PATHWAYS project
Exploring transition pathways to sustainable, low carbon societies
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Deliverable D2.2: ‘Analysis of stability and tensions in incumbent socio-technical regimes’

Country report 2: Regime analysis of the UK electricity system

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Preface

This report is produced in the context of work package 2 (‘Dynamics of transition pathways’) of the FP-7 funded PATHWAYS project (‘Exploring transition pathways to sustainable, low carbon societies’). More precisely, this report provides the UK country study of the electricity regime for deliverable 2.2. (‘Analysis of stability and tensions in incumbent socio-technical regimes’).

The analysis in this report is based on a research template that is shared between the different contributors to WP2 to enable comparative analysis of findings between countries (UK, Netherlands, Sweden, Portugal, Germany) and empirical domains (electricity, heat, mobility, agro-food and land-use).
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Executive summary

This report aims to analyse the degrees of stability and tension in the incumbent UK electricity regime. The report’s background perspective is the multi-level perspective (MLP), which suggests that transitions come about through interactions between processes at different levels: 1) niche-innovations gradually build up internal momentum (through positive interactions between learning processes, vision articulation, and social network building), 2) exogenous changes (at the so-called ‘landscape level’) create pressures on the regime, 3) destabilisation of the regime (cracks and tensions) creates windows of opportunity for wider diffusion of niche-innovations.

Deliverable 2.1 of the PATHWAYS project analysed the momentum of green niche-innovations in the UK electricity domain. This report analyses the influence of landscape pressures and the degree of regime stability. The guiding research questions are: 1) What are the main external landscape developments that affect the UK electricity regime? 2) Do external pressures and internal problems lead to tensions and destabilisation of the UK electricity regime? Or is the regime still fairly stable, with (most) actors focusing on incremental change?

To answer the second question, our analysis focuses both on ‘tangible’ developments in the socio-technical system (e.g. fuel inputs, prices, technologies) and on ‘intangible’ developments in the socio-technical regime (e.g. beliefs, norms, rules and strategies of relevant actors). Our analysis focuses on the entire electricity system, represented in Figure below.1

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1 Electricity consumption occurs not only in households, but also in industry and services, which each account for about a third of overall consumption. We have decided to focus our analysis on domestic consumption, however, because we want to provide a deeper analysis of the various user practices, cultural conventions and routines that shape electricity consumption.
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: 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.

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.

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<th>External landscape pressures</th>
<th>Lock-in, stabilising forces</th>
<th>Cracks, tensions, problems</th>
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<tr>
<td></td>
<td>- Neoliberal ideology and policy (since 1990s)</td>
<td>- Climate change</td>
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<td>- Development of ICT and information society</td>
<td>- Financial-economic crisis</td>
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<td>- further electrification of society (heat, mobility, ICT)</td>
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<td><strong>Utilities</strong></td>
<td><strong>STRONG</strong></td>
<td><strong>WEAK/MODERATE</strong></td>
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<td>- Geo-political tensions with Russia (gas)</td>
<td>- 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.</td>
<td>- 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)</td>
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<th><strong>Consumers</strong></th>
<th><strong>STRONG</strong></th>
<th><strong>WEAK</strong></th>
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<tr>
<td>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.</td>
<td>- 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.</td>
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<th><strong>Policy-makers</strong></th>
<th><strong>MODERATE</strong></th>
<th><strong>MODERATE</strong></th>
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<tr>
<td>- Climate change policy created some regime tensions in early 2000s, but these have been alleviated by renewed commitment to regime technologies (nuclear, coal, gas)</td>
<td>- 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</td>
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<td>Public debate and opinion</td>
<td>MODERATE</td>
<td>MODERATE</td>
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<td>Public concerns about high costs (and energy security) have helped to stabilise the existing regime by creating a more negative framing of renewable energy.</td>
<td>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.</td>
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<th>Pressure from social movements, NGOs</th>
<th>WEAK/MODERATE</th>
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<td>Most NGOs are critical and do not actively contribute to regime lock-in.</td>
<td>* 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.</td>
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<th>Overall assessment</th>
<th>STRONG</th>
<th>WEAK/MODERATE</th>
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<tr>
<td>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</td>
<td>* 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</td>
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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.

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.

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.

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<tr>
<th>External landscape pressures</th>
<th>Lock-in, stabilising forces</th>
<th>Cracks, tensions, problems</th>
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<tr>
<td></td>
<td>-ICT development and information society / smart home</td>
<td>- Financial-economic crisis, which may have affected electricity consumption levels over the last 8 years.</td>
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<td>-further electrification of households associated with persistent cultural conventions for convenience and expectations for rising standards across domestic practices</td>
<td>- Climate change and energy security place pressure on regime to address electricity consumption levels</td>
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<th>Industry</th>
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<td></td>
<td>-UK appliance retailers now compliant and active with efficiency policy agenda</td>
<td>-Possibility of some tensions between appliance industry interests and electricity supplier interests over extent and distribution of policy support</td>
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<td>-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</td>
<td>-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)</td>
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<td>-Consumption of electricity itself is largely invisible and abstract (inconspicuous consumption)</td>
<td>-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.</td>
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<td>-Proliferation of electric appliances in households – and of larger appliances (TVs, fridges)</td>
<td>-Concerns over price rises, but not apparently affecting electricity consumption behaviour.</td>
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<td>-Largely positive reaction to efficiency agenda (although less so than other European countries), especially for cold appliances</td>
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<td>-Persistent influence of cultural conventions for convenience, cleanliness, freshness and rising expectations for connectivity and entertainment underpin the dynamics of domestic practices</td>
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<th>Policy-makers</th>
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<td>- UK policy largely subservient and responsive to EU regulatory frameworks.</td>
<td>-Some political mobilisation (e.g. UKIP) to challenge the European led efficiency agenda.</td>
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<td>- Absence of visions for radical alternatives beyond acceptance of electricity efficiency agenda and likelihood that appliance use will continue to grow</td>
<td>-UK has adopted alternative positions compared to other EU countries that risks solidarity around the EU efficiency agenda.</td>
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<th>Public debate and opinion</th>
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<td>-Little public debate about electricity</td>
<td>- Debates about the price of electricity and</td>
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consumption levels
- Debates and visions around digital inclusion and smart homes point to further spread of ICT devices

security of supply (‘keeping the lights on’), but directed towards the generation sub-regime, rather than consumption and appliance use.

Pressure from social movements, NGOs, scientists

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<th>Pressure from social movements, NGOs, scientists</th>
<th>WEAK / MODERATE</th>
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<tr>
<td>STRONG Not a prominent campaigning issue for most NGOs. Those that do campaign are largely supportive of efficiency agenda, calling for more support and quicker policy implementation.</td>
<td>WEAK Scientific analysis criticises the technology efficiency agenda in terms of rebound effects and lack of focus on behavioural aspects of appliance use.</td>
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Overall assessment

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<tr>
<th>Overall assessment</th>
<th>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).</th>
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<tr>
<td>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.</td>
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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.

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<th>External landscape pressures</th>
<th>Independent regulator (Ofgem)</th>
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<tr>
<td><strong>Lock-in, stabilising forces</strong></td>
<td>- Neoliberal ideology and policy (since 1990s)</td>
<td><strong>STRONG</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</td>
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<td>- Development of ICT and information society (giving rise to debates about ‘smart grids’)</td>
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<tr>
<td><strong>Cracks, tensions, problems</strong></td>
<td>- Climate change</td>
<td><strong>WEAK/MODERATE</strong> 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).</td>
</tr>
</tbody>
</table>
been layered on top of these traditional goals, but has not yet been ‘internalized’.

| 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. |
1. Introduction

Context, goals and research questions: This report aims to analyse the degrees of stability and tension in the incumbent UK electricity regime. This regime analysis is an important step in the broader analysis of transition dynamics using the multi-level perspective (MLP). The MLP suggests that transitions come about through interactions between processes at different levels:

1) niche-innovations gradually build up internal momentum (through positive interactions between learning processes, vision articulation, and social network building),
2) exogenous changes (at the so-called ‘landscape level’) create pressures on the regime,
3) destabilization of the regime (cracks and tensions) creates windows of opportunity for wider diffusion of niche-innovations.

The first step has been analysed in deliverable 2.1 of the PATHWAYS project. Step 2 and 3 will be analysed in this report for the UK electricity domain.

The research questions are:

1) What are the main external landscape developments that affect the UK electricity regime?
2) Do external pressures and internal problems lead to tensions and destabilisation of the UK electricity regime? Or is the regime still fairly stable, with (most) actors focusing on incremental change?

Analytical framework

Work package 2 uses a socio-technical framework, which makes a distinction between:

* Socio-technical system, which refers to the configuration of elements necessary for the achievement of a societal function (such as mobility, heating, sustenance/food and light/power); these elements may include technical artefacts, production facilities, supply chains, infrastructure, markets, consumption patterns, repair facilities, public debates, formal policies.

* Socio-technical regime, which refers to the cognitive, normative and regulative institutions (Scott, 1995) that shape the actions, interpretations, and identities of the actors that reproduce elements of the socio-technical system. These actors include: firms, consumers, policymakers, civil society actors, wider publics, scientists.

Although socio-technical system, socio-technical regime and actors are obviously related, it is useful to analytically separate them because they refer to different dimensions of reality and methods. Socio-technical systems refer to relatively ‘tangible’ or ‘objective’ elements that can often be measured quantitatively (e.g. technical performance, price, market demand). The analysis of socio-technical regimes and actors is often more ‘intangible’ and ‘qualitative’, referring to beliefs, motivations, strategies, alliances, goals, norms that underlie concrete actions.

For the analysis of stability and tensions, we will look both at:

* ‘objective’ system developments, e.g. longitudinal market shares, techno-economic performance problems
* qualitative developments in regime and actor perceptions and commitments (e.g. belief in continued viability, confidence, will to defend and improve).

Characterization of electricity system and project focus

The electricity system forms one large, integrated socio-technical system. It is an integrated system, because production and consumption of electricity need to be balanced in real-time to prevent black-outs. Various upstream inputs (coal, gas, nuclear, biomass, water) are transformed...
into a single homogenous product (electricity), which may be used for many different end-uses (such as lighting, electric cooking, and powering various appliances and devices). Figure 1 presents a socio-technical representation of the electricity system.

A typical characteristic of the current electricity system is that electricity production and use are strongly separated by the electricity grid (transmission and distribution networks). This means that major changes may occur in electricity generation (e.g. shifts from coal to gas or to renewable electricity technologies) without any direct consumer involvement and without them noticing much, except for rising electricity bills (which are only partly related to changes in electricity-generation technologies). Similarly, many specific changes may occur in electricity-using consumer practices (e.g. shifts from incandescent light bulbs to CFL and LED lights, energy efficiency improvements in freezers) without any direct involvement of electric utilities.

Although ‘production’ and ‘consumption’ are obviously linked, their separation via the grid means that they can be studied as relatively independent regimes, characterized by different dynamics. The report therefore answers the research questions for both the electricity generation

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Figure 1: Schematic representation of socio-technical system in electricity

Electricity consumption occurs not only in households, but also in industry and services, which each account for about a third of overall consumption (see Figure 5 below). We have decided to focus our analysis on domestic consumption, however, because we want to provide a deeper analysis of the various user practices, cultural conventions and routines that shape electricity consumption in households.

This has begun to change somewhat with the emergence of decentralised electricity production by households (e.g. via rooftop solar-PV), which leads to more active consumer roles. In the UK, this is still relatively small, however, especially when compared to countries like Germany.
regime (with special attention for coal, gas, and nuclear technologies) and the electricity consumption regime (lighting, cold appliances, wet appliances, consumer electronics, home computing). With regard to consumption, the report focuses on domestic households (which accounts for about 35% of overall electricity consumption) rather than industry and services (see Figure 5 below). We also analyse the electricity grid as a separate regime.

**Data-sources**
The research was empirically challenging, because it addresses multiple dimensions (techno-economic, socio-cognitive, political). Quantitative information for ‘tangible’ system elements has been collected from energy statistics sources available from DECC (Department of Energy and Climate Change) and from reports by the Committee on Climate Change. Qualitative data and interpretations draw on the tacit knowledge of the analysts (who are sector experts), secondary sources (books, articles, reports) and primary sources (White Papers, policy documents, newspapers, company annual reports, industry journals). The heterogeneous data were integrated to construct an interpretive analysis.

**Report structure**
The report is structured as follows. Chapter 2 describes overall system trends and longitudinal developments, e.g. environmental performance, fuel mix and sectoral demand developments. Chapter 3 identifies the main external landscape developments that affect the electricity regime. Chapter 4 describes longitudinal developments in the UK electricity generation regime. Chapter 5 does the same for electricity consumption and end-use regimes. Chapter 6 addresses the electricity network regime (transmission and distribution). Chapter 7 provides conclusions on stability and cracks in these regimes.
2. Overall system trends and longitudinal developments

Environmental performance (CO2-emissions)

The environmental performance of the UK electricity system (in terms of CO2 emissions) improved steeply in the 1990s (Figure 2), because of the switch from coal to gas but worsened again from 1999 to 2006 (because of increased coal use). CO2-emissions fell by 11% from 2007 to 2012, driven by lower electricity consumption (due to the recession) and investments in new gas and low-carbon generation (CCC, 2014: 146).

![Figure 2: UK carbon-dioxide emissions from electricity sector in Mt (based on energy statistics from Department of Energy and Climate Change, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/193414/280313_g hg_national_statistics_release_2012_provisional.pdf)](image)

To achieve the targets in the 2008 Climate Change Act, the Committee on Climate Change suggests that CO2-emissions from electricity should fall rapidly in the next 15 years to achieve an energy intensity of 50-100 gCO2/kWh (Figure 3). This will clearly be a challenging task, especially when electricity demand will increase again when the economy recovers from the recession.
Longitudinal fuel developments in electricity generation

The actual production of electricity takes place ‘upstream’, where large-scale, capital-intensive installations convert the energy embodied in coal, gas, nuclear, water into power. The different fuel sources are converted into a homogenous product (electricity), which offers little opportunity for product differentiation. Figure 4 portrays longitudinal developments in the UK fuel-mix of electricity production.

Figure 3: Actual electricity sector emissions, compared with indicator trajectory (2000-2030) associated with ambitions in the Climate Change Act (CCC, 2014: 104)

Figure 4: UK electricity generation system (data from International Energy Agency)
**Longitudinal developments in electricity consumption and user practices**

Electricity has become a taken-for-granted background of modern life, enabling many end-use practices such as lighting, washing, cooling, freezing, cooking, entertainment (TV, radio, computer). Electricity consumption is hardly questioned and stabilised by daily-life routines and cultural conventions. Electricity consumption peaked in the mid-2000s after decades of increases (Figure 5). Electricity use fell by 7% between 2008 and 2012 (CCC, 2014), mostly because of the economic recession (which especially affected industrial use), and to a lesser extent because of energy efficiency improvements in some end-use sectors. Domestic electricity use peaked in 2005 at 125.7 TWh, and subsequently decreased, with some increases in 2010 and 2012 because cold winters increased the use of electric heaters. Electricity use in services remained stable.

![Figure 5: UK electricity consumption, 1980-2012 (DECC, 2013a: 29)](image)

Long-term electricity use is expected to increase (Figure 6) because of ongoing household electrification (driven by consumer electronics and ICT) and because of a possible electrification of transport (electric vehicles) and heat (e.g. electric heat pumps), in response to decarbonisation efforts. Growing electricity will require major expansion of electricity production and grid improvement (especially in case of bi-directional flows, smart meters, smart grids etc.).

![Figure 6: Past and projected (to 2030) UK electricity demand (CCC, 2011: 44)](image)
3. External landscape developments

The UK electricity system has been affected by several exogenous landscape developments:

1. The gradual shift towards an information society has two effects: a) a continued electrification of the home, based on the proliferation of ICT-devices (laptops, mobile phones, tablets, smart home electronics), is likely to increase electricity consumption, b) smart technologies (smart meters, smart grids) may change the functioning of the electricity grid, interactions between suppliers and consumers, and provide more information on electricity use to consumers.

2. Possible further electrification of society (e.g. electric heat pumps, electric cars) may increase electricity consumption in the coming decades.

3. Neo-liberal ideology led to privatisation and liberalization of the UK electricity system in the 1990s and the adoption of a hands-off policy style. Low electricity costs became a crucial goal for both utilities and policymakers.

4. The global issue of climate change has gained prominence since 1997, when Labour won the elections. The 2003 White Paper (Our Energy Future: Creating a Low-Carbon Economy) included the goal of 10% renewable electricity by 2010 and 60% reduction of GHG emissions by 2050. The 2008 Climate Change Act, which committed the UK to 80% GHG reduction by 2050, was a relatively radical policy (Carter and Jacobs, 2014) that further increased the political salience of climate change.

5. Geo-political tensions with Russia (since 2005) increased the importance of energy security in energy policy (especially regarding gas supply).

6. The financial-economic crisis affected the electricity system in several ways: a) it decreased electricity demand (from households and industry), b) subsequent austerity policies created pressure on available financial resources for the energy transition, complicating investments, c) it increased concerns about energy prices, leading to a political controversy in late 2013 which partly blamed the low-carbon energy transition for raising prices.
4. Developments in the electricity generation regime

4.1. Developments in (tangible) system elements

Fuel inputs and prices
UK electricity generation has long been based on three core technologies: coal, gas and nuclear power. Renewable electricity technologies (wind, solar-PV, biomass), which increased from the mid-2000s, were described in deliverable 2.1 of the PATHWAYS project. This report will focus on coal, gas and nuclear technologies, which changed in relative importance over the last 25 years (Figure 7).

Figure 7 shows how gas replaced coal in the 1990s in the ‘dash for gas’. Since 2000, the use of coal and gas fluctuated, depending on changes in relative prices (Figure 8). Gas use decreased in 2004 when prices increased (Figure 8), went up again in 2006 when gas prices decreased. Coal use increased strongly after 2010, when cheap American coal flooded the world market (because of the US shale gas revolution), which pushed prices down, and because of low carbon prices in the European Emissions Trading scheme (below 5 euros per tonne). Nuclear power increased in the 1980s (Figure 7), but decreased since the late 1990s.
The price index for domestic electricity (Figure 9) decreased in the 1990s (as a result of privatisation and cost-competition), but has increased steadily since about 2004. These price increases were, at least partly, due to price increases of fuel inputs (Figure 8).

**Industry structure**
The UK electricity industry was privatized in 1990 and further liberalized in 1998, which (eventually) resulted in the ‘Big Six’ companies: EDF, E.ON, SSE, British Gas, Scottish Power,
N-Power. These developments changed the guiding principles of utilities, which came to focus on price competition and sweating assets.

**Domestic production, import and export**

For both coal and gas, UK electricity generators have become increasingly reliant on imports from world markets (Figures 10 and 11). The use of domestically produced coal collapsed after privatisation with utilities increasingly switching to cheaper international coal (Figure 10). In the 1990s, the UK benefitted from substantial new finds of natural gas in the North Sea (Figure 11), which boosted the ‘dash for gas’ in electricity production. However, domestic gas production has declined since 2000, leading to greater gas imports. By 2010, gas imports overtook UK domestic production (Figure 11).

![Figure 10: UK coal production and imports, 1970-2013 (based on data from DUKES: Digest of UK Energy Statistics)](image-url)
Recent and future investments

Table 1 presents recent and future investments in electricity generation and transmission capacity. It shows that total investments between 2010-2013 were around £50 billion, largely in renewables generation and transmission grids. Investments up to 2020 are estimated to be about £100 billion (DECC, 2014), again largely in renewables and transmission grids. Table 1 somewhat mis-represents future investments in nuclear power, which will accelerate after 2020. The new Hinkley C nuclear power plant alone is estimated to cost £16 billion; its start-up date has been pushed back from early 2018 to 2023, because of delays. Two other plants, Wylfa and Moorside (£10 bn), are estimated to cost £20 billion and £10 billion respectively. The government hopes that up to eight new nuclear plants will be built by 2030, delivering 16 GW new capacity. These plants, which may be built in the 2020s, will require large investments.

The government also plans a substantial expansion of new gas capacity (16-25 GW by 2030), which will require investments. There are currently no plans for investment in unabated new coal-fired power plants. There are currently 72 coal-fired power plants in England, most of which were constructed in the 1970s and 1980s. Investments in new coal-fired power plants stalled during the ‘dash for gas’ in the 1990s. Since then, there has been very little investment in new coal-fired power plants. Utilities floated plans to construct new coal plants around 2008, but these were not built because of protests and procedural delays. Plans were put on the backburner in 2009, when the government announced that new coal plants would have to incorporate CCS technologies (carbon capture and sequestration). In recent years, (some) coal-fired power plants have been closed or converted to biomass (Table 2), because they reached the end of their life span or because of environmental legislation such as the European Large Combustion Plants Directive (LCPD).

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Renewables</td>
<td>£28.9 bn</td>
<td>£40-50 bn</td>
</tr>
<tr>
<td>Nuclear</td>
<td>£2 bn</td>
<td>£10-12 bn</td>
</tr>
<tr>
<td>Gas</td>
<td>£2.5 bn</td>
<td>$4.1 – 4.7 bn</td>
</tr>
<tr>
<td>Electricity networks (transmission, distribution)</td>
<td>£16 bn</td>
<td>£35 bn</td>
</tr>
<tr>
<td>Interconnectors</td>
<td>£1 bn</td>
<td>£2.4 bn</td>
</tr>
<tr>
<td>Subsidy for CCS demonstration projects</td>
<td></td>
<td>£1 bn</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£50.4 bn</strong></td>
<td><strong>£92.5-105.1 bn</strong></td>
</tr>
</tbody>
</table>

*Table 1: Estimated investments in new electricity generation and transmission (based on data from DECC, 2014)*

<table>
<thead>
<tr>
<th>Status</th>
<th>Previous capacity</th>
<th>New capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kingsnorth A</td>
<td>1940 MW</td>
<td>0</td>
</tr>
<tr>
<td>Cockenzie</td>
<td>1152 MW</td>
<td>0</td>
</tr>
<tr>
<td>Drax</td>
<td>Partially converted to biomass in 2013</td>
<td>3870 MW</td>
</tr>
<tr>
<td>Ironbridge</td>
<td>Converted in 2013</td>
<td>940 MW</td>
</tr>
<tr>
<td>Tilbury B</td>
<td>Closed in 2013</td>
<td>750 MW</td>
</tr>
<tr>
<td>Didcot A (coal/gas)</td>
<td>Closed in 2013</td>
<td>1036 MW</td>
</tr>
<tr>
<td>Ferrybridge C</td>
<td>Partially closed in 2014</td>
<td>1960 MW</td>
</tr>
<tr>
<td>Uskmouth</td>
<td>Closed in 2014</td>
<td>363 MW</td>
</tr>
</tbody>
</table>

*Table 2: Closed or converted coal-fired power plants between end-2010 and May 2014 (data from DUKES)*

The next section will discuss, in greater depth, the beliefs, strategies and institutions that shaped the actions and choices of various actors in relation to the electricity generation regime.

### 4.2. Developments in social groups and (intangible) regime elements

**Changes in electricity generation policy and governance style**

Some of the exogenous landscape pressures have led to changes in particular policies (goals and instruments) and governance style. Neo-liberal ideology led to privatisation of the UK electricity generation industry in 1990 and further liberalisation (of electricity markets) in 1998. This entailed government stepping back and adopting a more ‘hands-off approach’, which was symbolized by the disbanding of the Department of Energy in 1992 and the creation of independent energy regulator (Ofgem). This change in governance style introduced competition and market-principles in the electricity system, strengthening the focus of firms on low costs.
Climate change became a new topic in the late 1990s and early 2000s, leading to a 60% GHG reduction target in the 2003 White Paper. The labour government initially aimed to address this new problem within the existing market-based neo-liberal policy style, emphasising emissions trading as the main policy instrument (especially the European Emissions Trading Scheme). While the 2003 White Paper focused very much on renewable energy, subsequent policy papers (e.g. the 2007 White Paper, 2008 Climate Change Act) reintroduced nuclear energy, coal and gas (with carbon capture and storage) into the debate. The 2008 Climate Change Act, which introduced 80% reduction targets for 2050 and intermediate targets for subsequent carbon budgets (2008-2012, 2013-2017, 2018-2022, 2023-2027). In 2008, the government also created several new organisations: the Department of Energy and Climate Change (DECC) and the independent Committee on Climate Change (CCC), with responsibilities for monitoring progress against climate change targets and advising the government accordingly. These new policies and organizations created an internal policy momentum, which subsequently resulted in implementation-oriented documents such as the UK Low Carbon Transition Plan (2009), the amended Renewables Obligation (2009), the UK Renewable Energy Strategy (2009), the Green Deal (2010), the Carbon Plan (2011), the Energy Bill (2012) and the Electricity Market Reform (2013). This flurry of policy plans indicate not only substantial policy momentum, but also greater willingness to move away from a hands-off approach to a higher degree of interventionism (Lockwood, 2013). Nevertheless, the UK’s policy approach can still be characterized as ‘working with incumbents’ (Geels et al., 2014), in the sense that most policy instruments are oriented towards incentivizing incumbent utilities to reorient towards greener electricity production. This close alliance between utilities and policymakers also helps explain why (contrary to Germany) UK policy has emphasized the importance of existing technologies (nuclear, coal and gas with CCS) in meeting GHG targets.

Since the financial-economic crisis and the election of a new Conservative-Liberal government in 2010, UK climate change commitments are challenged by several socio-political counter-trends. First, public attention to climate change has diminished, leading politicians to realize that they were ahead of their voters, which resulted in a loss of cross-party support regarding climate policy (Lockwood, 2013; Carter and Jacobs, 2014). Especially the right-wing of the Conservative party has become more vocal, criticizing subsidies for wind power and questioning climate change science. Second, the financial-economic crisis and the austerity response by government have led to greater concerns about jobs, competitiveness and energy prices. The Treasury has used these concerns to issue warnings and to regain substantial influence on climate change policy. In the autumn of 2013, the cost argument escalated into a full-scale political row over rising consumer bills. Although the debate initially focused on the market dominance and pricing policies of utilities, the government and energy companies managed to reorient the debate towards green levies and energy-efficiency programs, which were subsequently scrapped, delayed or watered down in exchange for utilities promising to cut energy bills by £50. This politicization of energy bills has eroded green ambitions, and is likely to make future renewables expansion more difficult. Third, the government has not committed to long-term renewable electricity targets beyond 2020, despite repeated recommendations to do so.

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4 The 2003 White Paper (p. 13) states that: “Central to the future market and policy framework will be a carbon emissions trading scheme. (…) By setting caps on emissions the scheme will provide clear incentives for investment in energy efficiency and cleaner technologies at the lowest cost. We will be encouraging expanded opportunities for emissions trading at all levels. This created tensions with the hands-off policy style and the low-cost orientation.”
from the CCC. At the EU-level, the UK lobbied for 40% GHG emission reduction targets by 2030, but no renewables-specific targets. This (again) highlights the UK government’s vision of a low-carbon transition that to a large extent depends on an expansion of nuclear and coal/gas with CCS and some renewables.

As a result of these developments the balance of the three main criteria for electricity-generation policy (low prices, energy security, low-carbon) has shifted in recent years towards greater priority for low prices and energy security.

**Coal-fired power generation (and CCS)**
The dash for gas caused rapid declines in coal use for power generation. Although the government moratorium (in 1997) on gas-fired power plants created some protection, there were no plans to build new coal-fired plants. Coal also faced environmental pressures, initially from acid rain and later from climate change. When the acid rain issue emerged in the 1970s, the British government and electricity industry highlighted scientific uncertainties and costs to justify inaction. Throughout the 1980s, the Thatcher government frustrated and hindered international discussions, which, together with high sulphur emissions, gained Britain the reputation of the ‘dirty man of Europe’ (Turnheim, 2012). The British position changed in the late 1980s. In 1988, Thatcher gave a speech that acknowledged the problems of climate change and acid rain. This was followed by agreement on the European Large Combustion Plants Directive (LCPD), which prescribed progressive reductions in SO2 emissions, which was assumed to imply the installation of flue gas desulphurisation devices. The UK, however, did not immediately translate the LCPD into law or technological mandates, but instead used the dash for gas to cheaply achieve the targets. In the 1990s, increasing concerns about climate change created additional pressure on coal. As a result of various pressures, coal was perceived to be on its way out. Indeed, “nobody saw any coal revival in the EU, only further decline” (Smil, 2003: 236).

By the early 2000s, however, coal reappeared on the agenda for three reasons. First, rising oil and gas prices caused utilities to shift towards more coal use in existing plants (Figure 7). Second, concerns about energy security increased the interest in coal, leading to political support for so-called ‘clean coal’ initiatives. The trade and industry secretary (Johnson) explained that the UK would not place all its eggs in one basket: “If a new, cleaner coal generation is viable, then I think it could have an important part to play in making sure we have diverse generation in the future. Coal is easy to store and it comes from a variety of well-established sources around the world” (reported in The Guardian, 21 February 2006). Interest in coal also increased because policymakers realized that the approaching energy gap (related to the decommissioning of old coal-fired plants in 2015 because of the LCPD) would be difficult to fill with renewables and nuclear power (because of long lead times). The 2007 White Paper (Meeting The Energy Challenge) therefore acknowledged (clean) coal as part of the solution to climate change and energy security. Utilities also embraced coal: “Interest in new coal plants has been sparked by relatively low coal prices over the last five years, making them more profitable than gas plants. However, the strongest driver for new coal is the desire by companies to maintain a portfolio of generating capacity that includes a range of fuels, to hedge against

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5 The revival of coal was a world-wide phenomenon, as the IEA (2011:355) acknowledges: “For all the talk about natural gas and renewables, coal unquestionably won the energy race in the first decade of the 21st century”.
markets, security of supply or policy risk” (Lockwood, 2008: 6). In 2006, E.On and RWE announced intentions to build the first UK coal plants in 20 years to compensate for the closure of capacity under the LCPD (Turnheim, 2012). These plans were hardly influenced by the European emissions trading scheme (ETS): “So far the EU ETS has not been effective in driving down emissions, let alone influencing investment decisions” (Lockwood 2008: 30). By 2008, various coal-fired projects totalling just over 11GW were being planned or pending approval. But complicated planning permissions and environmental activism delayed these procedures (Turnheim, 2012), leading utilities to postpone or cancel investment. Activist groups like Climate Camp campaigned against a new coal-fired power station at Kingsnorth, leading E.On to shelve its plans in 2009, citing lower electricity demand as a reason.

The third contributor to coal’s revival was the discourse of ‘clean coal’, which related to technical innovations such as flue gas desulfurization devices, supercritical pulverised coal technologies and coal gasification. The most important innovation, however, was CCS, which promised to diminish GHG emissions. The 2007 White Paper announced a CCS demonstration programme supported by a £1 billion subsidy (Turnheim, 2012). The promise of CCS also provided legitimation to the White Paper’s endorsement of future coal. In 2009, DECC announced that no new coal-fired power plants would be permitted unless they incorporated carbon capture and sequestration (CCS).

But although CCS is technical feasible, there is much uncertainty about commercially viability. Utilities are not keen to deploy the technology and look for government support and hand-outs. Most of the corporate activity on CCS has therefore “been focused on basic scientific research and lobbying governments for subsidies and support rather than investments needed to deploy the technology on a commercial scale” (Bowen, 2011:2256). In 2008, four consortia (Peel Energy, BP, E.ON, Scottish Power) showed interest in the subsidized demonstration programme. The 2010 government coalition agreement included the ambition of supporting four CCS-demonstration projects). By late 2010, however, firms began withdrawing their interest in participation in these projects. The last consortium (Scottish Power) dissipated in October 2011, creating serious problems for the government’s energy strategy (which assumed widespread future use of CCS).

Opponents voiced concerns that CCS is a technological promise that will never materialize and is used as an argument to delay carbon abatement. The latest part of this controversy is the proposal by CCS proponents that new-built coal plants can be designed to be ‘capture-ready’, which means to convey the intention that firms will add CCS to coal-fired plants when it becomes feasible in the future (Turnheim, 2012). But opponents see this as a flimsy promise, which the industry uses to get permits to build new coal plants. They fear that ‘capture ready’ plants may never retrofit CCS because of the high costs involved. An additional argument is that investment in clean coal (and nuclear) will diminish the future space for renewables: “The government’s system [policy framework for energy, FWG] is designed to accommodate for large, inefficient and remote power stations owned by large companies like the coal and nuclear utilities such as E.ON. In other words, nuclear and coal power stand like two bouncers at the door blocking the way for renewables and efficiency, and perpetuating our outdated, inefficient and centralised energy system” (Greenpeace, 2008:12).

In 2012, the government tried to revive interests aiming for operational demonstration projects between 2016-2020. Four plants were shortlisted in 2013, with two preferred bidders identified: White Rose project in Yorkshire and Peterhead in Scotland. Front End Engineering and Design (FEED) studies for both plants started in late 2013. The White Rose consortium,
comprising Drax (the UK biggest power plant), Alstom, Bank of China and National Grid, was awarded €300 million under the EU New Entrant Reserve mechanism. The Peterhead consortium, comprising Shell and SSE (an electric utility), plans to use an existing pipeline and power plant and may therefore be operational sooner.

The Committee on Climate Change (2014) is negative about the government’s handling of CCS, highlighting “slow progress” and “little sign of urgency” (p. 127). The CCC hopes that the first two plants may be operational by 2020. Final investment decisions are not due until late 2015, however, which means that there is still much uncertainty about the future of CCS.

Meanwhile, coal use in existing plants increased after 2010 (Figure 7), especially in 2012 when coal use increased by 32% in one year (from 103.1 to 135.9 TWh). This increased total emissions (Figure 2) and the emissions intensity of electricity supply (Figure 12), which had not improved much anyway since 2009.

![Emissions intensity graph](image)

*Figure 12: Emissions intensity of UK electricity generation grams CO2/kWh (CCC, 2014: 104)*

Coal use decreased in 2013, when around 6 GW of coal-fired plants were closed under the European Large Combustion Plants Directive (LCPD) and air quality regulations. A further 2 GW were closed in 2014. The remaining 18 GW of coal capacity face further restrictions from 2016 and either need to close down by 2023 under the Industrial Emissions Directive or upgrade their equipment (e.g. fitting expensive NOx abatement devices) to meet stricter emission limits. The Committee on Climate Change hopes that low-carbon technologies will have progressed so far by the 2020s that remaining coal plants will either close or run at very low load factors to balance the electricity system. There is no guarantee, however, that this will happen, because the UK government has not given clear post-2020 signals. Coal is also facing pressure from a divestment campaign (‘Go Fossil Free’) started in 2015 by The Guardian newspaper and subsequently joined by other groups.
Gas-fired power generation

During the 1990s, the UK experienced an unanticipated ‘dash for gas’, with gas being used for base-load generation in combined cycle gas turbines (CCGT). The dash for gas was stimulated by various factors (Winskel, 2002): a) privatisation (in 1990) freed the electricity supply industry’s from regulated use of coal, enabling it to freely choose fuel inputs, b) a preference of utilities for small-size units (such as CCGT) with short lead times, low capital costs, and quick returns on investment; c) price/performance improvements in CCGT, d) environmental benefits of gas, which made it easier to meet European environmental regulations (regarding sulphur emissions and acid rain), e) availability of cheap natural gas from new North sea gas finds and international markets. The dash for gas caused such a rapid decline in coal-fired generation that the government issued a moratorium (in 1997) to maintain fuel diversity and protect the remnants of the coal-mining industry (Winskel, 2002).

The 1997 Kyoto protocol increased the political salience of climate change. The Labour party made the issue a central component of its 1997 election campaign. The 2003 White Paper (Our Energy Future: Creating a Low-Carbon Economy) made climate change a central policy issue and embraced renewable energy as the main solution.

Rising oil and gas prices (Figure 8) stimulated a change in policy thinking and priorities. Affordability and energy security gained in prominence, also because of Russian gas supply problems (related to a 2005 conflict between Russia and Ukraine). In 2005, Tony Blair announced a review of UK energy policy, resulting in the 2007 White Paper (Meeting The Energy Challenge: A White Paper on Energy), which established energy security (and affordability) as strategic policy issues besides climate change. It also endorsed nuclear power and carbon capture and storage (CCS) for fossil fuels (coal, gas) as low-carbon options, besides renewables. Utilities also took action in response to rising gas prices and market uncertainties, diversifying into other fuels such as coal (Turnheim, 2012). From 1999 to 2006, utilities increased the use of coal (Figure 7).

In the last few years, shale gas (based on fracking of shale rock to extract gas) has revolutionized gas supply. The International Energy Agency (2011) predicts a “golden age for natural gas”, suggesting that global gas use may rise by more than 50% between 2010 and 2035, outstripping the growth in renewables. Shale gas is a potential game changer, which caused a collapse in gas prices in the US and may transform that country from a gas importer into a gas exporter (Helm, 2012). The US are now predicted to have sufficient gas for many decades, which is already damaging investments in renewables in that country.

Inspired by the US ‘shale gas revolution’, the UK government strengthened its commitment to natural gas and shale gas. In 2012, the UK government lifted restrictions on fracking. Dozens of potential shale gas sites have since been identified across the country. In July 2013, the Chancellor outlined plans for generous tax breaks to shale gas companies, arguing that he wanted Britain to be a leader of the shale gas revolution “because it has the potential to create thousands of jobs and keep energy bills low for millions of people.” In 2013, the government also expressed desires for building forty gas-fired power stations, in response to which the Committee on Climate Change (CCC) warned that such an expansion would be incompatible with climate change targets, especially since these new gas plants are not obliged to use CCS. The second half of 2013 also saw heated local protests against fracking and shale gas. But the government decided to move ahead regardless, with the prime minister personally expressing firm commitment to shale gas in a letter to The Telegraph (11 August 2013).
Protesters were dismissed as uninformed NIMBY-activists, and attempts were made to convince local authorities by promising them one per cent of shale gas revenues in their locality.

**Nuclear power developments**
Most nuclear power plants in the UK were built in the 1950s and 1960s (Table 3) with heavy support from the UK government. Ten plants have since been closed, because they reached the end of their lifetime (approximately 40 years) or earlier because of boiler-related problems (e.g. Berkeley and Trawsfynydd). Most of the remaining nuclear plants are scheduled to be closed in the next ten years (Table 3). Combined with low-carbon ambitions, this closure schedule has led to plans to build new nuclear power plants, which is further discussed below.

<table>
<thead>
<tr>
<th>Power station</th>
<th>Construction started</th>
<th>Connected to grid</th>
<th>Commercial operation</th>
<th>Closure date</th>
<th>Commercial operational lifetime (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calder Hall</td>
<td>1953</td>
<td>1956</td>
<td>1959</td>
<td>2003 (closed)</td>
<td>44</td>
</tr>
<tr>
<td>Chapelcross</td>
<td>1955</td>
<td>1959</td>
<td>1960</td>
<td>2004 (closed)</td>
<td>44</td>
</tr>
<tr>
<td>Berkeley</td>
<td>1957</td>
<td>1962</td>
<td>1962</td>
<td>1989 (closed)</td>
<td>27</td>
</tr>
<tr>
<td>Bradwell</td>
<td>1957</td>
<td>1962</td>
<td>1962</td>
<td>2002 (closed)</td>
<td>40</td>
</tr>
<tr>
<td>Hunterton</td>
<td>1957</td>
<td>1964</td>
<td>1964</td>
<td>1990 (closed)</td>
<td>26</td>
</tr>
<tr>
<td>Hinkley Point A</td>
<td>1957</td>
<td>1965</td>
<td>1965</td>
<td>2000 (closed)</td>
<td>35</td>
</tr>
<tr>
<td>Trawsfynydd</td>
<td>1959</td>
<td>1965</td>
<td>1965</td>
<td>1991 (closed)</td>
<td>26</td>
</tr>
<tr>
<td>Dungeness A</td>
<td>1960</td>
<td>1965</td>
<td>1965</td>
<td>2006 (closed)</td>
<td>41</td>
</tr>
<tr>
<td>Sizewell A</td>
<td>1960</td>
<td>1965</td>
<td>1965</td>
<td>2006 (closed)</td>
<td>41</td>
</tr>
<tr>
<td>Oldbury</td>
<td>1962</td>
<td>1967</td>
<td>1968</td>
<td>2012 (closed)</td>
<td>44</td>
</tr>
<tr>
<td>Wylfa</td>
<td>1963</td>
<td>1971</td>
<td>1972</td>
<td>2015</td>
<td>43</td>
</tr>
<tr>
<td>Dungeness B</td>
<td>1965</td>
<td>1983</td>
<td>1985</td>
<td>2028</td>
<td>43</td>
</tr>
<tr>
<td>Hinkley Point B</td>
<td>1967</td>
<td>1976</td>
<td>1976</td>
<td>2023</td>
<td>47</td>
</tr>
<tr>
<td>Torness</td>
<td>1980</td>
<td>1988</td>
<td>1989</td>
<td>2023</td>
<td>34</td>
</tr>
</tbody>
</table>

*Table 3: Lifetime information about UK nuclear power plants (based on data from DUKES)*

In the late 1980s, preparation for privatization of the electricity sector revealed the poor economic performance of nuclear power. The government therefore withdrew nuclear power plants from the sale, and announced a moratorium on new nuclear power. Nuclear waste problems further undermined the cultural legitimacy of nuclear power (Verhees, 2012). The 2003 White Paper (*Our Energy Future*) seemed to seal its fate proclaiming that “its current economics make it [nuclear power] an unattractive option for new, carbon-free generating capacity and there are also important issue of nuclear waste to be resolved”. The White Paper further promised that possible future decisions to build new nuclear power stations would require “the fullest public consultation”.

In 2005, however, Tony Blair began calling for a ‘nuclear renaissance’ as a possible answer to climate change and energy security. In 2006, the Department for Trade and Industry
published an energy review (*The Energy Challenge*) which announced plans to build new nuclear stations over the next two decades. Greenpeace challenged these plans, arguing that the government had failed to engage in “the fullest public consultation”. In 2007, Greenpeace won a legal case on this basis. Although the government subsequently launched a public consultation, Tony Blair announced in advance that “This won’t affect policy at all”. Indeed, the 2007 White Paper (*Meeting The Energy Challenge*) and the 2008 report (*Meeting The Energy Challenge: A White Paper on Nuclear Power*) positioned nuclear power as a necessary option to address energy security and climate change (besides renewables and CCS for fossil fuels). In 2008, the new Prime Minister, Gordon Brown, announced plans for the construction of at least eight nuclear power plants by 2025 (Verhees, 2012).

The debate about nuclear power caused a schism in the environmental movement, with some activists (e.g. former Greenpeace director Stephen Tindale) perceiving nuclear power as a necessary evil to address climate change. This schism weakened public opposition to nuclear power, which partly explains why the 2011 Fukushima nuclear accident did not derail the government’s plans (unlike in Germany). A bigger problem for the government was the lukewarm interest from private companies to build and operate nuclear plants. The unfavourable economics of nuclear power, waste processing liabilities, decommissioning costs, and unclear future electricity prices created major uncertainties about the viability of nuclear investments, especially since the government had repeatedly stated that it would not provide any subsidies. In February 2013, the energy company Centrica abandoned plans to build new nuclear power plants, leaving only EDF in concrete negotiations with the UK government about a new 3.2 GW plant at Hinkley Point. To enable the deal, the government broke its pledge not to subsidize nuclear power, agreeing in October 2013 to pay EDF a guaranteed electricity price (£92.50 per MWh, twice the current wholesale price) for 35 years. However, compared to the 2008 ambitions, the nuclear programme is already 5 years behind schedule, with the opening date of first new nuclear power station pushed back from 2018 to 2023 (CCC, 2014: 123). Given these delays, it is impossible for the government to reach its stated aims of eight new reactors by 2025. In fact, besides the Hinkley C point reactor, there are presently no *concrete* development plans; only potential plans or planning applications, e.g. EDF is considering a 3.2 GW plant at Sizewell; Horizon aims to submit a planning application for a new 2.6 GW plant at Wylfa; the NuGen venture may consider a 3.6 GW plant at Sellafield (CCC, 2014: 124).

So, while the government and EDF foresee nuclear expansion in the coming years, on-the-ground progress and construction is facing substantial delays.
5. Developments in electricity consumption and end-use regimes

We have chosen to focus on domestic electricity consumption in this report because it allows a deeper analysis than would be possible if commercial and industrial consumption had been included. Domestic consumption is especially interesting because it foregrounds wider cultural trends in society that have a strong bearing on electricity consumption patterns across a range of domestic practices. We have also chosen to split our analysis into two parts. First, we discuss electricity consuming domestic practices and the associated appliance industry and policy as a whole because there are intelligible regime dynamics at this level. This is followed by a finer-grained analysis of specific domestic practices and appliance subsectors, because within the wider consumption regime, there are some important differences.

5.1. Developments in (tangible) system elements

Overall, the total number of electricity-using domestic appliances has grown significantly: an increase of 240% from 380 million appliances in 1970 to 1.3 billion appliances in 2012 (DECC 2013b). This increase reflects several diffusion dynamics: a) the spread of established technologies throughout the population; b) the trend towards multiple ownership within single households of appliances in specific areas (e.g. fridges, TVs, computers); c) the introduction of new devices, such as juicers, games consoles, tablets) (EST, 2011).

Domestic electricity consumption more than doubled between 1970 and 2006, at which point it appears to have plateaued and slightly decreased (Figure 13). It is unclear whether this recent plateauing is a consequence of economic recession or the impact of efficiency innovations.

![Figure 13. Total domestic electricity consumption (1000 tonnes of oil equivalent) in the UK, 1970-2013 (UK Government Energy Consumption in the UK data, chart compiled by authors)](image-url)
However, within the aggregate category, there has been significant flux in the electricity intensity of specific domestic practices and appliances (Figure 14), reflecting contrasting diffusion patterns and different innovation trajectories, including efficiency oriented innovation.

![Figure 14: Electricity consumption by household domestic appliance, by broad type, UK (DECC, 2013b, chapter 3, p. 7)](image)

The most dramatic increase in electricity consumption comes from the rise of consumer electronics, closely followed by home computing and many predict this to continue. Owen (2007, p. 3) for example predicts that by 2020, “entertainment, computers and gadgets will account for an extraordinary 45 percent of electricity used in the home”. Electricity use by wet appliances (washing machine, dishwasher, tumble dryer, washer-dryer) increased since the 2000s after plateauing in the 1990s. Electric cooking remained largely stable and electricity use decreased in two end-use categories: 1) In lighting, electricity reduction relates to the technological shift from incandescent light bulbs to CFL (compact fluorescent lighting) and LED (light emitting diodes); 2) In cold appliances (refrigerators, freezers), decreasing electricity use is mainly due to energy efficiency improvements.

Given the global character of appliance innovation and manufacture, analysis of prices, especially in relation to energy efficiency, is hard to find for the UK specifically. But international studies report general downward trends in prices for domestic appliances, despite innovations for energy efficiency (Ellis, et al., 2007). According to Weiss et al (2010), this is because appliances are subject to significant technological learning effects after their introduction.

The use of experience curve analysis has become a widespread approach to understand the prospects for energy efficiency in domestic appliances. Figure 15 shows a summary of different learning rates across a range of appliances, also comparing to some non-electricity using technologies. Learning rates in these analyses refer to reductions in cost according to
increases in cumulative production volumes (expressed as % cost decrease per doubling of cumulative production). Van Buskirk et al (2014) offer a stronger argument that energy efficiency standards and policy may have accelerated long term decreases in appliance cost.

Overall, domestic electricity consumption levels are subject to several countervailing innovation trajectories. Efficiency innovations play an important role in reducing electricity demand, but these gains are often offset by other types of innovations, which account for: 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); 5) the trend towards multiple ownership within single households of appliances in specific areas (e.g. fridges, TVs, computers); 6) overall decreases in manufacturing cost for electrical appliances (through learning mechanisms), leading to price reductions and therefore increased affordability for consumers.

5.2. Developments in social groups and (intangible) regime elements

**Actors and alliances**

The UK electric appliance sector, described by Beynon et al (2003) as a sector in secular decline, has become increasingly dominated by imports and by foreign company owned manufacturing facilities. While there has been a proliferation of brands sold in the UK, these are owned by a small number of multinational companies operating in a highly concentrated and oligopolistic market. The total UK market for electrical appliances is estimated to be worth £4.2 billion in 2014-15, of which an estimated 69.9% is satisfied by imports (IBIS world, 2014). Home computing and consumer electronics are also dominated by multinational firms and imports. As such, manufacturer innovation has not been a major UK concern, which means that retailers and UK appliance trade associations (which represent the interests of the appliance industry in the
UK) are the key commercial actors in the consumption sub-regime. After initial reluctance to engage with the electricity efficiency agenda (Boardman, 2004), during the mid 1990s and in the context of more stringent regulation, retailers started to become “adept at selling the benefits of more efficient products to consumers” (Winward et al 1998). Electricity suppliers are not currently active in the appliance sector, but had been heavily involved in promoting energy efficient appliances during the 1990s and early 2000s as a result of government policy, which placed mandated obligations on suppliers to reduce electricity consumption. For example, between 2002 to 2005, fridge freezers were promoted through the Energy Efficiency Commitment (EEC) obligation, which according to Defra (2009) brought forward an estimated 4.5 million sales of fridge-freezers compared to the existing market trends. This was brought about by energy suppliers collaborating with appliance retailers, who would promote efficient models through a combination of special offers, such as discounts and targeted in-store marketing strategies (AMDEA, 2014). AMDEA, the UK appliance trade association, represents the interests of international appliance firms active in the UK and UK based appliance retailers. It was initially resistant to the efficiency agenda, but has since changed orientation to campaign for a strengthening of support for it.

UK policy relating to the appliance sector is now dominated by European regulatory frameworks, which promote electricity efficiency innovations and consumer purchase of progressively more electricity efficient appliances. During the early 1990s the UK Government established the Energy Saving Trust as an independent body, which promotes the energy efficiency agenda and undertakes and publishes research in the area.

The main environmental UK NGOs are quietly supportive of the energy efficiency agenda; their campaigns in the electricity regime are overwhelmingly directed towards support for renewable electricity innovation and against fossil fuel electricity generation. The most prominent exception is The Green Alliance, which actively campaigns for the efficiency agenda, calling for a more aggressive approach to reduce delays in policy implementation and for more stringent regulation.

The aforementioned actor groups are now strongly aligned in their orientation towards the efficiency agenda, which reinforces the basic structure and institutions of the electricity consumption sub-regime. The efficiency agenda effectively maintains political and social legitimacy in the face of fluctuating concerns about climate change and more persistent concerns about electricity prices. Debate within this actor group does not question the existence or choice of policy instrument, but focuses on the setting of those instruments (i.e. largely technocratic debates about minimum efficiency thresholds, the timing of product phase-outs and layouts for energy labels).

Section 5.3 will provide detailed information about appliance diffusion patterns and associated changes in domestic consumer practices. But, in general, the diffusion trends across different products and practices discussed above are shaped by the persistence of deeply entrenched cultural conventions around convenience, comfort, cleanliness (Shove, 2003), freshness and newer expectations around socially appropriate and desirable standards for in-house entertainment and digital connectivity. Furthermore, electricity use only occurs as consumers use products in the course of engaging in everyday domestic practices; electricity use itself is largely abstract, invisible and therefore not subject to the same social processes that occur for products subject to conspicuous consumption (Shove and Warde, 2002).

There are two issues that have been raised by scientists, which do question the efficiency improvement orientation of the regime. First, some scientists argue that the efficiency focus will
not deliver expected carbon savings because of what has been termed the rebound effect (Sorrell, 2009). Second, some scholars have claimed that the overwhelming focus on appliance efficiency fails to properly acknowledge the fact that overall electricity conservation is also significantly affected by how consumers use appliances (Boardman, 2004). But, while acknowledged, the first critique is largely ignored (e.g. direct advice to businesses provided by the Carbon Trust assumes rebound effects are negligible, POST, 2012) and the second receives significantly less attention compared to the overarching objectives of appliance efficiency and consumer purchase behaviour.

Changes in governance style and actor responses
The overarching UK policy approach to reducing domestic electricity consumption falls under the Market Transformation Programme (MTP) and the more specific “Products Policy”. The MTP is implemented as part of the UK’s requirement to enact EU regulations. It is a fairly strong form of government intervention, combining the use of market instruments (information provision, subsidy) and control measures (phasing out products with the lowest energy efficiency performance). The governance orientation of this approach is to encourage the transformation of domestic appliance markets to become progressively more energy efficient, through two principal measures:

- The 2009 EU Framework Directive for the Ecodesign of energy using products which stipulates legally binding minimum standards for the environmental performance of energy related products available on the market (EC 2009). This revised the original policy of 2005.
- The 2010 EU Framework Directive on energy labelling (EC 2010) which mandates for comparable energy efficiency ratings to be supplied on energy-related products in order to encourage consumers to choose more energy efficient products. This revised the original policy of 1992.

The logic of how the two policies interact (in addition to other policies) is shown in figure 16. The basic mechanism is that within product categories, the eco-design policy sets a minimum efficiency threshold, below which products will be banned and graded energy labels A-G ‘encourage’ consumers to choose the most energy efficient option and encourage companies to innovate higher efficiency models. The intended outcome is for the whole range (from least to most energy efficient) of appliances in a given product category to become progressively more energy efficient. As a policy orientation it combines an approach of informing consumer choice through labelling information and a more directive approach of legislating the removal of the least efficient options from the market.
The EU regulations provide a strong overarching framework for electricity consumption policy for UK Government. But, the UK specific governance orientation needs to be understood through the ways that the regulations are implemented, other policy measures that fall outside of the EU regulations and the role that the UK has played in EU level negotiations.

In terms of implementation, during the early phase of the EU Energy Label and minimum efficiency standards, Boardman (2004) argues that UK Government essentially adopted a compliance-only approach. This meant that labels were introduced and product versions were phased out, with little effort from Government to raise public awareness. Boardman (2004) suggests that this lack of additional attention-raising was responsible for the comparatively (compared to other European countries) slow rate of market transformation in the UK.

On the other hand, the UK Government did introduce some additional measures beyond the EU regulations, especially by placing obligations on energy suppliers to achieve reductions in electricity consumption through the promotion of efficient appliances (especially lighting and cold appliances) through the EEC and CERT schemes. But, these obligations are no longer in place (after government analysis suggested CERT support for appliances would offer little benefit beyond the market transformation measures), with supplier obligations now focused almost entirely on space heating improvements. This could be interpreted as a weakening of UK Government intervention in the sense that energy suppliers are now ‘excused’ from having any direct responsibility for domestic energy demand.

During the early 1990s, “trade associations of appliance makers obstructed European Union efforts to impose mandatory standards for energy efficiency on their products, by refusing to supply data and cooperate in an energy efficiency study upon which to base policy, hampering the efforts of the EU to meet its obligations under the Climate Convention” (Newell and Paterson, 1998; Acid News, 1994). At this time and within the UK context, AMDEA, the UK appliance trade association, believed that energy efficiency was a marginal issue for consumers and argued that energy labels would therefore only impose costs on manufacturers (Toke, 2000). But, by 1996, “AMDEA had become convinced that they needed to protect their interests by
acting within, rather than against the energy efficiency lobby. Their world view had changed. Peter Carver, AMDEA Director commented: ‘Pressure on us to improve energy efficiency is never ending. Unless we agree voluntary codes, regulations at a European level are inevitable’” (Toke, 2000).

If anything, AMDEA now has an even more pronounced advocacy towards the efficiency agenda, lobbying UK government for more support: “A change in focus is required so that policies to reduce demand for electricity receive at least as much, if not more, attention than policies to encourage low carbon electricity generation.” (AMDEA, 2014). This, AMDEA argues, is critical to avoid a backlash against decarbonisation policies (on the generation side), which are likely to lead to higher bills for consumers (and large benefits to energy utilities from contractual guarantees) unless efficiency measures are successfully implemented. So, while there is strong alignment amongst firms selling consumer appliances, there appear to be mild cracks opening up between this group and the large energy suppliers operating in the electricity generation regime.

Regime actors now appear to be well aligned around the view that pursuing an efficiency agenda will provide a positive contribution to transitioning the electricity system to a lower-carbon trajectory, although this is often linked to issues of energy security and affordability. Controversies are fairly muted, with most debates centring on technocratic details relating to how specific policies are implemented (i.e. on the setting of instruments design features, rather than the choice of instruments or the policy goals more generally) and on the speed of implementation.

The Green Alliance is the most active NGO in the UK electricity consumption agenda. Its campaigning and lobbying argues that market transformation policies have been successful (and therefore demonstrably viable), but that more could be done (in terms of much faster and more stringent implementation). As a result of their respective positions and agendas, AMDEA and The Green Alliance have been directing very similar campaigns to put pressure on the UK Government (and at the European level) to intensify support. Their combined analyses of what has been achieved so far point to several issues that have meant efficiency gains are much less than could have been achieved – and may lead the UK (and other European countries) to underperform against overall energy and climate change targets – as much as 40% below the UK Government’s projection of householder bill savings of £158 by 2020 (Cary and Benton, 2012; AMDEA, 2014).

These current assessments echo Boardman’s (2004) analysis of early (1990s to early 2000s) policy implementation, which pointed to delays in general and showed that the UK had been slower to implement EU policy than other European Nations. Implementation of the latest EU Ecodesign Directive appears to be equally slow. Regulations for different products were due to be implemented in two tranches. The Directive was introduced in 2009 but by 2012 only 13 out of 25 products in the first tranche of eligible products had regulations applied to them. No regulations for the second tranche were currently in place (Cary and Benton, 2012).

Policy implementation under the Ecodesign Directive is highly technocratic, involving lengthy analysis and stakeholder consultation processes to specific precisely the minimum efficiency threshold and the phase out period for those appliances that fall below the minimum. Analysis by the Green Alliance shows that implementation process is lengthy, with an average of 4 years to establish the regulation, 3-4 years grace period for producers to fully comply and a further 10-15 years for full market transformation to occur. Their analysis also suggests that for many appliance categories this process is further delayed with disagreements among
stakeholders (figure 17; Cary and Benton, 2012). The precise source of these delays is unclear. Is it an inevitable consequence of technocratic negotiations over the setting of thresholds or more subtle delaying tactics to give industry more time to adjust and innovate?

The energy labelling system, which also has fairly wide general support regarding its overarching aim, has been subject to persistent criticism for over a decade because it has not been adapted effectively to deal with further improvements in the efficiency of appliances (ECOFYS, 2012). Again, there has been a highly technocratic debate about how best to respond to efficiency improvements with redesigned labels. The debate centres on whether to recalibrate energy consumption levels for each grade, A-G in the traditional scheme, or whether to introduce A+, A++, and A++++ to capture further efficiency improvements. Although highly technocratic in nature, this debate, according to Evrard (2011) provides an interesting insight into the orientations of different nations and organisations towards the energy efficiency agenda and especially how it connects to other issues (and storylines) confronting the sector.

Figure 18 shows the three candidate labels. According to Evrard (2011), there was a policy coalition among the European Commission (DG TREN), manufacturers and some member states (Germany, Italy, Poland and Spain) in support of propositions X and Y, which are argued to protect industry economic interests (Evrard does not spell out why exactly). A rival coalition, supporting proposition Z, included the European Parliament, Environmental and consumers’ associations (BEUC, ANEC) and significantly for the current analysis, the UK, because it has a much smaller appliance industry than certain other European countries. Scientific assessments and consumer group campaigns argue that the recalibration model (Z) provides a much clearer signal to consumers and therefore a much stronger imperative for manufacturers to continue to invest in efficiency innovations. Conversely, as Meißner et al (2012) argue, the X and Y formats “might have unintended consequences: with regard to the new European energy label design, for instance, manufacturers who show technological leadership might get a lower return on their investment in R&D with the introduction of the new classes A+, A++, and A++++” (p. 249).
To date, there has been little opposition to the efficiency agenda in public debates and discourse. However, there are signs that some opposition is starting to emerge as the regulations are implemented to cover an ever greater range of appliances. Vacuum cleaners are one of the latest product ranges to fall under the rules, which specify a maximum power rating for the motor. This led to significant negative media attention and reactions from a range of organisations. For example, the consumer group *Which?* encouraged consumers to quickly buy powerful vacuum cleaners while still available; the vacuum cleaner manufacturer Dyson mounted a legal challenge because it claims the whole life electricity efficiency of its vacuum cleaners is underestimated (although the company supports the overall aim of the new rules); and the issue was even used by UKIP as another reason for the UK to withdraw from Europe (Guardian, 2014). AMDEA reported a significant uplift in powerful vacuum cleaner products after the furore.

Beyond the efficiency agenda, there has been some attention to the prospects for targeted campaigns to stimulate changes in domestic electricity consuming behaviour. Most of this attention is associated with the introduction of smart meters and the potential for feedback of energy consumption information to stimulate behavioural changes (this was discussed in D2.1). But, there have also been a number of information campaigns run by the Energy saving Trust and government departments aimed at encouraging consumers to switch off lights when they are not in the room, to avoid using standby functions on many consumer electronic products and to not over fill kettles. There is no evidence that these campaigns have been successful to any significant extent.

Finally, there is now growing interest in peak electricity demand (figure 19), because this is a key factor in terms of required additions to generation capacity. Reducing peak electricity demand has emerged as a potential strategy for demand side management, including “time-of-use” tariffs and innovations in appliances, such as washing machines, to automatically shift their use to non-peak periods. This approach is being promoted by the Energy Saving Trust (Owen, 2012), but has not yet produced any tangible policy or manufacturer responses.
5.3. Analysis of specific domestic practices / appliances and actor strategies, beliefs, actions

In this section we offer a finer-grained analysis of subsectors within the appliance category. Rather than providing a fully comprehensive analysis, we have selected some appliance categories to show that there are significant differences in terms of innovation trends, environmental impacts, organisational networks, dynamics of domestic practices and governance approaches. Therefore, in terms of the standard categories that fall within this regime, we focus on cold and wet domestic appliances and information, communication and entertainment technologies. Consequently, we do not discuss lighting (because CFLs were analysed in D2.1 as a niche technology with high momentum) or cooking appliances, because the electricity intensity of this category has remained fairly stable and significant intangible regime dynamics are captured in other categories. Nor do we focus on the proliferation of other electricity using ‘small devices’ that are becoming more prevalent in UK, beyond noting some examples and their associated electricity intensity (Table 4).

<table>
<thead>
<tr>
<th>Kitchen appliance</th>
<th>Average consumption (kWh/year)</th>
<th>Average running cost (£/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottle warmer</td>
<td>27.2</td>
<td>4.00</td>
</tr>
<tr>
<td>Bread maker</td>
<td>23.5</td>
<td>3.42</td>
</tr>
<tr>
<td>Coffee machine</td>
<td>31.8</td>
<td>4.6</td>
</tr>
<tr>
<td>Extractor hood</td>
<td>11.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Food mixer</td>
<td>0.5</td>
<td>0.07</td>
</tr>
<tr>
<td>Food steamer</td>
<td>52.7</td>
<td>7.60</td>
</tr>
<tr>
<td>Fryer</td>
<td>52.0</td>
<td>7.54</td>
</tr>
<tr>
<td>Grill</td>
<td>12.8</td>
<td>1.86</td>
</tr>
<tr>
<td>Toaster</td>
<td>21.9</td>
<td>3.18</td>
</tr>
<tr>
<td>Yoghurt maker</td>
<td>8.0</td>
<td>1.18</td>
</tr>
</tbody>
</table>

Table 4. Electricity consumption for selected ‘small appliances’
**Washing – “wet appliances”**

“Wet appliances” include those used for laundry and dishwashing. Figure 20 shows a 4-fold increase in the volume of these appliances installed in UK households. Efficiency innovations have largely been focused on reducing electricity consumption of washing machines. Since the mid-1980s electricity consumed by washing machines has declined substantially from 268 kilowatt hours to 166 kilowatt hours, (EST/DECC/DEFRA 2012). This means that tumble dryers now use the most electricity in this category (figure 21). Sales are moving towards larger capacities for washing machines and tumble driers, but there is a converse usage trend towards smaller loads for washing machines and tumble driers. According to the Energy saving Trust, “Sales of larger washing machines, with load capacity of 7kg and over, are increasing. Using bigger machines for smaller loads means not only running the machine more times, but running a bigger machine more times” (p.22). Other technology trends in this area include higher spin speeds for washing machines and the introduction of lower wash temperature settings. Tumble driers include higher proportions of condenser driers and an increase in the proportion of those with sensors (Defra, 2009).

![Figure 20. Number of laundry / dishwasher technologies (1000s) owned by UK Households, 1970-2013 (UK Government Energy Consumption in the UK data, chart compiled by authors)](chart)

Beyond the efficiency agenda, the washing category is perhaps the most prominent instance of purposive attempts at behavioural change. In this case, the behavioural ‘target’ involves reducing the washing machine temperature, captured by the “wash at 30” campaign. Multinational consumer goods firm, Proctor and Gamble has been the lead firm in mounting this campaign, largely through marketing and communication campaigns to educate consumers. This campaign has been further supported by AISE, the European detergent trade association, which has established a network of detergent manufacturers, washing machine manufactures, some clothing companies and retailers to promote the behaviour change campaign (Mylan, 2015).
While there is evidence of a gradual shift in habits towards washing at lower temperatures in the UK, arguably this campaign has diverted attention away from other factor and trends: increased sorting of laundry loads is leading to more and smaller washes; the focus on washing has had more prominence than the energy used by tumble drying, which now accounts for more energy. The focus on washing machines, in terms of efficiency and behaviour, has been heralded as a success by regime actors, and has arguably contributed to their ability to maintain socio-political legitimacy in the face of pressures to act on energy consumption levels and climate change. But, this focus on one aspect of laundry has deflected attention from that fact that the electricity intensity of laundry practices is still increasing. Persistent cultural conventions concerning socially acceptable standards of cleanliness contribute to the rise in the frequency of washing clothes, and the further adoption of tumble-dryers is partly driven by desires for greater convenience (Evans and Yates, under review).

**Food Preservation – “cold appliances”**

The number of ‘cold appliances’ has increased 4-fold during the period (figure 22), also marked by substitution of refrigeration-only appliances by fridge-freezers, and the rise of multiple appliance ownership in households. But, figure 23 shows that overall electricity consumption for cold appliances started to fall from 1987 as a result of energy efficiency innovations. This outcome has been possible due to a 56%-86% increase in the efficiency improvement of cold appliances between 1990 and 2012 (table 4), demonstrating the potential for efficiency innovations to deliver absolute energy savings in the context of increasing volumes of appliances in households.
However, the UK appears to lag behind other European in terms of the diffusion rates of the most energy efficient products. In 2011, the most efficient cooling appliances (those with an efficiency rating of A+ to A+++ ) contributed towards 87% of sales in Germany. But in the UK these same appliances made up just 30% of sales in the same year. The market share of these appliances was also substantially higher in Italy (79 %), Spain (76%), Netherlands (70%) and France (58 %) (AMDEA, 2014).
A shift towards multiple cold appliance ownership, larger appliances, along with the introduction of US style side-by-side appliances and the introduction of correction factors erode energy efficiency savings (Defra, 2009). This suggests that more foods and drinks are being stored in cold appliances, arguably as a consequence of consumers increasingly associating chilled goods (as sold in retail spaces) with conventions of freshness and naturalness (e.g. the case of orange juice (Foster et al, 2012)).

During the period 1970-2013, freezer ownership and use has gone from novelty to normal. Patterns of use have shifted: initially used to deal with surpluses of fresh food products, the freezer has increasingly become intertwined with the introduction of microwaves and ready-meals. In combination, they contribute to and are shaped by cultures of convenience and have consequently become significantly entrenched in modern ways of living (Hand and Shove, 2007). It is interesting to note that Gatley et al (2014) found this trend towards ‘convenience eating’ significantly more pronounced in the UK than in France.

Information, Communication and Entertainment (computing and consumer electronics)
The rise of home computing and consumer electronics reflect long-standing landscape changes of continued electrification of society and the rise of an ICT paradigm (Freeman, 1992; Steinmuller, 2007). In terms of domestic practices and associated devices, these two long-term trajectories have become increasingly intertwined and are typically analysed as such in the academic literature. Information, Communication and Entertainment (ICE) technologies form the basis of a massive global industry in which the UK plays a relatively small part. In terms of innovation, the sector is characterised by rapid product lifecycles (version cycles) and technology improvements that lead to higher processing power, improved connectivity and additional functionalities. Official DECC figures provide a basic picture of ownership levels for some of the main product categories. Figure 24 shows rapid and accelerating diffusion rates for home computing technologies, with desktops increasingly substituted by laptops and multidimension devices replacing printers. Figure 25 shows that TV ownership has more than trebled between 1970 and 2013 to aggregate level of nearly 1 per person in the UK and over 2 TVs per household. The same period witnessed the emergence and rapid diffusion of set-top boxes, games consoles and DVD/VCR products (which have subsequently declined with the advent of digital TV).

But even these significant patterns of rapidly diffusing ICE technologies perhaps mask even more dramatic changes because they ignore the emergence of tablet computer and smart phones and hide the significance of the internet for domestic ICE practices. Figure 26 offers a

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**Table 4: Efficiency gains in new cold appliances bought in the UK, 1990 to 2012 (DECC 2013a)**

<table>
<thead>
<tr>
<th>Electrical appliance</th>
<th>Efficiency improvement from 1990 to 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest Freezer</td>
<td>66%</td>
</tr>
<tr>
<td>Fridge-freezer</td>
<td>50%</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>56%</td>
</tr>
<tr>
<td>Upright freezer</td>
<td>86%</td>
</tr>
</tbody>
</table>

---

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But even these significant patterns of rapidly diffusing ICE technologies perhaps mask even more dramatic changes because they ignore the emergence of tablet computer and smart phones and hide the significance of the internet for domestic ICE practices. Figure 26 offers a
useful depiction of successive waves of computing towards multiple ownership of a range of devices per person with visions of ubiquitous internet connected devices in the future.

**Figure 24** Number of home computing technologies (1000s) owned by UK Households, 1970-2013 (UK Government Energy Consumption in the UK data, chart compiled by authors)

**Figure 25** Number of consumer electronic technologies (1000s) owned by UK Households, 1970-2013 (UK Government Energy Consumption in the UK data, chart compiled by authors)
The carbon implications of this massive growth of ICE technologies are complicated. Appreciation of the energy intensity of computing is not new. Huber and Mills (1999) wrote for the need to ‘dig more coal – the PCs are coming’. This draws attention to one aspect of the environmental impacts of ICE technologies, which leads to the results depicted in figures 27 and 28.

Figure 26. The evolution of computing technology Miles, n.d.

Figure 27. Total energy consumption (1000 tonnes of oil equivalent) of home computing technologies in the UK, 1970-2013 (UK Government Energy Consumption in the UK data, chart compiled by authors)
These figures show increasing levels of domestic electricity consumption for ICE technologies and provide a more granular account of how ICE technologies have now become the most energy-intensive domestic appliances. They also display patterns that underpin expectations that by 2020 ICE technologies will account for 45% of electricity used in the home (Owen, 2007, p. 3). But, other studies have pointed out that the energy intensity of ICE is much greater than this: For example, Willum (2008) estimates that: ‘when 1 kWh is consumed in the residence, 1 kWh is consumed to manufacture, transport and dispose of the hardware and 1/2 kWh is consumed to run the Internet and the applied ICT infrastructure outside the residence’. This has led scholars such as Ropke (2012) to distinguish between:

1. First-order effects: energy intensity directly related to the life cycle of ICE products including the production, use, recycling and disposal of ICE.
2. Second-order effects: environmental impacts of substitutions involving the substitution of products with ‘services’, such as the shift to digital music and books, including the energy implications of the infrastructures that have developed to support such shifts.
3. Third-order effects: environmental impacts related to wider economic and social changes through the spread of ICEs, such as shifts towards teleworking and teleshopping.

This widening of analysis shows the significance of the electricity intensity of sever parks that support the ever-increasing volume of digital content available for domestic consumption, something that is missed in the DECC figures because the electricity powering this infrastructure is beyond the household. Also, the potential rise of teleworking and teleshopping are examples of wider societal shifts in everyday practices that reallocate energy intensity across mobility, commercial and domestic domains; as yet, there are major uncertainties over the extent to which these shifts might lead to overall reductions in electricity consumption.
The rapid diffusion of ICE technologies into households provides a partial explanation for increasing electricity consumption, but a fuller account can be offered by considering the impact of product innovation and changing use patterns. TV provides a good example of the former, because of the introduction of new technologies, especially plasma, LCD and LED (substituting the traditional cathode ray tube), the shift to digital platforms (substituting traditional analogue) and most significantly, the accompanying increases in the size of televisions (Crosbie, 2008); already realized and potential efficiency improvements deriving from improvements in LED/LCD technology are at least partly offset by the trend towards larger screens (Park et al, 2013). Regarding shifts in domestic ICE practices, Pantzar and Shove (2010) have noted that ICE products appear to offer opportunities for multitasking (i.e. the simultaneous use of electricity-using devices such as TVs, mobile phones, tablets etc.). Similarly, Kenyon (2008) notes that ‘internet use may be expected to influence multitasking in two ways beyond the mere substitution of activities from offline to online: by increasing the number of activities that can be multitasked (activities amenable to multitasking); and by increasing the accessibility of a greater number of activities (activities accessible for multitasking)’ (p. 291).

Given these trends, it is surprising that there has been so little attention to ICE technologies by policymakers compared to other appliances (Crosbie, 2008). ICE technologies have not been subject to the same level of governance through EU regulations as other appliances, although there are expectations that this will happen in the near future. In anticipation of this, the Energy Saving Trust established a ‘voluntary retailer initiative’ in 2010 for PCs and TVs, encouraging retailers to promote more energy efficient models. This is likely to draw attention to the efficiency of devices, but brackets out any consideration of the aforementioned trends in domestic ICE practices, including the persistent use of standby functions, multi-tasking and the proliferation of devices per household (Ropke, 2012).
6. Developments in electricity network regime

6.1. Developments in (tangible) system elements

**Physical structure, operational and governance responsibilities**

The GB electricity network is divided between: a) a high voltage *transmission* network for bulk transfer from 181 power stations to 575 sub-stations, and b) a low-voltage *distribution* network for localized electricity delivery from sub-stations to end-users.6

The GB *transmission* network consists of 26,000 km of overhead lines, 575 sub-stations and over 1000 transformers, which transform electricity from high to low voltage (Cotton and Devine-Wright, 2012). The onshore transmission grid, represented in Figure 29, currently has only two connections between Scotland and Wales (where many wind farms are being constructed) and England (where most electricity is used). Since privatization in 1990, the GB transmission grid as a whole is operated by a single system operator (SO), *National Grid Electricity Transmission* plc (NGET), which manages the balance between supply and demand of electricity flows (which always needs to be finely tuned to prevent operational problems and black-outs). Then, there are three Transmission Network Operators (TNOs) who own the transmission system in the area they operate and are responsible for its long-term development (including maintenance and upgrading): 1) *National Grid Electricity Transmission* plc (NGET) for England and Wales, 2) *Scottish Power Transmission* Limited for southern Scotland, and 3) *Scottish Hydro Electric Transmission* plc for northern Scotland and the Scottish islands groups. Electricity companies pay a fee to the transmission operators for use of the transmission grid.

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6 The electricity grid includes England, Wales and Scotland, but not Northern Ireland, which has its own grid. So, it is better to talk about the GB grid.
The distribution system is organized into 14 regional area monopolies. Operational rights to these service areas are licensed to distribution network operators (DNOs) by the regulator Ofgem (‘Office of Gas and Electricity Markets’). Many of the DNOs are owned by the big energy companies, meaning that ‘unbundling’ between generation and distribution has remained incomplete. The DNOs maintain local distribution networks and are paid a fee by the electricity generators to distribute power to consumers and other end-users. So, the DNOs business model is relatively simple and does not involve direct interaction with end-users (which is done by the electricity companies). DNOs operate one-directional passive networks, which simply distributes power from electricity generators to end-users. DNO’s don’t measure or monitor their distribution networks, which remain relatively ‘dark’ in the sense that DNOs cannot see technical problems or black-outs, but rely on customers calling them that they don’t have power. So, whereas transmission networks are already ‘smart’ to a degree (having implemented information and communication technologies that allow monitoring and control of electricity flows), distribution networks are decidedly ‘un-smart’ (Lockwood, 2013).

The National Grid, TNOs and DNOs are overseen by the independent regulator Ofgem, which implements and monitors regulations (such as price controls) and approves network investments plans. Since electricity networks are a highly regulated market, Ofgem plays a central role.

**Pressures on electricity grids and possible innovations to address challenges**

The expansion of UK renewable electricity, which occurred relatively rapidly since 2009 (Figure 30), is creating several pressures on the electricity grid.

*Figure 30: Percentage of UK renewable electricity, 1990-2013 (data from DUKES)*
The first (immediate) pressure comes from the creation of new wind farms in remote locations (e.g. Scottish islands, Welch coast, offshore). These wind farms require the creation of new transmission networks, both onshore and offshore, to connect them to the transmission grid.

The second pressure consists of increasing electricity flows from Scotland and Wales (where most wind parks are situated) to England (where most electricity is used). To address these increasing electricity flows, the onshore transmission grid needs to be upgraded and extended (e.g. building new transmission lines between Scotland and Wales and England).

The third pressure comes from particular operating characteristics of wind and solar energy, namely its *intermittent* and fluctuating character (because of varying strength of winds and sunshine). This is very different from the steady operating characteristics of traditional coal, gas and nuclear power generation. To match supply and demand (and prevent black-outs), several grid innovations are possible to address this pressure: 1) building new interconnections to other countries (which enables import and export of electricity), 2) creating a smart grid (i.e. introducing information and communication technologies into the grid) to better measure, monitor and manage electricity flows on relatively short time scales, 3) introduce 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 (i.e. power generators switch on extra gas turbines to meet fluctuating 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), 4) electricity storage with batteries or ‘pumped hydro’, which grid managers can draw on when supply falls short.

The fourth pressure comes from another characteristic of some renewable electricity options (e.g. roof-top solar PV, community energy, small dedicated biomass plants), namely distributed generation, which means that new generating capacity is dispersed and situated locally. Whereas the traditional ‘centralized’ electricity system entailed one-way flows (from generators into the transmission grid and then towards end-users via the distribution network), distributed generation entails two-way flows, in the sense that localized production is first fed into distribution networks and then into the transmission grid. Addressing this pressure requires more active DNOs and smarter distribution networks that enable the monitoring and management of electricity flows, as well as new payment methods and organizational models.

The first and second pressures are relatively immediate (connecting wind farms to the grid and enabling new electricity flows), whereas the third and fourth pressures are perhaps more long-term and (potentially) more transformative.

**Actual developments and implementation of grid-innovations**

Actual implementation of innovations has gathered pace since the Climate Change Act (2008) and substantial increases in renewable electricity. Most of the actual implementations have focused on three relatively well-known (incremental) kinds of innovations, which all entail dealing with hardware (i.e. new cables, lines, connectors, transformers):

1) Strengthening and extending the *onshore transmission grid*. This includes, amongst others,: a) extensions within Scotland (including to Scottish islands), b) new North-South connections, including ‘bootstrap’ connections down the east and west coast via sub-sea cables (Figure 31), c)

---

7 Common spikes in electricity demand occur in the evening during TV commercials when many people put on the kettle to make tea.
new connections between Wales and England. Table 5 provides an overview of estimated costs (until 2020) of various changes in the onshore transmission grid, indicating that the most costly changes are like to occur in Scotland and between Scotland and England.

<table>
<thead>
<tr>
<th>Region</th>
<th>Generation accommodated</th>
<th>Estimated cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotland</td>
<td>10.2 GW</td>
<td>£2.5 bn</td>
</tr>
<tr>
<td>Scotland-England</td>
<td>1.1 GW</td>
<td>£3.56 bn</td>
</tr>
<tr>
<td>North to Midlands and Midlands to South</td>
<td>3.7 GW</td>
<td>-</td>
</tr>
<tr>
<td>North and Central Wales</td>
<td>3.8 GW</td>
<td>£1.2 bn</td>
</tr>
<tr>
<td>Mid Wales</td>
<td>0.36 GW</td>
<td>£200 m</td>
</tr>
<tr>
<td>South West</td>
<td>6.0 GW</td>
<td>£450 m</td>
</tr>
<tr>
<td>English East Coast and East Anglia</td>
<td>10.8 GW</td>
<td>£790 m</td>
</tr>
<tr>
<td>London</td>
<td>3.3 GW</td>
<td>£200 m</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>39.26 GW</strong></td>
<td><strong>£8.82 bn</strong></td>
</tr>
</tbody>
</table>

*Table 5: Estimated costs of reinforcements and extensions in onshore transmission grid (ENSG, 2012: 21)*

![Figure 31: Current and planned reconstruction activities in GB electricity grid (Hodson and Marvin, 2013: 66)](image-url)
<table>
<thead>
<tr>
<th>Project name</th>
<th>Offshore Transmission Owner (OFTO)</th>
<th>Project developer</th>
<th>Distance</th>
<th>Transfer value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robin Rigg East and West</td>
<td>Transmission Capital Partners</td>
<td>E.ON Climate &amp; Renewables UK</td>
<td>11.5km</td>
<td>£65.5m</td>
</tr>
<tr>
<td>Sheringham Shoal</td>
<td>Blue Transmission Capital Partners</td>
<td>Scira Offshore Energy Limited</td>
<td>21.4km</td>
<td>£191.1m</td>
</tr>
<tr>
<td>Barrow</td>
<td>Transmission Capital Partners</td>
<td>Barrow Offshore Wind Limited</td>
<td>12.7km</td>
<td>£33.6m</td>
</tr>
<tr>
<td>Greater Gabbard</td>
<td>GET Balfour Beatty</td>
<td>Greater Gabbard Offshore Winds Ltd</td>
<td>32.5km</td>
<td>£317m</td>
</tr>
<tr>
<td>Gunfleet Sands 1 and 2</td>
<td>Transmission Capital Partners</td>
<td>Gunfleet Sands Ltd</td>
<td>7.4km</td>
<td>£49.5m</td>
</tr>
<tr>
<td>Ormonde</td>
<td>Transmission Capital Partners</td>
<td>Ormonde Energy Limited</td>
<td>12.3km</td>
<td>£103.9m</td>
</tr>
<tr>
<td>Walney 1</td>
<td>Blue Transmission</td>
<td>Walney (UK) Offshore Windfarms Ltd</td>
<td>19.3km</td>
<td>£105.4m</td>
</tr>
<tr>
<td>Walney 2</td>
<td>Blue Transmission</td>
<td>Walney (UK) Offshore Windfarms Ltd</td>
<td>22km</td>
<td>£109.8m</td>
</tr>
<tr>
<td>Thanet</td>
<td>Balfour Beatty Investments Limited</td>
<td>Thanet Offshore Wind Limited</td>
<td>17.7km</td>
<td>£164m</td>
</tr>
<tr>
<td>London Array</td>
<td>Blue Transmission</td>
<td>London Array Limited</td>
<td>27.6km</td>
<td>£459m</td>
</tr>
<tr>
<td>Lincs</td>
<td>Transmission Capital Partners</td>
<td>Lincs Windfarm Ltd</td>
<td>9.1km</td>
<td>£307.7m</td>
</tr>
<tr>
<td>West of Duddon Sands</td>
<td>Not yet licenced</td>
<td>Morecambe Wind Ltd</td>
<td>20.1km</td>
<td>£296.2m</td>
</tr>
<tr>
<td>Gwynt y Mor</td>
<td>Not yet licenced</td>
<td>Gwynt y Mor Offshore Wind Farm Limited</td>
<td>18km</td>
<td>£352m</td>
</tr>
<tr>
<td>Westermost Rough</td>
<td>Not yet licenced</td>
<td>Westermost Rough Ltd</td>
<td>11.2km</td>
<td>£172.3m</td>
</tr>
<tr>
<td>Humber Gateway</td>
<td>Not yet licenced</td>
<td>Humber Wind Limited</td>
<td>10.1km</td>
<td>£194.7m</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Total</strong></td>
<td><strong>£2921.7m</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Characteristics of current and planned offshore transmission grids, not including round-3 offshore wind projects\(^8\) (*Transfer value here as calculated by Ofgem- cost of developing and constructing the related transmission assets*)

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\(^8\) These data have been collected by Miles ten Brinke in the context of his PhD research on the reconfiguration of the UK electricity grid.
2) Creation of a new *offshore transmission grid* that links the offshore wind farms to the mainland. Current offshore grids are relatively close to shore (10-30 km), connecting wind-farms that were constructed under round-1 and round-2 of the licensing process. Future offshore grids, which will connect round-3 wind farms, will be located deeper out (100 km or more from shore). While most realized offshore grids use HVAC-systems (high voltage alternating current), future offshore grids are likely to use HVDC systems (high voltage direct current), which forms a (minor) technical challenge (Andersen, 2014). There are currently nine offshore grids in operation and a further two with approved licenses, amounting to **£1.9 billion** investment. Four more offshore grids are in the midst of the bidding process, amounting to about **£1 billion** investment (Table 6). These offshore grids are owned and operated by Offshore Transmission Owners (OFTOs), which are mainly investment consortiums (further discussed below).

3) Building new *inter-connection transmission cables* with other countries. The UK currently has four inter-connectors, providing a total capacity of 4GW, that connect to France, Northern Ireland, the Republic of Ireland and the Netherlands. Future plans aim to build new inter-connections with France, Belgium, Denmark, Iceland and Norway (Table 7; Figure 32).

<table>
<thead>
<tr>
<th>Connection to which country</th>
<th>Expected operational year</th>
<th>Capacity, length</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>ElecLink</td>
<td>France via the Chunnel</td>
<td>2015</td>
<td>1000MW; 51km; £330m*</td>
</tr>
<tr>
<td>NEMO Link</td>
<td>Belgium</td>
<td>2018</td>
<td>1000MW; 130km; £648.8m</td>
</tr>
<tr>
<td>IFA2</td>
<td>France</td>
<td>2020</td>
<td>1000MW; 240km; £580m*</td>
</tr>
<tr>
<td>Viking Link</td>
<td>Denmark</td>
<td>2020</td>
<td>1,000-1,400MW; 600-700km; £1400m*</td>
</tr>
<tr>
<td>Ice Link</td>
<td>Iceland</td>
<td>2022</td>
<td>800-1,200MW; 1000km; £1620m*</td>
</tr>
<tr>
<td>North Sea Network</td>
<td>Norway</td>
<td>2020</td>
<td>1400MW; Over 700km; £1240-1650m*</td>
</tr>
<tr>
<td>NorthConnect (Scotland- Norway Interconnector)</td>
<td>Norway</td>
<td>2021</td>
<td>1400MW; 570km; £1240m*</td>
</tr>
<tr>
<td>FABLink</td>
<td>to France via Alderney (Channel Island)</td>
<td>2020</td>
<td>1400MW; Length TBA; Cost TBA</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>£7.029 bn</strong></td>
</tr>
</tbody>
</table>

Table 7: Planned GB Inter-connector projects, based on Ofgem and National Grid data⁹ (*: Capital cost estimates from 2014 Policy Exchange report on GB Interconnection)

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⁹ These data have been collected by Miles ten Brinke in the context of his PhD research on the reconfiguration of the UK electricity grid.
The investments in these (incremental) grid-innovations have been of a similar order of magnitude as those in renewable generation capacity (Figure 33). Between 2010 and 2013, £16 billion has been invested in onshore and offshore transmission grids, and about £1 billion in inter-connection projects (DECC, 2014). Much greater investments are still to come up to 2010 with estimates of: £8.82 billion for onshore transmission (Table 5 above), up to £15 billion for offshore transmission that connects offshore wind farms to mainland substations (CCC, 2013: 93), and about £7 billion for inter-connector projects (Table 7), many of which don’t become operational until after 2020.
The implementation of more radical innovations in distribution networks (which could substantially reconfigure grid functionalities) has been much slower, however:

- There has been much talk about smart grids, but less implementation. In 2009, the Electricity Networks Strategy Group produced a high-level plan and a cost-benefit analysis for smart grids in the UK (ENSG 2009), followed by a ‘route map’ (ENSG, 2010). In 2011, DECC and Ofgem established a Smart Grids Forum, including representatives from the DNOs. The Forum produced reports with a detailed description of expected functionalities of a smart grid by 2020 and 2030 (Smart Grid Forum, 2011, and with assessments of regulatory and commercial barriers to the smart grid (Smart Grid Forum 2012). These smart grids discourses have been accompanied by increasing R&D investment, but not yet by real-world implementation and roll-out. Instead, attention has focused on the roll-out of smart meters (which are only one element of smart grids). The roll-out of 53 million smart meters is scheduled to occur between 2015 and 2020 for all households and small businesses, at an estimated cost of £10.927 billion. It is hoped that smart meters will help reduce energy demand and facilitate supply-side benefits such as removing the need for meter reading site visits; making the consumer switching process cheaper and simpler for suppliers; improving theft detection and debt management. It is also hoped that smart meters will facilitate the development of smart grids, but these benefits have not yet been quantified (because of many uncertainties, including limited commitment to actual implementation).
- **Demand-side response** (DSR) refers to the possibility of managing electricity demand to accommodate fluctuations in electricity supply (from intermittent sources such as solar-PV and wind power). It is hoped that demand can be managed through a combination of smart meters and new kinds of electricity tariffs, such as time-of-use tariffs (in which the price of electricity varies according to the period of the day) or real-time (‘dynamic’) tariffs (in which prices vary every 10 minutes depending on interactions between supply and demand). DSR (in which demand follows supply) would entail a change in entail a reversal of the current functional principle (in which supply follows demand). Although time-of-use tariffs already exist, DSR is not currently widely implemented for consumers.

- **Electricity storage** already exists in the form of pumped hydro. But the decreasing prices of batteries have led to new discussions about introducing electricity storage options as a buffer between demand and fluctuating supply. This would require substantial investments and changes in the distribution grid to enhance flexible management of electricity flows.

Although implementation of these innovations has been slow, DNOs have substantially increased R&D investment since the introduction of Ofgem’s Innovation Funding Incentive (Figure 34).

![Figure 34: R&D spending on electricity distribution networks (Bolton and Foxon, 2011: 17)](image)

### 6.2. Developments in social groups and (intangible) regime elements

Section 6.1 showed that pressures on the GB grid have, so far, been met with incremental innovations in *transmission* networks (extensions and intensifications of onshore grid, creation of new offshore grid, building more inter-connectors), which do not substantially change its architecture. Innovations that would change the *distribution* network have been implemented to a lesser degree. This section discusses the various actors and routines, beliefs and institutions that help explain these developments (i.e. mainly incremental change, limited radical change).

An important part of the explanation is that governance of the electricity networks is characterized by relatively closed ‘club governance’ (Moran, 2003) by actors that know each
other well, share mindsets and outlooks, and take each other’s interest into account. The most influential actors in the electricity network regime are Ofgem, the System Operator (National Grid), the three Transmission Network Operators (TNOs), and the Distribution Network Operators (DNOs). These actors and a few others (e.g. DECC, energy companies) are part of the ENSG (Electricity Networks Strategy Group) which provides a high-level (relatively invisible and closed) forum for discussions of policies, plans and challenges.

**Ofgem**

The independent regulator Ofgem was created in the 2000 Utilities Act.\(^\text{10}\) Ofgem’s core remit was to “protect the interest of consumers, present and future, wherever appropriate by promoting effective competition”. Articulated in the midst of privatization and liberalization processes, this remit signaled the neo-liberal economic belief that competition is the best way to drive prices down and serve consumer interests. To achieve its mission, Ofgem has focused on minimizing costs, improving cost-efficiency and driving down consumer prices. For electricity transmission and distribution this led Ofgem to introduce price control regulation (called RPI-X), which sets the fees that TNOs and DNOs can charge for transmission and distribution services for 5-year periods. Ofgem also agrees minimum infrastructure investment programs with TNOs and DNOs.

The RPI-X regulation shapes the overall revenue allowance of TNOs and DNOs by adjusting it, firstly, to take account of inflation, or Retail Price Index (RPI), and secondly by a factor \(X\), which is intended to induce efficiency gains (Jamasb and Pollitt, 2007). The RPI-X regulation, which was inspired by economic theory and policy considerations, has been successful in increasing efficiency and decreasing costs. But focus on efficiency and cost decreases hindered innovation, as it stimulated TNOs and DNOs to ‘sweat the assets’ (by postponing network investments) and downscale R&D investments (see Figure 7).\(^\text{11}\) RPI-X also discouraged a long-term strategic orientation, because investment proposals to Ofgem had to be legitimated in terms of **demonstrated needs** (Lockwood, 2013). This approach of “wait for proven need and then choose the optimal solution” (Shaw, 2010) may be efficient according economic theory, but discourages radical innovations that do not address well-articulated needs.

Since the early 2000s, the rise of climate change on the policy agenda led to increasing pressures on Ofgem to: 1) pay more attention to sustainability (besides costs), 2) stimulate innovation (besides efficiency).

To address the first issue, the 2004 Energy Act introduced ‘sustainable development’ as a secondary statutory duty for Ofgem, but this was **layered** on top of the old remit instead of being internalized by the organization. In 2007, a critical report by the Sustainable Development Commission questioned whether Ofgem had “kept pace with the climate change imperative and whether the government framework within which it operates is fit for the challenge of moving to a completely decarbonised electricity system by 2050”, and recommended changing Ofgem’s primary duty to reflect this imperative (SDC 2007: 6-8). Indeed, the 2008 Energy Act raised sustainable development (and greenhouse gas reduction) to become part of Ofgem’s primary duty. In 2010, the government issued further guidance that Ofgem should stimulate TNOs and DNOs to plan for a low carbon future. In October, 2012, the Labour Party announced plans to scrap Ofgem, because it was no longer ‘fit for purpose’. And in July 2013, Members of

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\(^{10}\) Before 2000, the electricity sector was overseen by OFFER (Office of Electricity Regulation), which was created in 1989.

\(^{11}\) By 2004, UK network companies were spending less than 0.1% of revenue on RD&D (Pollitt and Bialek 2008).
Parliament from the The Energy and Climate Change Committee criticized for having a “relatively light touch approach” of energy companies (see http://www.bbc.co.uk/news/business-23462072). So, there have been increasingly heated pressures and policy debates about Ofgem’s remit. These debates have, arguably, not yet led to major changes in Ofgem’s (or in actual electricity networks), because the regulator Ofgem has a substantial degree of autonomy and discretion in relation to policymakers (Lockwood, 2013). The reason is that Ofgem was set up as an independent organization with a broadly formulated remit (“protecting the interests of existing and future consumers”), which provides it a high degree of interpretive flexibility and leeway.

With regard to the second issue (innovation), Ofgem introduced two sources of funding in the 2005-2010 period to stimulate technological and commercial innovation: the Innovation Funding Incentive (IFI) and Registered Power Zones. Although the IFI (which allowed DNOs to spend up to 0.5% of its revenue on R&D) increased R&D spending (Figure 7), these new instruments had limited implementation effects, resulting in only a handful of technology schemes (Lockwood, 2013). For the 2010-2015 period, Ofgem therefore created a new Low Carbon Network Fund (LCNF), which was an order of magnitude larger than IFI and allowed DNOs to bid for up to £500 million over 5 years.

Additionally, Ofgem started its own ‘root and branch review’ (in 2008) of the regulatory framework, which it called ‘RPI-X@20’.12 RPI-X@20, which was motivated by the low-carbon energy agenda and ideas of regulating for outputs rather than simply cost, opened up the debate on network regulation to new ideas, including direct competition in distribution at local level and a more strategic long-term approach to investment. The review led to what Ofgem (2013) itself called a “new regulatory model” that would stimulate innovation and promote a “step-change” in the prominence of low-carbon futures. The new RIIO-framework, which stands for Regulation = Incentives + Innovation + Outputs’, will come into force in 2015. RIIO involves several new incentives and instruments that aim to (Lockwood, 2013): a) improve engagement with major customers, including distributed generators, b) penalize failures to meet minimum connection times and quality, c) improve customer satisfaction. They also include innovation-oriented policies such as: d) a Network Innovation Competition, in which DNOs bid for funds for large-scale projects, e) an Innovation Roll-out Mechanism to fund the roll-out of proven low-carbon innovations, f) a new requirement that DNOs consider innovative solutions to network problems and produce a smart grids development plan, g) a requirement to develop plans for how DNOs will accommodate the growth of low-carbon technologies (e.g. heat pumps, electric vehicles, solar-PV, wind) on their distribution networks.

While these incentives aim to improve innovation and (low-carbon) performance, the changes under RIIO do not amount to a major policy change (Lockwood, 2013), despite Ofgem’s claims. One reason is that the more radical ideas that were discussed in the RPI-X@20 review have been side-lined and were not included in RIIO. So, Ofgem’s self-instigated review enabled it control the process and to defuse criticisms. Another reason is that many aspects of the previous RPI-X regulation have been maintained in RIIO: “The overall form of regulation, i.e. price-cap, remains the same. At the same time, the principles of Ofgem’s approach to regulation, in which the main focus is on achieving minimizing costs, maximizing efficiency, and avoiding the risk of stranded assets, remain largely the same. Innovation is seen as arising out of incentives for efficiency, along with some additional resourcing. The regulatory paradigm remains in force” (Lockwood, 2013: 19). So, the new incentives and policies appear to have been

12 The choice for this obscure term was motivated by the fact that RPI-X regulation had been in place for around 20 years.
layered on top of the previous RPI-X design rather than displacing previous policies. So, despite Ofgem’s claims, policy change has been more ‘evolution’ than ‘revolution’ (Lockwood, 2013). Furthermore, the effectiveness of RIIO (which comes into force in 2015) in stimulating low-carbon innovation in distribution networks remains to be seen, and should perhaps not be taken for granted, given other lock-in mechanisms (further discussed below).

In 2012, Ofgem launched another policy project, called Integrated Transmission Planning and Regulation (ITPR), to address long-term challenges and to ensure that regulatory arrangements are suited to plan and deliver future electricity transmission networks in a coordinated and efficient way (onshore, offshore and inter-connection). Although the 3-year ITPR project had transformative potential, the final outcomes in 2015 were (also) relatively incremental. One change for onshore transmission networks is the introduction of competitive tendering for new projects. This deviates from the current regulations (in which TNOs propose new investment plans to Ofgem), but was already in use for offshore transmission grids. The main aim of this change is to attract more private investment for discrete infrastructure projects. This will be done by creating stable and financially attractive conditions. Another change is to give the System Operator (National Grid) greater power in terms of overall coordination (e.g. as a ‘system architect’). Details for onshore transmission will be elaborated through 2015 and 2016, with Ofgem aiming to run the first tender in 2016 or 2017.

For offshore transmission projects, Ofgem has created separate regulations, based on competitive tendering. This started in 2009, when DECC and Ofgem issued a joint statement on the Offshore Transmission Regulatory Regime. The offshore regulations were separated into a ‘transitional regime’ (2009-2012) and an ‘enduring regime’ (post-2012). Under the ‘transitional regime’, many offshore wind farm operators, which had constructed their own transmission grids, had to sell the grid to Offshore Transmission Owners (OFTOs). Under the ‘enduring regime’, offshore transmission grids are either build directly by OFTOs or transferred to OFTOs when construction is complete. The licenses to build and/or operate offshore grids are sold to the highest bidder. To attract private investments, the OFTO license regulations are deliberately appealing, offering investors a solid fixed 20-year return on a relatively low risk profile, underwritten by a stable regulatory framework (KPMG, 2012).

In sum, Ofgem’s transmission regulations (also) focus on competition and cost efficiency, based on a continuation of neo-liberal economic beliefs. This lock-in and the fact that most policy change has so far been incremental can be attributed to various factors: 1) close alliances between Ofgem, National Grid, TNOs and DNOs, leading to regulatory capture (Mitchell, 2008), 2) a conservative culture dominated by economists and engineers (Cary, 2010), who tend to focus more on efficiency and costs than on transformative change, 3) a siloed organisation in which sustainability has been separated off from the core of regulatory incentives (SDC, 2007), 4) the policy regime which gives Ofgem substantial independence from policymakers and a broad remit that offers the organization discretion to maneuver; this makes it difficult for government to introduce new policy objectives and creates regulatory inertia (Lockwood, 2013).

**Offshore Transmission Owners (OFTOs)**
The building and/or operation of offshore transmission networks is in the hands of OFTOs, which are investment consortiums that take advantage of Ofgem’s attractive regulations. As indicated in column 2 in Table 2, there are two dominant OFTOs: Transmission Capital Partners
(five licenses) and *Blue Transmission* (four licenses). The OFTO’s revenue stream is unrelated to the generating asset’s performance. The OFTO needs only to ensure the transmission infrastructure is available to transmit regardless of the power actually generated.

The OFTOs pay project developers to actually build the offshore grids. In most instances, so far, these have been the wind farm developers (Table 2). So far, most offshore grids are relatively near shore (10-30 kilometers). Future grids will be much further into the sea (100-200 kilometers) to connect the round-3 offshore wind farms.

In sum, the main actors in the construction of offshore transmission grids are large-scale investors, project developers, and the regulator Ofgem.

**Transmission Network Operators (TNOs)**

The extension, intensification, and reinforcement of onshore transmission networks has, so far, been driven by the three TNOs, which interact with the System Operator and supply chain firms (e.g. ABB, Alstom). They also interact with Ofgem which evaluates submitted proposals for infrastructure investments, issues licenses and approves costs. The proposals need to be argued in terms of technical details, costs and a proven need for the new infrastructure (Lockwood, 2013). This last point helps explain why progress and investment in new transmission networks has been substantially greater than in distribution networks: the newly constructed wind farms in remote locations constitute a clear demand for the extension and reinforcement of new infrastructure. Besides clear demand or regulatory pressure from Ofgem, TNOs don’t have an incentive to innovate, as they do not face competition. This helps explain why most innovations in transmission grids have been incremental.

Ofgem’s new rules means that onshore transmission projects will be tendered (just like OFTOs), which will introduce some competition, although probably mainly cost-oriented.

**Distribution Network Operators (DNOs)**

DNOs are passive distributors, who transmit power from sub-stations to end-consumers (e.g. households, offices, firms). They receive a fee from the electricity companies for transmitting this power, but do not have direct commercial relations with end-users (Lockwood, 2013). DNOs tend to have specific characteristics as companies (Ofgem, 2009). This regulated business model (which forbids direct contacts with end-users), makes it difficult for DNOs to become active network operators that would: a) actively monitor and manage electricity flows (through smart grids), b) provide access to distributed generation, c) develop electricity storage to deal with intermittency, d) develop demand-side response initiatives.

Furthermore, distribution networks are a low-risk business, attracting capital (especially debt) at a discount. DNOs are risk-averse and act when required to (e.g. when distributed power generators seek to connect to the distribution network) or by the regulator. They do not have proactive long-term innovation strategies, but react to the regulatory contract and focus on allowed revenue (Lockwood, 2013). For decades, the regulatory regime encouraged DNOs to focus on efficiencies and short-term cost reduction. DNOs have therefore lost technical capacity and skills.

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13 *Transmission Capital Partners* is an investment consortium of Transmission Capital, International Public Partnerships and Amber Infrastructure Group. *Blue Transmission* is an investment consortium of 3i Group Plc and Diamond Transmission Corporation (UK subsidiary of Mitsubishi Corporation).

14 The three TNOs are: 1) National Grid Electricity Transmission plc (NGET) for England and Wales, 2) Scottish Power Transmission Limited for southern Scotland, and 3) Scottish Hydro Electric Transmission plc for northern Scotland and the Scottish islands groups.
and lack the incentives for major long-term innovations, which helps explain why innovation in distribution networks has been relatively slow (Bolton and Foxon, 2015). Another reason for the slow implementation of the radical innovations, discussed above, is that there is no articulated need by concrete clients (which is an important contrast with the transmission grid).

So, there are various lock-in mechanisms that help explain the slowness of substantial low-carbon innovation in distribution networks. To incentivize DNOs to connect distributed generators (e.g. solar-PV, community energy), Ofgem introduced a financial Distributed Generation-incentive in 2005. Nevertheless, DNOs remained relatively inactive, leading Ofgem (2012) to admit that the incentive had had little effect. This reluctance stemmed from the perception that DNOs did not see connecting and managing DG as part of their core business (Mitchell, 2008). They therefore dealt with projects on a piecemeal basis instead of developing a longer-term strategy (Cary, 2010).

In response to Ofgem’s Innovation Funding Incentive (2005), DNOs increased their R&D investments (Figure 7), although real-world implementation remained slow. To address this problem and stimulate low-carbon innovation, Ofgem created a new Low Carbon Network Fund, which allowed DNOs to bid for up to £500 million in the 2010-2015 period. Ofgem has also made some changes in the regulatory model (via RIIO) with the aim of stimulating innovations such as smart grids, demand-side response and storage. It remains to be seen if these impulses will be sufficient to overcome the various lock-in mechanisms.

Local communities, NGOs, public debate
Most of the planning and decision-making around electricity networks is a very technocratic process involving a small group of actors. On-the-ground implementation and construction, however, also affects the lives of residents and local communities and requires formal consultation processes. Various infrastructure projects have encountered conflicts and delays because of protests from local residents. Several factors may underlie these protests (Cotton and Devine-Wright, 2012): 1) pylons and overhead power lines may cause visual intrusion in rural and suburban landscapes and cause zooming sounds that create noise pollution, 2) these factors may affect property and local amenity values, 3) some citizens are concerned about potential health risk, particularly questions over cancer risks due to electric and magnetic fields emitted by power lines, 4) distrust of large electricity companies (including National Grid), 5) feelings of being ‘bulldozed over’ and lack of consideration of local concerns (which are often dismissed as ‘NIMBY’).

These concerns have led to protests against various infrastructure projects:
* In Scotland, there have been fierce protests in the early 2010s against the creation of new pylons and wires across 220 km of Scottish highlands. The John Muir Trust, a wild land charity, was involved in these protests, which attracted much public attention.
* In Suffolk and Essex, protesters created the Essex & Suffolk Coalition of Amenity Groups, whose protests led National Grid to decide (in 2013) to postpone its plans for new pylons until the early 2020s.
* In Wales, there have been prolonged protests against new power lines between 2011 and 2014.

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16 See: http://www.bbc.co.uk/news/uk-england-suffolk-24950559
The protests in Scotland and Wales led to substantial delays in consultation and approval procedures: “Major delays of 2 to 4 years were announced late in 2012 for many projects in Northern Scotland and the reinforcements required in mid and north Wales remain behind schedule. Our indicators envisaged that construction would begin in 2012 (mid Wales) and this year (north Wales), but there have been continued delays in planning, largely due to local public opposition” (CCC, 2013: 92).

These protests against onshore cables are one reason that some of the new North-South connections use subsea cables rather than overhead lines (the ‘bootstrap’ connections down the east and west coast in Figure 3). To reduce problems and lessen protests, National Grid also recently introduced a new pylon design (‘T-pylon’), which is shorter (36 instead of 50 meters) and less obtrusive (Figure 36).

![Figure 36: New ‘T-pylon’ for electricity transmission, introduced by National Grid in 2015](http://www.theguardian.com/environment/2015/apr/09/new-style-of-uk-electricity-pylon-launches)

7. Conclusions about stability and tensions
Our analysis has focused on three sub-regimes in the UK electricity system: 1) electricity generation, which includes coal, gas and nuclear power, 2) domestic electricity consumption, 3) electricity networks (transmission and distribution grid). The discussion and tables below summarise the findings about stability and tensions/problems for these three regimes.

7.1 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.

<table>
<thead>
<tr>
<th>Lock-in, stabilising forces</th>
<th>Cracks, tensions, problems</th>
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<tr>
<td><strong>External landscape pressures</strong></td>
<td>- 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)</td>
</tr>
<tr>
<td><strong>Utilities</strong></td>
<td>STRONG</td>
</tr>
<tr>
<td><strong>Cracks, tensions, problems</strong></td>
<td>- Climate change - Financial-economic crisis</td>
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| 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).

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<th>Consumers</th>
<th>STRONG</th>
<th>WEAK</th>
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| 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. | 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. |

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<th>Policy-makers</th>
<th>MODERATE</th>
<th>MODERATE</th>
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| 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 | 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 |
(although there are complaints about dysfunctional markets, which led to an investigation by the Competition and Markets Authority).

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<th>Public debate and opinion</th>
<th>MODERATE</th>
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<td>Public concerns about high costs (and energy security) have helped to stabilise the existing regime by creating a more negative framing of renewable energy.</td>
<td>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.</td>
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<th>Pressure from social movements, NGOs</th>
<th>WEAK/MODERATE</th>
<th>WEAK/MODERATE</th>
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<tr>
<td>Most NGOs are critical and do not actively contribute to regime lock-in.</td>
<td>* 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.</td>
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<th>Overall assessment</th>
<th>STRONG</th>
<th>WEAK/MODERATE</th>
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<td>* 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 weakened in last 2-3 years with politicians giving more priority to costs and energy security.</td>
<td>* 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</td>
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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. 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.

7.2 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.
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<th><strong>Lock-in, stabilising forces</strong></th>
<th><strong>Cracks, tensions, problems</strong></th>
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| **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 |
| **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 |
| **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 |
| **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 movements, NGOs, scientists | STRONG  
Not a prominent campaigning issue for most NGOs. Those that do campaign are largely supportive of efficiency agenda, calling for more support and quicker policy implementation. | WEAK / MODERATE  
Scientific analysis criticises the technology 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). |

7.3 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 Table 4, disaggregated for different actor groups.

<table>
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<tr>
<th>actor group</th>
<th>Lock-in, stabilising forces</th>
<th>Cracks, tensions, problems</th>
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<tr>
<td>External landscape pressures</td>
<td>- Neoliberal ideology and policy (since 1990s)</td>
<td>- Climate change</td>
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<td></td>
<td>- Development of ICT and information society (giving rise to debates about ‘smart grids’)</td>
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<tr>
<td>Independent regulator (Ofgem)</td>
<td>STRONG</td>
<td>WEAK/MODERATE</td>
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<td></td>
<td>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’.</td>
<td>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).</td>
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<tr>
<td>Transmission</td>
<td>STRONG</td>
<td>WEAK/MODERATE</td>
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<td>Operators (TNOs, (OFTOs))</td>
<td>Operators of <em>transmission</em> grids have deep sunk investments, and are oriented towards stability, rent seeking and incremental change.</td>
<td>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.</td>
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| 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. |
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