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Distributing power, a transition to a civic energy future: Report of the Realising Transition Pathways Research Consortium 'Engine Room'

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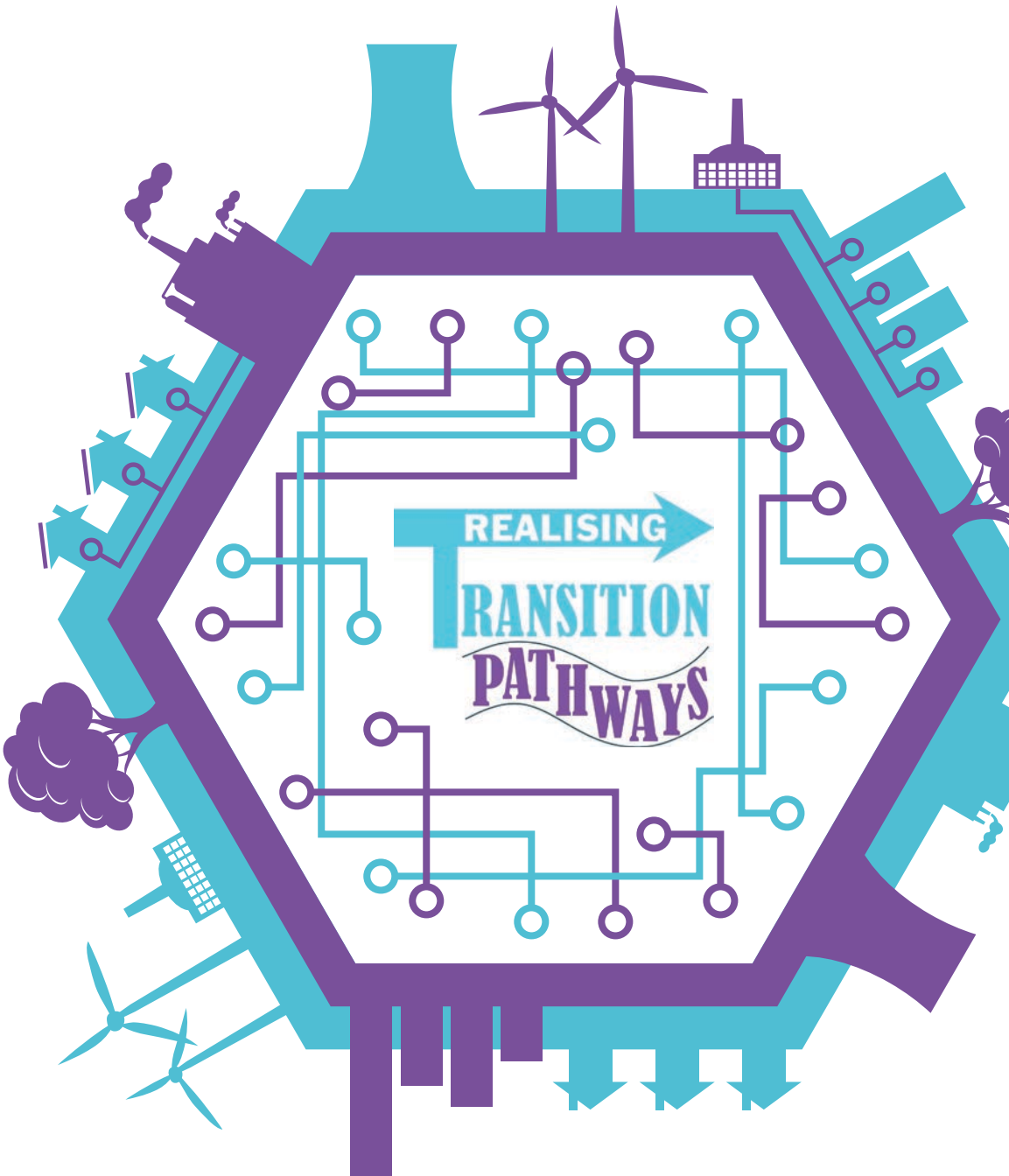
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Distributing Power

A transition to a civic energy future

Report of the Realising Transition Pathways
Research Consortium 'Engine Room'



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Glossary

AC	alternating current
ACS	average cold spells
CARES	Community and Renewable Energy Scheme
CCGT	combined cycle gas turbines
CCS	carbon capture and storage
CHP	combined heat and power
DECC	Department of Energy and Climate Change
DG	distributed generation
DNO	distribution network operators
DoE	Department of Energy
DSO	distribution system operators
DSP	demand side participation
EMR	Electricity Market Reform
EPC	energy performance contracts
ESC	energy supply contracts
ESCos	Energy Service Companies
ESI	electricity supply industry
EST	Energy Saving Trust
EVs	electric vehicles
FiT	feed-in tariff
GHG	greenhouse gas
GLA	Greater London Authority
ICT	information and communication technologies
LES	local energy schemes
MO-ESCos	Municipally-Owned Energy Service Companies
MPPs	major power producers
NEP	National Energy Programme
NG	National Grid
REP	Regional Energy Partnerships
ROCs	Renewable Obligation Certificates
RTP	Realising Transition Pathways
SDES	Southampton District Energy Scheme
STOR	short term operating reserve
TF	Thousand Flowers pathway
TP	Transition Pathways

Executive Summary

The overarching challenge for UK energy policy is to ensure the delivery of secure, affordable energy in a way that meets the emission reductions targets laid out in the Climate Change Act (2008). The EPSRC-funded Transition Pathways (TP) and, more recently, Realising Transition Pathways (RTP) projects have both argued that multiple logics of governance, ownership, and control of the electricity system can be followed to address the energy trilemma. This work has developed three transition pathways for the UK energy system, each driven by different governance patterns. Each pathway has a specific technological mix, institutional architecture, and societal drivers. These pathways are:

Central Co-ordination: Central to this pathway is the role of the nation state in actively delivering the transition.

Market Rules: After the creation of a broad policy framework, the state allows competition and private companies to deliver sustainable, affordable energy.

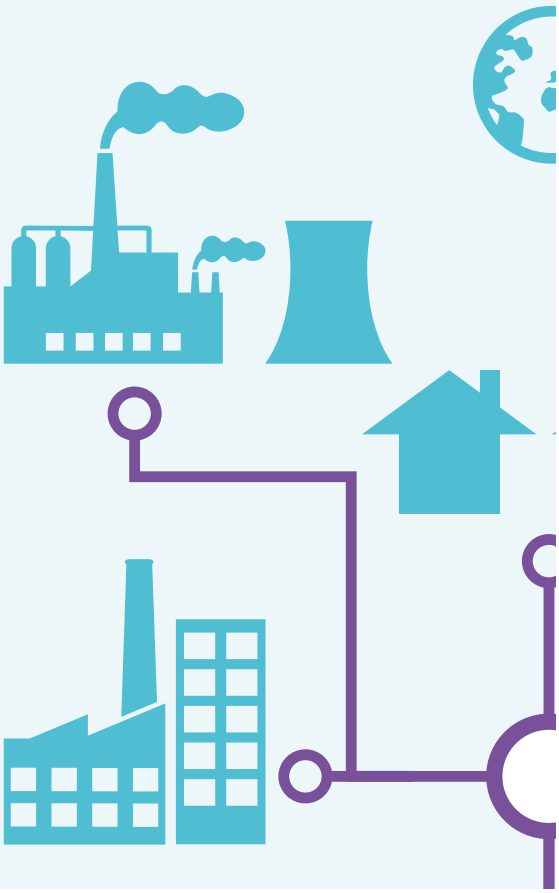
Thousand Flowers: This pathway is characterised by a greatly expanded role for civil society in delivering distributed low-carbon generation.

The following report focuses on the **Thousand Flowers** pathway.

There is growing interest, from a range of stakeholders, in the potential of distributed low-carbon electricity generation in delivering a low-carbon energy system. Yet there are still significant gaps in understanding, particularly regarding the feasibility of scaling up distributed generation from technological, governance, regulation, policy, and financial perspectives. The aim of this report is to address these gaps within the context of the Thousand Flowers pathway.

This research was carried out by the 'Engine Room' of the EPSRC-funded Realising Transition Pathways (RTP) consortium. The 'Engine Room' was established to facilitate interdisciplinary work across the consortium and consists of research fellows and doctoral researchers from different fields in the nine partner institutions. Engine Room workshops and meetings give researchers the space to present their work and develop and exchange ideas with their peers. This report is an output of a series of interdisciplinary Engine Room workshops held throughout 2013/14 which also drew on contributions from energy industry stakeholders. These workshops brought together the current research and cumulative findings of the Realising Transition Pathways consortium, to examine the consequences of a transition from a centralised energy system to one where distributed generation plays a much greater role (50% of final electricity demand), and is delivered by a civic energy sector.

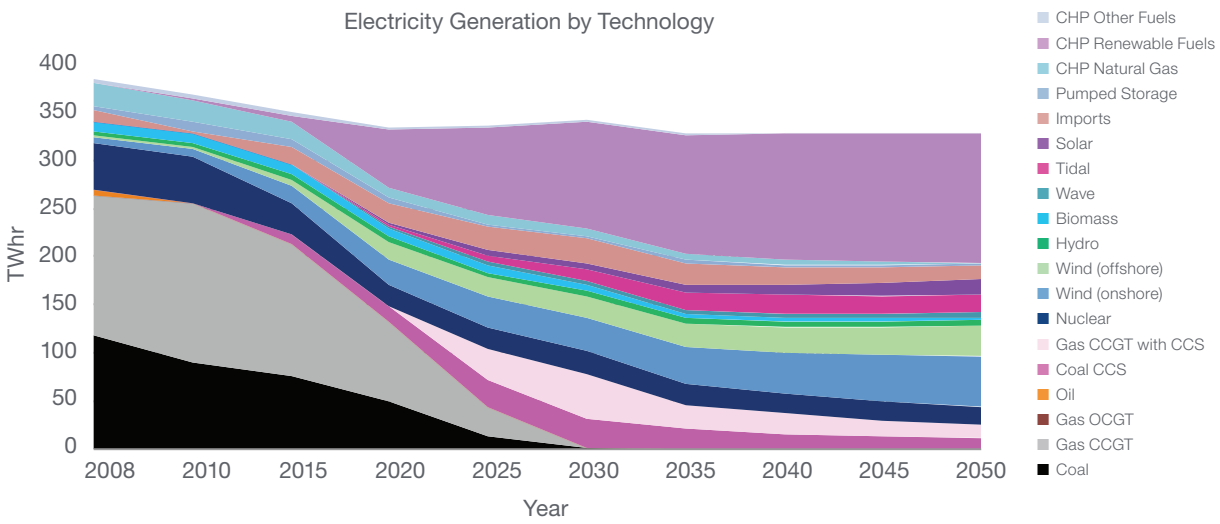
In this report we do not present any panaceas, attempt to preference a civil response to energy transition, or claim technological infallibility. We do, however, explore the potential of a distributed energy future and investigate the technological trajectory it could follow, along with an institutional architecture compatible with its development. We acknowledge throughout that this is a challenging but realistic system transition.



Part I: Technological transformation

Part I of this report explores the substantial technological transformation required to develop the current UK electricity system into a greatly expanded distributed system such as the Thousand Flowers pathway. Distributed generation provides 50% of final electricity demand in the Thousand flowers pathway by 2050, representing a dramatic departure from the current system, which relies predominately on 30 large generators (>1GW each) to generate the majority of UK's electricity.

The technological challenges this would present for the system are addressed in this section. The transitions of generators and transmission/distribution infrastructures are mapped, identifying major changes and issues which are likely to arise. Key technological milestones to be met in order to allow this future to come to fruition are identified. Finally, the future Thousand Flowers electricity system is elaborated, describing the basic system operation and the role that imports, storage, and responsive consumers would play.



The principal findings from examining this technology transformation out to 2050 are:

- **Technological milestones and archetypes**

  A crucial milestone is the large expansion of niche technologies from 2020, suggesting the need for planning and investment in the near term. Compatible policy and regulatory frameworks will also need to be in place before this expansion. The main drivers, build rates, issues, and barriers facing particular technologies in this pathway have been examined. Technology advancement is crucial to the realisation of this pathway, suggesting more support would be required for the more novel technologies such as electric vehicles, wave power, biomass gasification, and fuel cells.

- **Greater Interconnection**

  The Thousand Flowers pathway is reliant on greater interconnection at all levels (local, regional, national, and international) to ensure that system balancing can occur and to offer the best possible method to make use of all the low-carbon electricity being generated. Greater connectivity will give the system greater flexibility and allow the increased amount of renewable generation to be connected.

- **Grid balancing**

  Grid balancing presents one of the largest technology challenges of the Thousand Flowers pathway, moving away from the current top-down approach. Periods of large electricity surplus from inflexible renewable generation must be managed and coordinated with more flexible demand with increased demand side participation. To ensure a reliable supply at least cost, new services must be adequately incentivised in the trading arrangements.

- **Grid reinforcement**

  Substantial grid reinforcement will be required in this pathway to support the large-scale electrification of transport, alongside the rapid introduction of distributed generation (DG). Furthermore it will provide greater system resilience, particularly at times of localised heavy load.

- **Growth of smart grids**

  No one technological change is more crucial to the success of a 'Thousand Flowers' future than the development of smart grids due to its dependency on high levels of distributed generation, low-carbon technologies, and demand side participation. More sophisticated fault protection is also needed, requiring more information and communications technology (ICT) alongside incorporating new smart metering information.

- **Demand side participation and management**

  The prosumers (consumers who produce as well as consume electricity) become key actors in this pathway, leading to significant reduction in overall demand. Price incentives are the main signals used to achieve buy-in to demand side participation in this future. Compatible distribution systems must be in place to stimulate demand response actions, allowing for the process to be automatic, controlled, and stabilised. Equally, these systems can then also be managed at times of low generation, benefiting system balancing while also providing better value to consumers.

- **Skills and workforce**

  In order to facilitate this large transformation, there will need to be a substantial growth in the number of engineers and technology specialists. In the case of Thousand Flowers, growth of skills in relatively niche technologies (in the UK) such as combined heat and power, heat pumps and fuel cells will require greater explicit support.

- **Importance of energy storage**

  Although storage plays a minor role in this pathway it still provides substantial flexibility, demonstrating its value even at minor levels of system penetration.

- **Interdependence of energy across EU**

  This pathway needs to not only make the most of national renewable resources but also the resources of neighbouring countries to add resilience to the system. The system will not only rely more heavily on electricity imports, but also imports of substantial quantities of biomass for combined heat and power.

  This report assesses the impact of one distributed generation future; there are others which might have a greater role for solar, onshore wind, or other generation mixes. Furthermore, technological choice would be informed by geographic resources, and ensuring that the UK optimises its renewable energy potential. As such, the findings of this report are specific to a 'Thousand Flowers' future. However, it offers great insight into the barriers and the technological transformation required for a move to a highly distributed energy future.

Part II: Institutional architecture

A major driver behind the Thousand Flowers pathway is the step change in civic participation in energy futures. In this pathway civil society at individual, organisational, and local state levels, plays a much more active role in generation, distribution, and supply. Part II of the report comprises a number of 'institutional scenarios' concerning the various elements of a new institutional infrastructure that is designed to support distributed generation. These consist of:

Local Energy Schemes (LES)

Currently less than 1% of electricity is generated from local energy schemes (LES) within the UK's civic energy sector; the Thousand Flowers pathway demonstrates the potential for this to grow to a 50% share by 2050. Evidence from other European nations demonstrates that the levels of civic energy generation defined in the Thousand Flowers pathway are possible if the right mix of institutions, resources, finance, and expertise can be developed at the local level. Civic ownership and participation in energy assets can accelerate the deployment of renewable and low-carbon energy generation. This institutional scenario interrogates civic participation in energy generation.

MO-ESCos: A new supplier relationships

MO-ESCos (Municipally-Owned Energy Service Companies) are publically owned energy service companies that would provide institutional support to local energy schemes. Toward 2050, they may become sole suppliers of energy services within a defined geographic boundary. MO-ESCos facilitate civic generation by becoming the main purchaser of electricity generated by the local energy schemes. They also lead the development of distributed generation within their territories to meet supply requirements, purchase supply shortfalls from the wholesale generation market, and are incentivised to supply and reduce the energy demand of their customers. MO-ESCos would also have a core function to provide energy services and have a statutory duty to address fuel poverty and equity in energy provisioning.

OFGEM+: A regulator with a dual focus

The current system of regulating transmission level assets and utilities would continue initially as is, but over time move to a capacity auction model under a **National Energy Programme (NEP)** which is responsible for delivering capacity for system balancing. There is an expanded function of 'OFGEM+' operated through **Regional Energy Partnerships (REP)**, which enable and regulate distributed energy from Local Energy Schemes (LES) and regulate local suppliers (MO-ESCos).

Regional Energy Partnerships: The LES enabler and regulator

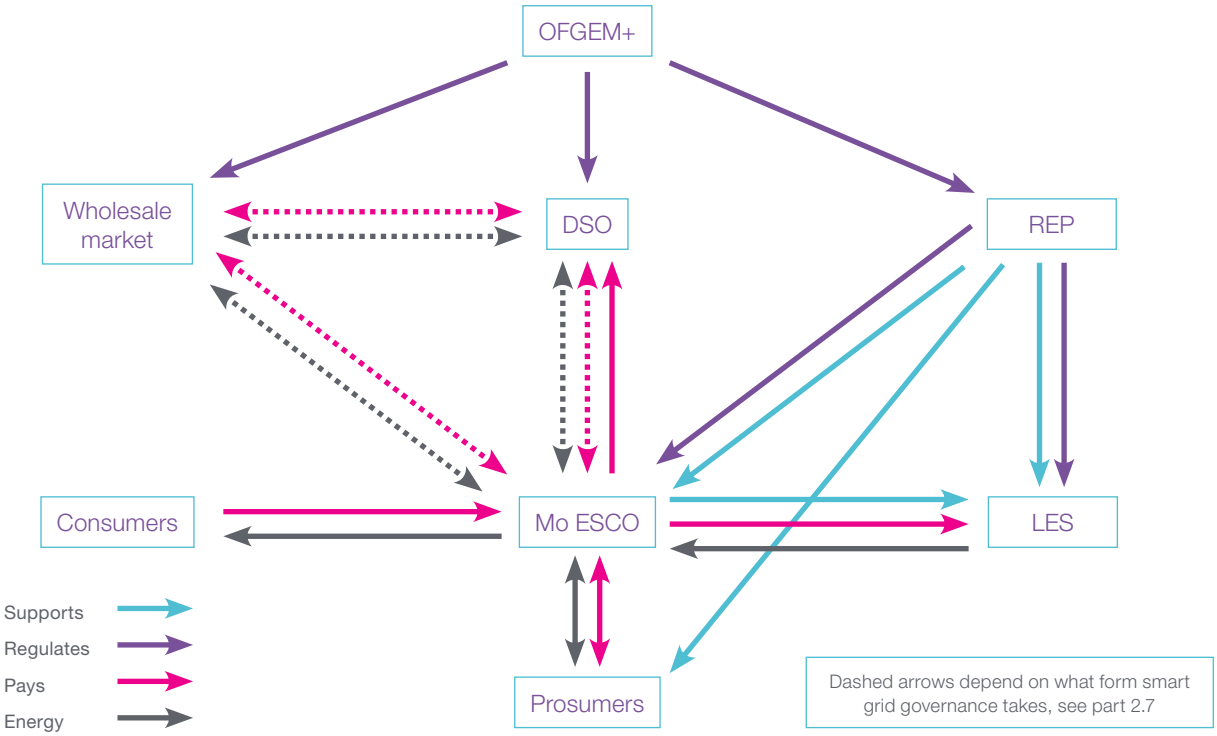
Regional Energy Partnerships (REPs) are new institutions which foster the new municipal ESCos and local generation schemes. REPs have legal responsibility for working with: all local energy generation schemes, local authorities, distribution network operators (DNOs), other statutory bodies, and civic energy actors. They set targets for energy generation and consumption, and communicate with the national level of OFGEM+ to co-ordinate the scaling-out of distributed energy. Importantly, the REPs would develop **strategic energy plans** for their regions, focusing on maximising distributed capacity. The REPs also regulate **Local Energy Schemes (LES)** and **Municipally-Owned Energy Service Companies (MO-ESCos)**, thus reducing the burden on the national regulator.

Transmission Level Generation

A distributed generation future would mean a diminishing market share for the large utility business model in both generation and supply markets. Under this scenario, market-led approaches are unlikely to deliver the investment required to construct the necessary transmission level assets for system balancing. The implications of expanded distributed energy provision on the national capacity auction system are considered; we find that deep penetration of distributed energy assets would mean the capacity auction system operating for base load as well as peaking transmission level assets. In this future, new ways of securing transmission level generation need to be investigated, and may mean new roles for the state.

Smart Grids

This institutional architecture will facilitate greater municipal and civic engagement leading to new business models and institutional arrangements for cost sharing and planning in the physical distribution networks. These developments have the potential to accelerate the deployment of smart grid solutions in the UK, but may require new business models for distribution infrastructures. The options facing the distribution system under a distributed future are presented in this institutional scenario.



Headline Messages

The headline messages from this work, which stand out as important considerations if the UK were to follow this largely distributed future, are:

1. A distributed energy system opens up new avenues for financing the energy transition, but challenges incumbent utility business models.

   A system based on many small and medium-sized producers reduces dependence on very large-scale finance and investment in centralised generation. This opens the energy system up to investment from citizens, municipalities, SMEs, and other forms of finance. This increases the types of capital available to the energy system. At the same time, traditional utility business models face challenges from increased renewable generation and decreased supply market share.

2. It is possible to meet 50% of electricity demand using distributed generation by 2050, but new infrastructures and emerging technologies are still necessary.

   The energy transition is reliant on smart grids, virtual power plants, and new household generation sources. The use of biomass gasification, widespread use of in-home fuel cells, and the operation of virtual power plants at the local level, are emerging technologies that would require intensive adoption.

3. All projections of the UK's energy future rely on some level of international interconnection and a distributed energy future is no different.

   Moving to a largely distributed generation system has traditionally been thought of as a step towards energy independence. However, this analysis of a distributed energy future has shown that high levels of distributed generation in fact make it necessary for higher levels of interconnection at regional, national, and international levels. This is true for the physical electricity system - which requires more interconnectors to move energy around regions as well as to/from regions, and its governance and regulation– which requires new institutions to ensure the system evolves to complement regional resources and inform transmission level investment decisions.

4. The Thousand Flowers pathway relies on strong demand reduction and demand side participation and management.

   Along with distributed generation technologies this pathway relies on significant per capita demand reduction. This requires effective changes in end-user behavioural patterns and a significant uptake of energy efficient measures alongside energy efficient technological diffusion. A civic energy sector features novel forms of citizen participation where the energy system is no longer an almost anonymous entity, but a critical infrastructure in which all actors play a role. These successful initiatives equip the system with greater flexibility, allowing the nation to make the most of its renewable resources.

5. A local and regional approach to distributed energy is vital.

   In order to move to a distributed approach, regional energy strategies and local capacity building will be essential for city regions, municipalities, communities, and citizens. This means complementing our national energy planning with regional and local support for a civic energy sector. This may mean a system of transmission level capacity auctions and contracts and regional level energy strategies and regulation.

Conclusions

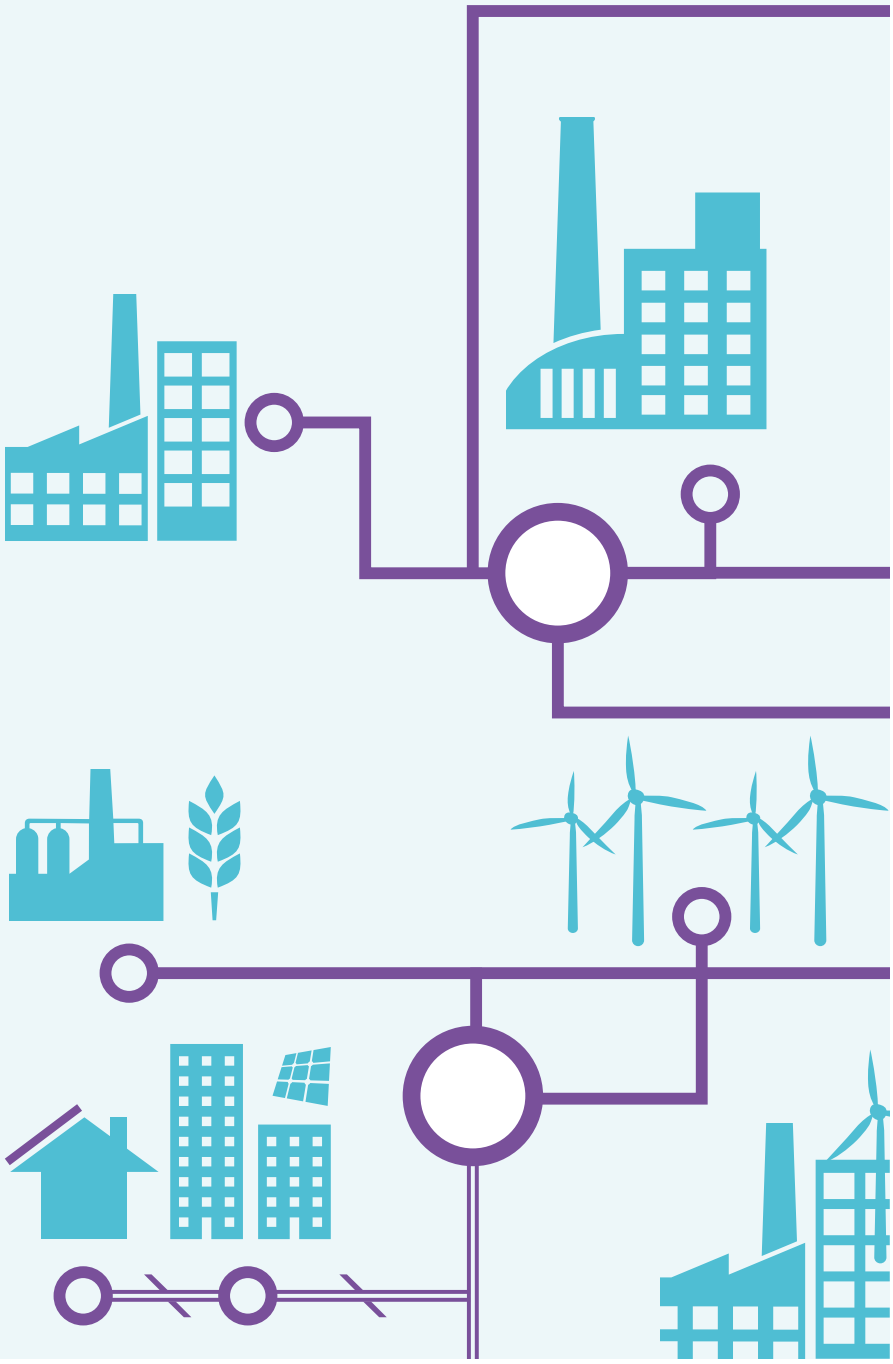
Our construct of a civic response to the energy transition defines a new understanding of the potential for participation in the energy transition by actors who, in the UK at least, have played only a passive or marginal role in energy system change. This analysis demonstrated that a distributed energy future akin to the Thousand Flowers pathway would require both rapid technological change and new institutions in the energy system.

Distributing Power

A transition to a civic energy future

Report of the Realising Transition Pathways Research Consortium 'Engine Room'

Full Report



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Purpose statement

This report explores what the UK energy system could look like if it followed a pathway of distributed energy provision led by civil society. This work is part of the EPSRC-funded Realising Transition Pathways consortium which seeks to explore the constraints and opportunities in realising a low-carbon UK energy sector. The consortium has developed a variety of tools and approaches to analyse the technical feasibility, environmental impacts, economic consequences, and social acceptability of three energy transition pathways. These pathways explore the roles of market, government, and civil society actors. The government- and market-led pathways emphasise either state control or private markets in leading the energy transition. Whilst these pathways incorporate tough challenges, they rely on leadership from largely familiar stakeholders in the UK energy sector.

The third pathway is different. This pathway, called 'Thousand Flowers', maps the potential for a much more active role for civil society, including individual householders and municipalities, in pursuing a largely distributed energy system. The analysis of this technological pathway shows new institutional structures would be required. In developing this pathway, the research consortium has raised many questions about the technological and institutional trajectories that such a pathway might follow. This report is designed to help increase the understanding of the Thousand Flowers transition pathway, by analysing and describing in detail the institutional, technical, and social landscapes that would be more compatible with what we term a civic energy future. It is through the lens of greater civic engagement in energy that we contribute to the policy, academic, and practitioner debates on managed decarbonisation, energy security, and affordability.

This report is not a forecast or a prediction; we do not attempt to preference a civil response to energy transition or claim technological infallibility. We understand that energy transition is fraught with complexity and contestation; and yet both can be unpicked and managed by careful analysis. We propose that this report moves us much closer to understanding what the technological and institutional elements of a more distributed energy future would look like, how quickly they would need to proliferate, and the governance issues they may bring.

Introduction

The EPSRC-funded Transition Pathways project and, more recently, the Realising Transition Pathways (RTP) project, have both demonstrated that multiple logics of governance, ownership, and control of the electricity system can be followed to achieve the transition to a secure, affordable, low-carbon energy system (Barton et al, 2013; Foxon, 2013; Hammond and Pearson, 2013). In particular, this work has argued that a low-carbon UK electricity system can be achieved through a number of different transition pathways (Foxon et al., 2010). Each pathway has a specific technological mix and one of three dominant logics of governance, ownership, and control:

Central Co-ordination

Central to this pathway is the role of the nation state in actively delivering the transition.

Market Rules

In the context of a broad policy framework, the state allows competition and private companies to deliver sustainable, affordable energy.

Thousand Flowers

This pathway is characterised by a greatly expanded role for civil society in delivering distributed low-carbon generation.

There is growing interest in the potential of distributed energy in the low-carbon transition from a number of different stakeholders – central and devolved governments, cities and regions, and communities. There are, however, still significant gaps in understanding the consequences of the transition from a centralised energy system to one where distributed generation dominates both from a technological and institutional perspective. This report aims to go some way in addressing this gap in understanding, in both technological and institutional terms, whilst simulating policy relevant debate.

Central to the achievement of the Thousand Flowers pathway, is the proliferation of local energy schemes (LES) delivered by a civic energy sector, which by 2050, has grown to supply 50% of final electricity demand. The remaining 50% of electricity demand is met by highly efficient gas plant with carbon capture and storage (CCS), offshore wind, nuclear, and hydro connected to the national transmission grid (Barton et al, 2013; Foxon et al, 2010). The large expansion of the civic energy sector is enabled by smart grid technologies, new business models, and institutional structures all of which transforms the way energy is financed, distributed, licensed, and supplied to consumers.

In order to better understand what this pathway would mean for the energy system, this report explores and describes technological and institutional changes more compatible with the Thousand Flowers pathway; this means an energy system with more civic ownership, distributed generation, and closer relationships between generators, distributors, and suppliers.

The report is an output of a series of interdisciplinary Engine Room workshops held between March 2013 and December 2014, as part of the RTP project. The workshops set out to examine the consequences of a transition from a centralised energy system to one where distributed generation, delivered by a civic energy sector, plays a much greater role (50% of final electricity demand). This is broadly defined as a 'civic' energy sector integrating new roles and ownership models for generating assets, distribution networks, and suppliers; with communities, municipalities, householders, businesses, and wider civil society. The Engine Room workshops comprised researchers from across the RTP consortium, including power systems engineers, social scientists, energy economists, and socio-technical transition scholars. Drawing on their collective research[1] the Engine Room interrogated the technological change described in the pathway and analysed the changes to physical and governance infrastructures these would likely require. This novel methodology proved extremely fruitful as an interdisciplinary exercise, and integrated a detailed technological pathway with social and governance analysis.

Where are we now?

The challenge for energy policy is to ensure the delivery of secure, affordable energy in a way compatible with scientifically informed global carbon budgets. The Climate Change Act (2008) commits the UK to reducing the net UK carbon account for the year 2050 to 80% below 1990 levels. This transition will require significant decarbonisation of the electricity sector. The direct emissions intensity of the sector in 2011 was 484gCO_2/kWh (DEFRA, 2013). Dependent on final demand projections, Ofgem (Office of Gas and Electricity Markets, 2009) assumes a goal to decarbonise the electricity sector by 2050. This is part of the 80% reduction target. As such, the carbon intensity of the generation sector should be in the region of 300g CO_2/kWh by 2020, and 75gCO_2/kWh by 2030 (Ofgem, 2009). Of the three pathways developed in the Transition Pathways project, the Thousand Flowers pathway was projected to have the lowest emissions, with 'whole systems' greenhouse gas (GHG) emissions of around 53gCO_2e/kWhe by 2050, and direct GHG emissions of 12gCO_2e/kWhe by 2050[2].

Technological view from today

Traditionally, electricity has been generated in the UK by large generators, transported to areas of high demand via the transmission network, and then transported to the consumer via the medium to low voltage distribution network. The electricity supply industry (ESI) today remains relatively unchanged, with 90% of electricity still generated by major power producers. The UK's ESI remains heavily reliant on carbon intensive primary fuels, particularly coal and natural gas. In 2012, renewable generation accounted for just 11.2% of total electricity generation. The UK's current generation mix at the end of 2012 was: 38.4% coal, 27.8% gas, 18.1% nuclear, with the remaining 4.5% coming from other fuels, including oil and pumped storage. The total CO_2 emissions from power stations implied by this generation mix was 158.1Mt CO_2e 2012[3].

According to National Grid, in 2011 there were 854 generators in Great Britain with a total capacity of 96,206MW (National Grid, 2011). Of these, 184 (87,242MW capacity) were dedicated to meeting Average Cold Spells (ACS) demand – generators that are required to meet peak electricity demand in winter.

Around 30 large (>1GW) power stations provide the majority of UK's electricity demand, reaching a peak demand of 57GW, and an annual demand of 376TWh in 2012. These consist largely of generators linked to the transmission network.

Institutional view from today

The UK energy market is currently divided into elements that constitute a potentially competitive market (generation and supply) and those which are regulated monopolies (transmission and distribution). Both competitive and regulated elements of the system are administered by Ofgem.

Post market liberalisation, electricity generation assets in the UK have typically been delivered by corporate utilities (BNEF, 2012; Toke et al, 2008; Breukers and Wolsink, 2007). In 2014, there were 32 companies classed as Major Power Producers, whose primary business is electricity generation, which accounted for 82.7% of total installed capacity (DUKES, 2014). Rutledge (2012) analyses the beneficial ownership of UK generation capacity and describes a 'Big Ten', which includes the 'Big Six' (British Gas, RWE NPower, SSE, Scottish Power, E.On, EDF Energy), alongside ESB, Drax, GDF Suez, and AES. In 2012 these ten companies collectively owned 85.8% of UK generation assets. The remaining 14.2% is made up of 64 medium sized private companies and corporate entities. The community energy sector owns only 0.3% of renewable capacity, approximately 60MW (DECC, 2014). Comparable figures for municipal generation assets are unavailable but are unlikely to exceed 1% (Hannon et al, 2013). The transmission system assets are owned by National Grid (NG) in England and Wales and SHET and SPET in Scotland, the GB system operator is NG, and the 14 original

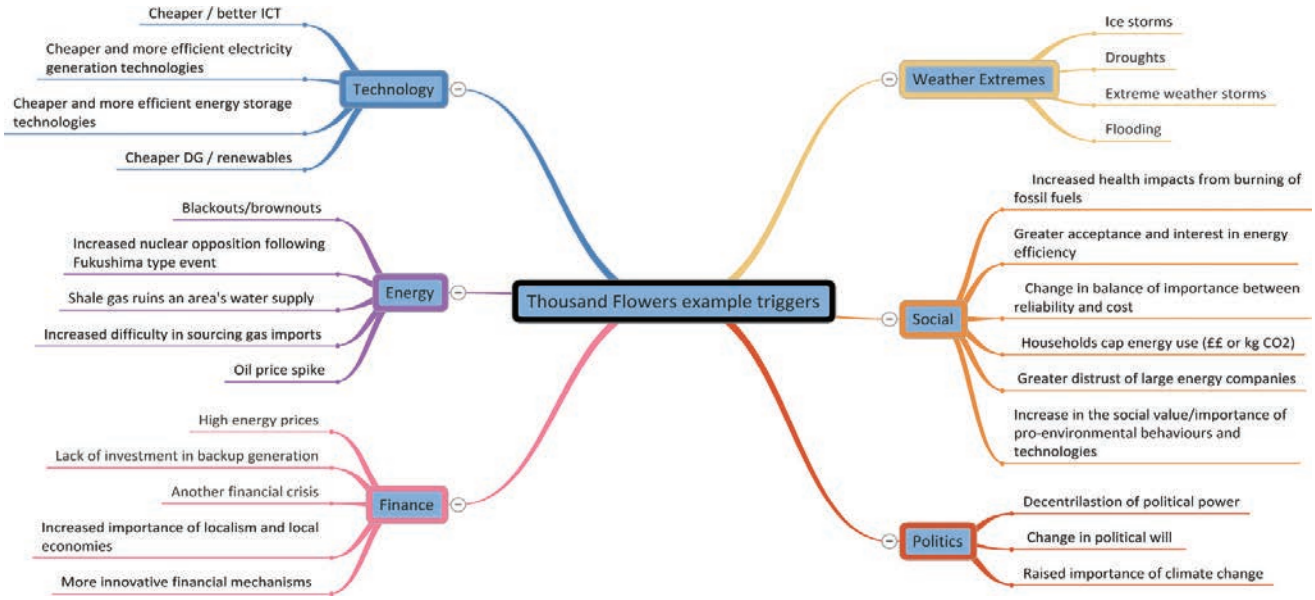
distribution board networks are now operated by seven private groups (Ofgem, 2014a) five of which are owned internationally (Cumbers, 2013; Pond, 2006).

The electricity supply market in the UK is dominated by the Big Six major suppliers who deliver around 95% of domestic supply and 80% of commercial supply (Ofgem, 2014b). At the end of 2013 there were 24 companies in total offering electricity and/or gas supply to households and 30 companies offering electricity and/or gas supply to commercial consumers (Buckley and Moss, 2014; Moss and Buckley, 2014). Whilst the market shares of the Big Six are falling overall, the domestic supply market can still be characterised as relatively uncompetitive and there have been concerns raised by the regulator as to the poor outcomes being realised by householders and SMEs (Moss and Buckley, 2014; Ofgem, 2014b).

Triggers for Thousand Flowers

Users interact with energy systems in diverse ways and at a number of different levels, with varying impact on the rest of their activities and daily lives. Therefore, system change to bring a transition pathway such as Thousand Flowers into reality, could be prompted by a number of co-evolving factors. Whilst the debate on why such change may come about is important, we have primarily focussed on how the TF pathway might be facilitated given our current energy system. It is out of the scope of this document to speculate in detail on the shocks, crises, turning points or slow transitions of attitudes which would lead to a Thousand Flowers future. Figure 1 below presents a number of possible trigger points. This is far from an exhaustive list, and it is unlikely that one trigger point would prompt such systemic change; instead a mix of triggers could co-evolve to lay the foundation for a shift to the Thousand Flowers scenario.

Figure 1 possible triggers for a Thousand Flowers future

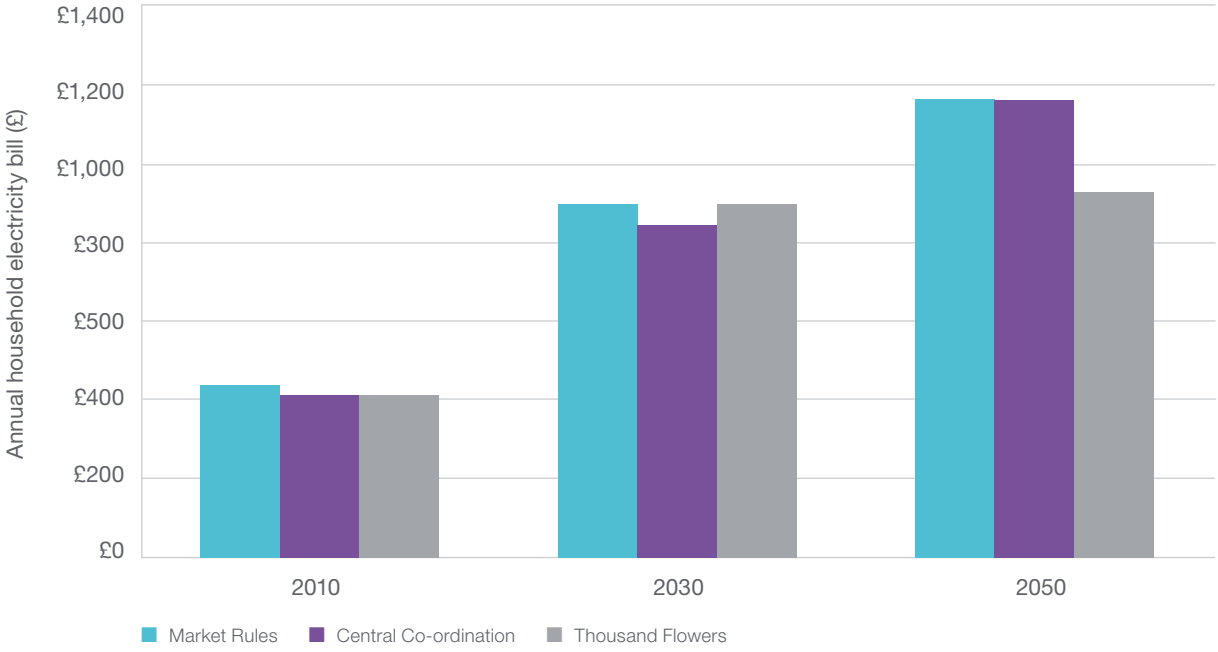


Consumer bills and costs

This report demonstrates the mix of technological and institutional change that one technological pathway would require. Here, we do not undertake comparative economic analyses of the impacts of each pathway on system costs or the impact on consumer bills. However, economic appraisal carried out by the Realising Transition Pathways consortium[4] has determined investment costs into the power sector for each narrative pathway, with and without the influence of a carbon price signal. Wholesale electricity costs under all three pathways peak in 2030 and then decrease, due to falling investment costs for low-carbon generation technologies and reduced use of fossil fuels, which are projected to become increasingly expensive. The results show that the Thousand Flowers pathway is estimated to result in substantially higher wholesale electricity prices than for the Market Rules or Central Coordination pathways.

However, research independent of the Realising Transition Pathways consortium (Cox, 2014) has calculated the costs of generation and network investment inferred by each pathway and extrapolated the impact of each onto average annual bills. The results (Figure 2) show the Thousand Flowers pathway as being marginally more expensive in the short to medium term but, due to strong demand reduction in this pathway, average bills in the medium to long term are significantly lower by 2050. This is compatible with the milestones for technological change identified in Part I.

Figure 2 Average annual household electricity bill (Cox, 2014)



View from 2050: The Thousand Flowers Pathway

The Thousand Flowers pathway is a scenario exercise ending in 2050[5]. In this section the end point of this pathway is described: i.e. it presents a 'view from 2050', in both technological and institutional terms.

Technological

In this pathway, by 2050, annual electricity demand has fallen from 337TWh in 2010 to 310TWh in 2050. Despite increasing levels of transport electrification, electricity demand falls due to high rates of energy efficiency improvements in the domestic and commercial sectors and a small, highly efficient industrial sector. Household annual electricity demand is reduced from 3.99 MWh/year in 2008 to 1.93MWh/year in 2050. In this pathway, a large proportion of domestic space heating and hot water demand is met by renewable (biogas) community-scale and micro-CHP (combined heat and power) systems rather than electric heating systems, helping to reduce electricity demand. In addition, the power generated by these local scale CHP systems replaces a significant proportion of centralised electricity supply.

Energy sector participation by civic society and local and regional energy service companies has led to a significant expansion of community and micro-scale renewable CHP installed from 2020 onwards, reaching a total of 37GW by 2030. The total capacity of the system is 149GW, with the majority of this being renewable generation (112GW). A significant proportion of demand is met by local scale low-carbon generation, reducing the need for centralised electricity supply. The largest single contribution to generation comes from renewable (biogas) community-scale and micro-CHP systems (44GW), followed by onshore wind (21GW), solar PV (16GW) and offshore wind (8GW). There is some investment in other low-carbon generation technologies in earlier periods, resulting in 22GW of coal and gas with CCS and 5GW of nuclear capacity by 2050.

Institutional

The institutional scenarios for this pathway have drawn on potential branching points in the energy system and international experience. In this pathway, continuing electricity price increases in the short term led to closer public scrutiny of profits gained within the electricity supply industry. With increasing international ownership of energy supply companies and generation assets, there was increasing public awareness of the value of energy to the national and local economy. This awareness led to a search for civic and more local alternatives to energy generation and supply. These drew inspiration from the anti-nuclear and environmental movements borne out of the 1973 energy crisis that were instrumental in the rapid expansion of the civic energy sectors of Germany, Denmark, and other European countries such as Austria and Sweden. Local energy ownership became a focus of local government economic development and sustainability policy between 2016 and 2017, as the scale of the opportunity became clear in terms of local value capture, net employment creation, and energy security.

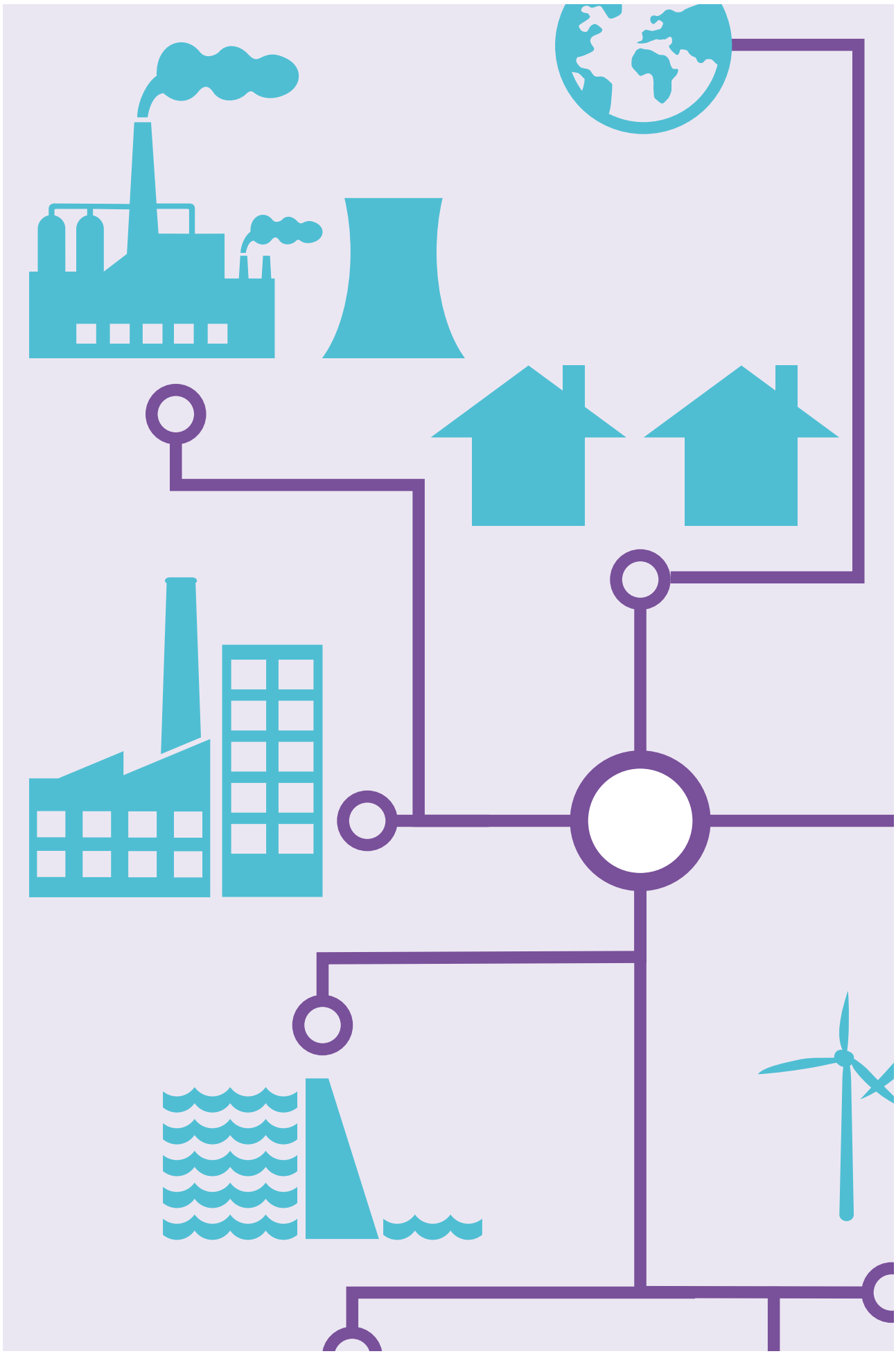
Local generation schemes in solar and wind became a feature of early mover English authorities, keen to replicate Scottish experience of co-operative ownership and local control.

By 2018–19, encouraged by the success of several major cities in setting up energy service companies, innovative partnerships between local communities and their local authorities were nurtured by Regional Energy Partnerships (REPs) delivered through Ofgem+. Local generators began to access new forms of finance and sold their electricity to new Municipally-Owned Energy Service Companies (MO-ESCos). These successful projects soon realised cash flows that, due to their non-profit business models, could be recycled into developing new smart grid solutions and generation schemes; including anaerobic digestion, community biomass CHP, and a rapid expansion of solar PV generation. Early mover utilities designed profitable third party contracts with other cities to enable wholesale system balancing to continue.

By 2022, Regional Energy Partnerships were making progress, with a regional energy strategy in place for each region, civil society actors were building a substantial capacity portfolio/expertise on local generation, and municipal supply ownership was growing. A local finance sector began to emerge as capital from early projects began to be recycled into further local generation assets. By 2030, civic generation projects held 22% of renewable generation assets and were beginning to repower early projects. Between 2030 and 2035 a sea change in energy supply had taken place as MO-ESCos were able to offer consistent energy services which delivered value locally. Increasing revenues were recycled into energy efficiency and renewable deployment until a stable landscape of power production emerged, which was characterised by co-operative, municipal, and citizen-owned generation assets. A mix of state and corporate-owned transmission level assets provided system balancing. Baseload was provided through a regulated asset base approach and peak plant was delivered through capacity auctions.

Local energy schemes developed stable and familiar financial relationships with the local banking sector, which viewed civic power generation as a safe asset. This was due to most renewables achieving grid parity after subsidy schemes were phased out in 2036. Marine technologies and tidal barrages still received subsidies due to their generation predictability and size across the UK.

Whilst the energy and socio-economic landscape of 2050 is dramatically different to that of 2014–15, the UK has met its emissions targets, energy remains affordable, and all regions have significant skills bases in energy management, finance, construction, maintenance, and supply.



Part I: Technological Transformation

Part I aims to describe the technical transformation that occurs within the UK's energy sector from the project's base year in 2008 to 2050 along the Thousand Flowers pathway. Part I is structured as follows: First, a brief systems overview describes the 'big picture' outlining the UK electricity system as a 'traditional' top down model and framing the technological challenge posed by the Thousand Flowers pathway.

This section continues with an overview of the transition of the generation mix, setting out key milestones. Following this short introduction we present our analysis of the substantial technical and infrastructural changes the pathway requires. This includes a whole systems overview, consideration of grid operation and development, and demand side changes as well as the role of storage and imports. A section on providing heat in domestic properties follows and Part I concludes with a short summary.

1. Introduction: The Big Picture

1.1 UK electricity system: 2008 base case

The Transition Pathways project began with 2008 as a base year from which to observe energy system change and run scenario development. Since the deregulation of the electricity supply industry in 1990, and its opening to full competition in 1999, generation companies compete in a liberalised market. Of the 407TWh of electricity supplied in the UK in 2008, over 95% (390TWh) was generated in the UK, of which 29 major power producers (MPPs) accounted for 91%. MPPs are 'companies whose primary purpose is the generation of electricity' (DUKES, 2014). The rest of the supply was produced by 'other generators'[6]. The majority of these generators are able to run continuously, and/or control produced load, ramping up during periods of peak demand and down during periods of low demand. Thus the power producers and associated infrastructures of electricity transmission/distribution have evolved to serve unidirectional, flexible power flows from relatively few, large power sources.

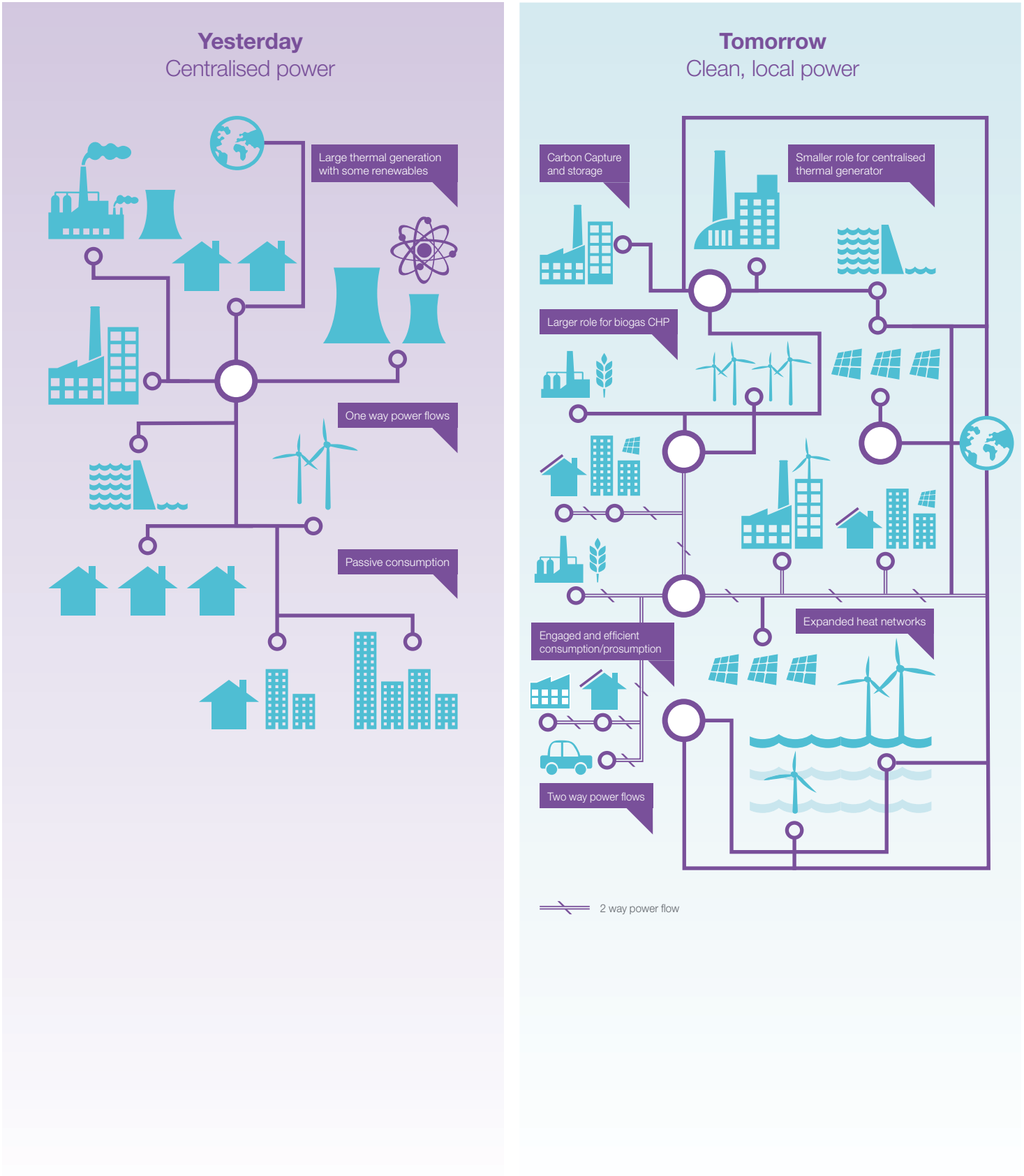
1.2 The challenge

In the Thousand Flowers pathway, the generation mix will evolve from a landscape dominated by large power generators providing predictable and mostly flexible electricity generation, to a scenario with a significantly greater proportion of highly variable and less flexible generation. This includes 50% from distributed generation, which will not only change the way in which electricity flows within the system but also change the roles of government, industry, and civil society. Further, for the Thousand Flowers pathway in 2050, 40% of electricity is produced from CHP, largely community CHP. CHP is a heat-led technology providing heat for hot water and space heating, meaning that it would not be as responsive as traditional thermal generation without sometimes discarding some of the heat generated. A new approach to balancing the grid will have to be taken, with more demand side participation (DSP) and smarter grid networks. Part II analyses the financial, regulatory, and governance impacts of this transformation; here, the changing mix of generation technologies and their effect on infrastructure networks and system reliability are discussed.

1.2.1 Generation transition timeline

The trajectory of change in generation technologies for the Thousand Flowers pathway is shown in Figure 3 (Barnacle et al, 2012)[7]. This shows the system undergoing the majority of the transformation between 2015 and 2035, when distributed generation grows from just over a quarter to almost half of total generation.

Figure 3: System of 2050 Thousand Flowers pathway.



From 2015 into 2020 there is a step change in generation mix for the Thousand Flowers pathway. The year 2020 has been identified as a crucial technological juncture at which point several niche technologies expand rapidly. This suggests that much planning and investment needs to be put in place in the near term if a future energy system of this nature is to be realised by 2050. An important message from this research is that these significant technological and infrastructural changes must be preceded by a compatible policy and regulatory framework, which retains the option of expanding distributed generation futures. This is closely linked to Headline Message 2: 'It is possible to meet 50 per cent of electricity demand using distributed generation by 2050, but new infrastructures and emerging technologies are still necessary'. The milestones between now and 2050 that would need to be met to maintain this pathway as a strategic option are highlighted in Table 1 below.

Table 1 Technological requirements and milestones for the Thousand Flowers pathway.

2014 – 2020	Substantial growth in investment and installations of local heat networks for use with community and large-scale CHP
2015 – 2035	Increased requirement for interconnectors – from three in 2015 to seven by 2035 (6.81GW)
By 2025	Coal phased out
By 2020	CCS technological and planning lead-in required Smart grid needs to be in place and operating Reinforcement of the north-south grid corridor to support offshore wind take Ensure adequate biomass gasification infrastructure and supply available to support increased biogas usage A change in operation of CHP must be either mandated by the grid operator or economically driven so it acts more as back up from 2020 onwards rather than being solely heat-led
2020 – 2025	Extensive demand side management comes on stream
2020 – 2050	Synthetic gas supply technologies are ongoing
2030	Large-scale gas and coal generation capacity is reduced as plant are mothballed
By 2030	Electric vehicle infrastructure (including public charging points) for an electrified transport sector required , at which time the last internal combustion engine buses are to be replaced
Until 2050	Gas plants to continue as a small contributor
Throughout 2020 – 2050	Construction of new grid infrastructure (especially to remote renewable generation) and renewal of ageing grid infrastructure Development and growth of new low-carbon generation technologies e.g. carbon capture and storage (CCS), wave generation, tidal stream generation, and fuel cells Training of a sufficient number and standard of qualified engineers and technical experts to facilitate and support system change

1.2.2 Technology archetypes

In order for the Thousand Flowers vision to be realised, technologies must evolve considerably out to 2050. Technology archetypes have been developed for each of the prevalent technologies that feature in the pathway (see Realising Transition Pathways (RTP) Working Paper 2014/2 forthcoming). RTP (2014/2) describes the proportion of demand each individual technology contributes in this pathway whilst addressing build rates, technological barriers, and grid connection issues. A summary of that analysis is presented in Table 2.

Table 2 Thousand Flowers pathway technology archetypes: Demand contribution, main drivers, build rates, issues, and barriers.

	Importance to pathway	Main drivers	Build rates	Issues and barriers
Combined heat and power (CHP)	Supplies 41% of total electricity demand (134.6TWh/year) Responsible for heating 60% of homes by 2050	Community scale Less area is needed for heating infrastructure in houses Reduced maintenance inconvenience in homes Security of supply issues Greater dependence on the gas grid Serves islanded heat networks but, by default, are still connected to the electrical grid Offers voltage and frequency control and regulation capability to the grid	The average net build rate of CHPs will be almost 3GWe per year between 2015 and 2020, declining thereafter with a rapid scale-up of installation required Could represent approximately 10,000 new schemes being installed. Compared to around 400,000 solar PV installations per year in 2012, the build rate of CHP is therefore challenging but not impossible.	Significant highway works for installation of community-scale CHPs with district heating Responsibility for CHP plant or deliveries of biomass under shared ownership needs consideration and legal basis Setting up community companies with individual households owning shares in the scheme requires more administration Competition with efficient combi-boilers
Biomass generation	Smallest contributor, providing 0.7% of total electricity demand in 2050 Very important dispatchable generator to help support intermittent generation	Sustainable energy source if fuel is locally sourced and replenished Dispatchable generator to help support intermittent generation and grid integrity	Biomass generation capacity falls from 1.89GW in 2008 to 1.5GW in 2050, reaching a peak of 1.96GW in 2015 and reducing to 1.5GW by 2045	More expertise in the UK is required for this technology Meeting sustainability criteria requires maintaining carbon neutrality over its lifecycle Security of supply guarantees may be problematic Transport costs of lower density fuel and associated emissions
Photovoltaics	16.2GW of solar PV generation capacity by 2050 producing 15.8TWh annually (4.8% of total electricity demand; 60% domestic, 30% industrial/ commercial, 10% ground-mounted farms)	Southern England receives similar total solar irradiation (1200kWh/m2/year) to that in Germany where solar PV use is much greater The supply chain and expertise for installation is already well established following the boom years of 2011 and 2012	2011 UK installation rate: 925MW/year 2012 Germany installation rate: 7600MW/year Thousand Flowers installation rate 2035–2050: 541MW/year Build rate is therefore feasible and future pathway versions will be able to revise rate upwards	High capital cost of purchase and installation Degradation of panel performance, component failure Roof repairs obstructed by solar PV panels Planning regulations do not encourage layout and design of housing to enable solar PV The electricity distribution grid needs to be compatible with two-way power flows Efficiency of panels are nearing the theoretical maximum for the current technology
Micro-hydro	Relatively modest role Increases from 1.2GW in 2010 to 1.7GW by 2020 and remains at that level	A mature technology Early movers of the micro-generation uptake Expertise already existing from sites in operation	Low build rates: 50MW/year between 2010 and 2020, no development thereafter	Limited availability of cost-effective sites Environmental concerns about hydro development (e.g. impact on fish) Expensive connection due to generally larger distance from the grid
Wind	In 2050, there is 20.5GW of onshore (52.6TWh) and 8.41GW of offshore (31.5TWh), corresponding to 25.6% of all generation Wind generation is greatest in winter, when energy demand is highest	The most mature renewable generation technology Large and growing prospect for employment in the UK Wind turbines leave land below them free for agriculture, biodiversity and recreation The potential wind resource is very large (offshore alone up to three times UK electricity demand)	Onshore wind has a maximum build rate of 800MW per year in 2015 falling to less than 350MW per year. Total installed onshore wind capacity is 20.5GW by 2050. Offshore wind has a maximum build rate of 680MW per year in 2020 falling to 93MW per year before rising again. Total installed offshore wind capacity is 8.41GW by 2050.	Variability of power output High cost of offshore wind power – installation, reliability, maintenance, grid connection Availability of offshore installation vessels Most manufacturing currently outside the UK Onshore sites are limited by: visual intrusion, shadow flicker, noise, hazard to birds and bats, turbulence, and low wind speeds caused by buildings, trees, or hills Offshore sites are constrained by: fishing, navigation, other maritime activities and seabed conditions

	Importance to pathway	Main drivers	Build rates	Issues and barriers
Tidal	Tidal power provides 5.72% of total electricity in 2050 Tidal power is variable, but predictable, renewable energy	The UK is a world leader in tidal stream technology Opportunity for UK employment	Tidal power has a maximum build rate of 566MW per year between 2020 and 2035. Total installed tidal power is 8.9GW by 2035, when new build stops	Relatively new technology with many designs Limited areas with high tidal range (tidal barrage) or high speed (tidal stream) Grid connection cost Availability of installation vessels No standardisation of tidal sites Unquantified impacts on fish, marine mammals, wading birds, and sediment flows
Wave	Provides 1.6% of total electricity in 2050 Generates more electricity in winter than in summer Less variable and more predictable than wind power	The UK is a world leader in wave power technology Opportunity for UK employment including export	Wave power has a maximum build rate of 127MW per year between 2015 and 2020. Total installed tidal power is 2.12GW by 2035 when new build stops	Immature technology Difficult grid connection off the west coast where wave resource is best Availability of installation vessels Reliability and maintenance costs Impact on navigation and fishing Unknown environmental impacts
Vehicles	EVs and PHEVs act as distributed storage to offer essential balancing to support integration of intermittent renewable energy sources (RES) Use 65TWh of electricity in 2050, covering 80% of total distance travelled	Opportunity to support RES integration through smart charging Participation in smart grid control Decarbonisation of road transport and reduction of local pollution and noise in urban/ suburban areas	Adoption rate of PHEVs increases to 1.5-2 million per year in 2020–2030; declines afterwards to zero beyond 2040 as EV technology matures New EV additions increase steadily from 0.8m/year in 2030 to 1.5m in 2040 and 2.7m in 2050	Customer perception: range anxiety, purchase cost, long charging times Availability of charging infrastructure High cost of upgrading electricity system infrastructure if no smart charging takes place Fiscal cost of supporting EV rollout Lack of clarity on potential second life applications for EV batteries
Heat pumps and air conditioning	By 2050, ground source heat pumps supply 28.6TWh space heating and 9.4TWh hot water heating This corresponds to meeting 30.9% of space heating demand and 10.9% of hot water demand in domestic properties	Ground source heat pumps are a proven technology Manufacturing expertise is already present in the UK	By 2050 just over 10 million of the UK's 35 million homes will have ground source heat pumps installed 6.7 million installed in existing buildings and 3.4 million in new builds	Better suited to under-floor heating than radiators because of lower temperatures The carbon intensity of grid electricity has a significant impact on the sustainability of heat pumps Performance is wide-ranging and does not always achieve an adequate level Households need to learn use the heat pump controls effectively for optimum performance UK heating engineers need to further develop skills/knowledge of installation and maintenance Ground source: best combined with building work or new developments rather than retrofit
Solar thermal	6% of total domestic hot water demands is met by solar thermal by 2050	Good generation potential across the UK as long as optimum positioning is employed	The 58TWh of solar heat in 2050 represents almost 30 million solar systems, each of 2kWth The build rates are around 0.5 million systems per year from 2010 to 2020 rising to almost 1 million per year by 2050	Domestic solar thermal installation can only provide about half of the hot water needed Less suitable in densely populated locations due to shading and small roof area per dwelling Behaviour determines if full potential savings are achieved therefore education of householders and installers is crucial
Waste heat	6.5% of UK households heating needs met by waste heat via district heating by 2050	Increasing industry efficiency reduces industry energy cost to help industry sector to remain competitive	First introduced in 2020, meeting a demand of 46.22TWh of heat This grows to a peak of 104.22TWh of heat by 2040	UK not set up for this technology Large infrastructure needed for district heating Lack of capital Heat network and market required for trading

The magnitude of the challenge that this transition sets is large, compounded by the need to provide affordable electricity and address environmental concerns while maintaining a reliable electricity supply.

Failure to meet this challenge, and lack of adequate planning, may lead to higher electricity costs, reduced economic competitiveness, and result in the UK missing its climate change targets.

1.3 UK Electricity System in Thousand Flowers 2050

The UK electricity system in the Thousand Flowers pathway represents a dramatic change from the present day system. Traditional large-scale generation makes up only a fifth of total generation in the Thousand Flowers pathway by 2050 (Table 3) but, due to high levels of intermittent renewable generation alongside CHP, transmission level assets must carry out important balancing duties[8]. This dispatchable generation is complemented by increased imports, modest levels of storage, and more engaged and responsive consumers to ensure a reliable delivery of electricity. When demand side participation (DSP) is implemented to shift power usage by a few hours, the peak demand and surpluses can be reduced from 38GW and 44GW to 27GW and 28GW respectively in the year 2050 (Barnacle et al, 2012).

Table 3 2050 Generation in the Thousand Flowers pathway (also see Barnacle et al, 2012).

Generation Type	Capacity (GW)	Percentage of total capacity	Generation (TWh)	Percentage of total generation	
Traditional large-scale generation					
Coal CCS	7.50	5.05	11.86	3.62	
Gas CCGT with CCS	14.20	9.56	12.78	3.90	
Nuclear	5.40	3.64	19.69	6.00	
Hydro	1.70	1.14	5.57	1.70	
Biomass	1.50	1.01	2.37	0.72	
Pumped Storage	2.78	1.87	2.54	0.78	
Imports	6.81	4.59	14.63	4.46	**21.17**
Renewable generation					
Wind (onshore)	20.50	13.80	52.56	16.03	
Wind (offshore)	8.41	5.66	31.54	9.62	
Wave	2.12	1.43	5.26	1.60	
Tidal	8.88	5.98	18.75	5.72	
Solar	16.24	10.93	15.77	4.81	
CHP – renewable fuels	52.49	35.34	134.63	41.05	**78.83**

Overall demand in the pathway is greatly reduced by 2050. Table 4 compares total electricity demand in 2010 and 2050 in all the sectors. Table 5 presents energy savings achieved by a range of demand reduction measures and practices in 2010 compared with savings achieved in the year 2050.

Table 4 Electricity demand (TWh) in the Thousand Flowers pathway (Barnacle et al, 2012).

Electricity demand (TWh)	2010	2050
Total electricity demand from all sectors	337	310
Commercial and Agriculture	104.5	70.9
Transport	8.3	52.7
Industrial	115.3	108.9
Domestic	99.5	68.9

Table 5 Comparing energy demand savings in the years 2010 and 2050 due to demand reduction measures and practices (domestic sector (Barnacle et al, 2012)

Demand reduction measures and practices	2010 (TWh)	2050 (TWh)
Improved energy efficiency in domestic appliances	2.8	35.0
Change in consumer behaviour	0.0	27.0
Uptake of conservation measures in existing buildings	30.0	132.0
New build efficiency improvements	0.0	68.0

The significant reduction in domestic demand in Tables 4 and 5 indicates that consumers in the Thousand Flowers pathway are engaged with demand management and efficiency. They achieve this through the use of energy efficient appliances, adoption of good energy management practices, and the uptake of conservation measures in existing houses as well as the improvement of new building fabric. For instance, an uptake rate of 95% is seen for wall insulation by the year 2050, 75% for floor insulation and 99% for loft insulation. Additionally, all suitable houses are fitted with double glazing by 2050. This high level of uptake in conservation measures is between level 3 and 4 of the Department of Energy & Climate Change (DECC) pathways, which implies that these uptake levels are close to the maximum level that is technically possible (DECC, 2010). Also by 2050 new build houses have reduced average space heating demand by 72%. This is feasible because it is close to that already achieved by passive houses in the UK which achieve a 90% reduction in demand (Feist, 2007). These demand reduction measures and practices help to reduce total electricity demand from 337TWh in 2010 to 310TWh in 2050, despite the increased electrification of transport as shown in Table 4 and electric heating demand (Hong et al, 2012). These levels of demand reduction and adoption of energy efficiency measures are dependent on increasing consumer engagement with a hitherto distant energy system. Part II describes an institutional framework more compatible with fostering close consumer engagement.

Furthermore, communities, industrial, and domestic consumers are seen to take a more proactive role in providing energy: the frameworks for which are also analysed in Part II. However, the Thousand Flowers pathway was not seen to completely decarbonise the projected emissions for the electricity sector, with whole systems GHG emissions of around 53gCO2e/kWhe by 2050 and direct GHG emissions of 12 gCO2e/kWhe by 2050 (Hammond, 2014).

Within Thousand Flowers the UK transmission network will function similarly to today, albeit with a reduced total supply. In contrast to today, the distribution network becomes a far more complex system, managing higher demand and supply by means of two-way power flows. This change in system dynamics means distribution network operators must adapt as the electricity system evolves.

1.4 The Grid

1.4.1 'Traditional' operation

Up to the present day, electricity in the UK has been generated mainly by large generators and transported to areas of high demand across the high voltage transmission network to distribution companies and large industrial consumers. The distribution companies – distribution network operators (DNOs) – then transport the electricity through the medium voltage distribution network to industrial consumers, and finally down the low voltage network to household and commercial consumers. The current grid infrastructure, which was largely built by the 1950/60s, was designed to function for this step down one-way power flow. The inherent characteristics of the system (i.e. the large sunk costs and long-term stakeholder investments) makes it difficult to move away from this paradigm.

Technical issues arise because today's distribution grid was designed for one-way power flow from large centralised generators through high-voltage transmission lines and transformers to the low voltage distribution system and on to individual consumers. The following sections describe some aspects of how the system works today, why DG presents a challenge, and describes some solutions to those challenges. First, grid structure is discussed in section 1.4.2 followed by the issues of balancing and ancillary services offered by generators in section 1.4.3 before going on to examine grid structure, a smart grid, and DSP in the context of alleviating the stress on the grids in Thousand Flowers. Two-way power flow presents some particular challenges to fault protection, but solutions are feasible as described in section 1.4.4.

1.4.2 The Grid in 2050

The Thousand Flowers pathway has a heavily reduced net demand by 2050, but high proliferation of renewable generation creates times of large electricity surplus from uncontrolled and inflexible generation and other times of low output from uncontrolled sources. This means that balancing is the largest transmission level challenge in the pathway (Barnacle et al, 2012, Barton et al, 2013).

The large-scale electrification of transport and heat demand alongside the rapid introduction of distributed generation (DG) (in particular micro-CHP schemes, small-scale wind and solar PV) both lead to the need for extensive reinforcement of distribution grid infrastructure paid for and regulated by the DNO but ultimately paid for in electricity bills. The clustering of DG technologies (i.e. in pro-active streets or communities) may cause localised overloading of grid infrastructure not designed to cope with such installations (Pudjianto et al, 2013). Consequently, in areas of high penetration of DG there will need to be renewal of, or additions to, overhead and underground lines and substations, with new operation management strategies in place. Administrative issues relating to planning consent and issues with regulation of smart grid expenditures drive a need for a more supportive institutional framework to help to reduce barriers to DG – one such proposed framework is discussed in Part II: Institutional Transformation.

The landscape within which distribution networks sit is changing. Smart meters are to be rolled out by 2020 and 'active network management' and 'customer engagement' (Xenias et al, 2014) will become more prevalent post-2020. This means that system design and operational management methods will also have to change to ensure that substantial barriers to the introduction of high levels of DG are overcome.

The vision for a smarter distribution network within the Thousand Flowers pathway is set out in Part I, section 1.4.6 and Part II, section 2.7. The distribution network will therefore become an active network with two-way power flows and voltages determined by the generation as well as the loads. This is because the majority of small-scale DG is likely to be connected though power electronics which can be used cost effectively to regulate distribution system voltage.

1.4.3 Grid balancing and ancillary services

Today's electricity system is dominated by large rotating machinery (e.g. generators with steam turbines and loads with electric motors) and by a transmission system that is more inductive than resistive. This results in a system governed by the frequency of the alternating current (AC). Centralised generators are linked to the grid frequency and respond to changes in demand. The rotating generators have inertia that helps to keep the system stable. When a generator trips out, a circuit breaker opens, or demand changes, today's system has several seconds to respond and usually does so automatically. In contrast, a system with a high penetration of renewable generators and distributed generation (DG) must either achieve grid balancing using the generators it has or use demand side participation (DSP).

Sometimes the adjustment of DG and DSP will not be enough and other grid balancing measures will be required such as energy storage; or when the grid balancing problem is localised, it can be alleviated by increasing the capacity of connections to other regions, to the transmission grid or by connection to other countries (i.e headline message 3). The control of all the various forms of DG, DSP, and other measures requires active network management, using information and communication technologies (ICT), a combination of which is usually referred to as the smart grid. The smart grid is particularly important to the Thousand Flowers pathway due to the high levels of DG, low-carbon technologies, and DSP (Barton et al, 2013).

Other services currently provided by large generators include being on part-load or standby and ready to increase output, known as short term operating reserve (STOR), voltage control and reactive power, frequency response, and the ability to restart the grid from a complete shutdown, known as black start. In order to achieve a reliable electricity supply at least cost and least inconvenience to all users, all these services must be incentivised and rewarded in the trading arrangements since they result in time-shifting or curtailment of some forms of demand or generation. The electricity market today includes hundreds of trading companies but in the future could include thousands of companies, ESCos, co-operatives, and individuals, increasing system complexity. More information on these entities is provided in Part II.

Short-term excursions of supply and demand lasting for seconds, minutes and up to several hours, including applications of STOR, are expected to be manageable using DSP measures, whose potential resources are quite large (Binding et al, 2010; Hong et al, 2012; Aunedi et al, 2013). On longer timescales the Thousand Flowers pathway has been validated using the FESA hourly time-step model of electricity supply and demand (Barnacle et al, 2012; Barton et al, 2013; Trutnevyte et al, 2014).

The system will remain as robust as today's but with some differences. System design will move from a focus on generating capacity margin (i.e. for asset redundancy) to using a combination of flexible DG, demand side participation (DSP), and energy storage alongside advanced network technologies to minimise the overall cost of operation and bring value to consumers. Essential loads will be served as and when they arise and so will continue to be met reliably, whilst the flexibility of deferrable loads will be exploited to ensure overall system balancing. The overall service provided by these deferrable loads will

however be maintained. For example battery electric vehicles will be charged in time for use; space heating and hot water will be available when needed, even if their electricity demand has to be time-shifted. The electricity system will be even more highly interconnected than today in the distribution network, the transmission network and in international interconnectors as described in section 1.4.5.

1.4.4 Fault protection

Protection is required for the safe operation of today's power system and will also be true for future power systems (including smart grids). As the power system will develop, departing from its traditional architecture, protection will still be an area requiring significant engineering input and expertise for the realisation of the Thousand Flowers pathway.

In today's system, circuit breakers and fuses protect against excessive currents and short circuits by disconnecting a part of the distribution network which has a fault from the healthy parts, thereby interrupting the supply to some consumers, but leaving the majority unaffected. When designing and configuring these fuses and circuit breakers, engineers have assumed historically that power will only flow into the local distribution network from higher voltages. Problems may occur therefore when DG feeds power into the local distribution network from smaller-scale generators and home mounted systems such as solar; these homes are known as 'prosumers' as they produce as well as consume electricity. Distribution lines can locally exceed their thermal limits without the fault being detected as either excessive current or low voltage level. Even when the local distribution line is disconnected from the rest of the system, DG can cause the distribution system to operate locally on its own (islanding). There is a danger that maintenance personnel working on the system may expect a line to be dead when it is not due to local islanding. This will require new working practices and training. There is also the danger that an islanded region will not be synchronised with the rest of the grid (operating at a different frequency and out of phase) when it is reconnected, causing damagingly high currents to flow.

As well as considering protection in the distribution network, it is also important to consider protection of the DG itself. DG must be able to detect faults beyond itself within the network and disconnect when necessary, while also being able to ride through minor or transient disturbances without causing a cascade of disconnections known as block tripping.

When the penetration of DG is high there is a relatively small amount of conventional dispatchable generation on the system, if any. The DG and its protection equipment, together with DSP therefore have to perform roles traditionally undertaken by flexible generators: voltage control, balancing supply with demand, and frequency control. This requires that DG detects high or rising frequency, or high and rising voltage, and curtails its output in a moderate, controlled way so that tripping or wider disturbances do not occur. This system is already specified for some installations in Germany (SMA, 2012), (EEG, 2014) and (Troester, 2009). This capability will make it more likely that islanding will occur (see above).

Islanding may or may not be desirable, and can be prevented (Noor et al, 2005; Jia et al, 2014). On the other hand, research has been done indicating that safe islanding is possible and can increase the reliability of electricity supply without the need for grid reinforcement (Lasseter, 2011; Lidula and Rajapaksi, 2011; Tumilty et al, 2006). Additionally, if DG were required to shut down automatically to prevent islanding, then it could not easily provide the ancillary services needed to stabilise the grid (De Brabandere et al, 2007; Balaguer et al, 2011). More research and careful system design are required to establish when and whether regions of the grid are allowed to intentionally island, and if so, how large or small those regions might be, from individual houses up to DNO/DSO regions. However, one thing is clear: in all aspects of protection within a system with such high DG penetration more sophisticated fault protection is needed.

1.4.5 Grid structure

The overall structure of the grid with today's variety of voltage levels and long transmission lines looks set to continue and expand as Thousand Flowers includes significant amounts of centralised generation and large-scale renewables (such as offshore wind). The roles and form of the grid are therefore not expected to change significantly; the technical features (e.g. reliance on AC) would remain but with some caveats. There will need to be an expansion and reinforcement of distribution grids to cope with the large quantities of DG and there may be a need for some DC cables to bring their significant benefits to offshore wind farms and to international interconnections. The Thousand Flowers pathway is reliant on greater interconnection at all levels (local, regional, national, and international) to ensure that system balancing can occur and to offer the best possible method to use all the low-carbon electricity being generated.

1.4.6 Smarter grids

The smart grid refers broadly to increasing penetrations of information and communication technology (ICT) at the level of the distribution network. This would mean that low-carbon technologies (such as micro-CHP, electric vehicles, smart appliances, and solar PV) installed by domestic consumers would all be connected via ICT networks. This would enable services that benefit the consumer in terms of comfort, convenience and cost, as well as benefitting the system in terms of network support, system balancing, and efficient markets (Clastres, 2011; Giordano et al, 2012).

As noted, the smart grid is particularly important to the Thousand Flowers pathway due to the high levels of DG, low-carbon technologies, and demand side participation (DSP) (Pudjianto et al., 2013). DSP is enabled through ICT, primarily through smart meters and in home displays, but links increasingly with people's preferred devices such as smart phones, televisions, and computers. This is facilitated by software innovation and low barriers to entry for new concepts and services. The introduction of a smart grid is enabled in part by the intended roll-out of smart meters to all homes by 2019, facilitating the provision of innovative energy services offered by new entrants to the energy service industry e.g. MOESCos, which is discussed further in Part II.

1.5 Demand Side Participation

Demand side participation (DSP), demand reduction, and demand response (i.e. the time-shifting of demand) are strong system determinants in the Thousand Flowers pathway. Technology installation has already been initiated with the introduction of home energy displays and smart meters (DECC, 2013). DSP is considered beneficial in two ways: first, from a system balancing perspective, there is considerable value in consumers being flexible about the times they consume electricity (Barnacle et al, 2012; Barton et al, 2013; Aunedi and Strbac, 2013). This allows a reduction in demand during periods when supply from renewables is low and an increase during periods when supply is less constrained. Second, the high penetration of low-carbon technologies such as micro-generation, heat pumps, micro-CHP, and electric vehicles places considerable strain on local distribution networks. This increasingly means that consumers with such technologies are encouraged to be flexible, to mitigate network impacts or risk paying high costs associated with network reinforcement (Pudjianto et al, 2013; Mu et al, 2014).

In this pathway price incentives are the main signals used to encourage demand response and consumers increasingly accept time variable prices as the norm, viewing the electricity supply infrastructure more like they do the public transport infrastructure today. While avoiding high 'peak' prices is an important factor in encouraging people to respond, in the Thousand Flowers pathway taking advantage of cheap prices associated with excess renewables, e.g. to avoid curtailment, is the main driver. When electricity prices do fall, the provision of low cost and perhaps occasionally 'free' electricity becomes a major influence on consumption patterns. Lower energy bills (in the longer term) would increase public support for renewables. Pricing signals would have to work with smart grids, smart meters, and smart devices to stimulate demand response actions, allowing for the process to be automatic, controlled, and stabilised. This avoids a self-defeating cycle of excess generation causing low prices, which prompt increased usage and a potential generation deficit. The MO-ESCo supplier's role (Part II) is key to facilitating these price incentives.

In this pathway, building on the success of the feed-in tariff (FiT) and its effect on encouraging those with solar PV to change the timing of their consumption to align with their output (McKenna and Thomson, 2014), electrical appliances are introduced with a requirement for flexibility (DSP) 'as standard', which acts as a major driver for the uptake of new flexible demand response practices in people's lives. Making compulsory the installation of DSP devices when investing in DG may make DG an expensive option. Instead, in the short- to medium-term, the savings on energy costs through use of DSP devices would incentivise uptake alongside DG, while regulation would ensure uptake in the long-term.

1.6 Storage

It is well documented that increased storage in a system allows for intermittent generation technologies (such as large-scale wind, wave, and solar PV to have higher penetration due to its ability to help 'even out' peaks and troughs in generation, by storing excess when supply is high and releasing power when supply is low (e.g. Giulietti et al, 2013). Similarly, storage can also be used on a much smaller scale in households for both electricity and heat, helping to 'even out' demand curves. Although the role of storage within Thousand Flowers in terms of national generation figures is small, its availability to help with grid balancing is essential to help support the high penetration of intermittent renewables. It should be noted, however, that whether storage is classed as a low-carbon solution depends upon the energy mix used to replenish the store. It is beneficial if it is recharged using renewables that would otherwise be curtailed.

Currently, storage in the UK system is largely pumped hydro with 2.78GW of generation capacity, serving a minor but crucial role in system balancing due to its rapid response capability.

Within the Thousand Flowers pathway, by 2050, storage supply capacity remains the same, releasing a total of 2.54TWh through the year. As the installation of batteries for domestic energy storage is not currently appropriate either economically or environmentally for properties that already have a grid connection, this is not part of the Thousand Flowers pathway. Whilst there is a potential to use electric vehicles (EVs) as a form of energy storage, it is highly dependent on the availability of the EV battery and the flexibility of the owner's willingness to allow sporadic charging and discharging. They could, however, become a vital source of electricity storage for the UK system (Aunedi and Strbac, 2013).

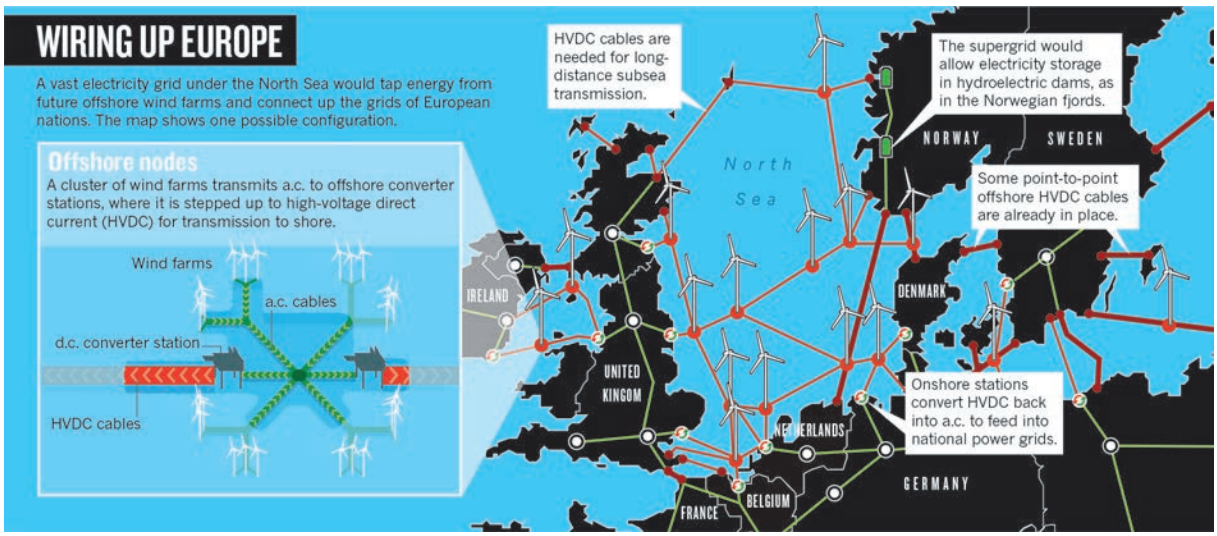
Thermal storage, used with solar thermal panels, heat pumps, or electric immersion heaters to contribute to space heating, needs to overcome size barriers to become prevalent, particularly when retrofitting domestic properties. There is a demanding requirement for enough space to accommodate a large, well insulated tank, between 500 and 5,000 litres, depending upon household size and storage duration. This compares to a typical hot water cylinder size of just 150 litres. Moreover, these sizeable water tanks were widely replaced after the introduction of the more compact combi boiler.

1.7 Imports

Net imports were 14.4 TWh in 2013, a 22% increase on 2012. The current interconnector capacity is 4.0GW (DUKES, 2014). The Thousand Flowers pathway sees a considerable growth of interconnectors with mainland Europe, Norway and Ireland. Interconnectors expand, from three in 2015 totalling 4.6GW capacity, to 7 by 2035 totalling 6.81GW. While the installed capacity of interconnections increases, and they are often fully utilised to cope with excess supply or shortfall of electricity, the capacity factor of these assets decreases over time as measured by net imported electricity: 62% in 2015 down to 25% in 2050. International government and financial support is therefore required in order for these assets to be developed and maintained, so that they can act as backup to the intermittency inherent in a system with increased renewables.

Interconnection is used alongside storage to increase the flexibility of the grid, assisting in system balancing requirements and counteracting wind power variability. Interconnectors also enable greater UK participation in the European 'supergrid' and support the move towards an integrated European electricity market (Figure 4). Due to the very high penetration of wind power in Ireland, interconnections between the UK and Ireland are particularly important as they can be used to export excess wind power to the UK rather than resorting to curtailment.

Figure 4 A European supergrid (Nature, 2010).



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Source: http://www.nature.com/news/2010/101201/pdf/468624a.pdf)

1.8 Heating Homes

1.8.1 Technological overview

Figure 5 and Table 6 describe the mix of technologies for heating domestic properties in Thousand Flowers. Domestic heating in 2050 is dominated by CHP technologies with 54.1% of homes heated by CHP through a mixture of Stirling engines, fuel cells, and community-scale biogas and biomass-fuelled generation. Despite having higher emissions than (woody) biomass, biogas is a good bridge from natural gas with lower emissions. As could be expected in a bottom-up, society-driven system with local communities coming together to think more about and participate in the energy system, community-scale/district heating generation is highly prevalent, delivering heat to more than one third of all domestic properties. Alongside CHP and community-scale schemes, there is an increased prevalence of non-traditional heating technologies with ground source heat pumps heating a quarter of homes. The demand for cooling of homes in the UK would be significantly lower than for heating, however cooling of homes was outside the scope of this current analysis and has not been examined here.

Figure 5 Heating technologies in existing and new houses (2050).

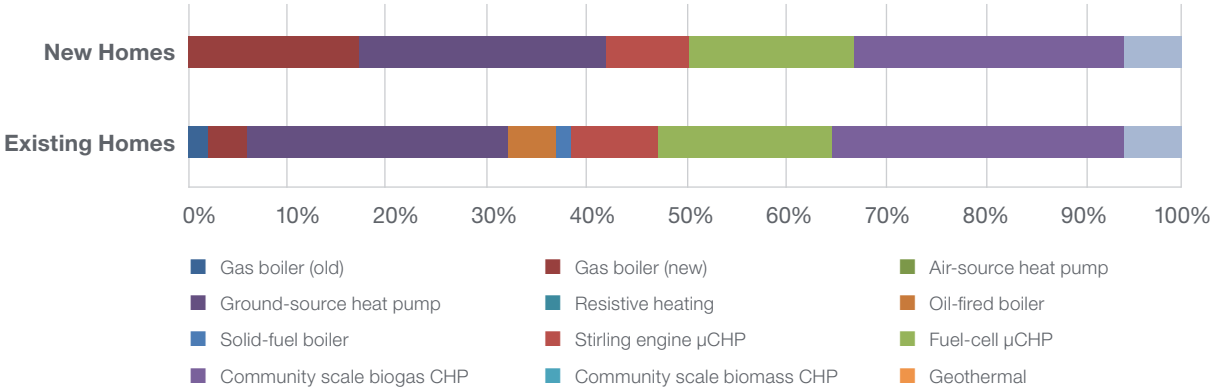


Table 6 Percentages of different heating technologies in existing and new build homes (2050).

Technology	Existing homes (current building stock) (%)	New build homes (%)	All homes (%)
Community-scale biogas CHP	29.0	27.2	28.4
Ground source heat pump	26.3	24.7	25.8
Fuel-cell micro-CHP	17.6	16.5	17.2
Gas boiler (new)	3.9	17.5	8.7
Stirling engine micro-CHP	8.8	8.2	8.6
District heating from power stations	6.1	5.8	6.0
Oil-fired boiler	4.7	0.0	3.0
Gas boiler (old)	2.3	0.0	1.5
Solid-fuel boiler	1.3	0.0	0.9
Air source heat pump	0.0	0.0	0.0
All CHP	55.3	52.0	54.1
Community-scale	35.1	33.0	34.4

By 2050, in the Thousand Flowers scenario, more than two thirds of homes will be existing homes standing today (of the 35.6 million homes, 24.33 million will be existing homes with 11.3 million new homes). Within new build properties, non-traditional heating technologies can be integrated at the design stage (examples of such property designs can be seen in community-scale projects). The following characterises the six most prevalent heating systems for domestic properties in 2050.

1.8.2 Suburban community-scale CHP delivered through district heating

The expectation with community heating schemes is that the heating system within a domestic property will be indistinguishable from today's standard in terms of day-to-day use, e.g. controls for the household temperature. However, behind the scenes this system would differ greatly and require a radical transition for the UK, where district heating is rare. If a property is in a district heating area, then the only available heating and hot water supply will be from a district scheme and there will be no market of providers (a situation similar to current water provision).

Substantial changes to physical infrastructures, socioeconomic, and institutional aspects of the heating and gas systems are essential if a district heating system is to come on line. Implementing a system would require the installation of hot water pipes under streets and the installation of heat exchangers within properties. Additionally, a move away from current ownership and regulatory structures for heat and gas would be necessary to displace the natural gas network as the exclusive local provider of heating services. This would make space for district heating systems to be owned by local authorities or civil society groups (see Part II, section 2.3). This vision assumes significant buy-in and local demand for community-scale district heating CHP systems with the duty on developers for installing schemes in new homes and on local ESCos for installing schemes in existing homes (Part II, section 2.3). Systems also benefit from some form of predictable baseload consumer, such as large public buildings.

A community-scale CHP system that is appropriately sized would have low running costs once in place with some sensitivity to fuel costs, FiT rates (or similar) and discount rates (Wood and Rowley, 2011). These systems do, however, require high up front capital expenditure, making financing difficult without long term guarantees of revenue. The exact contractual arrangements will depend on the ownership of the CHP system. However, financing is likely to take the form of ESCos building and operating systems and recouping the capital cost from service revenue (see Part II, section 2.3).

Another important point, from the perspective of current stakeholders, is that a non-gas-fuelled CHP system would not be compatible with continued gas connection at a household level (which would be uneconomical where district heating is taken up) making the local gas network a stranded asset. Similarly, a switch to community CHP from gas might also have an impact on electricity markets, due to a CHP system's generation pattern and ESCos feeding electricity from CHP into wholesale markets.

Novel service provision models would need to be adopted. For instance, the responsibility for maintaining elements of district heating systems need to be clear and the boundaries between what is owned by the household and what is owned by the operating company need to be established. This could be based on models of gas and water and on district heating contractual arrangements in other countries.

1.8.3 Ground source heat pumps

Ground source heat pumps, once installed, can be cheap and efficient sources of heat. They are especially suitable for rural and suburban properties and in locations that are not connected to the gas grid that have enough outdoor space. However, legislative and planning issues would need to be rectified for this technology to diffuse widely as ground source heat pump equipment requires substantial excavation.

Ground source heat pumps can be very economical in the long term as they only require one unit of electricity for every three or four units of heat they provide, it should be noted however that costs of heat provision are very sensitive to electricity prices (Rawlings, 1999). While they are likely to pay for themselves in reduction of heating bills, the up-front cost of installing a heat pump is high with the need to make changes to the rest of the household heating system; replacing radiators with under-floor heating and improving insulation to make the system more efficient. It is unlikely that many households would find the initial outlay attractive. However, this can be remedied by providing loans to households to install heat pumps directly or through local ESCo financing models. Another possible model is for ESCos to own the heat pumps and rent them back to the household.

1.8.4 Fuel cell micro-CHP

Within Thousand Flowers, fuel cell micro-CHPs heat more than a sixth of domestic heating systems and are alternative to traditional technologies in that they are comparable in size to a large combi boiler or other white goods. Fuel cell micro-CHPs produce electricity with high efficiency but also produce heat and are a more technically advanced alternative to combustion-based CHP, making them an attractive alternative in Thousand Flowers. Although no combustion takes place, fuel cells produce CO_2 and water vapour if gas fuelled (the main fuel source for this technology in Thousand Flowers), and only water vapour if they are hydrogen fuelled. Fuel cells therefore offer a method of heating homes that would help to improve local air quality. As with all heating systems they must be appropriately sized for the demand of a property to be economically viable.

Although the technology is yet to reach the stage of commercial readiness, fuel cells are quieter, more efficient, and have fewer moving parts than an internal combustion engine or a Stirling engine CHP. As a replacement for more traditional heating technologies (i.e. gas boilers) fuel cell micro-CHPs are, therefore, a very attractive option with little impact in the home (heating controls could be similar to the standard today), hence the large market share within Thousand Flowers.

1.8.5 New gas boilers

It may read as counter-intuitive that a relatively large proportion of 'new' properties in 2050 are using natural gas boilers in a society that makes such radical changes elsewhere. This is due, however, to the projected high build rate of properties with gas boilers as the preferred heating type between the 2008 scenario base year and 2030. These homes (and heating systems) are still in existence by 2050 with the original gas boilers still in use and systems are not replaced unnecessarily before the end of their life. For 'existing' homes, i.e. those in the current building stock, the normal cycle of heating system replacement continues and sees most gas boilers replaced with other heating types.

1.8.6 Stirling engine micro-CHP

This is an alternative type of micro-CHP that relies on a Stirling, rather than an internal combustion, engine to generate electricity. Stirling engines are 'external combustion' engines, meaning that the mechanical power is generated by the compression, heating, expansion, and cooling of a gas, just like internal combustion, except that the working gas of the engine gas is in a closed cycle and is kept separate from the combustion of fuel. High temperature heat is transferred from the burning fuel to the Stirling engine through a heat exchanger. Lower temperature heat is transferred from the cooling phase of the Stirling engine cycle through another heat exchanger to hot water for washing and space heating.

These systems are already available on the market and are smaller and less noisy than internal combustion engine CHP systems. They also have a low ratio of electricity to heat output, about 1:6, which may be beneficial for a CHP in a building that requires a lot of heat but not so much electricity, or where electricity export is limited (depending on the evolution of electricity demand and the electricity system). The cost is currently much higher than a gas boiler and it is uncertain whether the cost of manufacture can be reduced sufficiently for widespread deployment.

1.8.7 District heating (waste heat)

Waste heat from industrial or commercial sources can be used for domestic heating purposes rather than being dissipated as a waste product. The way the system could work depends on whether low- or high-grade heat is available. As with CHP-powered district heating there are substantial changes necessary to allow this technology to emerge and it is important that within domestic properties there is still the same level of control. District heating from waste heat can be more complicated, however, because unlike community-scale CHP plants, heat production would not necessarily match demand. This problem can be resolved with some form of storage, e.g. hot water tanks either within properties or, on a larger scale, within districts. The lower efficiency and slightly higher costs associated with district heating from waste may be justified since running costs are very cheap once the district heating system is built. However, financial and commercial arrangements within such a system are not universal and transferable, and how responsibility and rewards can be allocated within the scheme is under researched.

This short review offers a richer description of the technologies used to heat homes in the Thousand Flowers pathway. The interplay between transitioning domestic heating and the wider electricity system to low-carbon futures is less well understood than for each system in isolation. From the above a key institutional factor is the existence of the ESCo business model at a local scale, which is investigated further in Part II, section 2.3.

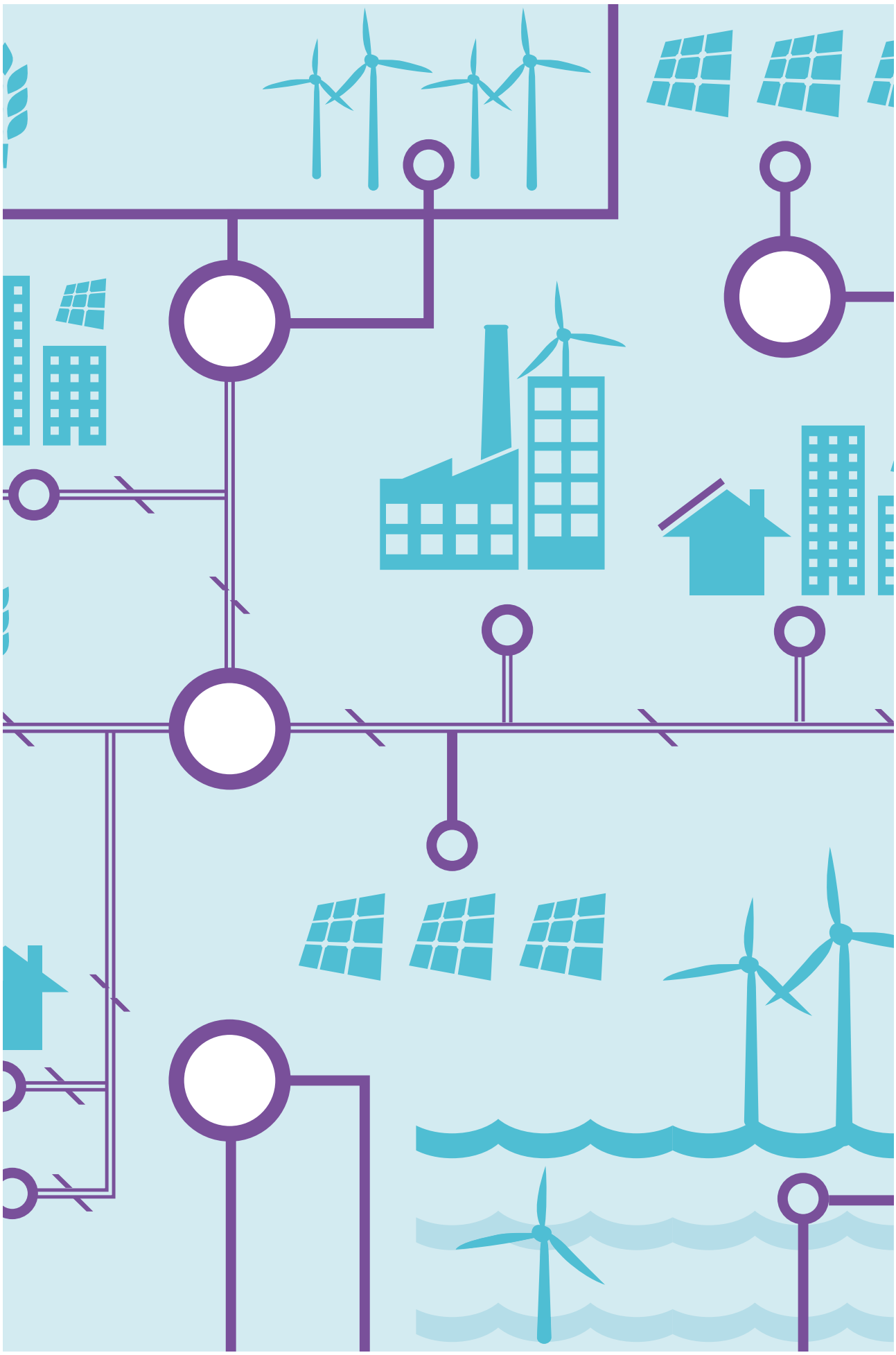
1.9 Summary

Part I has given an overview of the electricity system within Thousand Flowers in the year 2050. It described the challenge that is faced in transitioning from a system dominated by large, centralised, and dispatchable generation to a system where 50% of electricity generation occurs at the distributed level, with high amounts of intermittent renewables and heat-led CHP. It is clear that for this future to be supported a large number of technological milestones would need to be met by 2050.

There is a substantial need for reinforcement of existing grid infrastructure to increase connective capacity within the UK system; there is also a need for new interconnection infrastructures. Heightened connectivity will give the system heightened flexibility and allow the increased amount of renewable generation to be connected. There is also a need for advances in technologies, installation of smart grids, buy-in for demand side management and, importantly, the training of a sufficient number and standard of qualified engineers and technical experts to facilitate system change. The largest technological challenge for Thousand Flowers is the issue of grid balancing. This means that the method of grid balancing may have to change, both at transmission and distribution levels. The safe and reliable operation of the electric power system will be paramount in the future, as it is today. With a changing system electrical standards, protection, and operative training will have to adapt and would, for example, require more integrated ICT to realise the benefit of smart grids.

To complement demand management technologies, there is a need for increased storage within the system and increased connectivity. A further important change is increased participation from consumers. The pathway relies heavily on demand reduction, meaning that citizens need to be more engaged, whether through increased efficiency measures, demand response, or smart metering. This system also relies heavily on the use of biomass CHP as a key generation technology. On top of the infrastructural and technological uptake issues discussed above, it is important to note that imports of biomass will also feature in this pathway unless large amounts of agricultural land are converted to fuel crop production in the UK.

With regard to the technological transition outlined above, the following should be noted. First, this report analyses the impact of one distributed generation future; there are others which might have a greater role for solar, onshore wind, or other generation mixes. Further, technological choice would be informed by geographic resources and regional areas may prefer differing weightings of each technology. The technological transition outlined would require institutional supports to ensure that the governance of generation, distribution, and supply would be compatible with a future of distributed generation. As such we now turn to what this more compatible institutional architecture' might look like.



Part II: Institutional Transformation

The Thousand Flowers pathway goes beyond assessing technological feasibility of increased distributed generation by questioning what new types of governance, ownership, and control a distributed future would need. Moving to a distributed system would involve new roles for municipalities, communities, and householders within the energy system, as well as new business models at distribution and supply levels.

These new participants in the energy system are seen as essential enablers of new renewable capacity and significant demand reduction. Incorporating local ownership stakes can accelerate the deployment of renewable and low-carbon energy generation (Buchan, 2012; Foxon et al., 2005; Schreuer and Weismeier-Sammer, 2010).

The arrival of new actors in the energy system would require a new institutional architecture compatible with new flows of finance, new regulatory duties, and new business models; this would need to evolve alongside the technological transformation described in Part I. Here, we present a series of 'institutional scenarios' that examine this transformation in terms of the governance and ownership of the energy system in the Thousand Flowers pathway. We identify a role for a 'civic energy sector', which combines municipal, co-operative, and community action with existing activity from private developers, and residential/commercial prosumers/consumers. We consider the impact this could have on governance, regulation, policy, and financial structures in the energy system.

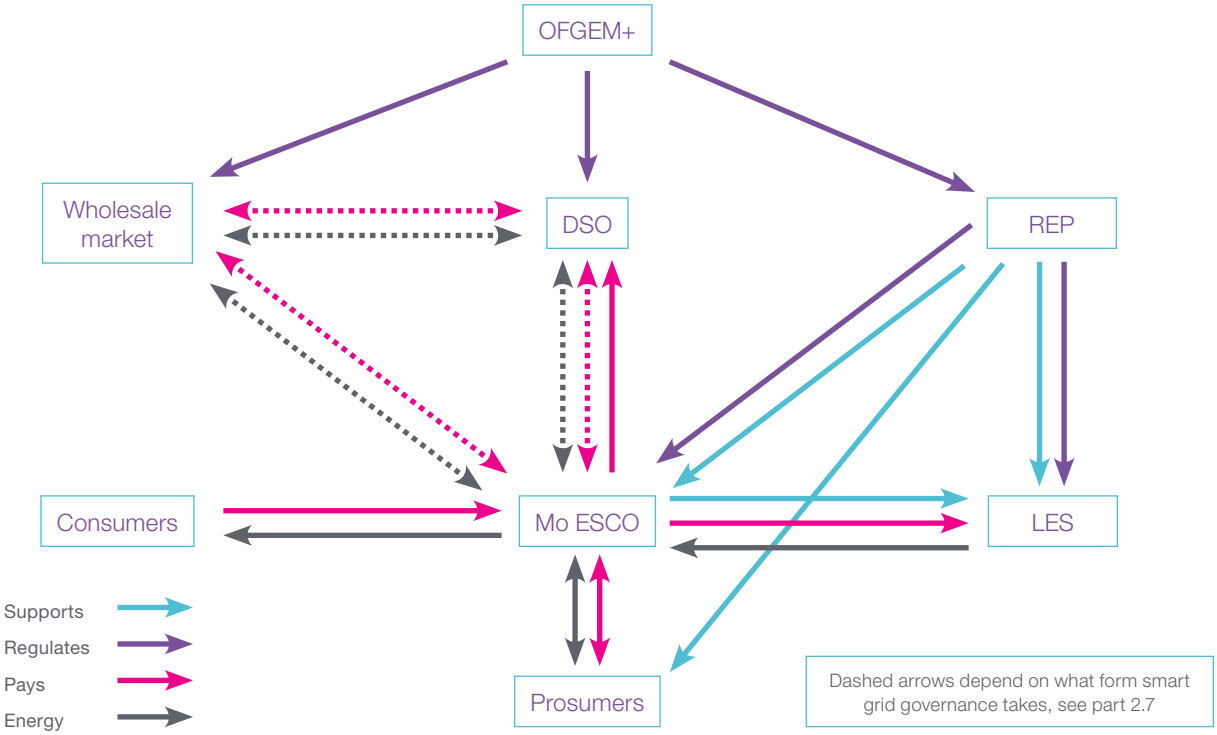
2.1 Mapping institutional transformation – our approach

To develop the concept of a new institutional architecture we undertook a series of focus groups with multidisciplinary researchers from the energy technology, economics, social science, and policy fields to explore how a distributed energy system might look in terms of generators, suppliers, distributors, and regulators. We also drew on live primary research from the Realising Transition Pathways research consortium. Furthermore, we undertook internal peer review with representatives from government, the energy regulator, and industry to build understanding of what a new institutional architecture more compatible with the Thousand Flowers pathway would need. Each 'institutional scenario' below outlines the current context in the UK and internationally, examining how the institution(s) might support a transition to a distributed generation mix by 2050. We proceed as follows:

We discuss the proliferation of local energy schemes (LES), describing changes to the financial and consumer supply landscape as key enablers for expanded locally-owned generation. We then outline the Municipally-Owned ESCo (MO-ESCo) structure into which local energy schemes (LES) sell energy and who manage energy efficiency relationships with households and businesses, and offer new financial deals on energy technologies to householders. We describe international examples of where the city region provides the natural geography for energy services. We then reflect on how a transition to 50% of final electricity demand met by distributed generation might affect the current vertically integrated utilities and central supply model in the UK. A new civic energy sector means that regulatory structures would change from pure regulation to a regulate and support function. We propose a dual approach within 'Ofgem+' wherein Ofgem continues to regulate national transmission level generation and national competitive supply, but where the new LESs and ESCOs are supported by a Regional Energy Partnership (REP). The final institutional scenario discusses the regulation of distribution infrastructures and the smart grid. As such our new institutional scenarios, forming a new institutional architecture, cover generation, distribution, regulation, and supply of energy.

This process aimed to identify how the Thousand Flowers pathway might be facilitated as opposed to why. Where we do address the question of causality these links are inevitably speculative or are based on previous descriptions of the pathways (see Foxon, 2013). We do recognise however that new consumer behaviour and technologies co-evolve (Foxon, 2011) with new business models and institutions in the energy system, and as such the institutional structure presented is one more compatible with a Thousand Flowers type transition, and significant variation may be present. Figure 6 presents an overview of the flows of energy, payments, regulation, and support within this institutional architecture.

Figure 6 The Thousand Flowers new institutional framework



2.2 Local energy schemes and the civic energy sector

It is technically possible for 50% of final UK electricity demand to be generated by distributed generation by 2050 (Barton et al., 2013). We asked who would be likely to expand distributed generation and what ownership structures might be compatible with the Thousand Flowers pathway. Traditionally, UK renewable energy capacity has been built by large-scale commercial developers and/or utilities, delivering projects above 10MW (Walker, 2008), whose finances and subsequent revenues are globally mobile (Rutledge, 2012), no proportion of which are captured locally, or by 'citizen' investors. The alternative is a proliferation of distributed energy generators which are owned fully or in part by municipalities, communities, or small-scale investors.

The Thousand Flowers pathway does not exclude traditional sources of energy finance and ownership; rather it adds to them. Under this pathway the UK moves from a corporate generation model to a mix of corporate, municipal, and citizen ownership. The pathway assumes substantial levels of individual installations in households and businesses, but also envisions civil society taking substantial stakes in commercial-scale capacity additions. The current alternative ownership models that exist in the UK are defined as the 'community energy sector' (Capener, 2014; Seyfang, 2013) and the 'Municipal ESCo model' (Hannon et al, 2013). Expanded into the future, the community and municipal energy generators together would constitute a civic energy sector.

2.2.1 Where are we now?

The current community energy sector provides less than 1% of final electricity demand (DECC, 2014; Hannon et al., 2013). Comparable figures for municipal or civic ESCo models that also own generation assets are unavailable. However, if existing trends continue, municipally-owned generation is unlikely to exceed 1% of final electricity demand due to extremely low market penetration in the UK (Hannon et al., 2013). 85% of generation capacity is under Big Ten ownership; private renewable energy and CHP developers comprise the remaining 15% including the 1% under community ownership (Rutledge, 2012). Expanding the 1% of electricity demand met by the civic energy sector to represent a significant element of capacity, will mean unprecedented growth of generation technologies (Part I) and ownership of generation assets by civil society. Individual household generation and efficiency can be supported by a MO-ESCo supplier model (section 2.3). We discuss below the latent civic energy sector which would need to deliver the high build rates of CHP plant and expanded local renewable generation described in Part I.

Recent rhetoric from government has recognised the role local energy schemes can play in meeting demand (Foxon, 2013) and has culminated in the Community Energy Strategy (DECC, 2014). The strategy sets out UK Government plans for incentivising community ownership of energy generation. Capener (2014) estimates, in the most optimistic scenario, that the upper estimate for the community energy sector is 3GW of installed capacity by 2020, meeting 1.4% of total UK electricity demand.

The DECC strategy represents a step forward in propagating new forms of energy ownership; importantly however, the definition of community energy limits the scope for new ownership to expand in the generation sector. We see a civic energy sector having wider scope, including institutional and technological definitions. DECC's 'community' definition does not include generation assets owned by institutions such as combined authorities, local authorities, town and parish councils, or social housing providers. We found no reason to exclude these organisations from the definition of the civic energy generation sector; indeed, in the Thousand Flowers pathway local authorities play a key role. Technological omissions from DECC's strategy include CHP, anaerobic digestion, wave, tidal, and biomass, each of which makes a substantial contribution to generation capacity in the modelled technological mix of the Thousand Flowers pathway; there is also no reason these technologies could not incorporate ownership by civil society actors. By widening the definition to include all types of civic ownership, a substantial proportion of UK final electricity demand could be met by this sector.

2.2.2 Where is it being done differently?

Whilst the UK (with the exception of parts of Scotland, see Box 1) has very little experience of civic participation in energy generation, evidence from other European nations demonstrates that this sector can be far more significant, but requires appropriate political, financial, and ownership institutions and models.

In Germany there has been a longer tradition of civic ownership of generation assets (Schonberger, 2013; Toke et al, 2008) including municipal ownership (Schonberger, 2013). Research has shown regular access to finance from co-operative, state-owned, and local banks as facilitating this sector (Berlin Landesbank, 2011; Bolinger, 2001; Bremer Landesbank, 2014). By 2010, energy assets with an element of civic ownership made up 40 to 50% of Germany's total renewable energy capacity (Buchan, 2012; Nolden, 2013); much of this was made up of local developer partnerships with local share issues. Current developments include taking energy distribution under municipal control and proliferating municipal utilities (Nolden, 2013; Schonberger, 2013; Vasagar, 2013). Current capacity owned by the civic energy sector in Germany is significantly higher than the UK government's highest targets for 2020.

Municipal, co-operative, and state-owned banks are cited by Bertram and Landgrebe (2014) as a key element of the German proliferation of civic energy ownership; local financial institutions are able to build project expertise, develop ties with municipal government, and co-ordinate local stakeholders from municipalities to local businesses and civil society (Bertram and Landgrebe, 2014).

In Denmark, the majority of wind turbine projects include an element of citizen ownership. This was mainly characterised by co-operatives throughout the 1990s and has diversified recently into larger-scale citizen ownership models. The proliferation of citizen and co-operative ownership has contributed to the rapid expansion of onshore wind, and citizen ownership is becoming a feature of offshore developments. In some municipalities this has led to significant economic development benefits: in one case, household earnings of over €1500pa were derived from local ownership of generation capacity (Olesen et al, 2004). Growth in the size of wind turbines into the MW range has introduced a need for partnership models to meet the high capital costs associated with large installations. DECC (2014) cite the Middelgrunden 40MW offshore windfarm off the Copenhagen

coast as a recent example of large scale citizen/developer partnership. Access to a financial sector with significant experience in financing citizen partnership and co-operative business models is cited as key to replicating installations (Bolinger, 2001; Olesen et al, 2004).

2.2.3 Where does this pathway take us?

There are a growing number of local generation schemes in the UK within the civic energy sector (Capener, 2014). In 2011, Lambeth Council entered a successful collaborative partnership with Repowering London, a not-for-profit organisation that facilitates the co-production of community-owned renewable energy projects. This partnership has used community share offers and citizen loans to raise £180,000 to co-produce community-owned solar projects on housing estates in Brixton that total 132kW installed capacity. Thameswey Energy is a MO-ESCo with generation assets in Woking and on a larger scale in Milton Keynes. Cities including Southampton, Sheffield, Newcastle, and Aberdeen have all developed municipal partnerships to deliver energy generation services. Co-operative wind ownership has become more widespread in Scotland; the archetypal Baywind co-operative is perhaps the most well-known example. New institutions such as Energy4All are endeavouring to expand the co-operative model, whilst new citizen finance institutions such as Abundance Generation are using new financial structures to capitalise local energy projects. Finally, in direct recognition of the role local and regional banks played in the proliferation of green energy in Germany, Hampshire is to set up its own community bank, whose first priority will be to invest in the low-carbon technologies sector. There is clearly scope to expand on the experience of local finance found in the civic energy sector of continental Europe and to draw on municipal expertise and borrowing channels to proliferate local energy schemes.

The challenge in the Thousand Flowers pathway is to aggregate these local energy schemes into a coherent civic energy generation sector, which can meet a substantial proportion of final electricity demand. The proliferation of the above examples to European levels of capacity, requires an understanding that these levels are achievable, and exceedable, if the right mix of institutions, resources, finance, and expertise can be developed at the local level. Table 7 shows a snapshot of some of the business models currently used by the UK's civic energy sector.

Table 7 UK civic energy sector business models.

Project name/lead organisation	Website	Description	Governance	Finance	Revenue
Baywind Energy	www.baywind.co.uk	Energy generation co-operative issuing shares on a co-operative basis to fund the purchase of wind turbines in new windfarms	Industrial and provident society co-operative	Shareholder equity	Units of electricity sold and ROCs
Abundance Generation	www.abundancegeneration.com	'Democratic finance' buying shares in renewable energy projects from as little as £5 for equal rates of return	Private company	Debentures	Debt service payments
Repowering London	www.repowering.org.uk	Energy generated by solar installations on tower block rooftops is consumed in communal areas. The excess is exported to the DNO. Direct household consumption is not possible due to individual metering.	Industrial and provident society co-operative	Shareholder equity	Units of electricity saved in project and FiTs
GWE Biogas	www.gwebiogas.co.uk	Municipal and agricultural waste biogas unit. Currently operational and hoping to extend private wire and heat network to new housing	Private company	Grant/private equity	Units of electricity sold, waste gate fees, biofertiliser, dual ROCs
Aston Hayes CIC	www.goingcarbonneutral.co.uk/our-community-energy-company	Community buildings solar project	Community interest company	Grant	Electricity savings, FiTs
Thameswey Energy	www.thamesweyenergy.co.uk	Established in 1999 by Woking Borough Council as an energy and environmental services company. Thameswey provide energy to commercial and residential customers to meet carbon reduction targets in the council's climate change strategy.	Local authority arm's length ESCo, municipal PPP	Private municipal mix	Units of energy sold

Ongoing research within the RTP consortium is highlighting several drivers and barriers to growing capacity and volumes of civic energy schemes. A fundamental necessity is a significant step change in the attitudes of government, municipalities, and individuals to collective, citizen, and municipal ownership of energy generation assets.

Following consultation with stakeholders from the UK's existing community energy sector by RTP researchers, we recognise this step change requires effective and innovative ways of engaging with community members. For instance, it is important to identify the needs of each particular community in order to determine the objectives of the project. This provides incentives for engagement and change. Findings suggest that in most circumstances, motivational factors are often unrelated to reducing carbon, climate change, and environmental concerns; for example, saving and generating money, an interest in renewable energy technologies, desire for self-sufficiency, local empowerment, and a greater sense of community cohesion have been reported as key social drivers for developing community-energy projects (Hall et al, 2014). Further, individuals active in community energy schemes report that although a motivated community and voluntary work is essential for these schemes to start, the implementation and sustainability of the projects lie in proper project management and professional expertise to deal with a range of technical, financial, legal, and administrative issues required for the successful delivery of community energy projects.

Early findings suggest the absolute structural barriers to expanding the civic energy sector in the UK are relatively low. Local authorities are already able to set up ESCos, sell power, and invest in renewable generation. Feed in Tariffs (FiTs) are becoming normalised and government is set to raise the FiT cap to 10MW for community energy projects. However, problems remain where schemes rely on motivated individuals, voluntary labour, and uneven skill sets across communities. Equally, recent energy policy has been designed predominantly to favour large-scale generation options and corporate ownership, to the detriment of building a strong alternative energy movement (Breukers and Wolsink, 2007; Toke et al, 2008). Also, importantly for this pathway, CHP electricity does not attract a feed in tariff rate (Toke and Fargaki, 2014).

DECC (2014) recognises that a finance gap exists for energy projects below £20m, where projects find it difficult to access capital with the right levels of support and interest rates and is providing support through the rural community energy fund and the urban community energy fund. Whilst projects with capital needs over £20m will be required to effect transformative change, small-scale projects are a way in to learning and skill building for community schemes. As such, we suggest that an understanding of the models and practices of the German and Danish citizen finance sector should be brought into the UK debate, alongside the existing, but hitherto niche, citizen finance of energy assets.

We define the local energy schemes (LES) within the civic energy sector as those which capture values from energy generation either through co-operative, municipal, charitable, or citizen investment business models. The expansion of this sector would capture much of the value from energy production and consumption that currently leaks out of the local economy (Gouldson et al., 2012; Sherwood and Tompt, 2013), and indeed the UK economy (Rutledge, 2012); it would also propagate low-carbon energy systems that are delivered close to where consumption takes place, and be able to engage customers more directly in demand management /energy efficiency due to the benefits of the MO-ESCo model.

An expansion of civic generation would require new business models in power purchase and generator co-ordination. These civic generation schemes would contribute significant distributed capacity, but consumer efficiency, residential and commercial 'prosumption' and the financial models that can enable these activities would need to proliferate rapidly. The next question this research addressed was which supplier models were compatible with a civic energy sector.

Box 1: Community energy in Scotland

Scotland is forging ahead in the installations of renewable energy generation for community benefit. Scottish Government policy is to install 500MW of community- and locally-owned renewable energy by 2020, using favourable Feed in Tariffs (FiTs), Renewable Obligation Certificates (ROCs) and appropriate renewable energy resources (Scottish Government, 2013). Support is available from the Energy Saving Trust (EST) through Local Energy Scotland and the Community and Renewable Energy Scheme (CARES) offering grants and loans for feasibility studies and start-up costs with the safety net that the loan does not have to be repaid if the project cannot go ahead. Together these factors offer good support to communities developing energy projects around Scotland.

A prevalent driver for current projects in Scotland is community benefit. The 'Onshore Wind Community Benefit Protocol' offers £5000 per installed MW for communities to invest in local priorities (Scottish Renewables, 2014). Although there are no targets for other forms of generation, the average community benefit in Scotland is still £2,779 per MW per year. These funds are being entered into a number of projects, including:

> building/refurbishment of community centres, sports clubs, parks and playgrounds; culture and heritage; aiding the elderly and youth in communities; fuel poverty alleviation and energy efficiency measures; and the building of properties to offer low rental accommodation for young people in communities where holiday lets and commuters are driving up prices.

The register for community installations held by Local Energy Scotland (2014) is the best source of statistics for community benefit from generation, though not exhaustive. From this we identified onshore wind generation as the most prevalent technology with 198 of the 223 entries in the register. Helped by highly favourable FiTs or ROCs (depending on the size of the installation) onshore wind generation has developed as a gateway technology for communities to engage further with renewables in Scotland by taking ownership stakes in new developments.

Whilst the community benefit protocol means that having a developer-led scheme in their area can mean new community resources, a community-owned and led project can see higher levels of benefit (financial and otherwise) capturing secure revenues from energy generation close to source.

Hydro schemes are another growing technology in Scotland, with 23 entries in the CARES register. Run of river installations make use of the water's natural flow to propel generation, and although they are of a smaller scale than the traditional hydro and pumped storage seen in Scotland, there is a significant resource available to be exploited. Installations are ongoing throughout Scotland with the Forestry Commission now also looking into installing hydro schemes and wind generation on its land (Forestry Commission Scotland, 2014).

The options for community benefit are to either receive income from developers or to invest alongside developers and receive a return on the profits. What can be seen in Scotland is a co-ordinated effort from developers, government, and civil society, led by Scottish Government targets, to increase the total amount of renewables in Scotland. The aim is to ensure that 100% of electricity consumed in Scotland is to be from renewables by 2030. Moreover, there is a drive to ensure that community benefit is an integral part of installations, and therefore more and more communities in Scotland are being encouraged to engage in the energy sector for their own financial, social, and environmental benefit.

2.3 The MO-ESCo model

The following institutional scenario examines the role of municipalities and the Energy Service Company (ESCo) model within the Thousand Flowers pathway. Municipally-Owned ESCos (MO-ESCos) have the potential to enable two key elements of the TF pathway; they can provide civic energy generators a route to market, and they can provide a business model compatible with the levels of energy demand reduction envisaged in the TF pathway.

The expansion of civic energy generation in the UK depends on Local Energy Schemes finding a route to market for the electricity and heat they produce. An expansion of small scale generation schemes would need to be matched with expansion of civic business models in the supplier relationship (Platt et al, 2014). Large generators are able to bear the transaction costs inherent in trading on the electricity wholesale market; for smaller generators however, these transaction costs are often too high relative to the power produced. As such, smaller scale independent generators tend to secure 'Power Purchase Agreements' (PPA's) with major suppliers. As small producers with intermittent generation do not offer an attractive prospect to major suppliers, they have often struggled to secure bankable PPA's (DECC, 2014; DTI, 2007). RTP researchers have argued that in order to proliferate distributed energy in the UK, there is a need for new, local supplier business models that have significant involvement from municipal actors (Bolton and Foxon, 2013; Hall and Foxon, 2014; Hannon and Bolton, 2014). We suggest that MO-ESCos could offer attractive power purchase agreements to the new generators in the civic energy sector.

As for demand reduction, in this pathway, by 2050 annual electricity demand has fallen from 337TWh in 2010 to 310TWh in 2050. Despite increasing levels of transport electrification, electricity demand falls due to: high rates of energy efficiency improvements in the domestic and commercial sectors, a small, highly efficient industrial sector, and a strong proliferation of Biogas CHP for heating homes (Part I). Other energy transition scenarios (using the MARKAL cost-optimising model and the DECC 2050 calculator tool) predict rising final electricity demand, much of which is due to projected growth in industrial electricity use and widespread but moderate commercial and domestic efficiency (Barton et al, 2013). However, industrial energy use from most fuels has fallen sharply in the UK since 1990, and electricity consumption remained relatively constant (DECC ECUK, 2014). For commercial and domestic efficiency the Thousand Flowers pathway envisages a 32% and 30% reduction in final electricity demand in each respective sector (Part 1).

Recent research has shown significant energy demand reductions are available by deploying energy efficiency measures that could secure an 18% reduction in GHG emissions from commerce, industry and domestic users by 2020; and that these reductions are available simply by exploiting existing cost effective or cost neutral energy efficiency measures (Gouldson et al, 2012). However, even those energy efficiency investments that represent commercially attractive returns, remain unexploited in the UK (Gouldson et al, 2012; DECC, 2012a; Grubb et al, 2014). As such, new business models for delivering energy efficiency investments at city regional scales are needed. Crucially for the TF pathway, Fang et al (2012) demonstrated the ESCo business model may enable energy demand reductions of between 22% and 35% against business as usual trends; these levels are compatible with the levels in the TF pathway.

'Business as usual' here refers to current supplier business models which rely on increasing 'units of energy sold' to grow; thus dis-incentivising demand reduction (Hannon et al, 2013; Roelich et al, 2015). To support the TF pathway, any civic energy supplier business model should be able to incentivise demand reduction. This led the research group to investigate the Energy Service Company (ESCo) model (Hannon et al, 2013; Foxon, 2013; Bolton and Foxon, 2014). RTP researchers have emphasised that municipal actors and the ESCo model, play a significant role in the TF pathway (Hannon et al, 2013; Foxon, 2013). ESCo business models are more suited to delivering energy efficiency, and financing individual prosumer installations such as household CHP/fuel cells than the conventional consumer – supplier relationship (Roelich et al, 2015; Boait, 2009; Steinberger et al, 2009). Equally, municipalities have the geographic focus and consumer trust necessary to foster both new consumer/supplier relationships and build relations with Local Energy Schemes. Research by YouGov shows that consumers would trust a community energy provider more than traditional energy companies to give them a good deal on their energy bills (OVO Energy, 2014).

Given their geographic focus, advantages in consumer trust, and ability to incur higher transaction costs when aggregating local schemes, the research group envisages a significant role for MO-ESCos in a future energy system analogous to the TF pathway. If MO-ESCos are to proliferate, the current utility model may become discredited in the late 2010s and 2020s due to growing public awareness of the ability of new business models to retain values in the energy system locally and deliver energy efficiencies. This could lead to a swing back

towards municipalisation in energy services. In this future the Big Six (and other suppliers) would become less vertically integrated and would gradually concede supply market share and sell into the wholesale market. Other small-scale generators might enter into supply agreements with their local MO-ESCo.

2.3.1 How do ESCos reduce demand and facilitate distributed generation?

ESCos provide energy services (e.g. heating, lighting) rather than sell energy by the unit. The focus on services incentivises them to reduce consumer demand, resulting in lower energy use and CO_2 emissions (Fang et al, 2012; Fang and Miller, 2013). It is also argued that ESCos have a closer relationship with the users/customers (Fang and Miller, 2013). ESCos have tended to be linked to specific capital projects (e.g. new buildings/refurbishments) lasting 5–10 years. The ESCo often designs, develops, finances, and manages the energy element of the project on a performance-based contract.

ESCos usually operate through energy supply contracts (ESC) or energy performance contracts (EPC). These contracts are often long term, circa 5–15 years (Hannon et al, 2013). The EU has described the EPC as a form of creative financing which allows energy efficiency upgrades from energy savings (Brodies LLP, 2007). This illustrates that many ESCo projects relate to retrofit or the introduction of new energy plants. The company Ameresco has recently entered the UK market and holds an extensive case study library demonstrating the demand reduction potentials of ESCo contracting[9].

Revenues are drawn from shared savings or guaranteed savings, with different models available for risk sharing between consumer and supplier (Bertoldi et al, 2006; Hansen, 2011). ESCos are often linked to provision/delivery of CHP. This is important because CHP meets a significant proportion of final energy demand in the Thousand Flowers pathway (Part I) and it is CHP that often provides the efficiencies that make ESCos viable. For example, many of the ESCos in Denmark involve CHP where energy infrastructure is seen to be a key responsibility of the public sector (Brodies LLP, 2007). These also benefit from existing district heating infrastructure.

2.3.2 Where are we now?

Currently, most domestic customers in the UK purchase their energy through the supplier market. In order to be a supplier a suppliers' licence is required, ensuring adherence to the suppliers' licence conditions (SLC). At the end of 2013 there were 24 companies in total offering electricity and/or gas supply to any household on the open market and 30 companies offering electricity and/or gas supply to commercial consumers (Moss and Buckley, 2014; Buckley and Moss, 2014). However, supply is dominated by the 'Big Six' (British Gas, EDF Energy, E.On, RWE NPower, Scottish Power, and SSE) who supply the vast majority of domestic customers. As it stands ESCos are currently a niche in the UK (Hannon et al, 2013). The use of ESCos by the public sector is generally regarded as a kind of outsourcing, and is sometimes part of public–private partnership deals or private finance initiatives (e.g. a hospital energy system; see Brodies LLP, 2007). Boait (2009) suggests that there are three current models for ESCos in the UK:

- ESCos operating on a business-to-business basis;
- Local public–private partnerships involving local authorities;
- Limited energy service offers from major energy retailers.

Bertoldi et al (2006) suggest there are around 20 private sector ESCos in the UK, including those operating as part of conventional energy providers. However, there are also some public sector examples which have often been established to minimise the risk to the local authority or to allow more flexibility to operate (e.g. finance) energy contracting. Those which fit with our definition of a MO-ESCo model include:

- Thameswey Energy (Woking)[10]. Often held up as the exemplar of ESCo development in the UK. Initially developed by Woking Borough Council and now also managing projects in Milton Keynes. It supplies energy to 800 domestic customers and 30 retail units.
- Aberdeen Heat and Power[11]. An ESCo set up in 2002 to refurbish social housing and address the problem of fuel poverty. It has completed several further projects since then.
- Southampton[12]. Southampton was a pioneering developer of the CHP ESCo model in the UK. It first developed a geothermal plant in 1986 in an outsourced partnership with the private sector. District heating in Southampton continues to be developed, with a new scheme in Millbrook connecting 4000 houses to the existing network (see Box 2).

What is notable about these examples is that residents need to access the local heat network in order to purchase energy from the MO-ESCo. Further growth of the CHP ESCo model is limited by the fact that the UK has a very low proportion of existing heat mains and the emergent models tend to be based around the development of new infrastructure (see Brodies LLP, 2007, p.49). Five hundred district heating schemes were developed in the UK during the 1960s/1970s. However, a perception of the heat network as a 'poor man's choice' and a range of problems (poor performance, inaccurate metering, lack of control) led council tenants to lobby successfully for disconnection and attachment to the (cheap) gas network (see Larsson, 2006; in Gearty, 2008). Some old infrastructure may remain in place but the potential for this to be reused is not clear at this stage.

At the time of writing some commentators and analysts see private sector ESCos as key players in the delivery of new energy efficiency packages such as the 'Green Deal' (Morris-Marsham, 2012). For example, the private company 'A Shade Greener' defined as an ESCo by Hannon et al. (2013) offers 'free' solar panels for households, the capital for which is repaid by the customer signing the FiT rights to the ESCo. This is just one example of where innovative business models can facilitate unprecedented levels of technology adoption such as those described in Part I.

2.3.3 Where is it being done differently?

Traditionally, ESCos have focused generally on the commercial and public sector in the UK and even internationally there has been little focus on residential markets to date (Boait, 2009; Hannon and Bolton, 2014), the largest being in Nepal (30% of activity) and South Africa (15%) (Vine, 2005). As such there are few examples that have municipal ownership and an ESCo business model. Our analysis often returned to the municipality as a key stakeholder in the development of local ESCos, due to their territorial focus, institutional strength, and compatible social and environmental objectives. Whilst the MO-ESCo model is only evident in isolated cases, there are many international examples of municipally-owned suppliers working on a 'units sold' business model.

The Berlin Energy Agency[14] is often held up as an exemplar of a public–private partnership which has significant successes in energy services development. Municipal energy is also widespread in the USA where there are 2000+ municipal power utilities and around 900 rural electric co-operatives. The largest municipal company is the Los Angeles Department of Water and Power[15], which has 1.4 million customers and a net maximum plant capacity of 7.2MW. The US Rural Electric Co-operatives collectively own assets worth $140 billion and deliver 11% of the country's electricity needs (NRECA, 2014).

Whilst there has generally been a trend of liberalisation in Europe over the last two decades (led by the UK) there is some evidence that remunicipalisation is becoming popular, such as the recent vote in Hamburg to repurchase the local distribution grid[16] and the revival in the same city of a municipal supply company. Since 2007 44 new public utilities have been established in Germany and about two thirds of all German communes are considering buying back both electricity generators and the distribution networks, including private shareholdings in some of the 850 Stadtwerke which already hold over half of the energy market (Hall, 2012).

Stadtwerke are multi-faceted local utilities which number around 1,400 and which have various ownership structures. In some cases there are strong elements of public control and certain Stadtwerke are leading in the development of distributed energy systems. Stadtwerke Schwäbisch Hall (GmbH) has a turnover of €237 million and generates 60% of its electricity from 30 CHP plants that it owns. Its three-part strategy of CHP, renewables, and energy efficiency has been copied by other Stadtwerke. In Schwäbisch Hall citizens are also able to invest directly in the solar farms that are being developed (Hockenos, 2013). Stadtwerke are, however, diverse organisations and where some play a supporting role in the transition to renewable energy in Germany, others remain conservative organisations with little desire to co-ordinate regional renewable generators and balance supply with the wholesale market.

Nevertheless, municipally-owned and co-operative utilities generally are in an excellent position to underpin a civic energy sector. Municipal utilities have the ability to trade on wholesale markets, balance several generation sources across a territory, and offer power purchase agreements to local generators. Combining these strengths with the ESCo business model would create institutions with strong incentives to support energy efficiency and local renewable energy generation.

2.3.4 Where does this pathway take us?

The Thousand Flowers pathway envisages a significant role for MO-ESCos in the future energy system. A MO-ESCo model is likely to be more compatible with a distributed energy system because MO-ESCos could:

- Eventually become the sole supplier of energy (gas and electricity) within their geographical boundaries after a period of transition. This gives the investment confidence needed to develop CHP, heat networks, and efficiency contracts as customers could not switch supplier. Clearly this requires regulatory change and new monopoly regulation, but this already exists for water supply and the electricity distribution network in the UK and the heat sector in Denmark.
- Combine the functions of a municipal energy company and an ESCo. In other words, the core function is to provide energy services at a low cost to the user, not to maximise the sale of energy units. The MO-ESCo is incentivised both to supply AND to reduce the consumption of energy with its customers (see Palm, 2006).
- Be oriented towards the purchase of distributed generation from Local Energy Schemes (LES).
- Lead the development of its own distributed generation capacity in order to meet its own supply requirements.
- Purchase the excess supply requirements from the wholesale generation market.
- Offer hire purchase agreements for micro-CHP and micro fuel cells, a key enabler of important technologies in the TF pathway.
- Have a statutory duty to address fuel poverty and ensure that questions of equity were considered within energy provisioning.

Further MO-ESCos would have several ownership structures available. Here we have focused on 'arm's length' structures, separate from the local authority but where municipalities maintained a controlling interest or otherwise guarded against hostile takeover. As an arm's length entity a MO-ESCo of this kind would be able to enter into commercial partnerships and raise finance from multiple sources, without the restrictions placed on local authority borrowing. Multiple MO-ESCo business models exist however (Hannon et al, 2013; Hannon and Bolton, 2014), and new models may emerge as regulation, policy and strategy evolve alongside new technology in the energy system. Equally, the success of the model would be driven by its popularity with consumers. In the TF scenario, MO-ESCos would have to develop iteratively to build public trust and consumer engagement.

The MO-ESCo model could significantly challenge the market share of utility suppliers up to 2020-30, leading to a point where the aggregate benefits of MO-ESCo models outweigh the benefits of legally enshrined supplier switching. A competitive supplier market is only one way to pursue societal, environmental and economic goals through the energy system. If the MO-ESCo model proved successful, the benefits of moving to a regulated monopoly approach in some areas may be explored. This would need amendments to current consumer switching legislation at EU level, to allow municipal supply monopolies. The legitimacy of this could be established by a requirement to secure popular mandate. Thus, an amendment to EU law to state that a territory with a popular mandate demonstrated by local referenda could opt out of the legally defined right to switch energy supplier, would allow MO-ESCos to offer much longer term energy service contracting to households and businesses. Even without this change to primary legislation, MO-ESCos are likely to be a viable proposition and could be a key stakeholder if the UK energy system were to transform along a Thousand Flowers style pathway.

The MO-ESCo model is also envisaged to deliver a number of non-technical benefits. First, because energy provision would be subject to democratic accountability, and energy values are retained in the locality, energy issues become part of civic dialogue. Under a system where localised generation directly benefits local people there is evidence of greater acceptance of distributed generation (Warren and McFayden, 2010). This partial geographical hypothecation of energy supply and value, can lead to a more productive debate about which energy technologies are utilised in which areas. Ultimately, citizens can hold local authorities to account for their energy provision through the ballot box, but there may also be more participatory methods for engaging citizens in the process of planning and developing energy infrastructure.

The slow development of the MO-ESCo model in the UK at the present time indicates that there is a need for a supportive policy framework, if the potential of the model is going to be realised on a national scale. Even then it will take time for them to be established. As such the research group identified a need for a further new institutional actor, Regional Energy Partnerships (section 2.6), which would be needed to build the requisite capacity. Before considering these support needs however, centralised generation in the Thousand Flowers pathway is addressed.

Box 2: Southampton District Energy Scheme: Municipally-led district heating

The Southampton District Energy Scheme (SDES) is one of the pioneering district heating schemes in the UK. With roots that stretch back to the 1970s, it has grown and evolved over the last 30 years to become a multi-faceted tri-generation (heat, electricity, and cooling) energy network that incorporates multiple technologies and serves a range of public and private clients. It is one of a handful of contemporary UK cases that illustrate how local authorities can play a leadership role in the development of distributed energy systems. SDES currently produces 40,000MWh of heat, 26,000MWh of electricity and saves 10,000 tonnes of CO_2 per annum.

The origins of SDES can be traced back to the late 1970s when the Department of Energy (DoE) drilled a number of test bore holes to explore the potential for geothermal energy in response to rising concerns about energy security. One of these bore holes was at Marchwood power station in Southampton. Although the DoE decided not to pursue geothermal energy at the original site the idea had caught the imagination of key council officers who lobbied for a second bore hole to be dug closer to the city centre in an area of proposed redevelopment. The second test bore revealed the potential for a limited scheme and, despite a lack of support from the DoE, the council were able to secure funding from the European level to undertake further feasibility work and develop the well. The scheme had cross-party political support which allowed it to proceed despite changes in the political administration. The council also brought in the necessary expertise to manage the technical side through the development of a partnership with the French utilities company Utilicom (now Cofely District Energy). A 20 year contract was signed between the council and Utilicom specifying the roles and responsibilities of each partner, enabling the latter to establish the Southampton Geothermal Heating Company as a wholly owned subsidiary.

The initial heat station was completed in 1986 permitting the connection of the first customer – the city's Civic Centre. In the following years the network continued to grow through new connections. Then, in the mid-1990s a number of critical developments occurred. First, the scheme developed the capacity to offer chilling as well as heat, stimulated by the connection of a new absorption chiller to meet the cooling needs of a new five star hotel. Second, a 5.7MW combined heat and power (CHP) generator was installed at the heat station in order to increase the capacity of the system. Following this the range of connections to the system continued to diversify with the first private residential schemes. A separate CHP scheme had also been developed for the Holyrood Estate, heating 300 residences. Further CHP capacity has since been added to the network such as the 725KWe CHP system at the Royal South Hants Hospital which was installed in 2002. Today, the significance of the CHP considerably outweighs the geothermal resource which catalysed the initial project. There are many interesting lessons that can be learned from the Southampton case, not least the way in which district heating systems can be started from scratch and the processes of evolution that occurs during their expansion. The city remains committed to the further development of distributed energy in the system meaning that this process is likely to continue into the future.

(See:http://www.cofely-gdfsuez.co.uk/solutions/district-energy/district-energy-schemes/southampton-district-energy/; http://www.greenpeace.org.uk/climate/case-study-southampton, Wiltshire, (2011), Smith (2000)

2.4 Centralised generation in the Thousand Flowers pathway

The aim of this section is to examine centralised generation in the Thousand Flowers pathway, and specifically how ownership of centralised generation capacity may change between now and 2050. Approximately 71% of the UK's electricity generation capacity is currently owned by the Big Six (British Gas, EDF Energy, E.On, RWE NPower, Scottish Power, and SSE). In an analysis of the current circumstances and how the proposed generation mix could be achieved by 2050, we argue that the most favourable scenario for ownership of centralised generation by 2050 in this pathway is a managed transition of centralised generation assets to a regulated asset base approach for baseload assets, with capacity payments for flexible generators.

2.4.1 Where are we now?

In 2011/12 there were 854 generators in the UK with a total capacity of 96,206MW (National Grid, 2011). Of these, 184 (87,242MW capacity) were dedicated to meeting average cold spells (ACS) demand – generators that are required to meet peak electricity demand in winter. These largely consist of generators linked to the transmission network in England and Wales and the two Scottish electricity grids, together with a small number of large generators that are, 'not so linked' and comprise some of the UK's largest wind farms. The second group of around 670 generators (8,964MW capacity) comprise smaller scale renewable energy and CHP generation (Rutledge, 2012).

Currently a group of vertically integrated energy firms hold a majority market share of both electrical generation and domestic electrical supply, with added benefits from operating in both markets. 'Vertical integration' applied here means that the companies households and businesses buy electricity from often have the same ownership as companies that generate comparable amounts to match their supply obligations.

The business models of the various large utilities are based on the capacity and flexibility of their generation mix and their ability to match their generation profiles to their supply commitments. They then use the wholesale market to buy or sell shortfalls or excesses. If the supply market were to diversify significantly (i.e. MO-ESCos penetration), each utility's supply market share would reduce. As a result a utility would have to decide what to do with excess generating capacity, which it could no longer match to supply to secure retail prices. It could sell the generating asset, trade the supply on the general wholesale market or, depending on the asset's generating flexibility, use it as peaking capacity. Peaking capacity typically receives high unit prices during cold, cloudy, spells when other technologies are unable to meet daily demand peaks.

Is there anything wrong with vertically integration?

Increased reported profits at a time of rising household energy bills (gas and electricity), declining real incomes, mis-selling of products, and confusing consumer tariffs have increased public mistrust in large utilities. This has led to growing political pressure for regulatory reform such as profit caps/consumer prices freezes (Green Party, 2012; Labour Party, 2013) and calls for renationalisation of the energy system (e.g. Cumbers et al, 2013; Ecotricity; 2013).

In late 2013, a YouGov poll reported that 68% of respondents were supportive of renationalisation of the energy system. It is noted, however, that generation, transmission, and supply are often conflated and confused in these debates. A problem with the existence of the large utility model relates to its vertical integration, as suppliers generate just enough to cover demand to ensure they receive the best retail price. Liquidity effectively refers to electricity available to trade in the open market. According to a Business and Enterprise Committee inquiry into energy prices, fuel poverty and Ofgem, vertical integration has created illiquidity in the wholesale market which:

> '…contributes to price volatility and poor price transparency. This, in turn, dulls market signals for potential investors in new capacity, outside of the Big 6.' (Business and Enterprise Committee, 2008, pp. 27)

This lack of liquidity has several implications. In particular, it has created an uneven playing field for smaller electricity suppliers. Vertically integrated firms are unwilling to sell their generation to firms that are effectively competing with them (Business and Enterprise Committee, 2008). Policy proposals following the energy supply probe (Ofgem, 2008), and outlined in the retail market review (Ofgem, 2013b), included a requirement of the Big Six to make a proportion of power generation available to the market through a monthly mandatory auction to enhance liquidity (Ofgem, 2014c). Overcoming the liquidity problem is being addressed by national policy and should lead to increased ability for suppliers without generation capacity to compete in the supply market. This new liquidity in the wholesale market would be necessary if MO-ESCos were to proliferate, as it is likely they will rely heavily on the wholesale market in the early stages, reducing as local generation portfolios build. As the supply landscape diversifies further, however, the civic

energy sector would have a more disruptive effect on the extant business models in the energy sector, affecting the incentives to construct necessary large-scale capacity.

2.4.2 Where does this pathway take us?

In the Thousand Flowers pathway, 50% of generation will be distributed and managed/owned by the civic energy sector by 2050. The remaining 50% of generation, whilst decarbonised, will need to be from transmission level generation, providing some baseload, peaking, and balancing capacity. The energy mix of this centralised generation will include three nuclear plants, several gas and coal plants with CCS, large-scale renewable energy (onshore and offshore wind, tidal, and wave) and super-efficient combined cycle gas turbines (CCGT) with CCS for backup (Barton et al, 2013; Foxon et al, 2010).

In the Thousand Flowers pathway new thermal plants, particularly dispatchable gas for peaking and balancing and nuclear and coal with CCS for baseload, will still be required. In order for this new capacity to be built, and/or maintained, it has to be economically feasible. This feasibility is unlikely in a future where small- and medium-scale renewables and CHP cover more and more demand, meaning these large plants generate lower than optimum capacities much of the time. Thus we believe that under this scenario of high renewables and CHP penetration, transmission level generation would need to play a balancing and peaking role with less space for baseload plants. To present a sensible economic case for constructing and maintaining transmission level assets, the owners of those assets must be compensated for keeping the plant open and available, not by generating enough energy to make a profit. This could be achieved by asking generators to bid to provide capacity in a 'reverse auction' where the bidder offering the cheapest capacity wins and is offered payments for future generation, providing investors with certainty that the plant will realise revenue.

The need for these capacity auctions is not peculiar to the Thousand Flowers pathway; in the UK's Electricity Market Reform (EMR) the government has legislated for capacity auctions, which are aimed at covering peak demand whilst renewables are not generating (DECC, 2014b). The UK's first capacity auction for projected peak capacity availability in winter 2018 was underway at the time of writing (National Grid, 2014a).

What is particular to the Thousand Flowers pathway is that demand reduction, along with much greater penetration of distributed generation sources, affects the business models of both peaking plants and baseload generators on the transmission network. This level of penetration of distributed renewables may lead to the need to run systemic capacity auctions i.e. for the majority of future transmission level assets. This issue has been investigated by Citigroup (2013) who similarly conclude that in the German case in particular, a move to capacity auctions for the majority of transmission level assets will most likely be driven by the penetration of solar and wind into traditional baseload as early as 2016 (Citigroup, 2013).

Is there anything wrong with capacity auctions for UK generation capacity?

Whilst running capacity auctions for peaking gas plants is currently acceptable to the public, it is unclear as to the public acceptability of charging consumer bills to build new nuclear and other thermal capacity (Macalister and McQue, 2014), especially where this capacity is to be owned by non-UK governments or companies. This raises the question of whether ownership matters under a capacity payments system.

Almost 75% of UK generation capacity is owned by large utilities not based in the UK (Rutledge, 2012), of which almost 20% is owned by non-UK companies with majority or significant state ownership[17]. While issues of economic nationalism may be of no consequence to a dispassionate view of the energy system, public acceptability is important. Foreign ownership of energy assets has not yet proved problematic from a public acceptability perspective; with increasing state subsidy, however, transparency may need to increase. The need to pay non-UK firms to build plants that lie idle much of the time may be enough to aggravate public acceptance of electricity prices. If the ownership of capacity auction plants were to deliver revenues within the UK, this might be more palatable. Yet the UK government does not own significant shares in any companies likely to invest in transmission level generation in the near future.

Concerns have begun to be expressed by several authors on the ownership structure of the UK energy system in terms of the investment priorities of non-UK firms in times of capital constraint (Cumbers et al., 2013; Rutledge, 2012; Newton, 2011; Macalister and McQue, 2014). Furthermore, it has been suggested that the growing trend of non-UK ownership undermines labour market skills and innovation (Mills, 2013). Cumbers et al. (2013) find the market for renewable manufacturing to be dominated by European firms, leading to a failure to realise the potential in terms of local employment, supply chain, and economic development in the UK, 'with fewer than 4,000 jobs so far created in manufacturing of renewable technologies' (Cumbers et al, 2013, pp.2).

Both these factors affect the health of the UK economy and could undermine future domestic development of the low-carbon generation sector in particular. One solution might be for the state to adopt the approach of several western European nations by taking a majority stake in a generation developer and participating in capacity auctions with an independent regulator. This would begin to solve the problem of 'offshoring' energy value and could gradually build up a skills base in constructing transmission level assets in the UK.

2.4.3 Options for centralised generation

The expansion of a civic energy sector, both in the generation and supply areas of electricity would disrupt the vertically integrated business model of large utilities. This analysis questioned the ability and willingness of incumbent actors to continue to build and maintain the necessary transmission level assets to meet the demand not generated by the civic energy sector. We have explored the alternatives for meeting this need and some of the likely pitfalls. Table 8 summarises these options.

Table 8 Options for centralised generation.

Options for transmission level generation	Description	Pros	Cons
Do nothing	Continue to allow the market to find ways of keeping transmission level assets viable	The responsibility for security of supply remains with the market, aided by National Grid, and Government.	Likely to lead to very high prices for peak capacity on the wholesale market to keep plants viable Risks no viable model being found and blackouts occur anyway
Run capacity auctions for peaking plant only	The state takes responsibility for the investment viability of peaking plant and runs capacity auctions to ensure availability	Peaking capacity subject to closer scrutiny Notionally ensures security of supply and continues to support some renewable deployment Provides certainty to investors on returns, lowering the cost of capital for asset builds	Does not deal with deep penetration of renewables into the traditional areas of base load May not achieve sufficient competition from market actors leading to inefficient auctions and higher prices State assumes de-facto responsibility for security of supply
Run systemic capacity auctions for majority of transmission level assets	The state takes responsibility for the investment viability of most transmission level assets and runs capacity auctions to ensure availability	Whole system costs subject to closer scrutiny Ensures security of supply and supports deeper renewable penetration Provides certainty to investors on returns, lowering the cost of capital for asset builds	May lead to problems with public acceptance due to majority foreign ownership May not achieve sufficient competition from market actors leading to inefficient auctions and higher prices Government assumes almost total responsibility for the viability of transmission level generation
Run capacity peaking or systemic capacity auctions with inclusion of state owner generator	The state takes responsibility for the investment viability of most transmission level assets, sanctions third party capacity auctions to ensure availability and participates in capacity auctions through limited liability majority owned company	Whole system costs subject to closer scrutiny Ensures security of supply and supports deeper renewable penetration Provides certainty to investors on returns, lowering the cost of capital for asset builds Ensures more competition as state can act as bidder of last resort Returns value to UK citizens from the energy system reducing public acceptability issues	Government assumes almost total responsibility for the viability of transmission level generation Current lack of adequate skills base Would need some capitalisation from national balance sheet.
Move to a fully regulated asset base approach for base load plant with capacity auctions for peaking plant	The state takes responsibility for the investment viability of most transmission level assets by moving remuneration to a regulated revenues approach	Ensures security of supply and supports deeper renewable penetration Provides certainty to investors on returns, lowering the cost of capital for asset builds System costs set via regulation	Can undermine innovation Allowable revenues structure would need to be very complex
Renationalisation	Renationalisation of generation capacity	Lower cost of capital – the state can borrow more cheaply Reinvestment of profits, investment into energy system and reduction in costs: would not have to pay a large proportion of its profits out to shareholders in the form of dividends Potential for longer-term planning and would make it easier to drive through policy goals	Would require large amounts of capital on the balance sheet of the state Transfers systemic and financial risk onto the state Leaves the energy system susceptible to state fiscal crises

If capacity payments are to underpin a significant proportion of peaking assets, and baseload were delivered by a regulated asset base (RAB) approach, the generation sector will be less market-led due to increased state control. If this is the case, the state assumes de-facto responsibility for system balancing through letting the correct level of capacity at auction. However, capacity auctions are already being run in the UK and the RAB approach is already in operation for distribution networks. It is important to note these issues are salient under any scenario in which renewable energy penetration is significant.

Our analysis suggests capacity auctions would reach deeper into the centralised generation system in a distributed energy future. As the local CHP generators are heat-led, there may be a need to use capacity payments to provide summer capacity, with the addition of a majority state-owned generation developer as bidder of last resort or as an active competitor, addressing some of the issues of non-UK ownership of generation. The notion of a 'baseload' may change considerably as transmission level assets essentially compete with distributed generators. The operation of an RAB approach in this scenario would then be a far more complex task than today, and would require strategic co-ordination between distributed generators and the body responsible for ensuring transmission level capacity is adequate. This **National Energy Programme** (NEP) would be a key function of system regulation. As such, our next concern in this analysis was the regulation of this system.

2.5 National energy system regulation, Ofgem +

The Thousand Flowers pathway characterises a substantially changed role for the regulation of the energy sector. We suggest a pro-active regulator would be best placed to facilitate this transition. This section discusses Ofgem+ and how energy regulation could facilitate a civic energy future.

Ofgem's primary duty is to protect the interests of consumers; it has hitherto measured this via metrics of security of supply and unit costs, pursued via means of market competition. The regulator's main objective is to protect existing and future consumers' interests in relation to gas conveyed through pipes and electricity conveyed by distribution or transmission systems. In principle, a liberalised energy system is dependent on private investment in generation capacity to meet final demand and appropriate government support. The RTP project understands this as a system of hybrid governance where, the policy regime is shaped to enable market forces to deliver electricity capacity.

The UK Government's Electricity Market Reform (EMR) (DECC, 2012) aimed to address concerns that the incentives for future private investment in generation assets would be insufficient to meet projected demand. This is based on Ofgem's (2009a) estimates of a £110bn investment requirement to 2020. EMR sets out a stronger role for the state by setting the price generators receive for renewable electricity, and running capacity auctions for future peak loads through the National Grid. Ofgem will oversee the performance of the system operator in its EMR delivery role, ensuring value for money and incentivising performance. As the independent energy regulator, Ofgem will continue to regulate the system operator as well as generation, distribution, and supply companies (DECC, 2012). We characterise this as a hybrid state/market logic as there is an expanded role for central co-ordination of generating capacity, i.e. the capacity auctions system. In order to keep the Thousand Flowers pathway open, the regulatory landscape would have to ensure the current EMR does not preclude development of the civic energy sector.

2.5.1 Where are we now?

Until recently energy companies, including small-scale low-carbon schemes, supplying above 2.5MW electricity to domestic customers in Great Britain had to obtain an electricity supply licence under the Electricity Act (1989). These licence conditions obliged suppliers to comply with the full set of regulatory and industry requirements irrespective of scale or ownership. These licenses facilitate wholesale market trading, real time system balancing, retail competition, and consumer protection (Ofgem, 2009). This placed significant burden on smaller producers who wished to achieve market rates for electricity and often led to smaller producers entering into power purchase agreements (PPA's) to avoid the overheads involved in full licenses. In order to facilitate a civic energy sector a regulatory regime would be required that makes space for civic supply and generation to compete on level terms with established market actors.

2.5.2 How might it be done differently?

Recent changes to policy and regulation may be creating these level terms, and could mean a much greater role for distributed energy production.

First, Ofgem's response to the overheads imposed by full licensing has been to offer Licence Lite an opportunity for generators and/or third parties to obtain a new type of licence in partnership with a fully licensed body, which will enable generators to achieve retail prices for electricity without being party to the full electricity trading system. The first Licence Lite application is being made by the Greater London Authority (GLA), which has made an application on behalf of the Mayor of London

as part of the city's aspiration to source 25% of London's energy locally by 2025 (GLA, 2012).

Second, DECC's community energy strategy (DECC, 2014) aims to expand the volume and capacity of the community energy sector in the UK. The strategy views Licence Lite as a significant incentive for community generation, and presages an increase to the upper limit of the community FiT to 10MW.

Finally, there is increasing interest in city and city regional participation in energy supply and generation. In particular, the Core Cities partnership has set out their aspirations on energy in 'Step 6' of their wider growth prospectus. Step 6; Power up the cities (Core Cities, 2013) amounts to a significant strategy of urban energy service and supply which has the potential to deliver substantial benefits to distributed generators and consumers. In particular, Step 6 envisages municipal-scale energy supply companies which are specifically aimed at aggregating PPA's from distributed generators. This closely resembles the MO-ESCo model described above.

Each of these developments comes at a time when EMR is incentivising an expansion of renewable capacity, much of which will benefit from new business models offered by a diverse licensing regime, and constructing the capacity mechanism to ensure security of supply.

2.5.3 Where does this pathway take us?

Recent analysis by researchers in the RTP project understands the Licence Lite development to be a positive step forward; however, it recognises there is no requirement on third party suppliers to provide the necessary services (Bolton and Foxon, 2013). The proliferation of a civic energy sector may begin to challenge the market share of incumbent utilities (who will initially be the third party licensed suppliers) and lead to a conflict of interest between vertically integrated utilities acting as third parties and independent power producers operating Licence Lite. Under this conflict of interest there is a clear incentive for willing municipalities to obtain full supply licences, offering an alternative to incumbent utilities, in order to grow the distributed generation sector in their locality and add to the economic health of the area in terms of employment growth, inward investment, energy security, and local decarbonisation.

To facilitate this we propose the regulator could adopt a dual focus. First, the current system that regulates transmission level assets and utilities would continue initially as today, but over time begin to operate a capacity auction model, including a UK state bidder, which operates the capacity mechanism deeper into baseload and may manage a regulated asset base. These capacity auctions and asset base regulation would be run by a National Energy Programme (NEP) which would ensure sufficient flexible capacity available for average cold spells or summer lulls in distributed CHP. This may need to be separate from the regulatory function at the national level.

Second, there would need to be an expanded focus on the distribution level to deal with city-scale suppliers (MO-ESCos) and distributed generators (LES). This distribution level focus includes a regional role for Ofgem in creating subsidiary regional energy regulators, focused on the operation of distributed generation and regional suppliers. These subsidiary regulators could run along the boundaries of the distribution networks (for conceptual clarity as opposed to technical necessity) and are described in more detail below as Regional Energy Partnerships (REP).

As such Ofgem+ would eventually need to regulate a national transmission system with a strategic capacity mechanism and/or RAB, alongside a regional civic energy sector that maximises utilisation of distributed generation potential.

Taken together, the regional role of Ofgem+ described below, and the need for a transmission level regulator to ensure balancing capacity, is more in line with a state co-ordinated role than a liberalised market approach. Whilst the liberalised market has delivered incremental cost reductions in supply (Bolton and Foxon, 2013; Hannon et al., 2013) it is unlikely to be able to deliver substantial system change under current incentives (DECC, 2012; Institution of Engineering and Technology, 2013) and unlikely to source investment for transmission level assets under declining market share as presaged by this pathway.

Analysis by the Institution of Engineering and Technology (2013) has demonstrated the need for a system architect for a future incorporating more distributed energy generation. This is compatible with our view that system regulation more compatible with the Thousand Flowers pathway would be achieved through the dual focus Ofgem+ approach, this National Energy Programme would act as a de-facto system architect. It is, however, unclear as to the conflict of interest between closer integration of the regulatory and system balancing function when this function is oriented toward ensuring backup peaking capacity for a predominantly distributed system. The next section describes the regional role for the regulator based on the understanding that transmission level balancing can be achieved in this way.

2.6 Regional Energy Partnerships

Our analysis of the Thousand Flowers pathway showed a gap between individual system participants and national regulation; put simply there is very little institutional energy co-ordination or planning at a regional level. Our analysis showed a role for Regional Energy Partnerships (REPs) to be collectively responsible for the strategic delivery of 50% final electricity demand by distributed generation. These bodies would have responsibility for regulation of both suppliers and generators in the civic energy sector, i.e. MO-ESCos and Local Energy Schemes (LES).

At the transmission level the National Energy Programme (NEP), which forms the other half of Ofgem+, is responsible for ensuring the capacity is available for system balancing.

The main role of the REPs is to create plans for, and facilitate, the achievement of regional distributed generation and energy efficiency targets. REPs have legal responsibility for working with all local energy generation schemes (LES), local authorities (LAs), distribution network operators (DNOs), and other statutory bodies. More specifically, the role of each REP is to work in collaboration with other regional institutions to:

- Develop spatial plans for distributed energy generation,
- Set strategic targets for expanding low-carbon supply and increasing energy efficiency,
- Facilitate the creation and regulation of MO-ESCos,
- Develop and implement energy efficiency schemes, and
- Communicate with NEP to contribute to building a national picture of distributed generation across the UK – and thus national capacity planning.

2.6.1 Where are we now?

Energy policy and regulation is delivered nationally and local governance of energy infrastructure is restricted to planning powers for projects up to 50MW; beyond which, in England and Wales, the major infrastructure planning unit is responsible; with the Northern Ireland Executive and the Scottish Government responsible for infrastructure decisions in their respective territories. Other infrastructural sectors, such as transport, housing, and waste, have found regional planning and co-ordination an advantage. For example, a regional focus is key to the ways economic development and transport are governed across the UK.

Prior to 1 July 2012, England was divided into eight regional development agencies (RDAs) whose aim was to promote economic development, co-ordinate transport infrastructure funding, and in some cases govern housing strategy. Under the Localism Act (House of Commons, 2011), RDAs were replaced by Local Enterprise Partnerships (LEPs) whose 'geography properly reflects the natural economic areas of England' (BIS, 2010, pp. 12) and whose local economy objectives are similar to the RDAs. The UK government hopes that LEPs will play an important role in promoting and delivering renewable energy at regional scales.

With the abolition of the RDAs came the abandonment of regional spatial strategies, some of which included targets for renewable energy development. Spatial planning for renewable energy projects has now been passed to local authorities who are expected to include renewable energy in their local development plans. There are also more local opportunities for communities to draw up neighbourhood plans which, combined with 'right-to-build' powers for building small-scale energy projects, is anticipated to encourage more community-scale renewable energy development.

Whilst spatial planning for renewable energy has been controversial (Betts, 2011) it has been advocated by environmental bodies such as the RSPB (RSPB, 2013). Scotland, for example, already requires local authorities to include a spatial framework for onshore wind in their development plans (Scottish Government, 2013).

In terms of monitoring renewable energy projects, there are only a few local authorities which have formal data monitoring systems to identify renewable energy projects (RegenSW, 2013). Nationally, Ofgem monitor the schemes they administer on behalf of the government by keeping a register of all renewable and CHP projects across the UK (Ofgem, 2013c).

Existing approaches to renewable energy have, therefore, recognised the importance of regional and local scales, but remain in the early stages of developing comprehensive regional energy strategies (Ove Arup, 2009). Regional Energy Partnerships would begin to address this problem.

2.6.2 Where does this pathway take us?

Under this new institutional structure we propose, for the Thousand Flowers pathway, a useful approach would be to divide the regulatory authority (Ofgem+) into two – the National Energy Programme (NEP) overseeing large-scale electricity generation and Regional Energy Partnerships (REPs) overseeing distributed, smaller-scale generation across the country.

REPs would be responsible for the issue of licences to LES and other distributed energy generators in the region. REPs would have a key role in facilitating MO-ESCo development through capacity building and license support. This would provide faster uptake of the MO-ESCo model and bring retail price PPA's close to the local energy schemes.

There are three main assumptions underlying the creation of Regional Energy Partnerships:

1. The geographical boundaries of each REP are determined by the extent of the areas covered by distribution network operators (DNOs). REPs are therefore coterminous with DNO boundaries. The geographical configuration used to align distribution network (DN) operation with a regulatory organisation requires a fully collaborative mode of operation between REPs, DNOs, municipalities, and LES.
2. REPs ensure that all energy generation projects are conducted within an agreement which reflects a commitment to transparency and procedural fairness. This framework is developed at a national level through the NEP and implemented at the regional level by the REPs, including scope for regional variation.
3. REPs provide feasibility, legal, policy, and financial support for the development and operationalisation of LES and MO-ESCos.

The development and support function assesses the potential for distributed generation and helps develop technically feasible schemes. This would also include helping to develop suitable financial models and assist LES in securing funds.

2.6.3 New geographies of energy governance

Previous research has shown that electricity network industries are largely hidden from consumers and this has, arguably, affected public understanding of the network and hampered network development efforts (Cotton and Devine-Wright, 2012). To address this, and other barriers to changing the electricity system, one of the main changes in the new structure is to provide an organisation which co-exists on the same geographical boundaries as the DNOs.

In creating geographical compatibility between DNOs and REPs, the aim is to align closely the generation potential and demand management aspects of the distribution network. Alongside this partnership is an increased role for local authorities in energy generation, monitoring, demand management, and efficiency initiatives. Specialist energy groups are established within each local authority to collaborate with the relevant DNO and REP co-ordinators, to create regionally-specific energy plans. Furthermore, the inclusion of LES in planning for energy widens the scope for public involvement.

Steps in this direction have already been taken, for example, with local authorities who have, at different points in time, and with varying degrees of success, designed spatial plans for renewable energy within their locality (Ove Arup, 2009). DNOs are also becoming more heavily involved in stakeholder engagement (e.g. UK Power Networks, 2013). These reflect some of the ways in which the collaborative approach advocated by the new institutional structure may develop.

However, as electricity distribution networks cross multiple local authority boundaries, a different administrative landscape would be overseen by REP. Within this, there would be opportunities for local authorities to work with DNOs in order to enable development based on strategic energy plans developed at local and regional levels, to enable efficient and cost-effective use of local resources. Denmark is already supporting its municipalities to do this by providing funding for partnership working (The Danish Government, 2011).

The regulatory priorities of the REPs, whilst still focused on reducing supply interruptions, avoiding the risk of asset failure, and maintaining energy affordability, would be extended to ensure that DNOs assume responsibility for managing a more dynamic system and encourage flexible generation combined with storage. This builds on current plans to transform DNOs into distribution system operators (DSOs) (UK Power Networks, 2013) and forms the basis of an integrated transition in regional energy development (see section 2.7.2).

The Energy Programme Agreement

In order to integrate and increase responsibility and commitment to local and regional energy generation, REPs would ensure that organisations across the region commit to an Energy Programme Agreement. This is drawn up through collaboration between REPs, LAs, DNOs, LESs, and local representatives, and contributes to defining both regional and local energy plans. Within the agreement are best practice procedures for energy consenting and achieving social objective targets (such as decreasing fuel poverty). This model of responsibility builds on the Courtauld Commitment, a voluntary agreement developed by WRAP (Waste and Resources Action Programme), which has been instrumental in improving resource efficiency and reducing carbon emissions and environmental impact in the UK's waste sector (WRAP, 2013).

Operational support for Local Energy Schemes

REPs are responsible for providing operational support to Local Energy Schemes (LES) and MO-ESCos. This includes help with arranging financing, developing and innovating new business models for LES development, encouraging local participation and involvement in LES, and spatial planning for energy. In order to facilitate efficient development and implementation, REPs are responsible for issuing licences to small electricity generators and/or MO-ESCos. In charging fairly for such licences, REPs could cover some of their operating costs. In addition, REPs' role would be to take an overview of all projects within a certain area, matching developments with regional spatial plans.

2.6.4 Defining the need for regional co-ordination

Whilst much of the discussion within this analysis is based on technical analysis and observed institutional issues with distributed generation, the need for a regionally-focused regulatory and capacity building body is a novel step. Throughout our analysis we returned to the capacity and skills issues within local communities, municipalities, and civil society as a barrier to broader engagement in distributed energy. The creation of regional facilitation and regulation arose frequently as an issue and has solidified in what we believe to be a sensible institutional response to a vastly increased regulatory burden and the need to provide institutional support to an emerging sector. Adopting a regional approach means resources and support can be flexible. The renewable energy capacity of different regions would define the needs of the civic energy sector. In the northwest for example, financial, regulatory, and technological development of wind capacity might be more important than solar PV, and vice versa in the southeast.

Further, the creation of a regional Energy Programme Agreement would form a key part of the evidence base for the National Energy Programme, as it would contain projections, build rates, and future generation predictions for distributed generators. This would allow for more foresight in planning the system balancing function.

What was clear is that in a future in which distributed electricity generation and municipal supply are prevalent, a nationally administered, one size fits all regulatory system is likely to be unsuitable. The exact specifications of regional regulation and content of regional strategies for energy provision were beyond the scope of this analysis. Nevertheless, we feel the Regional Energy Partnership approach outlined above would be a useful response to the local regulatory and institutional capacity challenges posed by this pathway.

2.7 Smart Grids and the Thousand Flowers Pathway

Under the Thousand Flowers pathway, the civic energy sector will rely on smart grids to facilitate expanded renewables connections and manage demand and supply within DNO networks. It will enable the aggregation of distributed energy schemes with demand management so that supply in one area can be matched to demand on other parts of an urban or rural network more effectively. The smart grid also facilitates storage and can deploy remote demand management, reducing the short term investment need for expensive reinforcement to accommodate expanded renewable generation (Papadaskalopoulos et al, 2014)

Smart grids form a key part of the transition to low-carbon energy systems, as stressed in Part I. The UK's energy regulator has estimated that meeting electricity system decarbonisation targets compatible with the UK's Climate Change Act (2008, see CCC, 2008) would require up to £32bn of investment in distribution assets by 2020 (Ofgem, 2010a). Here, we briefly describe what the Thousand Flowers pathway means for the smart grid, and link to scenario pathways research beyond the RTP project, which has focused explicitly on electricity distribution scenarios.

2.7.1 Where are we now?

Whilst there is no universal definition of what makes an electricity distribution grid 'smart', Xenias et al. (2014) define the main features of a smart grid as an energy network that can: manage distributed suppliers; communicate between producers and users of electricity; utilise ICT to respond to and manage demand; and ensure safe and secure electricity distribution. The current electricity distribution system in the UK does not incorporate these features and, except for some demonstration projects, is still a 'dumb' grid that is maintained to accommodate one-way power flow and ensure security of supply (Balta-Ozkan et al., 2014).

Hall and Foxon (2014) track the regulation of distribution companies through the allowable revenue RPI-X and RIIO (revenue = incentives + innovation + outputs) frameworks which structure the revenues distribution network operators (DNOs) can accrue from their assets. RIIO is a revenue structure considered more suited to the implementation of smart grid solutions (Müller, 2011), since it rewards innovation. It is not yet clear whether these new revenue structures will be sufficient to incentivise a shift to new roles and business models for DNOs that are more compatible with distributed generation and enhanced demand management. These questions are bound up with the changing business models of DNOs as they evolve into distribution system operators (DSOs).

Openshaw (2012) describes the need to shift from a distribution network operator (DNO) model to a distribution system operator (DSO) model. A DSO model would incorporate flexible demand response, system balancing, storage, and virtual power plant services, in addition to network maintenance and operation. Scarsella (in Newton, 2013) defines a DSO as having 'access to a portfolio of responsive demand, storage and controllable generation assets that can be used to actively contribute to both distribution network and wider system operation. A DSO will build and operate a flexible network with the ability to control local flows'.

2.7.2 Why transition to DSOs?

Under the current regime, a DNO simply has to expand the network in response to growth in maximum or peak demand. It is not required to influence demand or generation and is interested in flexibility only where such flexibility directly supports priorities imposed on it by the regulator (for example in reducing supply interruptions and protecting the network from infrastructure failures). A DSO, on the other hand, is envisioned to have access to a portfolio of responsive demand, storage, and distributed generation (DG) assets that are in some way controllable. These assets can help match supply and demand and increase the flexibility of the network while reducing peaks and enabling additional use of DG and reducing the need for large investment in low voltage network infrastructure (UKPN, 2014).

Many technologies likely to have a big impact on the distribution network, such as EVs, heat pumps, CHP, and solar PV, will not be distributed evenly but will have specific local hotspots. This will require a highly localised and flexible approach to the development of the smart grid (Balta-Ozkan et al., 2014). Responding to this clustering will require flexible and innovative organisations that are acutely aware of local resources and limitations. Few would argue that this description applies to the current UK DNOs, and the development of such skills and capacities would be an important part of their transition to DSOs.

2.7.3 Where does this pathway take us?

A recent contribution by the UK Energy Research Centre (UKERC) has analysed possible scenarios for smart grid development in the UK (Balta-Ozkan et al, 2014). Their research adopts a narrative scenario approach, similar to our own description of transition pathways, to describe plausible futures for the development of the smart grid, with different mixes of ownership, control, technological progression, and user engagement. The work by UKERC describes four scenarios in which smart distribution could occur: Minimum Smart, Smart Power Sector, Smart 2050, and Groundswell.

The Minimum Smart scenario envisages continuing reliance on centralised generation underpinned by unconventional fossil fuels. The Smart Power Sector scenario describes a higher penetration of large renewables but low consumer engagement leading to problems of system balancing. The Smart 2050 scenario is characterised by large renewables growth up to 2020, both large- and small-scale. In this scenario the ESCo business model is an enabler to grid and residential scale generation, storage, and load management. The final Groundswell scenario has most in common with the Thousand Flowers pathway in that it describes a 'state of the world in 2050' where 'a significant amount of electricity is generated at household and community level, although large, centralised generation still has a role to play in meeting demand from urban centres and industry' (Balta-Ozkan et al, 2014, p.37). Similar to Thousand Flowers, municipal and community engagement in the energy system is a key enabler.

The Groundswell scenario parallels our own analysis in that the role of the DNOs needs to change to accommodate a significant expansion of residential generation. DNOs become DSOs early in the Groundswell scenario (2020-2030), driven by municipally-led energy programmes aimed at decentralisation.

2.7.4 What will a DSO look like?

Research within the RTP project has analysed the barriers to local energy schemes imposed by DNO regulation (Bolton and Foxon, 2013) and the ways in which cities and city regions might interact with DNOs to accelerate the delivery of smart grids (Hall and Foxon, 2014). This research has found new license agreements, regulatory regimes, and business models are needed to manage an increase in distributed generation and facilitate a growing civic energy sector.

Here, four options for the operation of distribution infrastructures in the Thousand Flowers pathway are presented. Part I described the technical challenge posed by increased distributed generation in the pathway whilst here the ownership, governance, and control of the system are explored with reference to the institutional framework developed above.

Option 1 – Technological progression

Option 1 would be for the current role of DNOs to evolve into DSOs by incrementally adding ICT and new smart infrastructures to enable them to balance flexible demand with dispatchable resources, whilst undertaking non-regulated activity such as aggregation of commercial demand response (Openshaw, 2012).

Here, the roles of DNOs remain based predominantly on network stability and allow most trading of electricity and capacity services to continue at the national scale. DSOs could contract with MO-ESCos for flexible demand response on areas of network constraint, as MO-ESCos are assumed to have significant, if not full, market penetration in household supply.

Option 2 – Technological progression with ESCo micro grids

Option 2 is similar to Option 1 but with the added ability of MO-ESCos to take control of part or all of the lower voltage[18] distribution infrastructure in their respective territories. Hall and Foxon (2014) describe the multiple benefits municipalities can gain from ownership of distribution infrastructure and the innovative financing and funding arrangements that can be achieved outside the regulated revenues structure when municipalities are part or full owners of distribution infrastructures. The regional DSO would retain responsibility for medium to high voltages, but allow new business models to bring forward smart solutions at household, street, and neighbourhood level.

Option 3 – Tiered management

Another option for the step change from DNO to DSOs is that of a tiered system. This is where the transmission system operates in a very similar way to the current system but DSOs also operate nested regional markets that mirror the national market. This allows the trading of capacity and generation as well as demand response and other ancillary services between geographically proximate generators, suppliers, and demand centres. The multiple MO-ESCos within a DSO territory trade electricity and demand response on a regional exchange managed by the DSO in partnership with the Regional Energy Partnership; the shortfall in capacity is then bought by the DSO from the wholesale market and the costs passed to MO-ESCos. This would be closest to the notion of DSOs as operators of virtual power plants.

The Tiered management option would represent a significant new role for DNOs/DSOs. The principle of separating supply and network management is preserved. The ability of a regional stakeholder to balance distributed generation alongside household and commercial demand response contracting would enable much greater regional management of energy resources and provide the DNOs/DSO much greater foresight on network health and operation. Moreover, it is possible for the current geographical boundaries between DNOs to remain the same and, while DSOs will also have to manage internal markets within their network, the main actors at the distribution network level will not change substantially.

Option 4 – Meso-micro DSOs

This represents a more radical re-organisation of the current system and of its institutional arrangements. Under this option, the distribution network franchises would become much smaller and better aligned to local government boundaries. Contracts for managing distribution network franchises cease to be perpetual, but are instead auctioned at set periods (around every 20 years). MO-ESCos are free to bid (if they choose) for local distribution networks and to become DSOs and MO-ESCos at the same time.. This is similar to Option 2 but would require new franchisees to take responsibility for the entire distribution networks from 230V household connections to the 132kV network, which typically supplies large factories and heavy industry.

A number of possible configurations exist within this re-structure: a single MO-ESCo could bid for a number of franchises and operate them as a city-regional network thereby amalgamating previously separated areas; a group of MO-ESCos may bid collectively for several concessions, where it may be likely that the operation of these amalgamated grids would be run as a public private partnership with a third party specialised network operator. Distribution infrastructure under the ownership of one or more local MO-ESCos would enable new configurations of the flows of value within the energy system through generation, distribution, and supply, which may be more compatible with the expansion of a civic energy sector with high levels of distributed generation.

Each option for grid management presented here is designed to be more compatible with the emergence of a civic energy sector and the Thousand Flowers pathway than current institutional arrangements. Each option or hybrid of options would have to negotiate new contractual relationships, technological change, business models, and regulation. Each may have its own perverse incentives and problems, but each is a cogent response to the problems identified by several studies[19] in allowing distribution networks and their institutional practices to be more accommodating of energy system transitions.

2.8 Summary

This section has presented a number of different institutional scenarios dealing with what kind of governance and ownership arrangements might be needed to support an electricity system that relies on 50% distributed generation by 2050. They are underpinned by the rationale that any serious effort to develop a distributed energy system will inevitably require a different set of institutional arrangements to that which supports the centralised energy production systems of today. These scenarios are intended to be the start of a conversation rather than a conclusion, and, whilst such an exercise contains an inevitable degree of speculation, it is important to note that the institutional frameworks discussed do exist in similar forms either in other sectors, at niche scale in the UK, or are substantial system actors elsewhere. Therefore, the developments outlined above do not reflect a complete leap into the unknown, though they would imply a step change in the extent of civic, public, and private involvement in energy systems. The proposed institutional infrastructure builds on a trend that is clearly evident when observing the changes that have occurred in the energy system over the last 30 years and the broadening range of different actors who participate in the energy system. It is also clear that the active involvement of publics and communities needed to support the demand reduction envisaged by this pathway, will rely on new networks of trust, engagement, and public benefit, which are manifestly lacking in the current system.

It is a central contention of this report that new ways of investing in, and deriving value from the energy system open up new opportunities for participation and engagement in the energy transition. Consequently, we have coined the term civic energy sector to capture the diversity of possible new ownership relationships and organisational forms this requires. The use of the signifier civic – as opposed to the currently more prevalent community – reflects the importance of the municipalities and regions in the development of the Thousand Flowers pathway. The importance of the local state is indicated by the significance of the MO-ESCo model as a key actor. The MO-ESCo would link small-scale community-led generation to the wider system, engages consumers in demand management, offers new ways of financing retrofit and novel domestic heating technologies, as well as developing its own generation capacity.

Despite the existence of some exemplar pioneers, questions will inevitably be asked about the capacity of local authorities to take on such a critical role in the energy system. It is for this reason that the capacity building function of the Regional Energy Partnerships (REPs) is of importance. As part of this transformation, the role of existing actors will change, and we have proposed some ways in which the current regulator, incumbent generators, DNOs, and suppliers would adapt to incorporate new civic actors. Similarly, the emergence of smart grids is likely to have a profound effect on electricity systems and their various stakeholders. This includes a possible shift from distribution network operators (DNOs) to distribution system operators (DSOs), which could play an important role in a Thousand Flowers type future through the management of flexible demand response, system balancing, storage, and virtual power plant services.

In developing these institutional scenarios we hope to help frame the ongoing debate around energy transitions and distributed energy futures in particular. As with all scenarios, both technical and socio-institutional, these contributions are to some extent speculative. However, as an exercise in framing the systemic issues around decentralising energy provision, we have found developing these scenarios to be highly informative, and hope that they prove to be useful to the wider energy community.

Part III Conclusions

This report set out to explore what the UK energy system might look like if it followed a pathway of distributed energy provision. A team comprising researchers from engineering and social science disciplines combined their findings from the Realising Transition Pathways (RTP) consortium to explore and question technological and institutional changes compatible with the Thousand Flowers Pathway. The detailed output of this analysis has been presented above. Here we define five 'Headline Messages' that mark the important contributions of this analysis.

3.1 Headline messages

First, by interrogating this pathway the research consortium has identified a potential civic energy sector, beyond large private utilities or expanded state control, that combines community, co-operative, and citizen responses to energy transitions with municipal stakeholders and regional strategies. This civic energy sector encompasses alternative ways of financing, owning and operating generation assets, distribution networks, and new supplier relationships. Importantly, this pathway does pose challenges for incumbent utility business models due to the penetration of distributed generation into baseloads hitherto provided by large thermal plant and in the move towards a greater proportion of customers being served by municipal suppliers in the form of Municipally-Owned Energy Service Companies (MO-ESCos). This observation led to the first headline message:

1. A distributed energy system opens up new avenues for financing the energy transition, but challenges incumbent utility business models.

   A system based on many small- and medium-sized producers reduces dependence on very large scale finance and investment in centralised generation. This opens the energy system up to investment from citizens, municipalities, SMEs, and other new forms of finance. This increases the types of capital available to the energy system. At the same time, traditional utility business models face challenges from renewable generation and supply market share.

We have discussed the issues this may lead to throughout the report. We described the generation technologies that remained at transmission level and proposed options for the future financing of these assets. Equally, the financing of both the distributed generation assets and establishment of municipal supply companies is likely to rely on new forms of citizen investment, new approaches to municipal finance and other forms of innovation in energy investment. Future research will investigate the financial structures compatible with the civic energy sector and develop this knowledge within municipalities, the financial sector, and with civil society.

Second, our investigation of the technological transition in the Thousand Flowers pathway offers one interpretation of a distributed energy generation mix. The report outlined a systemic view of the transitions in Part I, describing the potential of each generation technology to contribute to a distributed energy future, the build rates, costs, and barriers to adoption. This led to the second headline message:

2. It is possible to meet 50% of final electricity demand using distributed generation by 2050, but new infrastructures and emerging technologies are key.

   The energy transition is reliant on smart grids, virtual power plants, and new household generation sources. The use of biomass gasification, widespread use of in-home fuel cells, and the operation of virtual power plants at the local level are emerging technologies that require intensive adoption.

It is clear that for this future to be realised there is a need for a large number of technological milestones to be met by 2050. The availability of biomass for solid fuel and gasification-based generation is a key concern of this pathway. The potential for the UK to increase the production of biomass is limited and this would necessitate sourcing biomass from sustainable supply chains. Further research should investigate the potential for sustainable biomass sourcing for CHP gasification given this technology's advantages in flexibility compared to intermittent renewables. The focus on distributed generation co-ordination has led to a proposal for a greater role for municipalities. Further research will investigate the business models for virtual power plant concepts to be operated on city and regional scales. Equally, smart grid solutions will need to be scaled out from demonstration level projects to network-wide applications. This is already happening through new pricing incentives for DNOs, but to achieve the investments necessary, new partnerships with generation developers, communities, and municipalities will need to be adopted. Combining engineering solutions to grid constraint with user practices and business models is key to the expansion of a distributed energy future.

Third, in every pathway analysed by the RTP consortium, international interconnection is a necessary feature. Most extant scenarios for the UK energy sector to 2030–2050 demonstrate a need for new interconnection infrastructures. Heightened connectivity will give the system heightened flexibility and allow the increased amount of renewable generation to be balanced internationally. Whilst a distributed energy future would mean a high proportion of energy is generated locally, this was not shown to lead to energy independence, even with the high levels of demand reduction adopted within the Thousand Flowers pathway. This led to the third headline message:

3. All projections of the UK's energy future rely on some level of international interconnection and a distributed energy future is no different.

   Moving to a largely distributed generation system has traditionally been thought of as a step towards energy independence. However, this analysis of a distributed energy future has shown that high levels of distributed generation in fact make it necessary for higher levels of interconnection at regional, national, and international levels. This is true for the physical electricity system, which requires more interconnectors to move energy around regions as well as to/from regions, and for its governance and regulation, which requires new institutions to ensure the system evolves to complement regional resources and inform transmission level investment decisions.

Interconnection is used alongside storage to increase the flexibility of the grid, in particular to assist in system balancing requirements and to counteract wind power variability. Interconnectors also enable greater UK participation in the European 'super grid' and support the move towards an integrated European electricity market. Whilst the capacity of interconnectors will increase from the current level, capacity utilisation will fluctuate. Thus, to remain financially viable, interconnectors may need to be operated on a similar capacity mechanism as centralised generation in this pathway. Further research is needed to investigate the viability of interconnector business models under a distributed energy future.

Fourth, this pathway relies heavily on demand reduction, meaning that citizens need to be more engaged, whether through increased efficiency measures, demand response, or smart metering. Electricity can no longer be an anonymous 'black box' delivering energy to the socket. The development of the Thousand Flowers pathway pushes the boundaries of what can be expected from energy efficiency to 2050. Even with an increasingly electrified society (transport and some heat), this pathway achieves significant demand reductions compared to other scenarios. This was deemed to be reliant on strong participation of end-users and led to our fourth headline message:

4. The Thousand Flowers pathway relies on strong demand reduction and demand side participation and management.

   Along with distributed generation technologies this pathway relies on significant per capita demand reduction. This requires effective changes in end-user behavioural patterns and a significant uptake of energy efficient measures alongside energy efficient technological diffusion. A civic energy sector features novel forms of citizen participation where the energy system is no longer an almost anonymous entity, but a critical infrastructure in which all actors play a role. These successful initiatives equip the system with greater flexibility, allowing the nation to make the most of its renewable resources.

In a civic energy sector the development of new generator business models and supplier relationships facilitates a high degree of user involvement. This is both due to the need to leverage finance from new citizen investment and the need to secure active participation from end-users. The MO-ESCo model offers a step change in the supplier–customer relationship, which is more likely to secure end-user engagement. This is especially necessary for achieving significant demand reduction. In the Thousand Flowers pathway, effective end-user participation and engagement results in significant electricity demand reduction from 337TWh in 2010 to 310TWh by 2050 in spite of the considerable increase in electrified transport. This was due to the intensive adoption of demand reduction measures and practices. Further research is needed on the potential for such changes in consumer behaviour and engagement to lead to systemic uptake of energy efficient appliances and conservation measures in buildings and improvement in new build efficiency.

Finally, expanded distributed generation will lead to an increase in the overall number of generators, with different organisational structures based in different regions generating energy at different times and retailing through new supply structures. This is true in most scenarios for the UK's energy future. This analysis has argued that, under the Thousand Flowers pathway, the proliferation of actors in the sector would lead to the need for a new regulatory structure, one which takes a regional focus on regulation, co-ordination, and capacity building of the civic energy sector. This regional approach would complement a national capacity management system, as regional energy strategies would inform capacity requirements on the transmission network. This led to headline message 5:

5. A local and regional approach to distributed energy is vital.

   In order to move to a distributed approach, regional energy strategies and local capacity building will be essential for city regions, municipalities, communities, and citizens. This means complementing our national energy planning with regional and local support for a civic energy sector. This may mean a system of transmission level capacity auctions and contracts and regional level energy strategies and regulation.

It is indeed one of the main contributions of this work to define the compatible interests of citizen, municipal, and community responses to energy transitions as a 'civic' issue and to define these hitherto disparate actors under a broad civic energy sector. In so doing the needs of this sector can be more closely understood, both in terms of synergies and tensions within and between municipal, community, and citizen actors in the energy transition. Taking a regional approach would be a clear step towards bringing civic actors into mainstream energy policy and augmenting the current sector with new forms of finance, ownership, and expertise. Further research will investigate how the interests of civic energy sector actors emerge, and highlight regulatory and financial barriers to, and opportunities for, the sector to achieve its potential.

3.2 Conclusion

This report examined the potential for a distributed energy future for the UK using the Realising Transition Pathways project's Thousand Flowers pathway. We did not present any panaceas, attempt to preference a civil response to energy transition, or claim technological infallibility. We explored the potential of a distributed energy future, noted several possible triggers, and investigated the technological trajectory it could follow, along with an institutional architecture compatible with its development. This was based on the understanding that an energy transition rooted in expanded energy efficiency and distributed generation would require greater levels of participation by civil society. Incorporating new players into the energy sector is fraught with complexity and contestation and yet these can be unpicked and managed by careful analysis. Our construct of a civic response to the energy transition has defined a new understanding of the potential for participation in the energy transition by actors who, in the UK at least, have played only a passive or marginal role in energy system change. In short, we hope to have contributed to the policy, academic, and practitioner debates on managed decarbonisation, energy security, and affordability through the lens of greater civic engagement in energy.

Footnotes

[1] The cumulative published output of the consortium, including journal articles, working, papers conference papers, and books can be accessed at http://www.realisingtransitionpathways.org.uk/publications/index.html

[2] Barton et al (2013)

[3] Department of Energy and Climate Change (2013) UK Energy in Brief. Office for National Statistics, London.

[4] Wholesale electricity prices per MWh of generated electricity, undiscounted, in £(2010)/MWh, based on Economic Appraisal by Trutnevyte E., Strachan N., Dodds P., Pudjianto D. and Strbac G also see Trutnevyte, E., Barton, J. O'Grady, A., Ogunkunle, D., Pudjianto, D., Robertson, E. (2014). Linking a storyline with multiple models: a cross-scale study of the UK power system transition. Technological Forecasting and Social Change, 89, 26-42. Available on request or at: http://dx.doi.org/10.1016/j.techfore.2014.08.018

[5] Foxon, T.J. (2013). Transition pathways for a UK low carbon electricity future. Energy Policy, 52, 10-24.[http://dx.doi.org/10.1016/j.enpol.2012.04.001].

[6] Other companies in include those that 'produce electricity as part of their manufacturing or other commercial activities, but whose main business is not electricity generation. Other generators also cover generation by energy services companies at power stations on an industrial or commercial site where the main purpose is the supply of electricity to that site, even if the energy service company is a subsidiary of a major power producer.' DUKES (2009).

[7] Further details of the technical elaboration of the pathways can be found in (Barnacle, 2012).

[8] Balancing duties are carried out by dispatchable generation, which support intermittent generation technologies through their ability to be responsive to varying demand, by ramping up and down production as required.

[9] See http://www.ameresco.com/page/case-studies-library

[10] See http://www.thamesweyenergy.co.uk

[11] See http://www.aberdeenheatandpower.co.uk

[12] See http://www.cofely-gdfsuez.co.uk/solutions/district-energy/district-energy-schemes/southampton-district-energy/

[13] see http://ashadegreener.co.uk

[14] see http://www.berliner-e-agentur.de/en

[15] See www.ladwp.com/

[16] See http://www.bloomberg.com/news/2013-09-23/hamburg-backs-eu2-billion-buyback-of-power-grids-in-plebiscite.html

[17] Firm (country; % state equity): Vattenfall (Sweden; 100 %) http://corporate.vattenfall.com/investors/key-facts/ownership/; Statkraft (Norway; 100 %) http://www.statkraft.com/financial-information/corporate-governance/; ESB (Eire; 100 %) http://www.esb.ie/main/about-esb/corporate-governance.jsp; Masdar (Abu Dhabi (UAE); 100 %) http://www.mubadala.com/en/who-we-are/overview; EDF (France; 85 %) http://shareholders-and-investors.edf.com/edf-share/shareholding-structure-42691.html; DONG (Denmark; 76 %) http://www.dongenergy.com/en/investor/ownership/pages/ownership.aspx; Statoil (Norway; 67 %) http://www.statoil.com/annualreport2010/en/shareholderinformation/pages/majorshareholders.aspx ; Fortum (Finland; 50.8 %) http://apps.fortum.fi/gallery/fortum_investor_material_november_2014.pdf; GDF-Suez (France, 36.7 %) http://www.gdfsuez.com/en/shareholders/gdf-suez-share/shareholder-structure-2/.

[18] 230V – 11kV, i.e. households and small commercial to medium factories and light industry

[19] Hall and Foxon, 2014; Balta-Ozkan et al, 2014; IET, 2013.

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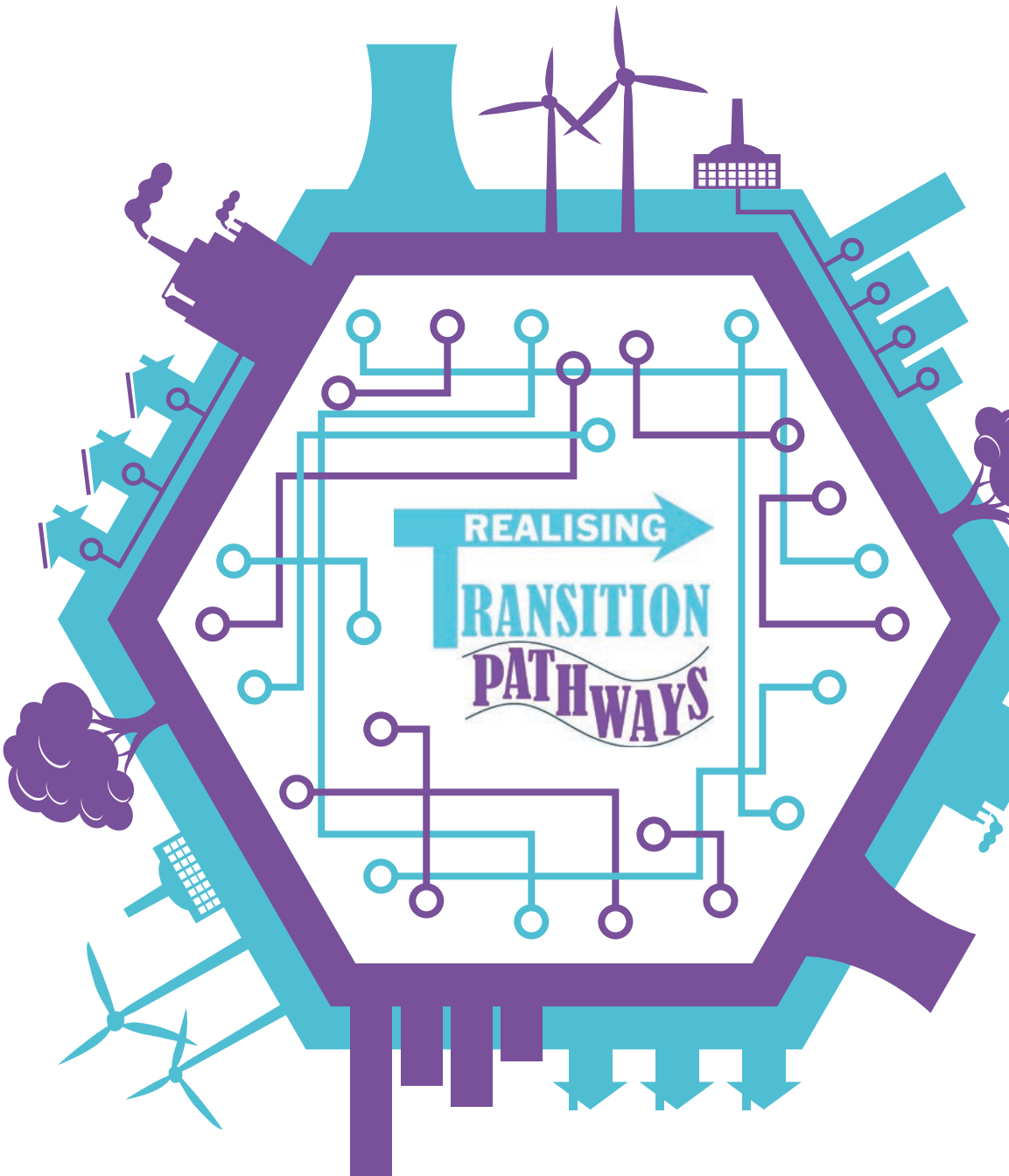
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Notes


REALISING
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