first part of the main report. Despite these quality control measures, the various research teams are responsible for the findings and quality of the different country-reports, including summaries.

Contents

Executive summary

This report constitutes Deliverable 2.2 in the PATHWAYS project ('Exploring transition pathways to sustainable, low carbon societies'). Deliverable 2.2 makes an analysis of incumbent socio-technical regimes, and provides an assessment of the degree of stability and tensions, for five empirical domains, in the following European countries:
1) Electricity: Germany and the UK
2) Heat: Sweden, Germany, the UK
3) Mobility: The UK and the Netherlands
4) Agro-food: The Netherlands and Hungary
5) Land use and bio-diversity: Portugal and the Netherlands.

This main report has two parts. The first part provides an introduction. Section 1.1 describes the general socio-technical framework that guides WP-2 (section 1.1). This multi-level perspective (MLP) suggests that transitions come about through interacting developments at three analytical levels: a) radical niche-innovations, b) incumbent socio-technical regime, c) exogenous socio-technical landscape. Deliverable 2.2 focuses on the level of socio-technical regimes and landscape. Section 1.2 summarises the literature on socio-technical regimes and develops a conceptual framework that considers lock-in and stability as well as causes of tensions and regime problems. Section 1.3 describes the research protocol that is used in each of country/domain report. This regime analysis protocol addresses the following analytical tasks:
1) Describe the overall system in terms of overall environmental performance, (sub)system and longitudinal developments
2) Describe the main external landscape developments that influence the system
3) For each sub-system (e.g. auto-mobility, trains, busses, cycling in case of the transport system), describe developments of the main tangible system elements.
4) For each sub-system, describe the main social groups and intangible regime elements (e.g. actions, strategies, beliefs, visions, preference).
5) Combine the findings from task 2, 3 and 4 to provide interpretive conclusions about the degree to which existing (sub)regimes are still stable and locked-in, and where (if at all) tensions are emerging.

The second part provides the results of the analysis of socio-technical regimes in the different domains and countries. These results are based on the executive summaries and conclusions from the 11 country sub-reports that underlie this main report. These results are presented in tables that explicitly address: 1) the stabilising forces that contribute to regime lock-in, path dependence and incremental change, 2) the cracks, tensions and problems in regimes that provide potential windows of opportunity for more substantial change. The main findings of task 2.2 are summarised in 11 sub-sections in chapter 2. The complete country-reports are available on the website of the PATHWAYS-project (http://www.pathways-project.eu/).

1. Introduction

1.1. General introduction: Our view on transitions and transition pathways in WP-2

The PATHWAYS project investigates transition pathways to sustainable, low carbon societies from three methodological angles: 1) integrated assessment models (quantitative computer models), 2) socio-technical analysis (qualitative case studies of socio-technical systems), and 3) participative action research (local projects working on 'transitions in the making').

Socio-technical analysis in WP-2

WP-2 is concerned with socio-technical analysis of transition pathways. *Socio-technical analysis*, which is an approach in the domain of innovation studies, investigates interactions between technical and social dimensions (including economic, cultural and political dimensions). It is sociological in the sense of focusing on the various groups of social actors that interact in the reproduction and change of socio-technical systems.

Socio-technical transitions

Transitions in a socio-technical perspective are about substantial changes in energy, transport, and agro-food systems, which entail not only technical changes, but also changes in markets, user practices, policy, cultural discourses, infrastructure, and governing institutions. As a shorthand, these changes are labelled 'socio-technical' transitions. Socio-technical transitions can vary in their *scope* of change (how many system elements change) and the *degree* of change (are changes more incremental or radical). The various system elements are reproduced or changed by actors and social groups (e.g. firms, supply chains, researchers, consumers, policymakers, wider publics, social movements). Consequently, transitions come about through interactions between actors and social groups, whose actions together change system elements. These interactions may entail power struggles (e.g. with regard to changes in regulations), building of new networks and coalitions, developing visions about sustainable future, exploring these visions through concrete learning processes (e.g. building new technical capabilities, learning about consumer preferences and market demand), economic investments and jockeying for market share.

Multi-level perspective on socio-technical transitions

Before introducing our view on transition *pathways*, we briefly discuss the underlying socio-technical conceptualisation of transitions used in our project. This is provided by the Multi-Level Perspective (MLP). The MLP (Rip and Kemp, 1998; Geels, 2002; Geels and Schot, 2007) and distinguishes three analytical levels:

* The *socio-technical regime* refers to the semi-coherent set of rules and institutions (such as shared meaning systems, heuristics, rules of thumb, routines, standardized ways of doing things, social norms, formal regulations) that shape the perceptions and actions of the incumbent actor groups who reproduce or change elements of socio-technical systems. So, a socio-technical system refers to the more tangible 'measurable' elements (e.g. technical artefacts, market shares, infrastructure, regulations, consumption patterns, public opinion), whereas regimes refer to intangible and underlying rules and institutions. Incumbent actors tend to be 'locked in' to existing regimes and systems (Unruh, 2000), because of sunk investments (in skills, factories, infrastructures), economies of scale, increasing returns to adoption (Arthur, 1988), favourable regulations, cognitive routines that make 'blind' (Nelson and Winter, 1982), social norms and behavioural patterns. Innovation in existing regimes and

systems is therefore mostly incremental, aimed at elaborating existing capabilities and protecting vested interests.
* Radical novelties that deviate on one or more dimensions from existing regimes are conceptualised as emerging in *niches*, i.e. particular domains of use, actor constellations and geographical areas with special characteristics. The novelty may be a new behavioural practice (e.g. car sharing), a new technology (e.g. battery-electric vehicles) or a new business model (e.g. energy service companies). Radical novelties emerge initially as unstable configurations with poor price/performance characteristics. Hence, niches act as 'incubation rooms' protecting novelties against mainstream market selection (Kemp *et al*., 1998; Hoogma *et al*., 2002). Niche-innovations are initially often developed by small networks of dedicated actors, often outsiders or fringe actors.
* The *socio-technical landscape* forms an exogenous environment beyond the direct influence of niche and regime actors (macro-economics, deep cultural patterns, macro-political developments). Changes at the landscape level can take various forms (Van Driel and Schot, 2005): 1) factors that do not change (or that change very slowly), such as physical climate, 2) rapid external shocks, such as wars or oil price fluctuations, and 3) long-term changes in a certain direction (trend-like patterns), such as demographical changes or climate change.

These three levels in the MLP refer to heterogeneous configurations of increasing stability, which can be seen as a nested hierarchy with regimes being embedded within landscapes and niches existing inside or outside regimes (Figure 1). Niche actors work on radical innovations (e.g. technical improvement, opening up markets, finding customers, lobbying policymakers for support), which they hope will eventually be used in the regime or even replace it. This is not easy, however, because the existing regime is stabilized by many lock-in mechanisms. Nevertheless, niche-innovations are crucial, because they form the seeds for systemic change. The MLP helps explain why there may simultaneously be a flurry of change activities (at the niche level) and relative stability of existing regimes.

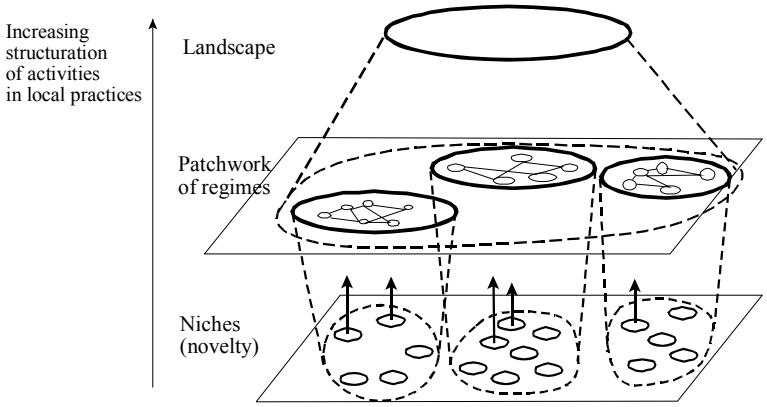


Figure 1: Static multi-level perspective as nested hierarchy (Geels, 2002: 1261)

The basic idea of the MLP is that transitions are non-linear processes that result from the interplay of multiple developments at the three analytical levels. Although each transition is unique, the general dynamic is that transitions come about through the interaction between processes at these three levels (Figure 2): a) niche-innovations build up internal momentum, b) changes at the landscape level create pressure on the regime, c) destabilisation of the regime creates windows of opportunity for the diffusion of niche-innovations.

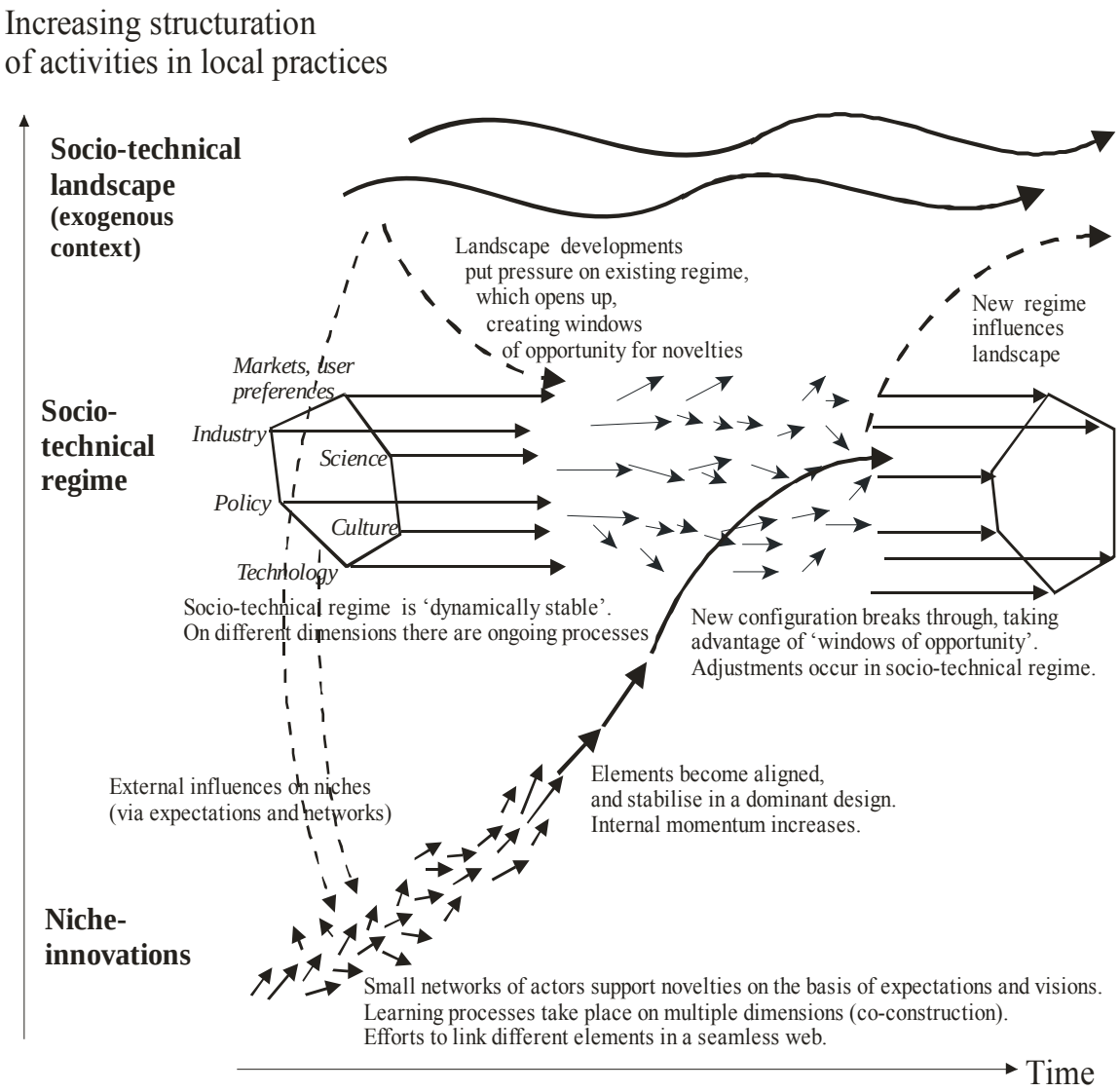


Figure 2: Multi-level perspective on transitions (adapted from Geels, 2002: 1263)

An important implication is that the MLP does away with simple causality in transitions. There is no single 'cause' or driver. Instead, there are processes on multiple dimensions and at different levels which link up and reinforce each other ('circular causality'). Another implication is that there is no guarantee that transitions will succeed: niche-innovations may fail to build up sufficient momentum or suffer setbacks (leading to hype-disappointment cycles); tensions in existing regimes may remain small so that 'windows of opportunity' for niche-innovations do not materialize.

Transition pathways

Having described our conceptualisation of the overall dynamics of socio-technical transitions, we can now discuss transition *pathways*. Based on a large number of historical case studies of transitions, Geels and Schot (2007) identified four transition pathways:

1) Transformation: In this pathway, incumbent actors respond to landscape pressures and regime tensions by adjusting the *direction* of existing development paths and innovation activities. Current practices are amended and improved (e.g. higher efficiencies, less waste) by adjusting R&D patterns, search heuristics, incentives, regulations and behavioural patterns (Van de Poel, 2003). The basic system architecture remains intact (including positions of

incumbent actors), but environmental performance is improved (many small changes over time can lead to substantial changes).
2) Reconfiguration: Niche-innovations are adopted into the regime to solve local problems, and subsequently trigger adjustments and knock-on effects in the basic system architecture. So, transitions come about through new combinations between niche-innovations and existing systems (Geels, 2006; Berkers and Geels, 2011). This transition pathway often entails alliances/collaborations between new entrants and incumbent actors.
3) Technological substitution: This transition pathway is driven by technical niche-innovations that substitute existing technologies. Geels (2005) distinguished different sub-patterns: a) technical component substitution, which (initially) leaves much of the wider system intact; the transition from propeller aircraft to turbojets is an example of a shift in engine technology, which enabled airplanes to fly faster, higher and longer distances (over time, however, this shift was accompanied by changes in runways, air-traffic control, aircraft size, and travel patterns), b) disruptive innovations and technological discontinuities overthrow existing technologies and associated systems; the shift from sailing ships to steamships, for instance, not only entailed substitution of technical artefacts, but also changed building materials (from wood to iron), shipbuilding practices, ports (which had to deepened and enlarged), shipping and trading patterns (because steamships were faster and more reliable, which allowed the introduction of liner services), a global fuel infrastructure (coal bunkers in ports), and new cargo-loading machines (to enable rapid turn-around),
4) De-alignment and re-alignment: In this transition pathway, large and rapid landscape pressures cause major internal regime problems leading to their disintegration (de-alignment of system elements); this erosion then creates space for the emergence of various niche-innovations; the co-existence of various niche-innovations creates uncertainty and may delay actors to make full-scale commitments for fear of betting on the wrong horse; eventually processes of re-alignment occur around one of the innovations, leading to a new regime.

To keep research in the PATHWAYS project doable, we have decided to adopt a simpler view on transition pathways, which distinguishes two ideal-types that differ on three defining elements: 1) the kinds of actors involved (relative to the established regime), 2) the depth of change (degree of radicality relative to initial system), and 3) the scope of change (number of socio-technical dimensions involved). Based on these defining elements, we identify two fundamentally different pathways (A and B), which are two different routes for realising major improvements in sustainability performance (Table 1).

Pathway A is close to technical substitution pathway in the Geels and Schot (2007) typology, while pathway B combines elements of 'reconfiguration' (changes in system architecture) and 'de-alignment and re-alignment' (broader social and cultural changes enacted by radically new entrants). These two ideal-types are a working hypothesis for WP-2, which can be rejected or amended. For instance, if research in some empirical domains (e.g. agro-food or land-use) finds that none of the green niche-innovations has great momentum, then it may be useful to include transformation or reconfiguration transition pathways in our thinking about future sustainability improvements. We may also want to place more emphasis on social innovation (either in Pathway B or in a new pathway), e.g. regarding car sharing, more cycling, eating less meat.

	Pathway 0: Business as Usual	Pathway A: Technical component substitution	Pathway B: Broader regime transformation
Departure from existing system performance	Minor (no transition)	Substantial	Substantial
Lead actors	Incumbent actors (often established industry and policy actors)	Incumbent actors (often established industry and policy actors)	New entrants, including new firms, social movements, civil society actors.
Depth of change	Incremental change	Radical technical change (substitution), but leaving other system elements mostly intact	Radical transformative change in entire system (fundamentally new ways of doing, new system architectures, new technologies)
Scope of change	Dynamic stability across multiple dimensions	1-2 dimensions: technical component and/or market change, with socio-cultural and consumer practices unchanged	Multi-dimensional change (technical base, markets, organisational, policy, social, cultural, consumer preferences, user practices)

Table 1: Ideal-type transition pathways and their defining elements

Table 1 also includes a baseline Pathway 0, which represents Business-as-Usual, in which actors do not seriously engage with sustainability transitions, or fail to do so in time (too little, too late). The contrast with Pathway 0 is also useful to highlight that both pathway A and B are radical (although in different ways) and require substantial efforts and policies.

Structure of work in WP-2

Informed by the above conceptual backgrounds, WP-2 consists of five tasks with different deliverables.

Task 2.1: Green niche-innovations and their momentum in the two pathways. The deliverable, due in Month 12, makes an analysis of various green niche-innovations in five empirical domains (electricity, heat/buildings, mobility, agro-food, land-use) in various countries. The analysis aims to assess which green niche-innovations have the greatest momentum, and how this maps on to the two ideal-type transition pathways.

Task 2.2: Stability and tensions of incumbent socio-technical regimes in five empirical domains (deliverable due in Month 18). This task aims to assess how stable/unstable existing regimes are (also in relation to landscape pressures), and what the strategies and beliefs of powerful incumbent actors are.

Task 2.3: Integrated analysis of D2.1 and D2.2 to assess feasibility of different transition pathways (deliverable due in Month 22). This task will assess what the chances are of the two ideal-type transition pathways. It will also reflect on the usefulness of the two ideal-types, and possibly consider other transition pathways from the Geels/Schot typology (e.g. if none of the green niche-innovations has sufficient momentum to break through more widely, or if existing regimes are still very stable and locked-in).

Task 2.4: Comparison of transition pathways in between countries (deliverable due in Month 28). This task will compare studies of different countries in the same domain (e.g. UK and German transitions in the electricity domain), and draw more specific lessons about actor strategies, governance styles and policy instruments.

Task 2.5: Forward-looking analysis of transition pathways (deliverable due in Month 32). This task will speculate about how different interactions in the MLP can lead to different future transition pathways.

Structure of introductory chapter and report

This report presents the findings from task 2.2 in WP2, which aims to make an analysis of socio-technical regimes, and provides an assessment of the degree of stability and tensions, in five empirical domains (electricity, heat/buildings, mobility, agro-food, land-use) for several European countries.

The remainder of this introductory chapter summarises the literature and debate on socio-technical regimes (section 1.2), and describes the conceptual framework that has been used as analytical research protocol for the different domain and country studies (section 1.3). Chapter 2 then present the core findings from the 11 country studies which have been done by different research teams in the PATHWAYS project (section 2.1 to 2.12). The complete country-reports are available on the website of the PATHWAYS-project (http://www.pathways-project.eu/).

1.2. Conceptual framework

The aim of this section is to briefly provide the main outlines of the conceptualisation of socio-technical regimes in the MLP.

Ongoing debates on 'regimes'

The goal of task 2.2 is to assess if, and to what degree, existing regimes are still stable and locked-in, and where (if at all) tensions are emerging. This is not an easy task, for several reasons. First, socio-technical regimes are multi-dimensional and complex, entailing economic, technical, business, political, social and cultural dimensions. This means that the analysis requires different kinds of information (both quantitative and qualitative), which the analyst needs to interpret to come up with an assessment.

Second, all the five domains in the PATHWAYS project entail interactions between *multiple* regimes, which is interesting academically (because much of the literature still focuses on single regimes), but demanding in terms of data-collection and interpretation.

Third, there is an ongoing debate about the definition and conceptualisation of socio-technical regimes in the MLP, and the most relevant dynamics and mechanisms. Some of these debates concern the following issues:

- Complaints about the lack of a clear regime conceptualisation of regime (Holtz *et al*., 2008; Markard and Truffer, 2008).
- Criticism that regime conceptualisation should pay more attention to power and politics (Lawhon and Murphy; 2012)
- Criticism that regime conceptualisation is too supply-side oriented, leading to suggestions to explicitly accommodate for users and demand-side dynamics (Hargreaves et al, 2013)
- Criticism that incumbent firms are portrayed too much as lock-in and resistant to change, leading to suggestions that incumbent firms can reorient towards more radical niche-innovations (Bergek *et al*., 2013; Berggren *et al*., 2015)

- Criticism that the regime is sometimes portrayed as too much of a coherent and monolithic entity, leading to suggestions to pay more attention to conflict and tensions (Jørgensen, 2012; Fuenfschilling. and Truffer, 2014)
- Suggestions that incumbent actors are not just locked-in to existing regimes, but may actively resist major reorientation, e.g. through organised fight-back against niches (Geels, 2014a).

While this report does not aim to resolve these debates, it is useful to flag up these ongoing debates to sensitise analysis.

Definition and conceptualisation of regimes

One reason for conceptual problems is that the regime concept has been used in the literature in two ways:
1) A loose conceptualisation, in which 'regime' represents the set of heterogeneous elements against which niches struggle. Smith *et al*. (2010: 441), for instance, propose the following definition: "Socio-technical regimes are structures constituted from a co-evolutionary accumulation and alignment of knowledge, investments, objects, infrastructures, values and norms that span the production-consumption divide"
2) A stricter conceptualisation, which distinguishes three inter-related elements (Geels, 2004): a) *socio-technical systems*, which are the relatively 'tangible' elements necessary for the functioning of a system to provide societal functions such as mobility, heating, sustenance/food and light/power; these elements may include technical artefacts, production facilities and supply chains, infrastructure (e.g. roads, fuel), market demand and consumption patterns, repair facilities, public debates, formal policies; b) *actors and social groups*, who reproduce and maintain the system elements, e.g. firms, universities, consumers/users, policymakers, wider publics/stakeholders, NGOs; c) the *socio-technical regimes* (semi-coherent set of rules and institutions) which shapes the actions, interpretations, and identities of social actors.[1]

For task 2.2, we use an intermediate conceptualisation that distinguishes between: 1) the socio-technical system (tangible elements) and 2) the incumbent actors and their strategies, beliefs, governance styles, social relations (intangible regime elements).

Stabilising mechanisms of lock-in, inertia, path dependence

There is a wide range of literatures offering many explanations of stability, lock-in and path dependence. Table 2 provides a summary of insights from these literatures, organised into:
* Lock-in mechanisms related to more tangible elements ('socio-technical system'), which are often advanced in economic and management/organizational literatures,
* Lock-in mechanisms related to more intangible elements ('socio-technical regime'), which can be found in more sociological and institutional literatures.

For both the socio-technical system and socio-technical regime, Table 2 identifies some of the core lock-in mechanisms for different social groups such as firms, consumers,

[1] Neo-institutional theory distinguishes different kinds of institutions (e.g. formal-regulative, normative, cultural-cognitive that shape action through different mechanisms, e.g. expedience, social obligation and taken-for-grantedness.

policymakers, civil society, and infrastructure. The last row in Table 2 suggests that the lock-in mechanisms for various groups collectively stabilise existing artefacts and products.

	Socio-technical system (tangible elements)	**Socio-technical regime (rules, institutions in relation to perceptions and actions)**
Industry, incumbent firms	Sunk investments in machines, skills, people, supply and distribution chains	routines and standard-operating procedures; technical knowledge, capabilities; strategic orientation and industry beliefs/logics
Consumers, households	Established consumption patterns and practices; sunk investments in appliances and artefacts	habits, behavioural routines, skills, consumer preferences, values, beliefs
Policymakers	Organizational and administrative capital (government departments, advisory bodies, political party machinery, implementation agencies, tasks, responsibilities)	policy implementation routines; policy plans and programs; policy paradigms and governance styles
Civil society, public debates, 'culture'	Organizational capital (NGOs, third-sector organisations, unions) and arenas for public debate (media, conferences, public events)	Storylines and discourses which are *routinely* used to make sense of societal problems and solutions; deeper ideology or cultural repertoires (e.g. 'modernity', 'progress', 'democracy').
Infrastructure, spatial patterns	Sunk investments in roads, pipes (gas, water, sewage, oil), wires, cables, canals, dikes, buildings, urban lay-out, land-use patterns	
Existing artefacts, products	Low cost (because of economies of scale, learning effects, increasing returns to adoption); circulation between producers and consumers	Embedded in and reinforced by: - technical skills and production facilities - lifestyles and consumer practices - standards, policies, subsidies that create an uneven playing field - positive public discourses that create enthusiasm and legitimacy (or make things look 'normal') - infrastructure (which creates a taken-for-granted material deep structure)

Table 2: Different mechanisms for lock-in and path dependence in socio-technical systems and regimes

An additional stabilising mechanism refers to power and political economy, particularly with regard to policymakers and big incumbent industries whose relations often lead to an alliance oriented towards maintaining the status quo (Geels, 2014a). This alliance has been noted previously with concepts such as the 'techno-institutional complex' (Unruh, 2000) and a 'historical bloc' (Levy and Newell, 2002). Big business has 'structural power', because states depend on industries to provide jobs, taxes, economic growth and dynamism (Newell and Paterson, 1998). This dependency leads to relational networks and close contacts between big business and senior policymakers. With regard to fossil fuel industries, Newell and Paterson (1998: 684) found that: "Governments routinely consult and take account of the interests of energy lobbies when proposals are being formulated." Frequent contacts may lead policymakers to internalize the ideas and interests of industries, which is a more subtle mechanism of influence. Market elites and governmental elites may have conflicts about specific policy instruments, but generally agree about basic directions, problem definitions and desired solutions (Lindblom, 2001). Big firms also use 'corporate political strategies',

which may contain information strategies, financial incentives strategy, organized pressure strategies, direct lobbying strategy, and confrontational strategies such as litigation (Hillman and Hitt, 1999).
The analytical implication for regime stability is that this alliance often results in 'green' policies (e.g. oriented at efficiency improvements) that can be met with incremental innovations that stay within in the bounds of existing regimes. It is relatively rare that policymakers introduce tough green policies that go against the interests of big incumbent firms.

The implication of the above considerations is that existing systems and regimes are stabilised in many ways on different dimensions. This stabilisation helps explain why transitions often come about slowly, and why green niche-innovations face many barriers. Nevertheless, tensions and cracks may arise with systems and regimes, which create windows of opportunity for transitions.

Tensions, cracks, stresses and the 'opening up' of regimes

Although some scholars portray socio-technical regimes as monolithic configurations or entities, they are better seen as 'semi-coherent' (Geels, 2004), because their stability depends on the alignment between the different elements and groups. Geels (2011: 31) explains that: "While regimes may appear as coherent blocks from the outside (and often present themselves that way through spokespersons such as trade associations), there are often internal tensions, disagreement and conflicts of interests. Neo-institutional theorists (Hoffman, 1999; Seo and Creed, 2002) have made the same point, arguing that organizational fields are full of debates on specific issues and problems. So, it may be better to say that, on the one hand, regimes have coherence, shared rules, and similarity, but on the other hand contain variety, disagreement on specific issues, debate, and internal conflict. Such a conceptualization would make the strength, homogeneity and internal alignment of regimes an empirical question rather than an assumption."

The implication is that the stability of regimes may weaken if problems and stresses appear within socio-technical system, leading to cracks and tensions between the social groups involved (e.g. conflicts, disagreements). These problems and stresses may arise from *external pressures* (e.g. from exogenous 'landscape' developments or from complaints by social movements, NGOs or scientists drawing attention to negative externalities) and/or from *internal problems* (e.g. diminishing returns, changing consumer preferences, stronger policies, diversifying firm strategies). Both external pressures and internal problems are further elaborated in the next two sections.

External pressures on socio-technical regimes

* *Pressures from landscape developments*, e.g. shocks (such as the financial-economic crisis, accidents, wars, rapid oil price changes) or gradual changes such as climate change, resource problems, demographic change, ideological change, geo-political change. These developments often need to be 'translated' or mobilized by particular actors in order to have effects (e.g. the Fukushima accident had big effects on German nuclear power, but little effect on UK nuclear power, because of different interpretations and mobilizations by policymakers and public discourse).
* *Negative externalities or social/environmental problems* are often mobilized by relative regime outsiders (Van de Poel, 2000) such as *social movements, NGOs and scientists*). These actors often act as outsiders who criticize the existing regime for causing externalities and problems and call for action to address the problems. This outside pressure is rarely enough, however, to lead to regime destabilisation. In order to create regime tensions, these warnings and criticisms need to enter public debates, lead to a societal sense of urgency, which creates

pressure on policymakers who (in some circumstances) introduce substantial policies. This is not a linear process, however, and public attention to social/environmental problems may also decrease (as happened with climate change in many countries in recent years).

Regime-internal tensions and stresses

Regime-internal tensions can arise from changes in the perceptions, strategies and actions of different social groups in Table 2, e.g. incumbent firms, consumers, policymakers and civil society organisations.

* Industries can face economic-financial problems (because of shrinking markets and sales), technical problems (because of technical 'bottlenecks' or 'diminishing returns'), reputation problems (because of negative public discourse or protests from NGOs) or legislative problems (because of tougher policies) (Geels, 2014b). In response to these problems, they can adjust existing routines and engage in incremental innovation, which stays within existing regimes. If problems continue, incumbent firms may engage in more substantial change, e.g. developing radical technical alternatives (first as 'hedging strategy', later perhaps as 'diversification' strategy) or new business models and beliefs.
* Tensions in regimes may also arise from changes in consumer practices or consumer preferences (Oudshoorn and Pinch, 2003). Consumer preferences may change for different reasons, e.g. concern about negative externalities, cultural changes, changes in relative prices and/or policies (taxes, subsidies, bans, information campaigns). Lead users may create small market niches for radical alternatives (new technologies or behavioural practices). Changes in mainstream consumer preferences are often more difficult to bring about, and may take longer times.
* Changing policies are likely to be important causes of tension with regard to sustainability transitions (because many environmental problems are collective good problems). In many domains, policymakers have fairly close alliances with industries. So, the introduction of tougher 'green' policies often requires changes in public discourse, social movement pressure, demands/concerns from citizens (sometimes triggered by shocks or accidents), and weakening alignment to industry actors. Following Hall (1993), we can distinguish three levels of policy change: a) change in setting of existing policy instruments (e.g. make energy efficiency standards a bit stricter), b) introduction of new policy instruments, c) change in policy paradigm, which entails new problem definitions and policy goals.
* Regime tensions may also come from changes in public debates and discourses, which can reduce the 'legitimacy' and 'taken-for-grantedness of existing socio-technical systems (Geels and Verhees, 2011). A strong public discourse is important for sustainability transitions, because it is a mechanism to: a) translate environmental concerns by scientists and NGOs into pressure on policymakers, b) shape consumer preferences (which may change market demand).

Multi-regime interactions

An interesting complication for task 2.2 is that the empirical domains in the PATHWAYS project are characterized by *multiple* regimes (although their interactions differ).

* The incumbent electricity system is characterized by a separation between supply and demand via an electricity grid, which acts as a buffer, meaning that the *electricity supply regime* (where coal, nuclear and gas can be seen as sub-regimes) operates rather independently from various *electricity end-use regimes* such as consumer electronics (e.g. TV, radio), home computing, lighting, cold appliances (refrigerator, freezer), wet appliances (washing machine, dishwater, tumble dryer, washer-dryer), and electric cooking. The transmission and distribution grid can be seen as a separate regime with its own changes, e.g.

new transmission lines, innovations to improve flexibility and address intermittency (e.g. storage technologies, smart grids), international interconnectors.
* Since most heat is used for space-heating, there are interactions between the building regime (houses, construction, insulation) and the heat production/supply regime (fuels, boilers, heat pumps, district heat system).
* The mobility system consists of a dominant car-regime (which in most European countries accounts for 85-90% of inland passenger kilometres) and subaltern train, tram, bus, cycling regimes.
* The agro-food system consists of dozens of regimes, organised as product-specific food chains. Most food-chains consist of suppliers (of seeds, machines, feed), primary producers (farmers), food processors/manufacturers, wholesale, retail (supermarkets), various consumers. WP-2 will focus on the regimes with the largest environmental impact (e.g. dairy, meat, fish). Agro-food researchers also address some incremental innovation trajectories that span multiple food chains, e.g. improvements in refrigeration, packaging, waste reduction (in supply chains and households).
* As land is used for various end-use functions, the land-use system can be divided into different land-use regimes (urban areas, agriculture, forestry, nature, water/wetlands).

This attention for multiple regimes is academically interesting, because much of the literature assumes that green niche-innovations struggle against single regimes (see also Figure 1 above). But it also creates practical space challenge, which means that the analyses of different regimes should be concise and focused on the main developments.

1.3. Research protocol for regime analysis in task 2.2 and report structure

Research protocol and tasks

Based on the discussion above, the research has used a shared research protocol that addresses five analytical tasks.
1) Describe the overall system in terms of overall environmental performance, sub-systems and longitudinal developments. This task aims to characterize the overall system, and describe the degree to which progress has been made to address environmental problems. In most domains this progress is likely to be incremental, and not enough to address the problems in a timely manner (i.e. Pathway 0 in Table 1 above).
2) Describe the main external landscape developments that exert *external pressures* on the system.
3) For each sub-system (e.g. automobility, trains, busses), describe developments of the main tangible system elements. Quantitative data may be very useful here to give an indication of the size and degree of developments.
4) For each sub-system, describe the main social groups and intangible regime elements (e.g. actions, strategies, beliefs, visions, preference). This task, which will require more qualitative information and interpretive assessments, is crucial to address the degree of *regime-internal stresses and problems*. The underlying motivation of this task is that external pressures don't automatically lead to regime-internal pressures, but are mediated through perceptions and social relations. So, in principle, it is possible that the regime remains fairly stable in the face of external pressures, if the social network of incumbent actors remains closed and actors remain confident in current practices.
5) Combine the findings from task 2, 3 and 4 to provide interpretive conclusions about the degree to which existing (sub)regimes are still stable and locked-in, and where (if at all) tensions are emerging.

Report structure

Each domain/country report will apply this protocol and use the following report structure top report the research findings.

Title page
Executive summary
Contents

1. Introduction
- articulates goal and research question
- provides a static or structural description of the overall system with multiple regimes
- articulates the focus (e.g. land-based passenger transport in mobility system).
- discuss data-sources

2. Describe overall system trends in terms of overall environmental performance, sub-systems and longitudinal developments

3. Describe the main external landscape developments that influence the system

Then successive chapters will analyse the different sub-systems and regimes, e.g. for mobility system this could entail car system, train/rail system, bus/coach system, cycling.

4. Development in car system and regime
4.1. Describe developments of the main tangible system elements
4.2. Describe the main social groups and intangible regime elements (including views/responses to external landscape pressures)

5. Developments in rail/tram system and regime
5.1. Describe developments of the main tangible system elements
5.2. Describe the main social groups and intangible regime elements (including views/responses to external landscape pressures)

6. Developments in bus/coach system and regime
6.1. Describe developments of the main tangible system elements
6.2. Describe the main social groups and intangible regime elements (including views/responses to external landscape pressures)

7. Developments in cycling system and regime
7.1. Describe developments of the main tangible system elements
7.2. Describe the main social groups and intangible regime elements (including views/responses to external landscape pressures)

8. Conclusions about stability and cracks/tensions in the different (sub)regimes. The conclusions will be reported in tables that explicitly address: 1) the stabilising forces that contribute to regime lock-in, path dependence and incremental change, 2) the cracks, tensions and problems in regime that provide potential windows of opportunity for more substantial change.

References

Arthur, W.B., 1989, 'Competing technologies, increasing returns, and lock-in by historical events', *Economic Journal*, 99(394), 116-131

Bergek, A., Berggren, C., Magnusson, T., and Hobday, M., 2013, 'Technological discontinuities and the challenge for incumbent firm: Destruction, disruption or creative accumulation?', *Research Policy*, 42(6-7), 1210-1224

Berggren, C., Magnusson, T., Sushandoyo, D., 2015, Transition pathways revisited: Established firms as multi-level actors in the heavy vehicle industry, *Research Policy*, 44(5), 1017-1028

Berkers, E. and Geels, F.W., 2011, 'System innovation through stepwise reconfiguration: The case of technological transitions in Dutch greenhouse horticulture (1930-1980)', *Technology Analysis & Strategic Management*, 23(3), pp. 227-247

Fuenfschilling, L. and Truffer, B., 2014, The structuration of socio-technical regimes—Conceptual foundations from institutional theory, *Research Policy*, 43(4), 772-791

Geels, F.W. (2002), 'Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study', *Research Policy*, 31(8-9), 1257-1274

Geels, F.W., 2004, 'From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory', *Research Policy*, 33(6-7), 897-920

Geels, F.W., 2005, *Technological Transitions and System Innovations: A Co-evolutionary and Socio-Technical Analysis*, Cheltenham: Edward Elgar

Geels, F.W., 2006, 'Major system change through stepwise reconfiguration: A multi-level analysis of the transformation of American factory production (1850-1930), *Technology in Society*, 28(4), 445-476

Geels, F.W. and Schot, J.W., 2007, 'Typology of sociotechnical transition pathways', *Research Policy*, 36(3), 399-417

Geels, F.W. and Verhees, B., 2011, 'Cultural legitimacy and framing struggles in innovation journeys: A cultural-performative perspective and a case study of Dutch nuclear energy (1945-1986)', *Technological Forecasting & Social Change*, 78(6), 910-930

Geels, F.W., 2011, 'The multi-level perspective on sustainability transitions: Responses to seven criticisms', *Environmental Innovation and Societal Transitions*, 1(1), 24-40

Geels, F.W., 2014a, 'Regime resistance against low-carbon energy transitions: Introducing politics and power in the multi-level perspective', *Theory, Culture & Society*, 31(5), 21-40

Geels, F.W., 2014b, 'Reconceptualising the co-evolution of firms-in-industries and their environments: Developing an inter-disciplinary Triple Embeddedness Framework', *Research Policy*; 43(2), 261-277

Hall, P.A., 1993, 'Policy paradigms, social learning and the state: The case of economic policy making in Britain', *Comparative Politics*, 25(3), 275-296

Hargreaves, T., Longhurst, N. & Seyfang, G. (2013), Up, down, round and round: connecting regimes and practices in innovation for sustainability. *Environment and Planning A,* 45, 402-420.

Hilman, A. and Hitt, M., 1999, 'Corporate political strategy formulation: A model of approach, participation, and strategy decisions', *Academy of Management Review*, 24(4), 825-842

Hoffman, A.J., 1999, 'Institutional evolution and change: Environmentalism and the US chemical industry', *Academy of Management Journal*., 42(4), 351-371

Holtz, G., Brugnach, M. and Pahl-Wostl, C., 2008, 'Specifying "regime": A framework for defining and describing regimes in transition research', *Technological Forecasting and Social Change*, 75(5), 623-643

Hoogma, R., R. Kemp, J. Schot, and B. Truffer (2002), *Experimenting for Sustainable Transport: The Approach of Strategic Niche Management*, London and New York: Spon Press

Jørgensen, U., 2012, Mapping and navigating transitions—The multi-level perspective compared with arenas of development, *Research Policy*, 41(6), 996-1010

Kemp, R, J. Schot and R. Hoogma (1998), 'Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management', *Technology Analysis and Strategic Management*, 10(2), 175-196

Lawhon, M. and J.T. Murphy (2012), 'Socio-technical regimes and sustainability transitions: insights from political ecology', *Progress in Human Geography*, 36(3), 354-378

Levy, D.L. and Newell, P. (2002), "Business strategy and international environmental governance: Toward a Neo-Gramscian synthesis" *Global Environmental Politics*, 2(4), 84-101.

Lindblom, Charles E. (2001). *The Market System. What It Is, How It Works, and What To Make of It.* New Haven, CT: Yale University Press

Markard, J., Truffer, B., 2008, 'Technological innovation systems and the multi-level perspective: towards an integrated framework', *Research Policy*, 37(4), 596-615

Nelson, R.R. and S.G. Winter (1982), *An Evolutionary Theory of Economic Change*, Cambridge (Mass.): Belknap Press

Newell, P. and Paterson, M., 1998, 'Climate for business: Global warming, the State, and capital', *Review of International Political Economy*, 5(4), 679-704

Oudshoorn, N. & T. Pinch (eds.) (2003), *How Users Matter: The Co-Construction of Users and Technology*, Cambridge, Massachusetts: MIT Press

Rip, A. and R. Kemp (1998), 'Technological change', in: S. Rayner and E.L. Malone (eds), *Human Choice and Climate Change*, Columbus, Ohio: Battelle Press. Volume 2, pp. 327-399

Seo, M-G and Creed, W.E.D., 2002, 'Institutional contradictions, praxis and institutional change: A dialectical perspective', *Academy of Management Review*, 27(3), 222-247

Smith, A., Jan-Peter Voβ, J.-P., and Grin, J., 2010, 'Innovation studies and sustainability transitions: The allure of a multi-level perspective and its challenges', *Research Policy*, 39(4), 435-448

Unruh, G.C. (2000), 'Understanding carbon lock-in', *Energy Policy*, 28(12), 817-830

Van Driel, H. and Schot, J., 2005, 'Radical innovation as a multi-level process: Introducing floating grain elevators in the port of Rotterdam', *Technology and Culture*, 46(1), 51-76

Van de Poel, I. (2000), 'On the role of outsiders in technical development', *Technology Analysis & Strategic Management*, 12(3), 383-397

Van de Poel, I. (2003), 'The transformation of technological regimes', *Research Policy*, 32(1), 49-68

2. Research findings from different country sub-reports

The sections below report the findings from the executive summaries of the 11 country-domain reports that underlie this main report for deliverable 2.2. The full reports are available on the website of the PATHWAYS-project (http://www.pathways-project.eu/).

2.1. Regime analysis of the German electricity system

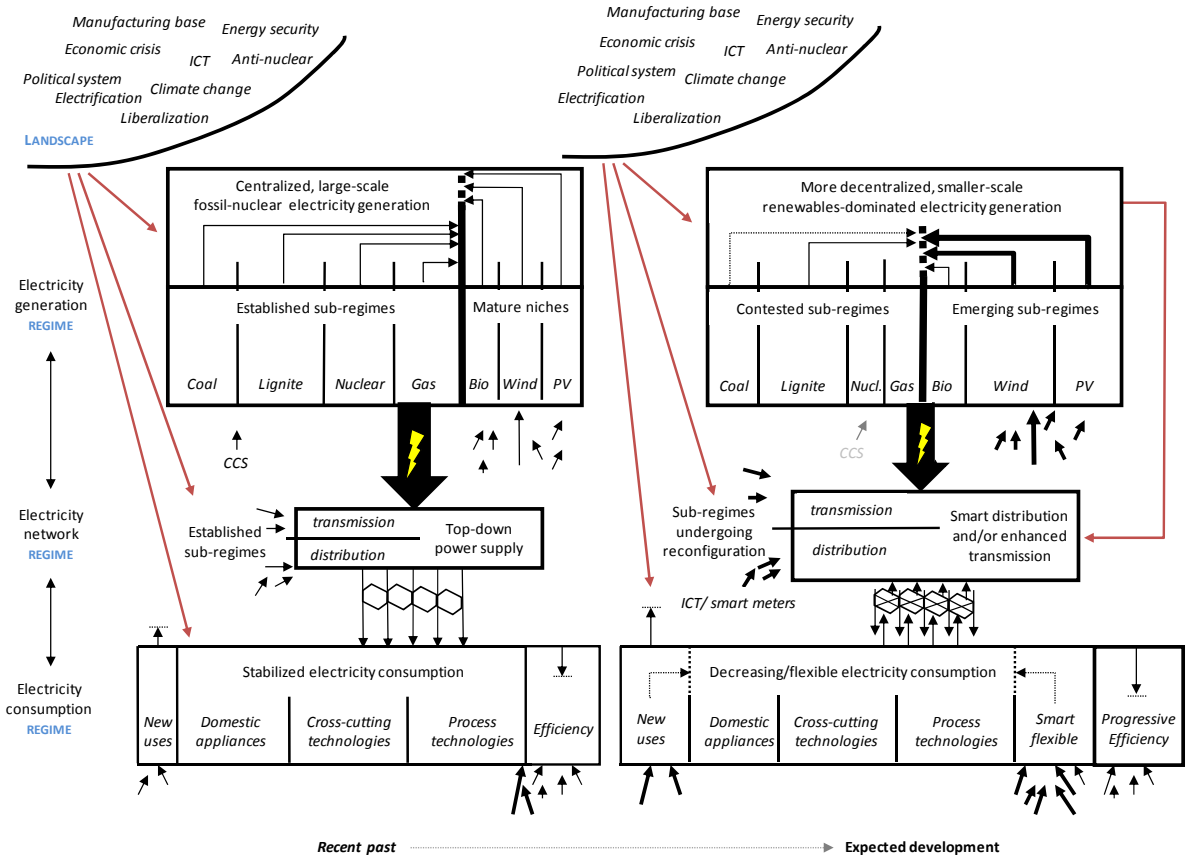
The analysis of stability and tension in the German electricity regime will shed light on two aspects: first, the main external landscape developments relevant for the German electricity regime which could potentially create pressure on the regime, and second, the development of the German electricity regime, which, if destabilized, could create windows of opportunity for a wider diffusion of green niche innovations, such as wind, PV or smart metering. Regarding the first aspect, we find that many of the exogenous landscape developments put pressure on the existing regime and thus destabilize it, although some factors also contribute to stabilizing the electricity regime.

- Perhaps the most influential landscape factor has been Germany's *strong anti-nuclear movement.* There was a very strong public reaction to two nuclear accidents abroad, the first one at Chernobyl in the Ukraine in 1986 and the second at Fukushima in Japan in 2011. This ultimately led to a cross-party agreement to phase out nuclear power in Germany by 2022, thus bringing the country back on track with the initial phase-out negotiated by the government of Social Democrats and Greens under Gerhard Schroeder in 2000.
- The global issue of *climate change* has been on the political agenda since 1989 (Helmut Kohl) and has increased in importance since then. This is evidenced by the European CO_2 price signal introduced through the EU emissions trading system in 2005, the pivotal role played by the "climate chancellor" Angela Merkel in adopting the EU's 20-20-20 energy and climate targets for 2020, and Germany's ambitious climate targets for 2050. However, attention to climate change at the top level of government has declined since 2008 and particularly since the failure of Copenhagen in 2009, although there have been some recent signs of a revival given the increases in CO_2 emissions and the lurking gap in target achievement.
- The *liberalization* of the electricity market and the unbundling of utilities driven by EU regulation broke up the oligopoly market structures in Germany and led to a restructuring of the industry, resulting in four big, internationally more active electricity suppliers and four big transmission system operators.
- The *German proportional voting system* that allows small parties (with a share over 5%) to send the corresponding number of representatives to parliament made it possible for the Green Party to enter the national parliament in 1983, thereby giving a parliamentary voice to "Green" concerns (about the climate, nuclear accidents, nature conservation). When the Greens became part of a coalition government with the Social Democrats (1998-2005), they were able to use their influence to introduce the Renewable Energy Act (EEG) in 2000 and defend it in 2004, despite strong opposition from regime stakeholders. With hindsight, the introduction of the EEG can be interpreted as the most influential policy change as it sowed the seeds for and functioned as a catalyst for the German Energiewende.
- As an *engineering and manufacturing nation* and export champion, Germany plays a driving role in developing renewable energy technologies, such as solar PV or wind, and the German government is harnessing this innovativeness through its High-Tech

Strategy and its recognition that environmental policy can function as industrial policy, creating green growth, jobs and income.

- The *financial and economic crisis* brought about a fairly moderate and relatively temporary decline of industrial electricity demand in 2009, but in the longer term it has led to a fairly strong decline in electricity spot market prices and thereby to lower profit margins for electricity generation.
- There are also wider *environmental sustainability concerns* such as nature conservation and the protection of biodiversity, which lead to public resistance to CCS, scepticism about shale gas, or debates about corridors for new transmission lines.
- The industrial structure in Germany with several *energy-intensive branches* calls for reliable supply and low electricity prices in order to safeguard its international competitiveness and safeguard jobs and income at home.
- *Energy security* concerns, particularly regarding the dependence on Russian gas, cast a favourable light on lignite as a domestically available energy source (but also benefit renewable energies).
- The *electrification of mobility and heat* is expected to increase electricity demand in the coming decades. This will supplement the expected rising demand from IT equipment (laptops, mobile phones, tablets), thereby providing good growth prospects for electricity suppliers.
- *Green ICT (smart technologies),* which is favoured by German policy and European Directives (Ecodesign and Labelling, Energy Star), could influence regime development, especially in the longer term, but has already had an impact. However, the potential use of smart meters, which are strongly driven by EU regulation, may be limited due to high data protection standards.

Regarding the second aspect – regime developments – we distinguish three interrelated sub-systems: electricity generation, electricity transmission and electricity use, as depicted in the figure below. For these three sub-systems, the analysis focuses on the regime level and splits this into different sub-regimes. For the electricity generation regime, we discuss sub-regime developments for coal and lignite, nuclear, and gas-fired electricity generation. For electricity grids, we differentiate between transmission and distribution networks. For electricity demand, we highlight developments in domestic appliances, cross-cutting and process technologies in industry and services, and new uses. The interplay and expected regime changes are summarized in the following graph:



The analysis of developments within the German electricity system has highlighted that the interconnected regimes of electricity generation, transmission and consumption are experiencing significant landscape pressures (anti-nuclear movement, climate change, energy security, liberalization) and knock-on effects from the resulting growth of increasingly mature niches and interactions between the three regimes.

The resulting change is most advanced in the electricity generation regime, in which the mature niches of wind, PV and bioenergy have expanded so radically that at least PV and wind are on the brink of becoming new sub-regimes that are driving the regime in the direction of much more decentralized and smaller scale electricity generation based on renewable energies. This transformation of the generation regime creates pressures on the transmission regime, which has started to adjust to the new circumstances of more fluctuating, at times bi-directional electricity flows. Even the quite stable electricity consumption regime, which so far has experienced mainly incremental changes, is coming under increasing pressure to make the changes needed for the overall success of the low-carbon transformation of the German electricity system, both in terms of radical cuts in electricity demand (despite additional uses, such as e-mobility) and increasing the flexibility of use. In the following, for each of the regimes, we summarize our conclusions on the most important stabilizing and destabilizing developments.

Electricity generation regime

Over the period from 1990 until today the German electricity generation system has witnessed major landscape pressures – most importantly a strong anti-nuclear movement paired with concerns about climate change. Additional tensions have resulted from the increasing impacts of the emerging niches of wind, solar PV and bioenergy, which have expanded significantly and can now start to be viewed as new sub-regimes (see table below).

The sheer size, different ownership structure and characteristics of these emerging green sub-regimes have meant fundamental changes along many dimensions of the German electricity regime. This regime is now transforming from one characterized by centralized, large-scale electricity generation dominated by large utilities to a much more decentralized, and smaller scale electricity generation regime based on renewable energies, with the ownership of generation capacities spread across a multitude of new entrants, including a high share of citizens, farmers and cooperatives. In addition, the established business models of the incumbent utilities are eroding. Indeed, while the large incumbents have undergone multiple changes in beliefs and are now investing in large-scale renewable energies, their long-term survival is still at stake because of their lack of business model capabilities to harness the chances and opportunities from the ongoing energy transition. In 2012 and 2013, however, the decarbonisation of the electricity generation system experienced a setback due to rising shares of lignite and hard coal in the generation mix – despite declining capacities. There have also been recent changes in the key policy instrument supporting the expansion of renewable energies, the EEG, which indicate a change in policy favouring larger investors. This is partly due to pressures to advance the market integration of renewables, and partly due to political concerns about the ever-increasing EEG surcharge, which is largely borne by private electricity consumers because of the exemptions for energy-intensive industries. Hence, while nuclear phase-out and the transition towards renewable energies are not being questioned, there are ongoing disputes about what the future regime will look like (e.g. regarding the degree of decentralization) and who the winners and losers will be.

GENER-ATION	**Lock-in, stabilizing forces**	**Cracks, tensions, problems**
External landscape pressures	WEAK - Further electrification of society (heat, mobility, ICT) potentially leading to increased electricity demand - Maintaining competitiveness of energy-intensive industries	STRONG - Very strong anti-nuclear movement - Climate change and nature conservation taken very seriously - Federal political system with proportional voting (enabling Green Party in government coalitions and initiatives at national, federal and local levels) - Liberalization and unbundling of electricity markets - Engineering and manufacturing nation benefitting economically from the development and sale of renewable energy technologies - Financial and economic crisis reducing electricity demand and electricity prices - Geo-political tensions with Russia (gas) and security of supply concerns
Utilities	MODERATE - Sunk investments in power plants, and commitment to existing technologies and resources (particularly lignite as domestic resource)	STRONG - Acknowledgement of climate change and policy target of decarbonisation of electricity system by 2050, but struggling with identifying aligned strategy

	- Business model and internal knowledge focuses on centralized, large-scale power generation - Attempts to socialize burden from second nuclear phase-out (court cases) - Especially in the early years, hardened fronts between utilities and renewable energies (losing market shares to new entrants) - Critical regime players for reliable electricity production, job creation, generation of public income due to still big, albeit shrinking, market shares - Beginning involvement in larger-scale renewables (e.g. offshore wind)	- Growing realisation of the misalignment between old business model (large-scale fossil-nuclear) and new market realities due to increasing shares of intermittent, decentralized renewable electricity and phase-out of nuclear (similarly pending for coal due to unavailability of CCS and politically stable long-term climate targets) - Financial difficulties, reduction in staff, restructuring in an attempt to survive the energy transition - Loss of influence in policy circles (compared to very close links between policy-makers and the "'big 4'" utilities (E.ON, RWE, Vattenfall, EnBW) in the past)
Consumers	MODERATE - Electricity consumption is an essential part of private and professional life and is taken for granted - Only limited switching of customers between electricity providers thereby reducing retail price competition and the pressure to pass on spot market electricity price reductions of renewables - Marketing efforts of retailers to sell existing hydropower as "green electricity" (greenwashing) successful to some extent - Consumers are paying for renewables through EEG surcharge, leading to complaints about rising electricity bills and concerns about distributional fairness	MODERATE - Several green electricity tariffs exist, but demand for these is lower than the current share of renewable electricity generation (15 vs. 25%) - Attempts to reduce electricity demand by switching off lights, using energy saving light bulbs or LEDS, and reading energy labels when buying appliances (see consumption regime)
Policy-makers	MODERATE - Strong support of new entrants and private investors in the past, but in recent years, increased attention to cost and management considerations favouring larger investors (having surpassed 25% of electricity generated from renewable energies, debates about rising EEG surcharge and pressure from the EU) - Economics ministry for a long time on the side of large incumbents and blocking transition to decentralized renewables, but with counterpart of	STRONG - Climate policy has introduced a new environmental policy style with targets supported by economic instruments (eco-tax, EU ETS), but political attention to climate change has ebbed since 2009 (lack of leadership in fixing low CO2 price in EU ETS, high priority to costs and competitiveness). Renewed momentum during the run-up to influential 2015 COP in Paris - German government has focused the most climate change attention on electricity generation, with strong policies supporting

	environment ministry, which was in charge of renewables and promoted new entrants - Explicit niche protection of offshore wind as large-scale renewable energy technology promoting industrial development of economically deprived coastal regions and accommodating big utilities (since 2002, but recent reduction of 2020/30 targets in 2014) - Regional governments of coal- and lignite-rich federal states block destabilization policies phasing out coal (e.g. NRW)	the expansion of renewable energies (EEG) and reconfirmed phase-out of nuclear (cross-party support in 2010 after Fukushima) - The energy transition is a political flagship project with front-page coverage - missing policy targets would damage the reputation of leading politicians such as the Economic Minister Gabriel (Vice Chancellor, responsible for energy transition) - Recent shift of energy expertise from environment ministry to economics ministry signals greater political attention to the energy transition's success and cost minimization, but could also undermine the focus on decentralized, citizen-investor-driven transition - Difficult search for safe site for future storage of nuclear waste
Public debate and opinion	WEAK - Debates about rising electricity prices and distributional unfairness caused by exemption rules for energy-intensive industry, but energy transition as such not questioned - Local concerns about loss of jobs in coal regions, but research has shown positive net employment effect from transition to electricity generation based on renewable energies	STRONG - Open and engaged debates about how to achieve a radical transformation of the energy system at all governance levels (including city initiatives), and central media coverage - High public acceptance of transition to electricity system based on decentralized renewable energies linked to strong anti-nuclear movement, negative image of large utilities, large share of private investors benefitting from feed-in tariffs (e.g. rooftop PV) and job creation effect of renewables - Strong opposition to storing CO2 underground and to shale gas, increasing resistance to coal-fired power plants
Pressure from social movements, NGOs, scientists	WEAK - Some neoclassical economists continue to argue for emissions trading as a least-cost solution, i.e. suggest abandoning the EEG, but despite high visibility, they have lost much of their influence in public and particularly policy debates	STRONG - Most NGOs advocate radical, decentralized renewable electricity technologies that deviate from the existing regime, and are important voices in public debates - Growth of environmental think-tanks and scientists with strong modelling capacities, who are actively advising policy-makers, industry and NGOs, highlighting cost-effective ways of achieving decarbonisation and renewables targets without nuclear - Highlighting high costs of nuclear and feasibility of electricity system based on PV and wind

Overall assessment	WEAK The electricity regime is undergoing radical changes which at this point seem irreversible, implying that the main future sub-regimes will be PV and wind with some flexible back-up (gas, biomass), but there is an ongoing dispute about the final regime dimensions. Resistance from regime actors is focused on reducing losses, buying time and identifying new business models to ensure survival in the new regime	STRONG There are major and most likely irreversible tensions and cracks in the electricity generation regime. The climate change problem and anti-nuclear movement has led to significant institutional changes, e.g. ambitious GHG reduction, RES expansion and nuclear phase-out targets and specific policies. The resulting structural changes in infrastructure (renenewable energy makes up 50% of generation capacity, with a negligible share owned by large incumbents) with their reduction of electricity market prices and thus decreased profitability of existing conventional plants are forcing large incumbents to rethink their beliefs and strategies

Stability and tensions in the German electricity generation regime

Electricity consumption and end-use regime

The consumption side of the electricity regime is evolving incrementally through the interplay of several dynamics which may have a reverse effect on the development of electricity consumption. Changes in the range and absolute number of electrical products and to production and employment in the industrial and service sectors have the predominant effect of increasing electricity consumption. These factors dampen the rise of electricity consumption only during periods of economic recession. Another growth-stimulating effect is the still ongoing trend to greater automation and widespread diffusion of new electrically powered applications and technologies (as e.g. information and communication technologies, electric vehicles and electric heat pumps). On the other hand, energy efficiency innovations have helped to suppress increases in electricity consumption. These manifested themselves in manufacturers' efforts to increase the energy efficiency of electric household appliances and cross-cutting technologies (e.g. electric motors, lighting, ICT) and the increasing market penetration of such technologies. This development was stimulated to a large extent by the EU's and national governments' policy measures. However, it is often unclear how behavioural and organisational changes impact the purchase and use of electric appliances and products in private households and companies. They can have a decreasing effect on electricity consumption, often stimulated by informational and advice programmes, but the opposite is also possible, e.g. through rebound effects.

These patterns can be understood in the context of competing landscape pressures (see table below). On the one hand, concerns about climate change and energy security as well as the favourable side-effects of energy efficiency have exerted pressure on the consumption regime, generating the drive towards greater energy efficiency. On the other hand, the trend towards greater electrification of households and companies is an important stabilizing force on the regime. The following table summarizes the countervailing pressures exerted by the different actors in the electricity consumption regime.

CONSUMP-TION	**Lock-in, stabilizing forces**	**Cracks, tensions, problems**
External landscape pressures	MODERATE - Future trend towards greater electrification in all end-use sectors (ICT, electric mobility, heat pumps)	STRONG - Favourable economic side-effects of energy efficiency on economic growth, employment, competitiveness of the economy and others (the so-called "multiple benefits" of energy efficiency; IEA 2014) are a strong argument to address more efficient use of electricity - Climate change and energy security also place pressure on regime to address electricity consumption levels
Industry	STRONG - For retailers and wholesalers, the energy efficiency of appliances and products sold is not at the top of their agenda - Producers of electricity-using products try to prevent progressive energy efficiency standards which would favour smaller appliances by lobbying activities - Weak control of compliance with the regulations for electricity-related products (minimum energy efficiency standards, labelling) concerning both retailers and producers in Germany limits these groups' actions on energy efficiency issues - Exemptions from several taxes and surcharges on the electricity price for large industrial electricity consumers lower their incentive to invest in energy efficiency - Electricity utilities (especially the "'big 4'") tend to be rather conservative and reluctant to develop new business models for energy services	MODERATE - German producers have a strong market position in the field of high-quality electrical household appliances and electrical cross-cutting technologies for industry and commerce; these products are usually also highly efficient - A relatively new association of the German energy efficiency industry (DENEFF) has become a stronger voice of German energy efficiency businesses
Consumers	MODERATE - Tendency to purchase larger and more appliances in the field of consumer electronics (e.g. large TV screens) and information technologies in private households and parts of the service sector (retail trade, hotels and restaurants) - Negative public reaction to energy	MODERATE - High electricity prices in Germany, especially for private households and small companies, favour investments in energy-efficient products and – though less pronounced – promote electricity-saving behaviour - Consumer groups and energy agencies at the national, regional and local levels

	efficiency standards for some goods, e.g. vacuum cleaners or shower heads, stabilize existing regime dynamics	campaign for the purchase of energy-efficient-products and behavioural changes with regard to electricity consumption
Policy-makers	STRONG - No support for progressive energy efficiency standards favouring smaller electrical products - Sufficiency aspects about the level of energy demand are widely neglected when designing policy measures	MODERATE / STRONG - Ambitious targets set for energy efficiency (also including a reduction target for electricity) in the Energy Concept of 2010 and implementing the policies from the new National Energy Efficiency Strategy of December 2014 mean that energy efficiency is becoming more and more established as the 2nd pillar of the Energiewende (alongside the expansion of renewable energies)
Public debate and opinion	MODERATE - High data protection standards limit the spread of smart metering, smart appliances and smart homes, which otherwise could help to reduce electricity consumption.	WEAK - Debates about the very high electricity prices in Germany for private households and small businesses, but these are mainly directed at the generation sub-regime, rather than at consumption and appliance use
Pressure from social movements, NGOs, scientists	WEAK - Some scientists (but not the majority) argue that specific policies addressing electricity efficiency and consumption at the level of end-uses are not necessary or even counter-productive if a well-functioning emissions trading system exists - In general, energy efficiency suffers from a relatively weak lobby, as it has fewer beneficiaries than, for example, investments in renewable energy	WEAK - Other scientists and NGOs criticise that rebound effects and sufficiency issues are not taken into account enough by the policy-makers
Overall assessment	MODERATE / STRONG The future trend towards greater electrification in some fields (ICT, electric mobility, heat pumps) and some rebound effects (e.g. in lighting) may counteract the efforts to reduce electricity consumption. There are some important actors for whom energy efficiency is not a top priority (esp. electricity utilities, retailers and wholesale trade); this may undermine the efforts to increase efficiency and reduce electricity demand.	MODERATE There is a relatively broad consensus of all affected groups on the benefits of energy /electricity efficiency and the political target of reducing electricity consumption.

Stability and tensions in the German electricity consumption regime

Electricity network regime

Over the period from 1998 until 2015, the German electricity networks have been experiencing major challenges to the traditional operating strategies of the power system. Major drivers were developments in the generation structure with the emerging niches of wind, solar PV and bioenergy as well as the nuclear phase-out driven by the anti-nuclear movement. Another major factor at landscape level was the push for liberalization and unbundling of the electricity sector initiated and pursued by the EU from 1996 to 2009 with three waves of liberalization directives.

Changes in generation structure have challenged and are still challenging the system physically and require network expansions. However, since network expansion is not keeping pace with the changes, is plagued by acceptance issues and might not always be the most efficient solution, adaptations in network operation and management are also required. To some extent, this is taking place already with network operators engaging in redispatch and generation management. However, so far, this is mainly being managed centrally via the network operators and (nearly) limited to emergency situations. A wider use of flexibility options is being discussed, but the framework to implement this is still missing. This shifts the focus to the flexible management of generation and supply, optimization via smart grids using intelligent control and metering as well as storage solutions. It may therefore push the niche development of smart metering. Overall, the system is moving from centralized, top-down management towards a more decentralized, interactive system, but so far this is mainly happening on a physical level. This represents a challenge for the networks, some of which are approaching their limits already, but which cope mainly using existing measures. In the future, roles, responsibilities and regulations will have to be modified to be able to adapt operations to these changes. At the same time, transmission networks are also being enhanced by innovative technologies and it is not yet clear what the network regime of the future will look like and how it will combine smarter distribution and expanded and enhanced transmission (probably also long-distance, high-voltage transmission to connect with other countries).

The network business as a centrally regulated activity is relatively stable per se, but is undergoing reconfiguration. Changes to regulation have been made to adapt it to the investment needs and quality demands which enable further changes in the future.

NETWORK	**Lock-in, stabilizing forces**	**Cracks, tensions, problems**
External landscape pressures	MODERATE - EU directives on network regulation, network tariffs as well as international technical agreements	HIGH - Increase of DG, (fluctuating) renewable generation, phase-out of nuclear and perhaps also coal/lignite within generation regime puts pressure on network with increasing congestion and need for redispatch - Development of ICT and information society -> new technological possibility such as smart grids may foster flexible integration of demand-side and generation-side resources into network management
Industry	MODERATE - Investments in grid infrastructure, long-lived assets	MODERATE - Some assets, particularly in distribution networks, are at the end of their lifetime and

	- Incumbent companies rooted in old model of centralized power generation and transport of power "top-down" - Problems of refinancing, insufficient interest in investments plus time lag in recognition of investments in regulation have since changed. Similarly, problems of refinancing innovative technologies (in particular operational advances) are now being at least partially addressed in the regulation	have to be renewed in any case, which may be a good moment to switch to more advanced network management/ intelligent components, i.e. combining network renewal with upgrades - Unbundling formerly integrated incumbents (generation and network) makes network companies more focused on solely network operation and cost-efficiency. Incentives for innovation and quality are set separately via regulation to contain cost-efficiency incentives. - Operational model for networks is changing forced by DG and RES -> reverse power flows -> network operators are under pressure to change and changes in the regulatory framework have been necessary (partially realized already) - New actors promoting the use of flexibility since they see a business model in it
Consumers	MODERATE - Recent concerns about rising network tariffs and spatial inequality - Whether or not potential new roles of consumers (e.g. with DSM) will actually have a large impact on the systems remains to be seen	MODERATE - Rising network tariffs partially caused by renewables plus locational inequality - Problem of self-generation and concerns about solidarity in cost sharing of the network (focus of debate is PV and household consumers, industrial self-generation not such a big issue) - Network tariffs and exemptions for industrial consumers are a big issue. More contribution from privileged consumers to relieve network desired and may be required for privileges to be granted in future
Policy-makers	HIGH - regulatory system - technical aspects and (international) guidelines (e.g. within the network of European Transmission System Operators ENTSO-E) limit or slow down the options for radical change - grid operators are not allowed to be active on the supply side due to unbundling of the sector; this limits their options to assume new roles, for example, by operation flexibility measures (this obligation derives from EU regulations) - regulatory incentives can help to steer	HIGH - The focus on expanding renewable generation also puts networks in the limelight since they are needed to integrate the renewable power. Several laws to speed up network expansion have been passed. Even though their effectiveness remains to be seen, this seems to be a big step in the right direction. - Attention only paid to transmission networks to start with but now increasingly to distribution networks as well. - Research programmes and financial support for RD&D in smart grids, networks for the future and innovative network technologies

	network development, but the Federal regulator seems to be conservative and relatively slow in adapting the framework for network development and recognizing expenditure for innovative activities. However, recent changes mean that some pure R&D activities are now recognized. So far, regulation does not clearly target a low carbon power system. - Strong opposition of state/local politicians to the construction of new transmission lines	with the aim to drive diffusion and practical experiences with new technologies and operational concepts featuring greater flexibility.
Public debate and opinion	HIGH - New transmission lines face massive acceptance problems - Some NGOs argue that the new transmission lines are more useful for lignite power plants than for renewables	HIGH - Plan N as a project to reconcile different positions and find a way forward
Pressure from social movements, NGOs, scientists	MODERATE - Local resistance/ citizen initiatives (at local level) against network expansion/ construction - Environmentalists (collision of birds with overhead lines)	HIGH - Scientists claim that more flexibility and more advanced flexible pricing are needed to reduce network congestion and restrict expansion - Inequality with respect to network tariffs and exemptions for energy-intensive industry
Overall assessment	MODERATE A long-lived assets structure and regulation stabilize the existing regime. Regulation changes (such as targeted investment incentives to spur certain developments) can theoretically be realized more easily, but seem to be slow and are not likely to result in radical changes but only gradual adaptations of the regulatory framework.	HIGH Renewable integration and increase in decentralized generation require adaptations to the network management and structure. This has already led to some changes being made to the regulatory framework that allow and encourage network operators to make such adaptations. The changes also improve the incentives for network expansion, increase acceptance and streamline administrative processes. There is a strong consensus that network expansion is needed at the transmission level as well as the expansion and greater intelligence of distribution networks. Further changes are targeted with adaptations in the regulatory framework and network access conditions and could trigger the reconfiguration of the network regime.

Stability and tensions in the German electricity network regime

2.2. Regime analysis of the UK electricity system

A characteristic of the electricity system is that the electricity grid acts as a 'buffer' between production and consumption. Our analysis therefore focuses on three sub-regimes in the UK: 1) electricity generation, which includes coal, gas and nuclear power, 2) domestic electricity consumption, which includes end-use functions such as lighting, electric cooking, and powering various appliances and devices, 3) electricity networks (transmission and distribution grid). The discussion and tables below summarise the findings about stability and tensions/problems for these three regimes in the UK.

Electricity generation regime

The UK electricity generation regime has been remarkably resilient in terms of ongoing commitment to regime technologies (nuclear, gas, coal) and in terms of the relative stability of the core alliance between policymakers and utilities, which led some scholars to characterize the UK policy style as 'working with incumbents' (Geels *et al*., 2014). The prominence of new entrants in UK electricity generation has remained relatively limited, although their numbers have increased on the fringes (but with small market shares). Coal and nuclear power seemed on their way out in the 1990s, the former because of the 'dash for gas' and the latter because of privatization/liberalization (with the new companies perceiving nuclear power as too expensive and risky because of legacy costs and waste problems). But both have made a come-back in the 2000s, because of low-costs and energy security concerns (for coal) and low-carbon emissions (for nuclear). The 2003 White Paper, which introduced climate change as a core issue into energy policy, created some tension because it privileged renewable energy and did not foresee a future role for nuclear power. By 2005, however, this threat was repaired (partly because of personal interventions by Prime Minister Blair, who used his power to reframe the policy agenda), leading to a re-appearance of nuclear power and coal on the energy policy agenda.

So, incorporation of the landscape issue of climate change into electricity generation policy initially led to some regime tension (and pressure on existing technologies). But ever since the 2007 White Paper, UK climate policy includes nuclear power and coal with CCS besides renewable energy technologies. The refusal of the UK government to commit to post-2020 renewable electricity targets suggests that policymakers and industry remain committed to existing regime technologies, although in different degrees and ways.

* The government has committed to a 'nuclear renaissance', based on plans to build 8 new nuclear plants by 2025, delivering 16 GW new capacity. The plan for the first new plant (Hinkley C) is already delayed 5 years, with the opening date pushed back from 2018 to 2023. Negotiations for two more nuclear plants are under way, but not yet concluded. Discussions about the other five plants have not yet started.
* The government and utilities plan a substantial expansion of up to 40 new gas-fired power stations, delivering 16-25 GW by 2030. These power stations are not expected to use CCS, which led the Committee on Climate Change (CCC) to warn that such an expansion would be incompatible with climate change targets.
* Many of the relatively old coal-fired power plants are supposed to be phased-out in the next 8 years under the European LCPD-directive. The utilities wanted to build new coal-fired power plants, but the government stipulated that this could not happen without the use of CCS. CCS is progressing very slowly, however, without a great sense of urgency. Plans for two subsidized demonstration projects are already 5-6 years delayed. So, although the government envisages a future for coal-with-CCS in the 2020s, current developments are not pointing in that direction. Under current developments and policies, coal-use would gradually be phased out, which would create serious capacity problems, especially since the

construction of new nuclear plants is facing major delays. The government has not unequivocally said that all coal-fired plants need to be phased out in the 2020s.

So, current developments in generation technologies will create serious tensions in the next 10 years. If the government sticks to climate change targets and current coal policies, then the electricity-generation regime will face serious capacity problems. If the government wants to address the capacity problems by building new coal-fired plants *without* CCS, then it is unlikely to meet its climate change targets. One should not ignore the (devious) possibility that the second option is actually the government's strategy (i.e. using capacity problems as an argument to build new coal-fired plants, thereby forcing a debate about dropping or weakening the climate change targets of the 2008 Climate Change Act (see also Lockwood, 2013). This would be in line with recent political counter-trends such as concerns (especially in the Conservative Party) that climate change has gained too much political importance and has unhelpfully contributed to rising energy costs (which led to a political controversy in late 2013). The plan to expand unabated gas-fired plants also points in this direction, as the government has simply brushed aside warnings that this expansion will threaten climate change targets.

Social networks in the electricity generation regime have remained relatively stable, especially the alliance between policymakers and utilities, which consult and negotiate in many ways. Nevertheless, there have been some changes in institutions and governance styles:

- The 2008 Climate Change Act has been followed by a raft of implementation plans, and changes in policy instruments (e.g. 2009 amendments in the Renewables Obligation, the 2013 Electricity Market Reform with 'strike prices' for various low-carbon options).
- A shift in governance style from a hands-off approach to greater interventionism (but the policy style still remains very market-oriented, based on reshaping markets by creating attractive financial incentives for low-carbon technologies)
- Utilities and other private actors have changed their beliefs in terms of acknowledging climate change as an important issue that needs to be addressed (although this belief may have weakened because of recent political counter-trends and cost debates). This belief has also affected innovation and investment strategies (e.g. new nuclear power, new gas turbines, and some exploration of CCS yet no firm commitment).

In sum, there are not yet major cracks in the existing regime. Instead, core regime actors (utilities and policymakers) are gradually reorienting themselves by adjusting their beliefs and strategies. So, the unfolding pattern is a negotiated and controlled transformation of the existing regime, tailored to incumbent interests rather than to meeting long-term climate change targets. There are currently limited signs of 'opening up' of the regime, because of major cracks and tensions. Future tensions may, however, arise from capacity problems resulting from slow nuclear expansion, phase-out of unabated coal, and slow progress of CCS-and-coal.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	- Neoliberal ideology and policy (since 1990s) - Development of ICT and information society - further electrification of society (heat, mobility, ICT) - Geo-political tensions with Russia (gas)	- Climate change - Financial-economic crisis
Utilities	STRONG	WEAK/MODERATE

	- Sunk investments in power plants, electricity networks, business model (centralised power generation) - Commitment to existing technologies: * - Most nuclear plants are scheduled to be closed in the next 10 years because of end-of-life considerations. To replace them, the government plans to build eight new nuclear plants. EDF and government have agreed to build one new nuclear power plant (Hinkley C), and are negotiating about more nuclear plants. Actual construction is already 5 years behind schedule. * Substantial expansion of gas-fired plants is foreseen (including speculation about shale gas) * Utilities would like to build new coal-fired plants to replace the plants that will be phased out in coming years. But the government does not allow new coal plants without CCS. CCS is developing slowed than planned, however. So, in effect, coal is currently on a phase-out trajectory in the UK.	- Many coal plants are scheduled to be phased-out in the coming years (under European LCPD regulations), while new coal-plants are only allowed if they include CCS. This phasing-out will create capacity problems as well as an opportunity for new investment. - Awareness and acknowledgement of climate change - Utilities resist rapid reorientation by advocating a 'high cost' discourse of climate change mitigation. - The pace of change is controlled/managed by utilities in tandem with policymakers to suit their interests (this is slower than what is needed to meet long-term targets as the Committee on Climate Change has repeatedly warned)
Consumers	STRONG Electricity is a background assumption of modern societies. Electricity use is hardly questioned. Consumers have limited awareness of the 'world behind the socket', but do care about rising electricity prices. Nevertheless, customer switching between utilities (to get better prices) has (so far) remained limited, partly because manifold tariffs complicate comparison, partly because of customer inertia. Both reasons led to complaints that the electricity market is not functioning properly.	WEAK - There is limited direct demand for 'green electricity' (consumers signing up to special schemes). - But consumers are indirectly paying for the greening of electricity generation, because utilities pass on extra costs to customers. So, government policy has created a market for green electricity, even though this mostly remains 'hidden'. - Recent concerns about rising energy prices have created a negative discourse around green energy ('green crap'), which hinders a low-carbon transition. These concerns actually help consolidate the regime in its traditional cost orientation.
Policy-makers	MODERATE - Climate change policy created some regime tensions in early 2000s, but these have been alleviated by renewed commitment to regime technologies (nuclear, coal, gas) - Policymakers work closely with utilities. There has been limited effort to facilitate or support new entrants (although there are complaints about dysfunctional markets, which led to an investigation by the Competition and Markets Authority).	MODERATE - Electricity generation is the sector where the UK government has focused most climate change attention, leading (since 2008) to stronger and more interventionist policies that incentivize utilities to go green. These policies remain market-based, using more carrots (attractive financial incentives) than sticks. - Political attention for climate change has weakened in last 2-3 years with politicians giving more priority to costs and energy security.

Public debate and opinion	MODERATE Public concerns about high costs (and energy security) have helped to stabilise the existing regime by creating a more negative framing of renewable energy.	MODERATE Certain public concerns have created some regime tensions, e.g. - The public is very critical about utilities which are seen to offer poor (customer) service, use confusing tariffs, and raise prices. - The public is worried about climate change (although attention has decreased substantially since 2008) and relatively positive about renewable electricity (although there are also some concerns about effects on landscape, birds, noise). - Public debate does not seem worried about CCS or (the risks of) nuclear power - There is some public debate and controversy about shale gas, which is supported by the government but opposed by local communities.
Pressure from social movements, NGOs	WEAK/MODERATE Most NGOs are critical and do not actively contribute to regime lock-in.	WEAK/MODERATE * There have been visible NGO protests against shale gas and (proposals for) coal plants, including a divestment campaign against coal (led by The Guardian newspaper and joined by other groups). * There have been few protests against nuclear power, gas-fired power plants, or CCS. * Many NGOs advocate more radical and decentralized renewable electricity technologies that deviate from the existing regime. These actors have only limited effect, however, on wider public and policy debates, where they are relatively marginal compared to voices from industry and political parties.
Overall assessment	STRONG * Electricity regime is fairly stable in terms of core social networks (alliance between utilities and policymakers), tailored incumbent interests. * Varying commitment to regime technologies: - A revival of nuclear power is envisaged, but implementation and construction faces delays - Substantial expansion of gas-fired power plants is foreseen (without CCS obligation). Intention to develop UK shale gas (despite great uncertainties about availability and economic feasibility) - There is commitment to phase-out unabated coal; new coal plants only allowed with CCS; CCS technology is progressing very slowly, however, with no clear commitments.	WEAK/MODERATE * There are no major tensions or cracks in the electricity generation regime. * There are some problems around public legitimacy (negative perceptions) and policy concerns about mal-functioning markets. * The climate change problem has led to some institutional changes, e.g. ambitious GHG reduction targets and specific policies, as well as some changes in beliefs and strategies of utilities. These institutional changes are indicative of gradual green regime transformation (enacted by incumbent actors) is occurring rather than major cracks. * The political commitment to long-term climate change policies appears to be weakening, with the UK government not willing to commit to post-2020 targets. * Various specific policies (e.g. CCS, nuclear) 5-6 years behind schedule.

Stability and tensions in the UK electricity generation regime

Electricity consumption regime

Overall electricity consumption peaked in the mid-2000s after decades of increases across the industrial, services and domestic end-use domains. Electricity use fell by 7% between 2008 and 2012, mostly because of the economic recession (which especially affected industrial use). UK domestic electricity consumption, the focus of this report, doubled between 1970 and 2006, at which point it also appears to have plateaued and slightly decreased as a result of efficiency innovations.

Domestic electricity consumption levels are subject to several countervailing innovation trajectories. Efficiency innovations have helped to suppress increases in domestic electricity consumption, although the pattern has been very uneven across appliance categories and their associated practices (i.e. efficiency has been a significant driver for innovation in cold appliances, but has been almost completely absent in consumer electronics and home computing until very recently). In the absence of efficiency innovation, electricity demand would have continued to rise significantly because of: 1) the increase in the variety of types of appliance adopted by households (i.e. new consumer electronic products, such as coffee makers, juicers, games consoles etc.); 2) the continued spread of established consumer electronic appliances throughout the population (e.g. dishwashers, microwaves); 3) the addition of extra functions to existing technologies (e.g. ice-makers for fridges, photocopiers and scanners for printers); 4) the trend towards larger appliances (e.g. TV and PC screens, fridges); 5) the trend towards multiple ownership within single households of appliances in specific categories (e.g. fridges, TVs, computers); 6) an overall decrease in manufacturing costs for electrical appliances (through learning mechanisms), leading to price reductions and therefore increased affordability for consumers.

These patterns can be understood in the context of competing landscape pressures. On the one hand, concerns about climate change and (to a lesser extent) energy security have exerted pressure on the consumption sub-regime, generating the drive towards greater energy efficiency. On the other hand, the continued development of an ICT-based information society and the further electrification of the household have provided economic opportunities for international firms to proliferate innovations in the context of domestic practices that appear insatiable for opportunities to incorporate ever more technologies and functions. In this sense, the efficiency agenda has been layered into the electricity consumption sub-regime, without displacing long-standing institutional forces and cultural expectations that shape innovation life-cycles of the sector.

The incorporation of energy efficiency into the regime has helped to maintain regime stability and socio-political legitimacy by insulating regime actors against potential criticism for doing nothing in the context of landscape pressures. The efficiency agenda has been largely driven by European policy, enacted through the UK Government's Market Transformation Programme (MTP). In 2010, EU policy was consolidated through revisions to the two main energy efficiency directives: 1) the Ecodesign Directive, which stipulates minimum standards for the environmental performance of products available on the market – i.e. banning those that do not meet those standards; 2) the Energy Labelling Directive, which mandates the provision of comparable energy performance ratings to be provided by manufacturers to encourage consumers to choose more energy efficient products. Therefore, the governance approach mixes market and control measures, which, in the context of a stable sub-regime, represents a fairly high degree of intervention.

Initially, international appliance manufacturers, UK retailers and trade associations (especially AMDEA in the UK) were resistant to government intervention around the

efficiency agenda during the early 1990s. This changed in the mid 1990s, with supply side actors becoming increasingly compliant and less resistant (i.e. a reduction in lobbying). Moreover, by 2014, the UK's appliance trade association AMDEA had started to call for *more* policy attention to the efficiency agenda in order to prevent a potential backlash against the electricity regime as decarbonisation in electricity generation puts upward pressure on consumer electricity prices. As such, the efficiency agenda now has *pro*-active support from regime actors, presumably as a strategy for regime protection and reproduction. Political and public debate around the efficiency agenda is therefore fairly muted. The policy process itself is dominated by technocratic debates about specifying the minimum level for environmental performance and the most appropriate layout of labels to communicate information to consumers. NGOs and social movements are largely supportive of the efficiency agenda, but apart from the Green Alliance, which does continue an efficiency campaign, most groups are fairly silent. Within this context of strong regime actor alignment, there are occasional bursts of opposition when new appliances become subject to the EU directives (e.g. vacuum cleaners), but this opposition is typically short-lived.

UK government and other actors operating in the UK have also made some attempts to promote demand-side management through behavioural change campaigns, typically information based. A network of firm (especially Proctor and Gamble), trade associations and government departments has promoted lower temperature laundry and there is evidence of a gradual shift to lower temperature laundry habits. In contrast, efforts by DECC and the Energy Saving Trust to encourage households to switch off lights and abstain from using stand-by functionality have yielded no evidence of change.

Finally, in the context of all the gains made through the efficiency agenda, many aspects of the regime have been subject to significant lock-in and stabilising forces. The rules of the game for commercial regime actors have maintained a focus on persistent innovation in domestic appliances for firms to maintain or improve their competitive standing. This seems to be deeply intertwined with persistent cultural conventions for convenience, cleanliness and freshness as drivers of demand for domestic appliances and with continuing expectations for ever-increasing standards in ICE products.

In sum, the domestic electricity sub-regime is subject to strong stabilising forces. It has largely incorporated the efficiency agenda as a regime dimension, which has led to some re-orientation of industry strategies and beliefs towards efficiency innovation, and therefore some tangible gains in terms of reductions in electricity use. But, countervailing tendencies associated with longer standing regime characteristics on both the supply and consumer side continue to shape innovation trajectories that dampen the effects of improvements gained through the efficiency agenda.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	-ICT development and information society / smart home -further electrification of households associated with persistent cultural conventions for convenience and expectations for rising standards across domestic practices	- Financial-economic crisis, which may have affected electricity consumption levels over the last 8 years. - Climate change and energy security place pressure on regime to address electricity consumption levels
Industry	STRONG -UK appliance retailers now compliant and active with efficiency policy agenda -UK appliance trade association campaigns for further support for efficiency policy to protect regime interest from potential backlash. It believes the efficiency agenda is required to maintain social and political legitimacy of the sector	WEAK -Possibility of some tensions between appliance industry interests and electricity supplier interests over extent and distribution of policy support -UK appliance trade association, AMDEA believes there is potential for backlash from consumers about rising electricity costs (if costs of renewables are passed to consumers)
Consumers	STRONG -Consumption of electricity itself is largely invisible and abstract (inconspicuous consumption) -Proliferation of electric appliances in households – and of larger appliances (TVs, fridges) -Largely positive reaction to efficiency agenda (although less so than other European countries), especially for cold appliances -Persistent influence of cultural conventions for convenience, cleanliness, freshness and rising expectations for connectivity and entertainment underpin the dynamics of domestic practices	WEAK -Maybe some cracks in the regime with some consumer groups campaigning that policy should force efficiency agenda more, while others challenge further spread of efficiency agenda to other products (vacuum cleaners), arguing that consumer choice should be preserved. -Concerns over price rises, but not apparently affecting electricity consumption behaviour.
Policy-makers	STRONG - UK policy largely subservient and responsive to EU regulatory frameworks. - Absence of visions for radical alternatives beyond acceptance of electricity efficiency agenda and likelihood that appliance use will continue to grow	WEAK -Some political mobilisation (e.g. UKIP) to challenge the European led efficiency agenda. -UK has adopted alternative positions compared to other EU countries that risks solidarity around the EU efficiency agenda.
Public debate and opinion	STRONG -Little public debate about electricity consumption levels -Debates and visions around digital inclusion and smart homes point to further spread of ICT devices	WEAK - Debates about the price of electricity and security of supply (‘keeping the lights on’), but directed towards the generation sub-regime, rather than consumption and appliance use.
Pressure from social	STRONG Not a prominent campaigning issue for	WEAK / MODERATE Scientific analysis criticises the technology

movements, NGOs, scientists	most NGOs. Those that do campaign are largely supportive of efficiency agenda, calling for more support and quicker policy implementation.	efficiency agenda in terms of rebound effects and lack of focus on behavioural aspects of appliance use.
Overall assessment	STRONG Electricity consumption sub-regime remains stable because of alignment between key actors around the efficiency agenda, which helps to protect sector from criticisms about electricity price rises and carbon emissions. Efficiency agenda has delivered significant efficiency gains offsetting other factors that have seen increased use of appliances.	WEAK Only significant pressures come from scientific concerns about the efficiency agenda: rebound effects and absence of attention to behavioural aspects of appliance use (cf. technology efficiency).

Stability and tensions in the UK electricity consumption regime

Electricity network regime (transmission and distribution)

The electricity network regime has remained relatively stable, despite various pressures stemming from increasing electricity production from renewable sources:
1) The creation of new wind farms in remote locations (e.g. Scottish islands, Welch coast, offshore) requires the creation of new transmission networks, both onshore and offshore, to connect them to the grid.
2) Increasing electricity flows from Scotland and Wales (where most wind parks are situated) to England (where most electricity is used) requires upgrading, extension and intensification of the onshore transmission grid.
3) The intermittency of wind and solar power creates problems for matching supply and demand, and requires changes in the electricity networks to better manage and direct electricity flows.
4) The gradual increase of *distributed generation* (e.g. roof-top solar PV, community energy, small dedicated biomass plants) needs to be connected to (local) electricity distribution grids and requires two-way flows instead of traditional one-directional flows (from generators to users).

These pressures have, so far, been met with *incremental changes* in the high-voltage *transmission* networks: 1) extensions of *onshore* power lines and cables to remote locations; new *onshore* connections between Scotland and England, 2) the creation of a new *offshore* grid, 3) the building of *inter-connectors* that link the UK to other countries (currently France, Netherlands, Ireland with future plans for sub-sea connection cables to Iceland, Norway and Denmark). These changes don't substantially change the transmission architecture, but are very costly: about £17 billion between 2010-2013, and much greater investments up to 2020, up to £35 billion (Table 1, DECC, 2014).

Potential changes are more radical in the low-voltage *distribution* network, which delivers power from sub-stations to end-users. These possible changes entail: 1) creation of a smart grid (by introducing information and communication technologies into the grid) that would better measure, monitor and manage electricity flows, 2) electricity storage with batteries, which grid managers can draw on when intermittent supply falls short, 3) the introduction of demand-side response (DSR) options, which would enable demand to be adjusted to supply-side fluctuations; this would entail a *reversal* of the current functional principle in which supply follows demand; DSR may involve smart meters, variable pricing

(e.g. time-of-use tariffs or real-time tariffs) or 'direct load control' and smart appliances (which enable grid managers to temporarily switch off appliances like washing machines or fridges). The implementation of these innovations in the distribution network has been rather slow, because of reluctance, resistance and lock-in mechanisms, especially with regard to Ofgem (the independent regulator) and the DNOs (Distribution Network Operators). Ofgem, which is dominated by economists and engineers, has been reluctant to accommodate climate change and sustainability as an additional criterion besides its traditional focus on competition and low costs. Ofgem has also been created as an independent regulator, which has provided substantial shelter from increasing criticisms from policymakers and politicians. DNOs have long been low-risk firms that focused on cost improvements and efficiency instead of innovation. Despite various policies (which aimed to stimulate R&D and innovativeness), DNOs are reluctant to engage with the various radical innovations, because they have lost technical capabilities, have limited future planning skills, and are constrained by business models that focus on efficiency and cost reduction.

More generally, the actors in the electricity network regime form a closed-knit network, operating a form of 'club governance', which means that they share mindsets and take each other's interests into account when negotiating future plans and policies. So far, these actors have mainly implemented incremental innovations that keep the regime relatively stable. There are some pressures from policymakers (who worry that electricity networks need to be adjusted quicker in low-carbon directions) and local communities (who protest against new power lines), but these are not (yet) causing major regime tensions. The various lock-in mechanisms (stabilizing forces) and tensions in the electricity network regime are summarized in the table below, disaggregated for different actor groups.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	- Neoliberal ideology and policy (since 1990s) - Development of ICT and information society (giving rise to debates about 'smart grids')	- Climate change
Independent regulator (Ofgem)	STRONG The independent regulator Ofgem has (so far) remained relatively sheltered from policy pressures. Changes in Ofgem's network regulations have been incremental. Ofgem is dominated by engineers and economists. Its main focus is low cost (through economic competition) and energy security. Climate change has been layered on top of these traditional goals, but has not yet been 'internalized'.	WEAK/MODERATE Ofgem has faced criticisms from policymakers at DECC (and others) that it does not do enough to stimulate low-carbon innovation in electricity networks. It has managed these criticisms via an internal review and some (incremental) changes. There are also deeper complaints from politicians that Ofgem is 'not fit for purpose' (which may become a bigger problem in the future).
Transmission Operators (TNOs, (OFTOs)	STRONG Operators of *transmission* grids have deep sunk investments, and are oriented towards stability, rent seeking and incremental change.	WEAK/MODERATE Transmission operators face some pressure from new wind farms in remote locations. These pressures are being addressed with grid extensions and reinforcements that build on existing capabilities. These infrastructure changes are (increasingly) paid for by private investors, which are rewarded with long-term attractive contracts, with costs (ultimately)

		passed on to consumers.
Distribution Network Operators (DNOs)	STRONG DNOs are locked-in and reluctant to change because of: risk-averse orientation, regulated business model (around passive distribution), atrophied technical capabilities, limited long-term planning skills.	WEAK/MODERATE DNOs face some pressure from distributed generation and radical innovations like smart grids, storage, and demand side response. Ofgem has introduced incentives for DNOs to address these innovations, but with limited effects so far.
Consumers	Consumers play no significant role in electricity network regime	WEAK There is some pressure on distribution networks from distributed generation (e.g. consumers with roof-top solar-PV who deliver power back to grid).
Local communities, NGOs, public debate	MODERATE UK public debate about electricity infrastructure is relatively muted, compared to electricity generation or other countries (e.g. Germany).	WEAK/MODERATE Some local protests from communities and NGOs against plans for new grids (cables and pylons), leading to delays in planning procedures. Some debate about costs of grid extensions + concerns that new cables and electricity pylons will negatively affect the landscape and amenity
Overall assessment	STRONG Electricity network regime is stable in terms of a relatively close-knit network of actors (Ofgem, DNOs, TSOs) that share beliefs, mindset and orientations and negotiate gradual change amongst themselves.	WEAK/MODERATE Core actors implement gradual changes (e.g. extension and upgrade of transmission grids), but are (so far) reluctant to commit to more radical change.

Stability and tensions in the UK electricity network regime

2.3. Regime analysis of the Swedish heat system

Existing dominant systems and regimes are stabilised in many ways on different dimensions, e.g. stabilising landscape developments and undeveloped niche innovations. This stabilisation helps explain why transitions often come about slowly, and why green niche-innovations face many barriers. Nevertheless, tensions and cracks may arise with systems and regimes, which create windows of opportunity for transitions. On the one hand, regimes have internal coherence, shared rules, and similarity, but on the other hand they may contain variety, disagreement on specific issues, contentious debate, and internal conflicts. Such a conceptualization would make the strength, homogeneity and internal alignment of regimes an empirical question rather than an assumption.

The stability of existing regimes may weaken if problems and stresses appear within the socio-technical system, leading to cracks and tensions between the actors involved. These problems and stresses may arise from external pressures, e.g. from exogenous landscape developments or from 'below', i.e. consumers, social movements, NGOs or academia drawing attention to negative externalities, and/or internal problems.

In this report, we have assessed two separate, but inter-connected, regimes, the heat generation regime and the housing regime. We have analysed the tangible and intangible aspects of the socio-technical system in order to assess the degree of stability and path dependence of the regimes; specifically by evaluating the stabilising forces that contribute to

regime lock-in and the cracks, tensions and problems that have the potential to destabilise the regime and make way for alternatives. The work is summarised in the tables below.

Heat generation regime

The Swedish heat generation regime has shown remarkable stability in terms of the long-term domination of DH. In the regime's establishment, DH is facing market saturation and there are several policy challenges from both future energy efficiency measures and climate change, which will both lead to less demand for heating. DH is almost exclusively in multi-dwellings but the market is becoming saturated leaving little room for expansion. The system is experiencing difficulties through stagnation and competition from other sources, such as HPs, particularly in the one- and two-dwelling buildings sector. However, notwithstanding the recent development, there are few signs indicating that HPs might disrupt the DH dominance in the long-term.

The strong development of DH was made possible by strong public support during its early phases. However, much has changed since and a gradual transition towards more liberalised planning and energy systems has led to a weakened planning monopoly for municipalities and more liberal political and economic ideas are being implemented. The issue of TPA has led to two national inquiries (SOU, 2005, 2011), and finally to proposed changes in the District Heating Act (2008:263) that will allow TPA under certain circumstances (MoEEC, 2014; Swedish Energy Market Inspectorate, 2013). Regarding the future development of DH, although the market is becoming saturated, new waste-burning CHP plants are still being built. This has led to a debate about overcapacity, waste lock-in and waste import dependency from other countries. Future projections indicate a strong increase of waste import. A recent report predicts 30% waste incineration increase in the near future (Avfall Sverige 2009). Conversely, The EU directives and the government's climate bill will decrease heat demand through efficiency measures, as well as demand for less waste, which powers a large part of Swedish CHP plants, and thus risks destabilising the regime.

But there are also strong stabilising forces strenghtening the regime. TGC and the Carbon-tax are beneficial to both DH and cogeneration through CHP plants. Moreover, the pressure from HPs has so far mainly complemented DH by increasing its share in single-dwellings rather than multi-dwelings and strenghtened the current regime rather than being in direct competition. This is somewhat starting to change and there is more direct competition, which may destabilise the regime in the long-run. Additionally, the legislation and policy premiering HPs over DH might also destabilise the regime.

On the other hand, an indication of future regime stability can be found in a Danish study, which analysed the role of DH in a future 100% renewable energy system. It found that the best solution to complement DH is with HP (Lund et al., 2010; 2014). Other alternatives for a future DH system include further development of combined CHP systems in the remaining DH plants (Åberg and Henning, 2011), the development of district cooling systems (SEA, 2012a; Johansson et al., 2011) and solar thermal energy combined with DH.

Lastly, and perhaps surprisingly, is that there is very little opposition from civil society and academia towards the current regime.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	- Energy (oil) independence - Societal values on climate change and sustainable development - Natural monopoly of DH	- Climate change (warmer temperatures equals lower demand) - EU policy directives (energy efficiency and waste)
Industry	STRONG - Sunk investments in DH infrastructure – pipes, plants (centralised power generation) - Natural monopoly of DH - High investment costs for HPs - High level of renewable energy in system and low amount of CO_2 in electricity generation - Interconnectedness between HP and DH - Strong trade associations - Large forestry sector means easy access to biofuels for DH	MODERATE - Stagnation and saturation in the heat domain - Increased competition between DH and HP - Waste incineration lock-in - Increased import of waste - TPA for DH
Consumers/ households	STRONG - Sweden has a high demand for heating - Generally low interest in heating from consumers and households - Natural monopoly of DH - High investment costs for HP	WEAK/NON-EXISTING - No tensions. Very stable regime dynamics from consumer side
Policy/gover-nance	MODERATE - Public sector own the majority of DH companies - Historically strong policy support for HP - TGC premiers DH (through CHP) over other less developed renewable energy sources	MODERATE - New legislation for TPA might threaten DH dominance. - Current political attention on nuclear energy might affect electricity prices and future HP sales.
Public debate and opinion	STRONG - Strong support of carbon-tax - Strong support of renewable energy - 70-80% of heat is renewable, which leads to little contention in the public opinion towards the current regime.	MODERATE - Negative opinion about long-term dependence on waste import and waste incineration
Pressure from civil society and academia	STONG - Sweden is a world leader in both DH and HP, which have a strong support from academia through research programmes – supported by the government together with the trade associations – which are contributing to the lock-in of the regime	- NON-EXISTING
Overall assessment	STRONG - The heat domain is more or less fully renewable. DH and HP have in the past decades formed the new regime and the stabilizing forces are strong	MODERATE - Most interesting cracks and tensions are with the new interactions between DH and HP, and for the processes opening up DH for competition.

Stability and tensions in the Swedish heat generation regime

Housing regime

The housing regime is characterised by two main findings. First, the lack of interest on low energy buildings by the incumbent actors; and second, by the renovation need of the housing stock, mainly the million programme multi-dwellings.

The first point can be mainly attributed to the heat generation regime and the fact that the heat domain is more or less fully renewable, which means there is little necessity for the industry to act. In general, there is much more focus on the supply side than on the demand side. Even on the consumption side, there are few incentives. IMB, for example, is included in the rent for multi-dwellings and indoor temperatures are difficult to lower because of the collective heat control, which give residents little individual control. Moreover, there is little opposition from both public debate and opinion and the civil society on stronger action on energy efficiency and low energy buildings.

Regarding the second point, the renovation need and the EU Directives on energy efficiency and energy performance of buildings will put pressure on the regime in the future. Furthermore, the changes in the building code, which give preference to HP over DH and other supply sources, might create cracks and tensions on both the building regime as well as the heat generation and the electricity regime.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	- Collective societal values explain culture of leaving limited control over heat to residents.	- Very limited
Industry	STRONG - 70-80% of heat is renewable, limited pressure on industry to further change practices - Low interest from industry towards low-energy buildings and passive houses	NON-EXISTING
Consumers/ households	STRONG - Single-dwellings – Residents rarely move, which encourages large investments in e.g. HP. - Multi-dwellings – Heat is usually incorporated in the rent and, thus, is not usually controversial or something on which users have capacity to act - Stable culture of high indoor temperatures.	WEAK - Smart-meters could decrease the demand for heating, but very few signs that this put any substantial pressure on the regime
Policy/gover-nance	MODERATE - Very few polices and governance arrangement that influence heat consumption. Some information campaigns on energy savings. - Some norms from health policy makers on indoor temperature makes lower indoor temperature in multi-dwelling hosing difficult to implement.	MODERATE - Policy on additional energy efficiency measures, such as lower limitations on energy use /m2 in buildings and stronger regulation on passive houses, might contribute to destabilise the regime. - The building code gives preference to HP over DH and other heating systems
Public debate and opinion	STONG - 70-80% of heat is renewable,	MODERATE - Public opinion against the higher costs (due

	which leads to little contention. - Little interest in demand-side actions for heat reduction	to the natural monopoly) for connecting a building to the DH infrastructure. - Flagship constructions (such as the New Karolinska Hospital) opting for HP over DH. - Some debate on energy efficiency measures, through Energy Performance Contracting
Pressure from civil society and academia	WEAK - Few campaigns from NGOs on reduced heat use.	NON-EXISTING
Overall assessment	MODERATE/STRONG - General low interest in heat demand side from many actors as system has high share of renewables, and the regime is stable. Stabilising forces that limit low energy buildings, maintains regime stability with regard to high heat demand focus.	WEAK - Very limited cracks and tensions in the buildings regime due to high degree of renewable energy. Some tensions on renovation of housing and energy efficiency, else the tensions that exist are rather related to the implementation of the two dominating supply technologies DH and HP.

Stability and tensions in the Swedish building stock regime

2.4. Regime analysis of the German heat system

For this analysis the German heat domain was sub-divided into two regimes, heat generation and heat demand, that were examined regarding the central regime elements relevant to space heating: Heating technologies and building stock. For each regime-element different incumbent sub-systems were identified. Heat generation in Germany is mainly based on gas and mineral oil and to a minor share on district heat. As a consequence, these subsystems were analysed. For the building stock, we focused on residential buildings. Each of the incumbent subsystems offers different potential onsets and restrictions for a low carbon transition. While e.g. heat generation suggests pathways primarily through environmentally friendly technologies and energy sources, heat demand and the building stock respectively, offer a huge potential for energy efficiency and energy savings through refurbishment.

Before the regimes themselves were examined, an analysis of landscape development revealed support for a transition of the German heat domain from outward sources. Even though not perceived as the major problem by the general public, environmental issues are an essential part of the political and societal debate in German society. This leads to a generally positive perception of environmental friendly technologies and an accordingly high acceptance in society and to support from the political side. German commitment to global and EU-targets and policies for climate protection and reduction of GHG-emissions contributes to a favourable landscape as well. Moreover, a concern for the security of resource supply manifested itself over the last years caused by volatile markets and political instability of some supplying countries leading to more intensive debates on measures for a transition.

For the heat domain itself the development over the past decade reveals decreasing energy consumption and CO_2-emissions. This development occurred despite of an increase of average living space per capita, a trend towards less inhabitants per unit and main heating technologies that are still relying on fossil energy sources (gas has a current market-share of 49 % and mineral oil has 29%, district heating ranges at about 12% (cf. BDEW 2013)).

The German government has set clear targets for emission reduction and energy efficiency that deeply affect the heat domain ("Energiekonzept"). Several measures have been introduced to reach those goals. They mostly aim to stimulate the markets and increase the adoption of green technologies in society. We hence see significant cracks and tensions in the German heat demand regime due to the political will and effort for change.

Since investment cycles are extremely long, retrofitting and replacement will play much more important roles than new construction. Next to legislative effort, the government promotes a transition by setting up funding schemes and monetary incentives to trigger refurbishment in the building stock. Another factor playing towards a transition in this regard is the age structure of the building stock. Almost 70 % of which was built before 1978, has not been refurbished yet and thus offers large potential for an increase of overall building energy efficiency through retrofit measures. Still, to reach an almost climate neutral building stock in 2050, the retrofitting rate would need to be raised from 1 % to 2 % of the building stock per year, and thus would effectively need to be increased by 100%. However, the assessment of many other actors in this field shows strong stabilising forces. Their main objections are related to the economic reasonability of investments (amortisation time) and the split incentive dilemma, which leads to non-investment on the side of homeowners who cannot raise rents in accordance with the sums invested. Since a large amount of German housing is based on renting this leads to considerable disincentives for retrofitting. Also, many of these actors judge current policy design as not appropriate. The refurbishment rates needed for a fast transition are hence not reached.

We suggest that a more intensive refurbishment rate would yield knock-on effects to the technological subsystems in heat supply which has been identified as rather stable and locked-in. However, even though the external landscape promotes a shift away from fossil fuel to renewable energy solutions, here too, the present constellation favours regime stability. The present infrastructure is well established and an industry with strong associations as well as other interest groups stabilise the incumbent systems. Related to this, there are clear signs of asset specificity[2] leading to re-investment into known and already installed gas- or oil-installations and infrastructures, coupled with rather long re-investment cycles. Constant improvements of the related technologies with regard to efficiency are very favourable in this respect, too. Consumers perceive e.g. gas heating systems as an environmentally friendly heating solution due to its efficiency and cleanliness. A possible application with organic gas and the potential to couple both gas- and oil-heating with other renewable installations like solar-thermal also work towards a continuation of existing technologies.

Due to this lock-in situation, and especially caused by the dominance of gas heating systems, we do not expect a full regime shift in the heat supply regime. However, the assessment hints to (relatively) positive developments for a future transition towards a low-carbon society dependent on the refurbishment rate and the progress of technologies. Due to constant incremental changes in technologies concerning, for example, energy efficiency or compatibility with renewable energy sources (e.g. organic gas), an overall improvement in environmental regime performance could be expected.

[2] Asset specificity is embedded in the transaction cost theory (Williamson, 1975) describing the economic reusability and use of a capital good to a narrow purpose. "The asset specificity of a transaction refers to the degree to which the transaction needs to be supported by transaction-specific assets. An asset is transaction-specific if it cannot be redeployed to an alternative use without a significant reduction in the value of the asset. Asset specificity may refer to physical or to human assets" (S.Douma, H. Schreuder: Economic Approaches to Organizations, 2002).

All in all, we see the German heat domain on a critical point in its development towards a transition. If the amendment of incentives for retrofitting measures in the heat demand regime is convincing and knock-on effects to the heat supply subsystem follow, a regime shift may become much more possible. The resulting transition pathway could then be classified as a stronger Pathway A, with incumbent actors being lead actors, radically changing the (e.g. insulation) technology but leaving the other system elements as they are. The social dimension, e.g. the trend of increasing living spaces and other consumer related behaviour would not foreseeably be changed by this transition.

Assessment of degree of stability and tensions of heat supply regime

The analysis of the heat generation sub-systems gas-, oil- and district heating revealed a clear lock-in situation towards existing technologies, which is slowly amended (especially in the case of oil) but not replaced by renewable technologies. However, there is a within-regime development from oil towards gas and an unclear picture for district heating. Even though the external landscape promotes a shift away from fossil fuel to renewable energy solutions the well-established infrastructure and an industry with strong associations and interest groups stabilises the incumbent system.

Constant technological developments with regard to efficiency were very favourable in this respect. Consumers perceive e.g. gas heating systems as an environmentally friendly heating solution also because of the possibility to use them with organic gas. Oil heating systems on the other hand fell behind in recent years, which might indicate a further downward trend for this respective sub-system in agglomeration areas. For decentralized and rural areas oil-heating systems have still importance in security of supply.

Policymakers have set goals for CO_2-reduction that affect the regime, but they mainly rely on market-based incentives and set monetary incentives for refurbishments of heating systems e.g. when applying a combination of gas with renewable energy sources. Currently there is only one mandatory and binding regulation set by the government: oil- and gas-heating systems older than 30 years have to be replaced, but this replacement can be done within the same resource based technology, yielding no stronger effects for regime change. In combination with the current framework and actual consumer preferences, this regulation further stabilises the regime, since consumers connected to the gas grid tend to stick with their current heating system, the same holds true for oil-consumers. In the table below we summarise the most important statements from the regime analysis, related to lock-in factors as well as cracks and tensions. We focus this on oil and gas since DH is less important and was mostly analysed for subsequent use in cross-country comparison.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	For gas: MODERATE • Gas maintains a constant and growing role for German heat energy supply • Discourse about climate change is stabilising gas, as it is perceived to be a more reasonable resource than oil (bridge technology) For oil: MODERATE • In more peripheral areas oil plays an important role for energy supply when there is no connection to the gas grid. This will likely remain for	For gas & oil: MODERATE/STRONG • Strong discourse about climate change and CO_2-emissions and fossil fuels as finite resources • Political unrest in eastern Europe reveals import dependency as a weakness. For gas: MODERATE • Criticism on fracking For oil: STRONG • Oil crises in the 1970s, and • Recent volatility of prices

	at least the mid-term	
Industry	For gas & oil: STRONG • Well organized in associations and interest groups • Strong German enterprises: producers, suppliers etc. • Extensive investments in recent and upcoming years into (already well developed) gas infrastructure. • Development of new technologies follow consumer preferences: more efficient and combinable with renewable energy sources but no essentially new technologies.	For gas & oil: MODERATE/WEAK • Low domestic potential of gas and oil exploration shows evidence of import dependency leading to public concern. For gas: MODERATE • Development of technical alternatives for gas heating (organic gas). But these function as hedging strategy not as full reorientation strategy. For oil: STRONG/MODERATE • Low share of oil-heating systems on the sales market • Innovation potential of the oil heating technology is assumed to be exhausted caused by a lack of investments in the sub-system.
Consumers	For gas: STRONG • Gas is most appreciated heating technology by the consumers. • Majority would choose gas-heating system in the future (75% of the overall new installed heating generators are gas-heating systems, consumers formally using oil heating tend to stick to this technology). For oil: MODERATE • Oil is best available conventional resource in rural areas without access to the gas or DH grid. Effects of asset specificity. • Still appreciated by consumers that already own a oil-heating system	For gas: WEAK • No objections of customers against gas-heating systems. For oil: MODERATE • Since the oil-crisis in the 1970s and the rising prices for heating oil: declining acceptance of the oil-heating sub-system • Perceived as dirty and out-dated by the majority of consumers and thus very low share in new constructed buildings
Policy-makers	For gas & oil: MODERATE/STRONG • On a political level, fossil fuel-based heating is integrated into the funds and subsidies schemes that provide incentives for refurbishments For gas: MODERATE • Fracking law: no legal prohibition of fracking improves resource supply outlook.	For gas & oil: MODERATE/WEAK • CO_2-reduction and climate protection policy provides steps towards less fossil fuel-based technologies but has strong ties to prevailing regime. • Funds are only available for refurbishments applying a combination of gas & oil with renewable energy sources. • Legal enforcement to replace oil- and gas-heatings older then 30 years For gas: MODERATE • Fracking law: harsh penalties for fracking related environmental contaminations somewhat reduces the supply prospect. For oil: MODERATE: • A central overall strategy to promote the industry like it exists in the case of gas is missing.
Public	For gas & oil: STRONG	For gas: WEAK

debate and opinion	• No general ban of either technology but incentives for refurbishment with the same (but more efficient) technology. • Especially for gas: strong support as bridge technology both in single-house and DH due to flexibility of use with organic gas and good image of environmental performance.	• Concerns about fracking, especially due to possible ecological damages • Dependency on gas-imports is critically discussed • Biofuel production leads to critical debate on competing land use and mono-cultures. For Oil: MODERATE • In light of the discourse about climate change, oil is generally perceived as an energy source with no future prospects in the long term.
Pressure from social movements, NGOs, scientists	For gas and oil: MODERATE • Present importance of gas as a heating medium is generally acknowledged. • Focus on implementing changes WITHIN the heating sub-system, like modernization of existing gas-/oil- heating systems instead of replacing the system	For gas & oil: WEAK • Critical on implemented political measures (funds, subsidies for refurbishments) as ineffective, contradictory and non-transparent.

Stability and tensions in the German heat supply regime

Assessment of degree of stability and tensions of heat demand regime

To evaluate stability or possible tensions for the heat demand regime, it is important to define what we understand as change of the residential building stock which is the sub-system under investigation here. Since the rate of new constructions is negligible compared to the existing building stock, and a complete demolition and new construction is neither economically nor ecologically feasible, a sustainable transition concerns the reduction of total energy consumption per capita and thus an increase in energy efficiency instead of replacement. Since a lot of the existing housing stock is expected to need such retrofitting, a movement to a new shape of the subsystem is implied, which relates to a Pathway A design.

It is the political will to change from which we identify significant cracks and tensions in the German heat demand regime. The government promotes this transition by legislation, as well as by the provision of funding schemes and other monetary incentives to trigger refurbishment. Nevertheless, also because of current policy design, which many significant actors judge as not appropriate, the refurbishment rates needed for a fast transition are not reached yet.

Consequently, the assessment of many other actors shows strong stabilising forces. The main objective is related to the economic reasonability of investments (amortisation time) and the split incentive dilemma between owners and tenants (see chapter 5 of the country report). The uncertainty on the side of investors is even more increased by contradictory information. While on the one hand, refurbishment is promoted by the government and affiliated organizations, a study published by KfW reveals that the total investments needed until 2050 will not be covered through the energy saving potential.

Overall, the situation of the heat demand regime appears to be undecided. The condition of the building stock in place and the political programs towards retrofitting hint towards a Pathway A movement. The given potential of improvement in the shape of reduction of resource consumption through efficiency measures, point this way, too. However, reluctance on the side of many key actors – real estate owners as well as tenants –

to commit to investments imply very slow change. Also the present change in lifestyles for larger flats and single occupancy do not work in favour of a more sustainable regime. Nevertheless, one should remember that investment cycles in this sub-system are rather long, so that no fast processes are to be expected unless significant unexpected occurrences like a breakdown of supplies occur.

The table below gives an overview on the main stabilising and destabilising influences as a result of the analysis in chapter 5.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	MODERATE • General inertia of society visible in low retrofitting rate (0,9 – 1,3% p.a.) • Environmental problems caused by housing not perceived as major national problem in society	MODERATE • Global-, EU- and Federal conventions towards lowering GHG-emissions/improving climate friendliness • Insecurity of supply and uncertainties in energy prices as a general motivator
Industry	STRONG • Low rate of new construction provides little opportunity for basic innovations • A study of the KfW indicates that needed investments for a complete refurbishment of the residential building stock cannot be covered by energy saving potential. • Homeowners and investors lobbying for market-based measures for refurbishment (incentives). They fear the political ordinances due to uncertainties of economic profitability. • Tenants lobbied successful for a "rent brake" strengthening the "split incentive dilemma", reducing owners' motivation for investment.	WEAK • Need for refurbishment of 50% of the current building stock within the next 20 years; but owners and tenants are reluctant. • Some lobbying for flexible alignments and gradual development opportunities in terms of energetic refurbishment measures (instead of whole house retrofit) and an increase of subsidies. • Support for the new exchange platform ("Energiewende Platform Gebäude") implemented by the Federal German Government • Some open-mindedness for debates and re-adjustment of EnEV and more specific incentive programs
Consumers	STRONG • Growing living space per capita and age. • Changing lifestyles towards self-fulfilment and single households lead to a flexible way of life and therefore to a low ownership rate. • Low ownership rate (43%) resulting in a disproportionate "split-incentive dilemma" especially in multi-flat houses. • Long-time investment cycles.	MODERATE • Rising awareness for energetic saving behaviour • 50% of all owners are 60 years and older. Therefore a change of ownership will occur in the near future creating windows of opportunity for energetic investment measures • Urban-rural gap leads to residential shortages in urban spaces and to vacancies in peripheral areas → changing requirements to the residential building sector.
Policy-makers	MODERATE • Ordinances and subsidies in the past decades support especially	MODERATE/STRONG • Legislation enforces change: Enactment of first Thermal Insulation

	Whole House Retrofitting (WHR) building up barriers for gradual development. • Lack in flexibility of subsidies, lack of transparency regarding support and orientation	Ordinance (WSVo 1978) and the enhancement to the Energy Conversation Ordinance (EnEV 2002 and later). • Since 2014 stepwise re-adjustment of subsidies, ordinances and guidelines to meet the specific needs of homeowners and investors • Measures to improve market transparency are being taken
Civil Society & Public debate and opinion	STRONG • Interest in energetic refurbishment rather low with a view to the entire population • Lack of appropriate and objective information on refurbishment in the media (WHR is discussed controversially which results in uncertainties.) • Disagreement on the economic feasibility for private homeowners (investment vs. amortisation cycles) though energetic performance and reduction of energy costs are the most relevant factors for homeowners to conduct refurbishments	MODERATE • The basic attitude towards energetic performance of house owners is positive • Change in the public, scientific and political debate towards a re-adjustment of current ordinances, subsidies and guidelines resulting in build-up of pressure on policy makers • Rising awareness for energy saving behaviour through media and debates
Pressure from social movements, NGOs, scientists	MODERATE/STRONG • Most active are groups that represent tenants or owners working mostly towards regime stability or mild modernization. • No specific pressure groups towards drastic regime transformation	MODERATE/STRONG • Scientific studies and public awareness pushed the critical debate addressing current barriers for energetic refurbishment • Pressure for adoption of financial and tax aid schemes addressing energy efficiency, strengthening of energy consultancy, widespread refurbishment guidelines and campaigns and also flexible alignments of the current ordinances • NGOs rather work toward refurbishments than for drastic measures • Government seeks to initiate an alliance with important players through a common exchange platform.

Stability and tensions in the German heat demand regime

<u>Overall conclusion on transition pathways in the heat domain</u>

The two regimes analysed show different potential for transitions. All in all, we see the German heat domain on a potential verge towards a Pathway A transition. This is especially due to the heat demand regime where imminent but slow change can be expected.

Due to political targets set by the German government, there is significant political support for an energy-efficiency transition in the building stock. However, change will be subject to a relatively long period of time. First-steps towards a transition of the building stock already took place (first ordinances from the 1970s) and the regime actors had time to develop strategies and respective technologies to adjust. Therefore incumbent actors, many of them German companies, are part of the transition, which might make changes less detectable than e.g. in the energy regime. Promoting energy and resource efficient heating systems is a win-win situation for the German government: Offering incentives for refurbishment and whole-house retrofits directly leads to investments into the local economy as many appliances are bought from the German companies in the heat-supply regime and are installed by local craftsmen. Supporting retrofitting thus also causes knock-on effects for the heat-supply system. The analysis of barriers for refurbishments, and thus lock-in factors in favour of the current regime, revealed that most arguments relate to a lack of financial attractiveness and information. Potential transition pathways for this regime point towards Pathway A according to the PATHWAYS project terminology, with incumbent actors playing important roles, significantly changing the (e.g. insulation) technology but leaving the other system elements more or less as they are. The social dimension, e.g. the trend of increasing living spaces and other consumer related behaviour would not be changed by this transition.

For the second regime, the heat generation regime, we do not see a radical regime shift in the near future unless related to changes in building stock. The niches of relevant technologies (analysed in D 2.1 c.f. Berg et al. 2014) did not reveal significant momentum and the existing technologies, especially gas heating systems, dominate the current market. Even without a major change in the regime, but a pursuit of pathways 0 or a mild Pathway A, the assessment hints to (relatively) positive development for a future transition towards a low-carbon society of the heat domain with regard to heat supply. However, due to constant incremental changes in technologies concerning, for example, energy efficiency or compatibility with renewable energy sources (e.g. organic gas), an overall improvement in environmental regime performance will be visible.

2.5. Regime analysis of the UK heat system

The UK offers an interesting context for analysing the heat domain within a comparative setting as it clearly lags behind other Western European countries in terms of efficiency and innovation. However, having only recently ‘discovered’ heat as an important issue—at a critical point in time where multiple pressures seem to be aligning—the UK is setting a number of ambitious commitments in the frame of its first Heat Strategy. If it manages to develop the necessary skills and markets, it may hence well pick up on technological innovations developed elsewhere. Projecting or assessing the feasibility of future developments, however, is difficult given the high uncertainties related to technical aspects and the credibility of long-term policy commitments. We here provide conclusions by reviewing the extent of lock-in and tensions of the current regime. These are summarised in two tables for the heating and the housing regime, respectively, although many overlaps exist.

Domestic (individual gas-fired) heating regime

The heating regime is fairly stable in particular due to strong infrastructural lock-in (gas grid / housing stock), the concentration of powerful actors on the supply side, the captivity and relative lack of awareness on the demand side (consumers), and a tendency for business as usual in the equipment installation and maintenance trade. However, this stability does not seem to be strongly related to active resistance strategies, which is hopeful for future change

There are major tensions ahead for the heating regime, potentially developing towards a high degree of alignment (energy security and price stability, climate concerns, emergence of credible alternatives elsewhere). The current heating arrangement, relying on an increasing proportion of imported gas is seen as unsustainable in the long run. There are some signs of willingness to make strategic decisions and commitments on the policy side (although the credibility and durability of such discourse remains questionable). There are however substantial sources of uncertainty regarding current ambitions to stimulate a transformation in this domain.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	Low cultural significance of 'heat' Low policy salience of 'heat' Financial crisis Neoliberal ideology and policy	Climate change and awareness of sustainability matters Gas and energy prices (related to resource availability and geopolitical change) Self-sufficiency and energy independence agenda Fuel poverty
Heating equipment supply	STRONG/MODERATE Gas boiler efficiency improvements over the years (incremental change) Gas assumes dominant market position No strong alternative in UK context Industry characterised by slow rate of change in skills and practice bases with preference for established solutions	WEAK/MODERATE Plans to rapidly phase out of existing gas boiler by 2030 (Heat strategy) (are these credible?) Many leadership and best practice examples in different European countries. Awareness of UK as laggard in comparative perspective
Gas supply and distribution infrastructure	STRONG Strong infrastructural lock-in (sunk costs, etc.), well-functioning network. Competitive advantage from past network investments. Organisational linkages with electricity supply 'Unconventional' gas may attenuate supply squeeze. Gas grid could in a distant future be adjusted to distribute other energy carriers.	MODERATE Rising price of gas is major concern Opening to competition beyond Big Six (though weak) Gas supply under increasing criticism and dissatisfaction
Users /consumers	STRONG/MODERATE Consumers do not actively pursue heat-related choices. Individual users do not interact much with this kind of technology. Heating equipment purchases are often not planned but follow from breakdown. Awareness and interest about different heating and energy efficiency options are relatively low.	WEAK Gas prices lead to greater interest in more efficient options Low levels of engagement, trust and consumer satisfaction with gas suppliers Increasing sources of information about heating alternatives for interested consumers (e.g Energy Saving Trust)
Policy-makers	MODERATE 'Unknown territory' for policy, as low-carbon heat has only recently been put on the agenda. History of support for micro-generation measures, but highly criticised in their effectiveness and scope Historic instability of energy policy in the	**POTENTIALLY** STRONG (but uncertain) New phase of low-carbon heat policy programme (Heat Strategy): - ambitious technological rollout vision (mainly energy efficiency and electrification via heat pumps) - specific instruments that follow from that (Renewable Heat Incentive)

	UK not conducive to long-term financial commitments (of consumers and investors)	*but how effective and realistic is this? Difficult to distinguish symbolic discourse from substantial action at this early stage*
Public debate and opinion	MODERATE/STRONG Gas framed as relatively clean heating option (compared to coal and oil) Lack of salience of heating as issue not conducive to change	MODERATE Potential alignment of climate change, energy price and security concerns in favour of destabilisation
Pressure from social movements, NGOs, scientists	MODERATE Low cultural visibility and salience of heat makes social mobilisation difficult.	MODERATE NGOs and energy researchers have contributed to put Low-carbon Heat on the policy map (e.g. Green Alliance 2007). NGOs and scientists critically evaluate policy progress to date as relatively poor, and roadmaps ahead (high uncertainties) but with little leverage.
Overall assessment	MODERATE/STRONG	MODERATE

Stability and tensions in UK heat regime

Building regime

The building regime in the UK is characterised by strong inertia, which is predominantly related to infrastructural elements such as the housing stock, but is also translated in low consumer interest, and unpreparedness of the construction sector. The sources of inertia are mainly structural, rather than the fruit of active resistance strategies.

The scope for change in terms of crack and tensions is currently relatively low, and unlikely to counterbalance the current stability. A number of early changes in social mobilisation, awareness raising with respect to energy efficiency, and the development of the Heat Strategy are however signs that the current situation could be changing.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	Inertia of the building stock Low policy salience of 'heat' Neoliberal ideology and policy	Climate change and awareness of sustainability matters Gas and energy prices (related to resource availability and geopolitical change) Fuel poverty
Construction sector	STRONG/MODERATE Diffusion of basic insulation options and techniques (loft insulation, wall insulation, etc.) but not always integrated, leading to only minor improvements on average Low awareness and proficiency of advanced energy efficiency refurbishment skills and techniques There is a need for skills and supply chain improvements in the building industry, e.g. improved training, professionalisation, and greater standard requirements.	WEAK Development of specialised companies catering for a niche market of high efficiency retrofits. Emerging markets elsewhere in Europe, developing supply chains, skills, markets.

Housing stock	STRONG Strong infrastructural lock-in in exiting housing stock, which is on average old and energy inefficient. Replacement rates are very low.	WEAK The energy performance of newly built houses has much improved, but replacement rates are low.
Users /consumers	STRONG/MODERATE Retrofitting remains a voluntary measure and can lead to partial solutions (caused by structure of financial incentives) Spontaneous customer demand for retrofitting is low due to high upfront costs, uncertainty about economic gains, and technical difficulties Insulation and energy efficiency improvements are disruptive and often coincide with major refurbishments Awareness and interest about different heating and energy efficiency options are relatively low	WEAK Rising gas prices lead to greater interest in efficiency matters Increasing interest among house owners to retrofit but not in private tenancies due to principal-agent problem Emergence of 'greener' homeowners Energy efficient refurbishing increasingly recognised as growing market Increasing sources of information for interested consumers (e.g. Energy Saving Trust)
Policy-makers	MODERATE 'Unknown territory' for policy, as low-carbon heat has only recently been put on the agenda. Energy efficiency improvements have largely been instigated by home owners with only limited government support Historic instability of energy policy in the UK not conducive to long-term financial commitments (of consumers and investors)	**POTENTIALLY** STRONG (but uncertain) New phase of low-carbon heat policy programme (Heat Strategy): - ambitious technological rollout vision (mainly energy efficiency and electrification via heat pumps) - specific instruments that follow from that (Renewable Heat Incentive) but how effective and realistic is this?
Public debate and opinion	MODERATE/STRONG Gas framed as relatively clean heating option (compared to coal and oil) Lack of salience of heating as issue not conducive to change	MODERATE Potential alignment of climate change, energy price and security concerns in favour of destabilisation
Pressure from social movements, NGOs, scientists	MODERATE Low cultural visibility and salience of heat makes social mobilisation difficult.	MODERATE A number of organisations promote the development of low-energy skills in the building sector (e.g. UK Green Buildings Council lobbies for energy efficiency in buildings to become an infrastructure priority) NGOs and energy researchers have contributed to put Low-carbon Heat on the policy map (e.g. Green Alliance 2007). NGOs and scientists critically evaluate policy progress to date as relatively poor, and roadmaps ahead (high uncertainties) but with little leverage.

Stability and tensions in UK building regime

The importance of implementing large-scale changes in the heat regime is progressively being recognised. The UK has recently shown ambitious commitments for a transition to a

low-carbon heat regime, including an anticipated full decarbonisation of residential heat by 2050. There are however a number of challenges and barriers for reaching its goals. An inefficient and slow moving building stock and a generally poor track record with low carbon heat are two challenges to be named. Nevertheless, if these commitments are taken seriously and hence the necessary steps implemented sincerely (e.g. effective roll-out of efficiency measures, a virtual replacement of all gas boilers with heat pumps, and support for District Heating (DH)), vast opportunities can open up for the development of a sustainable heat industry. However, a history of 'changing moods' in UK energy policy and the failure to guarantee long-term stable conditions for low carbon solutions raises further doubts as to the feasibility of the current ambitious strategic objectives for heat.

2.6. Regime analysis of the UK mobility system

This report analyses the automobility, rail, bus and cycling sub-regimes which, together, contribute to the socio-technical land-based passenger transport regime. It assesses the degree of lock-in and path dependency of these regimes, the possible cracks and tensions that arise within them and whether each is in decline or ascendancy (see Tables below). The report's main findings are as follows.

Although it faces several problems, the automobility regime is still dominant and stable, although less so than twenty years ago. Some tensions and cracks have appeared such as: a) public concerns about Peak Oil and climate change, b) government policies (European CO2 regulations, national innovation programs) aimed at the 'greening' of cars, c) some urban policies that restrain cars and encourage alternatives to cars (often for reasons of urban regeneration and quality of life), d) green innovation strategies by automakers, which are mainly focused on incremental innovation, but also explore alternative options (BEV, HEV, FCV), e) decreasing overall car-mobility (Peak car), stagnant car sales, and some indication of less car desires amongst young people. But these tensions are not yet very strong, whereas the mechanisms of inertia and stability are still substantial.

Alternatives to the automobility regime in the UK remain marginal. This is the case even with rail, where passenger journeys have more than doubled since 1994/5, where rail passenger miles have increased 51% since 2001, but which still accounted for only around 3% mode share of surface transport trips in 2013 and just over 8% of 'total inland passenger km' in 2012. Overcrowding and congestion on the railways have highlighted a capacity problem. This capacity problem is not being addressed in a systemic-strategic way. Instead there is spatially selective prioritisation of parts of the network (e.g. HS2, Crossrail) for large-scale infrastructure investment in corridors and enclaves - notably within London and connecting to London.

Similarly, passenger kilometres and trips by bus remain marginal relative to automobility, as part of a long-term trend of decline that has levelled off and in some cases begun to reverse over the last decade. The neoliberal reformulation of transport prioritised the car and portrayed car users as 'successful' and bus users as economic 'failures'. This resonates with the dominance of bus use by 'lower' socio-economic classes and the young and elderly. The bus regime has been shaped since the 1980s by the idea and principles of competition, through deregulation and fragmentation. In London, where there was not deregulation and where there was a well-developed range of modal alternatives, bus usage performed well (45% increase in bus trips between 1995/7 and 2013) vis-à-vis other parts of the UK.

Cycling, likewise, remains marginal in a UK context, despite small increases in distance travelled by cycling in recent years. The longer-term trend shows the scale of decline

since the Second World War where cycling accounted for 33% of all vehicle miles travelled in 1949 and only 1% by 2009. Though a similar trend affected many European countries cycle use remains comparatively low in the UK. In the last two decades there has been a developing policy-push around cycling and associated infrastructure particularly through national programmes focused on urban areas, and also the development of a wider UK cycling economy. Realisation of cycling infrastructure has been limited and cycling is still seen as an 'abnormal' activity which is often incongruent with employment, family, leisure or other activities. There is a gap between policy-push and limited realization which can be attributed to policy being embedded in a wider, fragmented governance of multiple private agencies and actors. There are though examples of significant spatial variations in use where, again, cycling in London has grown significantly over the last decade.

Binary oppositions between pro-car and anti-car have been fuelled by neoliberal efforts to frame single modes of transport. Neoliberalism has sought to reduce organising transport to calculable choices competing with one another. This was at its height in the era of predict and provide. Though there was a shift to discussing more integrated forms of sustainable mobility in the 1990s there were only small tangible shifts in actuality. Yet, there has been no large-scale re-assertion of predict and provide.

We have seen over the last decade an increasing tension between this competition-based market model and a gradual development of tools by national policymakers for local transport authorities to build coordination. With pressures for further significant transport devolution to regional and metropolitan authorities there remain possibilities for 'pockets' ('niches') of more inter-modal forms of localised transport system to be developed.

Automobility	**Lock-in, stabilising forces**	**Cracks, tensions, problems**
External landscape pressures	- Financial-economic crisis - has resulted in a defence of the automobile industry by the state	- Financial-economic crisis - declining sales - Climate change - requirements for largescale transport CO2 emissions reductions - Rising oil prices (Peak oil), although weakened with recent price decline - ICT development and information society - growth of alternative modes of home-working/shopping/leisure
Industry	STRONG - Sunk investments in machines, people, factories, knowledge - Commitment to internal combustion engines - Firms believe that the ICE still has substantial technical development potential for incremental improvement in green directions - CO2 emissions have fallen annually in new vehicles for the last 16 years and a 30% fuel efficiency improvement in new petrol vehicles 2000-2013.	WEAK - Economic problems (cut-throat competition, stagnant sales in Western countries) lead to focus on core business and entrenchment - Aware of climate change and peak oil (which are expected to get worse in long-term) - Development of radical technical alternatives, but as hedging strategy not as full reorientation strategy
Consumers	STRONG -Car embedded in lifestyles and mobility patterns (shopping, commuting, bringing children to school).	WEAK/MODERATE - Depressed car sales after crisis, with some recent signs of picking up - Some dissatisfaction about fuel prices, congestion and parking problems - though

	-Many consumers prefer the car as a mode of transport in terms of speed, time, convenience - except perhaps in the centres of large cities, where parking problems may hinder car use.	overall costs of motoring are claimed to be falling while those for rail and bus passengers are steeply rising -There was a reduction in the average number of trips by car, average distance travelled and time spent travelling on average 1995-2013 ('Peak car') - Perhaps less desire for cars amongst younger generation.
Policy-makers	MODERATE - Policymakers supportive of cars (although less than 20 years ago) - Policymakers are constrained by electorate (many of whom prefer cars), lobby groups, and economic importance of car industry	MODERATE/WEAK - Some climate change pressure from EU policymakers (CO2 regulations not yet technology-forcing, but could get stronger) - Limited climate change pressure from national policymakers (no targets, regulations, etc.), but support for green technology development/deployment - Some pressure from local policymakers, who introduce some car-restraining measures and stimulate alternatives (bus, cycling)
Public debate and opinion	STRONG - Many positive cultural associations with cars (freedom, individuality, excitement, success, power). - Powerful pro-car lobby groups - Enduring (though weaker) neoliberal view of single, competitive modes of transport governed by 'choice'	WEAK - Long-standing presence of an anti-car discourse, which has drawn attention to negative side-effects of car use - 'Sustainable mobility' emerged as a phrase, but with limited concrete effects (less strong discourse than 'renewable energy')
Pressure from social movements, NGOs, scientists	MODERATE -There are powerful - often industry-linked - pro-car lobby groups -Road and car safety groups contribute to incremental improvements in automobility	WEAK -Anti-roads protesters had success in curtailing a road-building programme in the 1990s. Weakened by fuel protests in the 2000s. There may be windows of opportunity following announcement of new road-building programme
Overall assessment	STRONG -Still fairly stable automobility regime (although perhaps less than 15 years ago) -Alternatives to automobility remain marginal.	WEAK/MODERATE -Some cracks and tensions from: a) hedging car industry, leading to development of technical alternatives, b) less car-based lifestyles amongst younger generation, c) EU and local policy (which do not yet provide strong push for alternatives), d) presence of critical discourse (but limited wider appeal)

Stability and tensions in the UK auto-mobility regime

Rail	Lock-in, stabilising forces	Cracks, tensions, problems
Industry	MODERATE -UK train system privatised and fragmented since 1994 -Infrastructure, train operations and rolling stock separated into multiple units with no system controller -Last train maker in Britain, the former state-owned operation in Derby, owned by the Canadian engineering company Bombardier	MODERATE -Political rows since 2011 over whether state should prioritise UK train manufacturer in awarding contracts - mixed results - New train capacity being built by Japanese-firm Hitachi in new English facility -Prioritisation of premium parts of the system (HS2 and Crossrail) and 'alternatives' of light rail plans for other urban areas
Consumers	MODERATE -Long-term decline in rail use reversed in the UK in the last two decades - approximate doubling of passenger KMs travelled – yet rail's contribution to overall transport share remains small	MODERATE -Post-privatisation (between 1997 and 2014) fares increased on average by 102%, a 23% increase in real terms -Majority (62%) of all rail journeys started or ended in London with implications for system investment -Capacity a serious issue (including sharing of lines between local /inter-city trains)
Policy-makers	MODERATE/STRONG -Unitary control of the railways abolished in 1993 when policy promoted fragmentation of rail system to create market economies -Numerous government reviews have not fundamentally rejected the post-privatisation organisation of railway system	MODERATE -Though passenger numbers have increased post-privatisation public subsidy has risen sharply, counter to a key objective of privatisation -Assessments of privatisation as policy response suggest a mixed record of success -Policy is selectively prioritising parts of the rail system, primarily into and through London
Public Debate and Opinion	MODERATE -Rail passenger use has seen significant increases - this is in tension with debates about the costs of use	MODERATE/STRONG -Increasing debates about cost of rail to public purse and passengers -Growth of rail use has emphasised capacity and congestion issues -The development of high-speed lines and their costs, focus on London and local effects of new lines has become and is likely to increase as an issue -Some debate about whether rail should be in private or public hands and also about refranchising of train operators
Pressure from social movements, NGOs, scientists	MODERATE -Campaigning groups appear to have moderate influence on government and subsequently the rail system. Groups exist to champion passengers, to	WEAK -Limited downward influence on fares

	campaign on fares and to oppose privatisation- there is a mix of insider and outside groups	
Overall assessment	MODERATE -There is no great challenge to the privatised rail system. It is expensive, congested but also heavily used by passengers	MODERATE -Modest cracks and tensions in relation to: a) congestion, b) costs, c) the private organisation of the rail system

Sstability and tensions in the UK rail regime

Bus	**Lock-in, stabilising forces**	**Cracks, tensions, problems**
Industry	MODERATE -Complicated landscape of bus operators across the UK - local variety. But three operators - through mergers - together account for almost half of market share -There are nine bus and coach manufacturers in the UK and the number of buses/coaches in Britain has stayed reasonably steady over the decade to 2014 at around 52,000 vehicles	WEAK -Relatively settled operator landscape after series of mergers in the 1990s. -Incremental moves to bring more control over the bus operating companies through local authorities
Consumers	MODERATE -Bus use remains significant at around 30 billion passenger KM a year and remains used for a wide range of purposes from commuting, to shopping, education and leisure activities	WEAK/MODERATE -Bus use has been in long-term decline outside of London but this has levelled off. There is though geographical variation to bus use with London seeing significant growth in passengers but rural areas showing significant reductions Buses are disproportionately used by the poor, the young and elderly and bus fares have increased faster than inflation. Furthermore, significant usage by pensioners is through concessionary travel which may come under threat in times of austerity
Policy-makers	MODERATE -Deregulation and privatisation since 1985 shifted ownership and operation of the buses from public to private bodies and enshrined the general principles of competition law in the operation of the bus system	WEAK/MODERATE -The tension between competition law and a greater role for local policymakers in the governance of the bus system has incrementally increased in the 2000s
Public debate and opinion	MODERATE -The overarching narrative of the bus system in the UK remains wedded to the effects of deregulation, almost three decades on -The political power of the over-60s remains strong and has implications for the continuation of concessionary bus	WEAK -Bus use suffers some negative perceptions. This can be traced to the binary debate of the 1980s between the desirability of automobile ownership and use and the perceived personal economic 'failures' associated with bus use.

	passes	
Pressure from social movements, NGOs, scientists	WEAK -There are numerous groups, working with government and operators incrementally	WEAK -Campaigning groups appear to have limited influence on the bus system and its operation
Overall assessment	MODERATE -The dominant organisation of the bus system remains shaped by the privatisation and deregulation of the 1980s. -There have been incremental changes in ownership of operators since then and a period of relative stabilisation of operating companies, passenger numbers and fleets	WEAK -Incremental change means that cracks in the system - for example, efforts to bring more local authority control of the bus system - are addressed slowly over a long period of time

Stability and tensions in the UK bus regime

Cycling	**Lock-in, stabilising forces**	**Cracks, tensions, problems**
Industry	MODERATE/WEAK -The vast *majority* of bicycles bought in the UK are manufactured outside of the UK. Bicycle manufacture in the UK has become specialised and niche -Growth of a wider cycling industry of associated products (clothing, accessories)	MODERATE -The UK has no mass producer of cycles -There has been a growing cycling economy - but a view that this growth may have peaked
Consumers	WEAK/MODERATE -The long-term trend of cycle usage in Britain is one of decline since the Second World War - but with an increase in cycling KM of around 20% between 1998 and 2013 -Around 43% of the UK population owns or has access to a bicycle. Yet, cycling is seen as an 'abnormal' activity in the UK and low by comparative EU standards	WEAK/MODERATE -There is a poor understanding of the cultural dimensions of cycling and hence limited congruence between cycling and some practices, such as travelling to school for example -There are huge variations in use by age and gender and notably by geography. This links to the cultural dimension of cycling
Policy-makers	WEAK/MODERATE -No real national cycling policy prior to the 1990s -National cycling strategy in 1996 placed a renewed policy emphasis on cycling - subsequent targets to triple cycling trips in a decade failed	WEAK -Cycling policy emerged in a neo-liberal state that means capacity is outsourced and fragmented and policy is difficult to realise locally -Individualisation of cycling policy underpinned by notions of 'active' and 'responsible' citizenship has presented cycling as perceived as being peripheral to the main business of 'transport'
Public debate and opinion	WEAK -Views that people hold of cycling are often ambiguous and sometimes	WEAK/MODERATE -There is significant geographical variety in

	contradictory -Cycling remains a marginal activity	use with Greater London, for example, seeing relatively large growth since 2000 -There is some challenge to reductionist, 'derived demand', rational, cost-based, quantitative approaches to transport use decision-making. More expansive understandings of the meaning of cycling mobility focusing on the immaterial embodied and sensory have begun to emerge
Pressure from social movements, NGOs, scientists	MODERATE -Variety of NGOs working to promote different elements of a cycling agenda but with ad hoc connections between them	WEAK/MODERATE -Cycling at local authority level requires a statutory response but there is limited in-house capacity. This creates some possibility to build capacity through NGOs and social movements, although this may be constrained through lack of finance and institutional barriers
Overall assessment	WEAK/MODERATE -Cycling remains marginal in a UK context, despite small increases in distance travelled by cycling in recent years -In the last two decades there has been a developing policy-push around cycling and associated infrastructure particularly through national programmes focused on urban areas, and also the development of a wider UK cycling economy -Realisation of cycling infrastructure has been limited and cycling is still seen as an 'abnormal' activity	WEAK -There are examples of significant spatial variations in use where, for example, cycling in London has grown significantly over the last decade – these present exemplars of 'alternative' cycling cultures

Stability and tensions in the UK cycling regime

2.7. Regime analysis of the Dutch mobility system

We first provide an overview of the prevailing mobility domain in the Netherlands, and a rationale for focussing specifically on individual land-based mobility. We also discuss the presence of subaltern regimes, and their relationship to the prevailing regime. The bulk of the document is dedicated to description of the prevailing regime(s), focussing on main developments and tangible system elements, as well as on active social groups and intangible regime elements. In the concluding section, we analyse the inertia of the prevailing regime in the Netherlands' mobility domain, and relate it to the PATHWAYS typology. The assessment of stability and tension in the regime is presented in the summary tables below.

The Netherlands offers an interesting context for the analysis of the mobility regime in a comparative setting, as it is characterised by a number of developments that are compatible with vision of more sustainable mobility systems – including the co-existence of multiple regimes and transportation modes (and a particularly strong share of cycling), and

the concentration of urban settlements.[3] We here provide a summary and conclusions by reviewing the extent of lock-in and tensions of the described regimes (see full report for detailed explanations). These are presented in separate tables for the prevailing automobility regime and the two sub-regimes that were considered, i.e. public transport and cycling, at the end of this Executive Summary. We first report an overall assessment of regime stability in the following paragraphs.

The existing **automobility** regime in the Netherlands is deeply entrenched and relatively stable. It is stabilised by reinforcing initiatives and institutions that contribute to existing lock-in. These include: a powerful industry, continued technical improvements and sophistication, and supporting policies. Despite strong inherent stability, the automobile regime in the Netherlands is showing some signs of change. Recent trends point to increasing recognition of external pressures and challenges by the automobile industry itself, with greater attention to environmental and safety issues, innovation strategies geared towards lesser emissions (catalytic converters), fuel efficiency improvements, the exploration strategies with different alternative fuels, and the emergence of new business models for mobility. The emission intensity of new cars is steadily decreasing.

However, there are also signs of change ahead, as the prevailing automobile regime is increasingly being challenged on environmental, convenience, safety, economic, and technological grounds. Most responses so far, however, are currently met by incremental regime responses. Furthermore, there seems to be a disinterest in car ownership among younger people, which has the potential to challenge the dominant automobility regime.

Public transport is generally an integrated and coherent affair in the Netherlands with a strong role for public planning and harmonisation. The Netherlands is striking in its ability to retain public control over public transport (from national government down to municipality), which is one main reason why lasting support and continuity can be expected. Multimodality has been successfully supported (e.g. through integration and simplification of ticketing and fares; increasing ease of connection between modes of transport). To date the emerging issues have been successfully addressed as they arose.

The Netherlands has the highest **cycling** rate in Europe; cycling is culturally deeply embedded and has profited from successful policy interventions. The Netherlands has a well-established, extensive, safe and convenient cycling infrastructure network, all of which contributes to a strong stability of this regime. In recent years, e-cycling has been replacing some far-distance conventional bicycle journeys. The Netherlands is striking as a leading example in terms of the highly stable role of cycling, its integration in landscape, infrastructure, culture and lifestyle. The co-existence of cycling with other mobility modes in urban centres and for short-distance commuting is unprecedented in Europe, perhaps with the exception of Denmark. These two countries are decades ahead in the integration of cycling as a credible mainstream mobility alternative, and have accumulated a wealth of technical, administrative and policy experience in how to deal with this transport mode.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	Culture of the age (individualism, private ownership, etc.) Precedence of economic rationale Infrastructure: Sunk costs; planning patterns	Environmental awareness (especially, pressures to reduce GHG emissions) Revitalisation of sustainable alternatives Rising fuel prices; debates on Peak oil;

[3] Furthermore, we have already seen in Deliverable 2.1 that "the Netherlands presents an interesting context for experimentation in the mobility domain, and is positioning itself at the cutting edge of many of the innovation presented in this report, providing a 'test-bed' for niche experiments and their development".

	that favour commuting Ageing society (more older citizens with reduced autonomous mobility capacity) Globally ever-growing automobility	Congestion, leading to inconvenience and air pollution Information society New forms of mobility services as growing alternative to conventional car ownership Ageing society (new, specialised demand pockets)
Technology and market developments	STRONG Market segmentation: greater diversification of models; greater price ranges; more efficient vehicles (incremental changes) Incremental innovations to improve ICE performance: improved engine performance; greater in-car ICT; and safety devices Better environmental performance of new vehicles ICT: improved performance (e.g. ABS); user interface and convenience; entertainment. Safety and comfort improvements	WEAK/MODERATE Indications of a 'saturation' of the car market in the Netherlands Signs of changing mobility patterns in urban cores
Actors and Institutions	STRONG Powerful (global) automobile industry that ensures continued attractiveness of car and creates barriers for introduction of new technologies; some leading Dutch companies involved in global supply chains Petrol suppliers and distributors (especially Shell) are crucial actors in the Netherlands Turbulence in the automobile industry could lead to 'greening of cars', hence incremental changes	WEAK/MODERATE Turbulence in the automobile industry could lead to radical transformation (new engines, infrastructures, forms of ownership and organisation, etc.) either through new fringe players or absorption by automobile industry
Users	STRONG Socio-cultural preference for the car; normalcy of ways of life based on the car (reinforced by advertising, policy objectives, and future scenarios)	MODERATE Potential disinterest or unaffordability among younger people
Policy-makers	MODERATE Recent policy developments—in difficult economic times—have been reinforcing the automobility regime, e.g.: more and wider roads to tackle congestion problem; 'commuter compensation' which encourages commuting Environmental policies—especially to tackle air pollution—introduced successful 'end-of-pipe' or 'incremental add-on' solutions (e.g. catalytic converters), but do not address climate change challenges frontally	POTENTIALLY STRONG Ambitious decarbonisation objectives (currently met, however, predominantly through incremental changes, e.g. transport efficiency and energy efficiency in vehicles) CO_2 labelling scheme for cars (implemented at EU level in 2011), making carbon-efficiency explicit to consumers High fuel taxes Parking and driving restrictions in urban areas
Public debate and opinion	STRONG Society is still highly dependent on the car	STRONG Environmental awareness, health concerns,

	(or partly perceived to be); Individualism, private ownership, a strive for independence, and other 'modern-day' societal trends and norms are reinforcing this perception	urban lifestyles, etc.—especially among young people—are showing moves away from automobility, supporting in particular cycling
Social movements, NGOs, scientists		STRONG (but highly localised in city centres) From the 1970s onwards, activists have been challenging pro-car urban planning (in city centres), reclaiming urban cores and seeking benefits in terms of urban life, health and environment, which influenced e.g. the development cycling infrastructure
Overall assessment	STRONG	MODERATE

Stability and tensions in Dutch automobility regime

	Lock-in, stabilising forces	**Cracks, tensions, problems**
Technology and market developments	STRONG Public transport is thoroughly developed in the Netherlands Rail is the main public transportation means for long-range mobility (its network covers most of the national territory and all major cities) Buses share infrastructure elements with cars, which strengthens their existence and gives them flexibility in planning and operation (as opposed to the rail) As the bus system depends on the same infrastructure as cars, it is relevant for niche experiments with e.g. alternative engines and fuels (potential incremental 'green' changes) There have been important efforts to integrate public transport (e.g. making connections between rail and buses easier) and support multimodality (e.g. park and ride; cycle sheds at train stations) Ticketing simplification and reliable travel information	WEAK Railway: In 2001, a series of infrastructural failures and strikes caused user dissatisfaction. (since then, however, quality of service has been improved) Buses suffer from a somewhat negative cultural representation, i.e. 'people transport', slow, infrequent, etc.
Actors and Institutions	STRONG Although public transport concessions have gradually been opened to tenders, the government retains the responsibility for the infrastructure Mainline railway services are overwhelmingly operated by a single company: Nederlandse Spoorwegen (NS) which faces literally no competition (Provincial and regional railways are operated by different companies)	WEAK Multiple service operators at local level since liberalisation

Users	STRONG Due to relatively high standard of service, public transport has a good reputation among users Students make up a large percentage of public transport users	WEAK In the early 2000s, some issues caused user dissatisfaction (see above)
Policy-makers	STRONG Public transport is seen as an area of public utility for which lasting support and continuity can be expected Policies aim at improving accessibility; provide diverse options; improve overall wellbeing; and maintain high comfort and safety record. Also efforts are made to increase reliability and frequency of service as well as to geographically expand the network. These policies implicitly aim to attract more users Financial incentives to encourage public transport use (often, these lead to a shift from soft modes and to higher intensity of travels)	MODERATE In line with spatial planning strategies (compact city; network of cities), urban cores have been stronger connected through railways and highways, which partly led to longer travel distances and partly also reinforced car usage
Public debate and opinion	STRONG Public transport has a good reputation based on its well-functioning	WEAK The public transport system does not seem to be currently experiencing negative or challenging public debates and opinions
Overall assessment	STRONG	WEAK

Stability and tensions in Dutch public transport regime

	Lock-in, stabilising forces	**Cracks, tensions, problems**
Technology and market developments	STRONG High-density territorial organisation and dedicated infrastructure (comprehensive network of bicycle paths) Integrated traffic planning Cycling generates a major commercial market (more than 1 million bicycles sold yearly) Rental service operated by NS (‘OV-fiets’), with 180,000 members in 2014	MODERATE E-cycling has contributed to overall increased cycling rates in recent years but, in part, been replacing conventional bicycle journeys (rather than car journeys)
Actors and Institutions	STRONG Civic society is largely supportive of cycling Bicycle manufacturers; know-how	n.a.
Users	STRONG Cycling is widespread in the Netherlands, contributing to 26% of total journeys and 50% of journeys between 1 and 2.5 km Deeply seated in individual habits and daily practices	WEAK Bicycle theft is a problem (nearly 750,000 thefts per year) Safety concerns, but also safest country for cycling

	Age, gender, or social background seem to not influence bicycle use, at least in Amsterdam	
Policy-makers	STRONG Cycling policy (implemented mainly by municipalities) is a major reason for success of cycling in practice Infrastructure policy, i.e. improvements of infrastructure quality (improved lanes, parking spaces, safety, etc.) are key Incentives like the cycle-to-work scheme (with financial rewards) have been implemented	n.a.
Public debate and opinion	STRONG Cycling has a long-standing cultural acceptance and the bicycle is globally a cultural reference for the Netherlands Cycling is considered beneficial for the environment, health, etc. and associated with flexibility	WEAK Cycling is associated with danger (although cycling in the Netherlands is very safe compared to other places, largely due to infrastructure arrangements) and, in parts, with inconvenience
Social movements, NGOs, scientists	STRONG From the 1970s onward, environmental activists and cycling clubs successfully challenged pro-car urban planning and through lobbying achieved the rollout of large-scale cycling infrastructure	n.a.
Overall assessment	STRONG The Netherlands has the highest cycling rate in Europe; cycling is culturally deeply embedded and has profited from successful policy interventions. The Netherlands has a well-established and safe cycling infrastructure network, all of which contributes to a strong stability of this regime. In recent years, e-cycling has been replacing some far-distance conventional bicycle journeys.	WEAK Highly stable role of cycling in the Netherlands, integration in landscape, infrastructure, culture and lifestyle.

Stability and tensions in Dutch cycling regime

2.8. Regime analysis of the Dutch agro-food system

The analysis of stability and the tensions within the Dutch agro-food domain, focuses on a number of sub-systems and sub-regimes: four production sectors (dairy, meat, vegetables, fisheries) and the retail sector, which is an important agent between consumption and production. The main conclusion is that there are indeed tensions within the various sub-regimes, but these tensions rather lead to adaptation within these sub-regimes than to new regimes. Most of the sub-systems and regimes are relatively stable. There are strong lock-ins, due to high investments on the production side, as well consumers' preferences on the consumption side. Moreover, there are yet no 'break-through' technologies in agro-food in the direction of a truly significant lower impact on biodiversity or GHG emissions (in the

magnitude of 80-90% lower emissions or land use). This is largely caused by the nature of agro-food production, which is still mainly based on crop productions (including grasslands), and partly based on fisheries. Major breakthroughs of niche innovation, such as in-vitro meat culture on the production side, and a substantial switch to locally sourced food or vegetarianism on the production side are not be expected in the near future. This is different from for example the electricity domain, where a complete change in regime is feasible (like from fossil to wind).

As is argued in Chapter 2 of this report, the changes required to meet a number of environmental and other societal goals are profound, but are less drastic than in the energy domain: a reduction of greenhouse gas emissions from agriculture by around 25% is required (2050 relative to 2005). To meet the biodiversity target the management of probably 5-20% of the current agriculture area need to be different. In other aspects, the required changes are larger: in order to reduce to external effects of agriculture, nutrient losses have to be reduced significantly, while the use of pesticide and antibiotics have be reduced considerable. Reduction of pressure on the environment will largely have to come from stepwise (or accelerated improvements) within existing regimes (notably in case of improvement through technological measures as in 'Pathway A'). Some regimes can become larger at the expense of others (for example more plant-based food and less animal-based food). Other identified niche innovations involve a change of the nature of a regime (for example conventional versus organic production), or global supply chains versus local supply chains.

This report has found that in agro-food many incremental changes occur, partly as a result of technological process, partly as a result of pressure from society. Due to incremental technological improvement in production regimes, the production of plant and animal products is generally becoming more efficient (in terms of land, water and energy use). Due to pressure from NGOs or the general public certain issues are put forward, leading to cracks in current regimes. In general this leads to adaptation of current regimes. Examples are the increased concerns around animal welfare (leading to higher animal welfare standards), as well as around overfishing (leading to a higher market share of MSC or ASC certified fish.

Also on the consumption side incremental changes are generally favoured over niche innovations. For example experiments with hybrid meat do only have a limited influence on the main actors' interests, but can lead to lower meat consumption. This example can be framed as an 'in-between' or hybrid solution. The minor changes that are occurring in the agro-food domain can be seen as reconfiguration, and as we discussed in Deliverable 2.1. most of the innovations belong to Pathway B.

As the different domains are relatively stable and locked in, because there are mainly big companies involved with high stakes, we can expect that the niche innovations described in D2.1. will mainly have some minor influences on the sector, but will not lead to a breakthrough. The Dutch fish sector (both on the consumption side as well as on the production side) has undergone major changes over the last 10 years. One development is the replacement of wild catch by fish from aquaculture. Another important development is the rise in MSC certified fish. Within the fisheries sector, this has led to a major shift in applied fishing methods, as from bottom trawling to pulse wing trawling. This is not only method with much lower negative impacts on marine biodiversity; it also saves lots of fossil fuels.

	Lock-in, stabilising forces	**Cracks, tensions, problems and opportunities**
Meat regime	STRONG • Very stable market, huge players involved and meat consumption is an important part of culture	MODERATE • There is societal pressure on the meat regime. However, as eating meat is also a cultural issue and the production system is locked in, it is difficult to change.
Fish regime	WEAK • As a result of the decreasing fish population changes are occurring and the sector is not so much locked in.	MODERATE • Awareness on the decreasing fish population has led to measures to stop that decline. • Public opinion, the pressure from society via NGOs and social movements and the development of MSC have led to changes in the fish sector.
Dairy regime	STRONG • The sector is relatively stable, because the large investments made in land, machinery and livestock. However changes can occur, but will be mainly within the dairy regime.	MODERATE • The dairy sector has a good image in the public debate and many actors would like to keep that. Dairy processors are asking for 'meadow milk'. • Technologies like milking robots can increase production and create flexibility (to a certain extent) for the farmer • The abandonment of the milk quota will probably have an impact on the dairy sector, but what the impact will be is not clear yet.
Vegetable farming regime	STRONG • Large investments in machinery, land and greenhouses make that only certain changes in cultivated crop type can occur.	MODERATE • The prices are under pressure, what makes people looking for alternatives. • The introduction of GPS and precision farming can increase production
Retail regime	STRONG • The market is competing and a couple of large retailers are dominating the market.	MODERATE • Discussions on animal welfare are influencing the supermarkets. Furthermore in consortia they set targets for example for sustainable fish. The retail is changing, but as they have a large market share and only a couple of retailers are dominating the market it is hard to change.

Stability and tensions in the Dutch agro-food regimes

2.9. Regime analysis of the Hungarian agro-food system

This report analyses the stability and tensions in incumbent socio-technical regimes within the Hungarian agro-food domain. Three distinct relatively stable sub-systems or regimes within the agro-food sector have been identified as being the most polluting ones with the highest environmental impact, and also most embedded in global food system: beef, pork and retail regimes. Their pathway is remarkable also because contrary to the EU tendencies they faced development (in beef), contraction (in pig) and stagnation (in retail) in recent decade. Finally the political salience of these agro-food regimes is the highest although their economic significance has remarkably diminished.

As a main conclusion the analysis contends that the tensions within the regimes are not strong enough to ignite radical change, therefore they will lead to adaptation of the regimes. Path-dependencies in the regimes create lock-ins, which cannot be easily changed. Being the most important pressure on the regimes economic tensions started to increase after the crisis in 2009.

The financial crisis drastically decreased demand of price-sensitive consumers, and also ignited austerity policies that exploited resources for the agro-food transitions. The analysis also points out that socio-technological innovations gradually push agro-food domain to decrease their impact on biodiversity or GHG emissions.

Any progress is expected to be part of a stepwise and planned process (or accelerated environmentally friendly improvements) within existing regimes. Furthermore, behavioural change and capability to act on the consumers' side would be an important prerequisite of any incremental change and mitigation of environmental impacts. Some cracks appeared in all regimes and created windows of opportunity for well positioned actors. Still, radical innovation is not to be expected within the agro-food sector.

The main manifestation of landscape pressure in each regime is price squeeze, competition and struggles for economic survival. Actors in beef, pork and retail regimes use different strategies to protect their own innovative niche against predominant market forces. A few actors including a few policymakers build coalitions and perform a protective role for niches to consolidate. Still, these learning processes towards sustainability transitions are relatively weak in the agri-food domain.

	Lock-in, stabilising forces	**Cracks, tensions, problems and opportunities**
Pork regime	STRONG Very stable market with hegemonic players involved. The production system is locked in through trade-offs between feed-related emissions, manure management, resource efficiency and energy use.	STRONG Many type of pressure from policy and market forces.
Beef regime	STRONG Stabilized regime that enjoys continuous policy support. Concerns about economic viability.	WEAK Tensions and problems do not have the power to change the system.
Retail regime	STRONG Fierce competition in the basic product categories. Large retailers buying power dominates the regime.	WEAK The cracks are weak and will not change the system that is locked in very easily.

Stability and tensions in the Hungarian agro-food regimes

2.10. Regime analysis of the Portuguese land-use system

Land use domain in Portugal is characterized by four regimes: agriculture, forestry, nature and urban, and one sub-regime the montado where both the agriculture and forestry regimes co-occur. The land use domain in Portugal has changed considerably in the last 100 years, both through changes between regimes, particularly the expansion of forestry and the conversion of agriculture to urban, but also through intra-regime changes (e.g. shift of pine plantations to eucalyptus plantations). Our study highlights the cracks and tensions for each of the land use regimes, and provides an assessment of the stability of the domain.

Agriculture regime

The agriculture regime in Portugal still represents a great percentage of the use of the land. Despite expected farmland abandonment still being expected in the future (crack and tension), the agriculture regime is also expected to remain as one of the dominant regimes in the national context. Overall the total surface of farmland has decreased mostly in marginal areas. We assess the agricultural regime to be a stable system.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	MEDIUM - EU policy e.g. CAP influences many of the decisions farmers take upon their agricultural practices. - Subsidies paid to farmers create dependency. In 2011, the government announced that farmers submitted 900 million euros of applications for 50 million euros offered under the European-backed rural development program PRODER. In 2012, the Portuguese government announced further incentives offering 63 million euros to support projects related to agriculture.	MEDIUM/ STRONG - Climate change. - Financial-economic crisis. - EU policy e.g. CAP and Natura 2000; agricultural CAP subsidies influence agricultural practices as well as EU policy like the Birds and Habitat Directives place requirements on how to use and manage land used for agriculture which is not always understood by farmers.
Farmers	STRONG - Investments in machinery and land. - Traditional values influence the way farmers manage the land.	MODERATE - Market prices can influence the mode of production. - Many farmers struggle to make their activity economic feasible.
Consumers	STRONG - Consumer food demands influence food prices, amount of land needed for agriculture production as well as mode of production. The market for bio-products is influenced by how many consumers are willing to pay extra for their food to be produced in a more environmentally friendly manner. - In general consumers have limited awareness of the costs of food production as well as the process.	WEAK/ MODERATE - Bio-physical constrains associated to economic capacity limit the expansion of agriculture when demand increases. - Retail sector determines much of the “rules of the game” as far as price is concerned for mainstream food market. - Farmers increasingly aware of added value for bio-food market but not always willing to pay premium price.
Policy-	MODERATE	MODERATE

makers	- National policy development is highly constrained by EU policies.	- European, National and local goals are not always completely aligned and may conflict in some cases e.g. nature and agriculture. - Some discontentment with European policies.
Public debate and opinion	MODERATE - Traditional practices and products like cork, olive, and wine are part of Portuguese landscape and culture.	MODERATE - Trend to support national products when prices are competitive (local vs. global).
Pressure from social movements, NGOs, scientists	WEAK/MODERATE - Farmers associations resisting changes, afraid of losing access to subsidies.	WEAK - Since the last financial-economic crisis (2009) some young people have turned to the rural areas and agriculture as a means of subsistence. Faced with decreasing opportunities in the cities and higher unemployment rates and new incentives offered from the Portuguese government, some young people are trying to set up businesses in rural countryside.
Overall assessment	MODERATE/ STRONG Agriculture regime is fairly unstable. The main stabilising force is probably policy and the subsidies offered. Cultivation of one crop to another changes fast in response to subsidies targets.	STRONG There are major tensions in the agriculture regime. Tensions are mainly related to a decreasing income from the sector and decreasing interest in agriculture (type of work) from younger generations.

Stability and tensions in the Portuguese agriculture regime

Forestry regime

The forestry regime assumes a great percentage of the use of the land in Portugal. In combination with agriculture, in ago-forestry as a sub-regime, or on its own, the forestry regime has been increasing. Economically, the forestry system contributes a great share of the national economy and affords the country international visibility (exportation).
We assess the forestry regime to be a stable system.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	MODERATE/STRONG - Paper, pulp and cork market demand.	MODERATE - Climate change (biofuel and carbon trade markets). - Financial-economic crisis. - Market Timber value. - Alternative wine bottle sealers, which before used exclusively, cork tops.
Forest owners	STRONG - Significant economic importance of forestry in the national context. - Investments in land and technology associated with wood by-products production. - Property regime.	WEAK/MODERATE - Development of forest owner cooperatives to manage forest areas. - Risk of fire.
Consumers	STRONG	MODERATE

	- Demand for agro-forestry products (e.g. paper, pulp, cork and wood products).	- Demand for certified wood products. - Growing environmental awareness is pushing for substitute alternatives for paper and cork.
Policy-makers	MODERATE - Policy has supported mainly expansion of forest without placing enough attention to management.	MODERATE - Fires creates a lot of public pressure every year.
Public debate and opinion		MODERATE/ STRONG - Fire is usually on national news every summer causing public discontentment. - Increase of eucalyptus plantations is not well accepted.
Pressure from social movements, NGOs, scientists		WEAK/MODERATE - Concerns about increasing use of invasive species such as eucalyptus and the environmental consequences its increase use may represent for future national forest species.
Overall assessment	STRONG Forest represents a strong source of income nationally.	WEAK/MODERATE - Fire is a big issue in the context of national forest regime.

Stability and tensions in the Portuguese forestry regime

Nature regime

The nature regime can be mapped to a great extent to the Natura 200 network and the nationally designated areas. National policies reflect to the orientation of European policies and despite the cutting down of some European subsidies available to farmers to create incentives for farmers to practice a low impact agriculture practices on nature, we believe the nature regime to have some flexibility for change, less stable.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	- EU policy e.g. Birds and Habitats directives influences land use decision however the low economic importance of nature regime when compared with other land uses increases the pressure on nature regime.	- Climate change. - Land use change, intensification, extensification and abandonment of agriculture.
Protected Area Managers		MODERATE - Need to consider other stakeholders interests, which may not always have conservation as the number one priority.
Citizens	WEAK - Use of nature areas for recreation or tourism.	WEAK
Policy-	MODERATE	MODERATE

makers	- EU policy on nature guides national policy development. - Budget allocated for nature usually is the first to suffer from cuts in times of economic instability.	- Nature policy may conflict with other sector policy goals e.g. agriculture.
Public debate and opinion	MODERATE Public view of nature is still very stylized. Associated with parks and gardens where human intervention is high.	MODERATE - Biodiversity issues do not rank high in the list of priorities.
Pressure from social movements, NGOs, scientists	MODERATE - ICNF the national institute responsible for nature conservation has a well-defined role.	MODERATE - Pressure groups have occasionally contested the Portuguese government development authorization decisions that affected nature taking up the case to European courts e.g. Dam of Tua
Overall assessment		MODERATE There are opportunities for Nature regime to take over agricultural land estimated to be abandoned in the future, especially when such land is located in marginal difficult access areas such as mountains.

Stability and tensions in the Portuguese Nature regime

Urban regime

The urban regime is a locked-in regime. Once the built environment is built it is quite unlikely it will convert into another regime. There are however some tensions observed within this regime which on the long run may trigger a re-organization of the regime. Urban related policies as well as citizen demands will definitely influence the pace of change.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures	Physical constrains	- Climate change - Financial-economic crisis
Industry and Businesses	MODERATE Construction sector plays a big influence in the national economy, enabling it to influence political decision-making process. This influence is now weaker since after the 2009 financial crisis this sector lost power.	
Citizens	STRONG The majority of the Portuguese population live in cities.	WEAK - Some incentives from national government have been implemented to attract young people to rural areas but adhesion still negligible.
Policy-makers	MODERATE - Policies concerning urban areas and green spaces are separate; there is a lack of policy integration.	MODERATE Awareness of the need to introduce mechanisms for integrating more green spaces into cities.
Pressure from social		MODERATE - Movements to increase nature in the cities:

movements, NGOs, scientists		Birdwatchers and NGOs promote nature related activities in the city, national movement promote urban farming.
Overall assessment	MODERATE - Once cities are in place the physical space occupied by them is difficult to change. - Political apathy to change current cities, mostly due to financial constraints.	WEAK/MODERATE - Social demand for greener cities - Urban design solutions available

Stability and tensions in the Portuguese urban regime

Land use domain (overall conclusions)

The land use domain in Portugal has changed substantially in the past three decades. Such changes have mainly been driven by external developments e.g. globalization that has translated in significant socio-economic, social and biophysical changes. Despite land use change usually being a long-term process, it is also a dynamic one. With the exception of urban regime, which is difficult to be converted into another regime once it is established, all other regimes show potential to accommodate some degree of change. In Portugal the greatest amount of land use change for the coming years is expected to come from agriculture land use, which is estimated to become abandoned in the coming decades and hence, free to be used in another way. Land use domain includes multiple regimes which may occur simultaneously, varying their relative proportion, or discretely. In every case, as the previous tables demonstrate, each regime influence developments in other regimes and together land use domain.

	Lock-in, stabilising forces	**Cracks, tensions, problems**
External landscape pressures		- Climate change - Financial-economic crisis - EU policy e.g. CAP, Natura 2000
Land use stakeholders	STRONG - Different interest and goals, some conflict with others interests.	
Policy-makers	STRONG - Policy development responds largely to society pressures and demands. More attention given to certain land uses than others which influences on the ground for what use land is being used for. - Bio-physical constraints.	
Public debate and opinion	MODERATE Public concerns about prices of land.	MODERATE - Public concerns with future impacts of climate change.
Overall assessment	MODERATE Bio-physical constraints and policy can work as lock-in mechanism.	MODERATE Land use domain is fairly unstable, external and socio-economic factors may push for changes.

Stability and tensions in the Portuguese land use domain

2.11. Regime analysis of the Dutch land-use system

The land use domain consists of different regimes, namely the agricultural, nature, water and urban regime. Each of these regimes consists of a socio-technical system (tangible elements) and a socio-technical regime (intangible elements). This report describes the different regimes with the goal to assess the stability and tensions in the different regimes. Besides the analysis of the different regimes the overall system trends and developments and external landscape developments are described.

In the external landscape we can make a distinction between destabilizing and stabilizing developments. The main destabilizing developments are climate changes, increasing pressure on land, urbanization, the economic crisis, increasing demand of energy by households and digitalization of society. Furthermore external events like floods or animal diseases have an impact on land use as well. Recent policy changes have led to shifts in the policy on land use and for example the nature regime.

The main stabilizing developments are the fact that land use is hard to change as the character of land use is stable. The way land is used is not easy to change and investments, that are often large, have a long time horizon. Furthermore institutions are locked in, especially in the water and nature regime.

The main challenges related to multifunctional land use are dealing with biodiversity goals. Greenhouse gas emissions do a play a role as well, but the most visible direct effect is on biodiversity. The global goal is to stop the decrease in biodiversity. In order to reach the targets for biodiversity, different pathways can be taken. In this report we will mainly focus on the decentralized pathway, in which solutions are found in consumption, land use and reduction of emissions. The plan for the Netherlands is to expand the nature network with 80,000 hectares new nature between 2011 and 2027. However, much will depend on choices made regarding policy.

For every regime the developments in the socio-technical system and socio-technical regime are discussed. The table below provides an overview of the overall assessments of the different regimes. The analysis showed that the different regimes, except for the nature regime are strongly locked in. Large investments (agriculture, water, urban) with a long time horizon make that change cannot be realized easily. Furthermore institutions are strongly organised.

The main cracks and tensions seem to be caused by policy changes. In all regimes, except for the nature regimes, cracks and tensions are moderate or weak, what means that radical changes are not to be expected on the short run. The nature regime is different as recent policy changes have caused differences in organisation and managing the nature regime. In the land use domain we see that the lion's share of the changes is caused by crises, often originated from the landscape, such as animal diseases, the financial crises or floods. What is characteristic for the land use domain is that as a result of competing claims on land the regimes are influenced by other land use regimes. Examples of regimes influencing each other are the nature and agriculture regime. These two regimes are sometimes conflicting, but can also strengthen each other. Multifunctional land use is, as is already suggested by the name, a combination of different regimes, and not necessarily a modal shift in which one regime is growing and another one is declining. In order to be able to study multifunctional land use it is important to take into account different regimes. Often changes are caused by changes in other regimes.

In general the main changes in the land regime can be called transformation of existing regimes, rather than 'opening up' the regime for niche innovations emerging into new regimes as a result of major cracks and tensions.

	Lock-in, stabilising forces	**Cracks, tensions, problems and opportunities**
Agricultural regime	STRONG • As the lobby in the agricultural sector is strong and relations are established by the chain, the agricultural sector is strongly locked in.	WEAK TO MODERATE • Recently some cracks and tensions are getting visible, mainly caused by public debates and pressure from NGOs on topics like animal welfare, sustainability and healthy food.
Nature regime	MODERATE • The origin of nature conservation and the institutions organizing it are somewhat locked in. But changes are occurring in conservation practices and financial constructions.	STRONG • There is a policy shift from protecting nature towards a more central role for nature in society. Furthermore financial resources are changing what makes that the organisation/management of nature is subject to change
Water regime	STRONG • Not easy to change, as projects are determined for a long term. The institutionalised environment is locked in.	WEAK • There seem to be opportunities to couple the water regime with nature or housing; however water safety is often the core of developments.
Urban regime	STRONG • Once buildings are there, it will not be easy to change in another type of land use. • Regulations regulate most of the issues with build-up areas.	MODERATE • There are not many radical tensions or problems to be expected. The build-up area is not so much under discussion (in the Netherlands). However cities are an interesting place where new initiatives start, like urban farming, smart cities and green roofs.

Stability and tensions in the Dutch land use regimes