The water-energy-food nexus in 2050

Understanding challenges and opportunities for up-scaling innovations

A report on workshop proceedings
Lloyd's Register, London 18th October 2017

A report prepared by the Tyndall Centre for Climate Change Research, University of Manchester. Authored by Claire Hoolohan, Alice Larkin & Carly McLachlan. **F*unded by EPSRC (Grant No. EP/N00583X/1)***

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Introduction

Stepping Up innovations in the water-energy-food Nexus

Stepping Up aims to understand processes of innovation, so as to support the effective up-scaling of innovations that have beneficial impacts across the water-energy-food nexus. The nexus refers to the inextricable linkages between water, energy and food domains. For example agriculture is the largest consumer of freshwater resources, more than one-quarter of global energy is expended on food production and supply, and decarbonising the energy system has implications for land and water resources. Nexus research explores these intersections, and also seeks to understand the common challenges these domains face such as population growth, changing patterns of consumption and climate change.

The story so far

To date, researchers on Stepping Up have identified an array of innovations that might transform the way that water, energy and food are produced and consumed. We refer to these as nexus-innovations. Amongst these, the research team has focussed three case studies: anaerobic digestion, next generation proteins (particularly insects), and the redistribution of surplus food. In each of these case studies we see seeds of transformation, as they necessitate and provoke changes in product-service systems and therein have the potential to reconfigure water, energy and food systems. We've interviewed extensively within these three sectors and developed Agent Based Models to understand the processes and implications of up-scaling. Next, our aim is to examine the future challenges these innovations might face and understand how to support their effective up-scaling in conditions of uncertainty.

Participatory backcasting workshop

On the 18th of October, at Lloyd's Register in London, Stepping Up brought together 25 stakeholders and 9 researchers to participate in a backcasting workshop. These included individuals and organisations from each of the key case studies, as well as those with a broader outlook on water, energy and food management. Using a novel methodology for rapid scenario analysis the workshop addressed two core objectives:

1. To understand the implications of social, technological and climatic change for nexus-innovations, and the challenges and opportunities different futures present.

2. To understand the changes in policy, business, society and technology that are needed to support effective up-scaling of nexus innovations under different circumstances.

Prior to the workshop the research team developed three scenarios for 2050 by synthesising existing transdisciplinary research. The discussions in the workshops allowed these scenarios to be tested and to substantiate and validate the visions presented in these scenarios in the real-world experiences of the workshop participants. This report presents these scenarios alongside a summary of the workshop proceedings. Further details on the methodology and analysis will become available in open access publications and on request in due course.

Generating scenarios, understanding nexus futures

The future is fundamentally uncertain. There are limits to what we know, and how the information that we have can be used to understand future conditions. What tomorrow's world looks like depends on decisions that are yet to be made, in a variety of sectors and at different scales. What is desirable in the future is highly subjective, and so a source of conflict and potential injustice.

These uncertainties are even more apparent when studying nexus systems. As the number of actors involved in decision making extends, so does the variation in perceptions and priorities. The data we have available on different aspects of the challenges varies in quality and granularity. Decision-making capacity is uneven, yet the consequences of decisions have extended effects that nexus-research seeks to acknowledge.

Scenario planning is a proven method for understanding uncertainty. Scenarios enable different futures to be visualised and their consequences understood. They provide a talking-point to allow learning across different resource management sectors, and between stakeholders operating at different scales. In doing so, scenarios provide a means to enable decisions to be made despite conditions of uncertainty.

To date, there are few published examples of scenarios that consider the implications of future changes for the nexus. Yet there is much to be learnt from existing research. Throughout the literature on water, energy, and food there are examples of excellent transdisciplinary research; where researchers and practitioners have worked together to understand the uncertainties that face individual resource domains.

To develop the *Stepping Up* scenarios, we drew on this existing body of knowledge to identify common drivers of change and their implications. We focus on studies relating to the UK, and those that either originate outside of academia or are developed through extensive programmes of stakeholder engagement (see Table 1). These studies are used to develop three scenario narratives; qualitative descriptions of how water, energy and food sectors might respond to changes in society, technology and climate.

To increase the narrative impact of our scenarios we drew upon additional studies that showcase emerging technologies and practices (business and domestic) that might change the way we use resources:

- Food Futures (Wrap, 2015);
- Future Energy Scenarios 'showcases' (National Grid, 2017);
- CONSENSUS (Davies *et al.*, 2013); and
- The water and wastewater sectors: The long view (PwC and Yorkshire Water, 2016).

We also reviewed the key documents on UK climate action (e.g. the Climate Change Act CCC, 2012, and the Paris Agreement UNFCCC, 2015), and climate projections (particularly UKCP09 Jenkins *et al.*, 2009) to situate the scenarios within this evolving landscape.

Table 1: Existing water, energy or food scenario studies (Source: Hoolohan *et al.,* forthcoming)

Study	Focus	Changes described
Tyndall decarbonisation scenarios (Anderson *et al.*, 2008, Mander *et al.*, 2008)	Energy	• Energy supply characteristics (e.g. availability of fossil fuels, nuclear, biofuels, hydrogen and renewables; success of CCS, and extent of centralisation); • Energy demand characteristics (household & industrial demand; transport; international shipping & aviation; shape of the economy).
Transition pathways (Barnacle *et al.*, 2013, Foxon, 2013)	Energy	• Dominance of actors involved in energy transitions (e.g. state, market, civil society); • Level of co-ordination in energy system development • Energy supply characteristics.
UK scenarios for a low carbon energy system transition (ETI, 2015)	Energy	• Level of co-ordination in energy system development • Role of central government; • Technological sophistication, social values and societal engagement in energy systems; • Implications for power, heat, transport and industry.
Future Energy Scenarios (National Grid, 2017)	Energy	• Energy demand characteristics (industrial demand; residential; transport); • Emerging energy demand technologies (e.g. EV's, internet of things, blockchain, robotics, and fuel cells); • Energy supply characteristics (energy generation, electricity generation, UK generation); • Emerging supply technologies (e.g. bladeless wind turbines, integrated PV, and methane hydrate).
Futureproofing Water (Atkins, 2013)	Water	• Societal value placed on resources; • Energy price and availability; • Technological sophistication; • (De/)Centralisation in the water sector.
Demand for water in the 2050's (Environment Agency, 2009)	Water	• Governance goals (i.e. growth or sustainability); • Extent of material consumption; • Water demand characteristics (e.g. domestic, agricultural and industrial demand).
The water and wastewater sectors: The long view (PwC and Yorkshire Water, 2016)	Water	• Level of co-ordination in the water sector; • Changes in the mix of private and public sector participation; • Technological advance; • Changes in regulation and retail of water sector; • Role of different actors in water governance.
Shaping the Future of Global Food Systems (World Economic Forum, 2017)	Food	• Resource efficiency of production and trade; • Level of "connectivity" in the marketplace (e.g. openness, trust and inclusivity) contains subtext about justice, equality and technological development.
What's cooking? Adaptation and mitigation in the UK food system (Bows *et al.*, 2012)	Food	• Global context (e.g. temp. rise, GDP, response to climate change); • Food production (e.g. technological advance, crop & livestock production, fertiliser & manure management); • Food consumption (e.g. diets, mealtime culture, shopping).

Understanding nexus futures

The result of this exercise is three new qualitative scenarios that depict possible changes in technology, society and climate and their implications for water, energy and food systems. These scenarios provided the basis for the workshop as the rich qualitative descriptions of future change were used as stimulus for discussion. In future, this method will also allow the Stepping Up scenarios to be coupled with quantitative data to inform further modelling processes.

Share and connect	**Create and Cope**	**Big and Smart**
Decentralised digital society with high levels of connection between producers, consumers and the environment.	A society troubled by climate change, but with vibrant innovation in services systems catering for most needs.	A highly centralised society where big infrastructure supplies for basic needs, regulated for transparency and efficiency.

Summary scenario narratives

Share and connect

In this decentralized digital society, tech-savvy millennials have led developments in domestic control and expanded the function of social networks. People work together to make the world in which they want to live. International trade has reduced, due to low levels of material consumption and as domestic manufacturing is more common. Working hours are lower, leaving more time for recreation, community work and entrepreneurism.

- **Energy:** Domestic demand is low and daily peaks are dispersed due to less-uniform working hours. Affordable gadgets allow sophisticated energy monitoring and control, and open-home retrofitting lets neighbours learn from one and other. Energy supply is mostly decarbonised, with renewables and heat networks deployed in towns and cities, and bioenergy catering for rural communities. Travel has reduced in frequency and distance as people have less need to travel, and are more inclined to slow-travel by bike or rail.

- **Water:** Like energy, people are able to sense and manage domestic water and extensive participation in local citizen science and conservation efforts mean people have a strong sense of connection with local environments. Demand has declined, partly a result of more careful water use, but predominantly due to having fewer cars to wash, reduced need to "get ready" for work, and more extensive use of recycled water in the garden.

- **Food:** Small food businesses are thriving, thanks to the trust invested in short supply chains. Many people are involved in food production, typically small-scale growing on tech-savvy community farms. They're also involved in service provision, as social networks connect consumers to producers, chefs and other consumers to change the way we shop and eat.

Create and cope

The impacts of climate change have occurred quicker and more strongly than anticipated, compromising central supply systems that weren't built to accommodate such rates of change, yet prompting a patchwork of innovation to provide alternatives. Demand for chemicals has risen, as has demand for textiles with properties that are beneficial to life in a resource-constrained society. Waste management is now an important source of materials.

- **Energy:** National energy systems are struggling, resulting in occasional blackouts, but entrepreneurs provide alternative supply systems and novel ways of accessing energy services. Few people own cars as fuel prices long since became unreasonable, yet public transport and cycle facilities have improved, sometimes funded by employers so that staff can reach work. Conventional fuels remain common with some expansion of biofuels.

- **Water:** In some areas long droughts are now usual, but floods are also common, both leading to supply issues. Innovation is happening, and a new cluster of water-service providers have developed low- or no-water ways of cleaning and washing clothes. Other advances are in the use of dual water systems, SUDs and decentralized water recycling.

- **Food:** Volatile overseas conditions and high shipping costs have led to a rise in UK production. Agricultural practices have diversified, trending towards closed-loop indoor growing and eating routines have also changed, for example high energy prices and occasional blackouts have made food courts a popular place to spend the evening.

Big and smart

International connections provide investment, skilled labour and expertise to develop national infrastructures. Big data enables sophisticated supply chain management and remote control. The 9-5 is uncommon, instead people either work shifts or have flexible home working arrangements. Landfills have closed, and extensive recycling is facilitated by a materials register and scrappage schemes. Material mining at landfill sites is lucrative.

- **Energy:** Fossil energy has declined, due to extensive investments in large-scale renewables, accompanied by some nuclear and bioenergy. Electrification has reduced demand for gas and transport fuel, and the remainder is met with biofuels. Demand has also reduced, thanks to extensive upgrades to UK housing and public transport. Some moderate growth in industrial and agricultural demand is met through on-site renewables.

- **Water:** The water network looks increasingly like a national grid. This maintains supply across the country, but rising costs and commercialism in the water sector are strengthening consumers' sense of entitlement, and the loss of connection between water users and the environment means companies are struggling to manage the environmental impacts of supply. Efforts to bring new water resources online include coastal desalination and dual water plumbing.

- **Food:** Strong regulations are in place to manage efficiency and transparency – supporting a trend towards climate controlled growing and automated processing. Convenience is king, and for many people ready-meals, take-away, and meals on the move are common. There are also meal replacement shakes and pills, and other super processed foods that provide high levels of control over nutrient intake, while reducing the amount of time people spend shopping, cooking and eating.

Exploring nexus futures

The scenarios were used to examine the implications of changing circumstances for up-scaling nexus-innovations. In the workshop, we considered who would be involved in today's nexus-innovations by 2050, at what scale, and what challenges they might be facing. The following tables provide summaries of these discussions, identifying key characteristics of the AD sector, insect production and changes in the landscape of food waste redistribution. Most noticeable is the consistency in structure that can be seen across the three innovations in the different scenarios:

- *Scenario 1: Share and Connect:* innovations are dominated by community ownership models, whether this is directly through local community projects or through share schemes that allow communities to buy into less local projects. Social relationships are substantially increased.

- *Scenario 2: Create and Cope:* This is a highly polarised scenario in which self-sufficiency is key. Sometimes self-sufficiency refers to the national resource security, and sometimes a more personal translation where individuals, or groups of individuals, fend for themselves.

- *Scenario 3: Big and Smart:* This is a society dominated by large-scale, centrally co-ordinated production systems. Solutions are generally high-tech, often automated and with high degrees of standardisation.

Anaerobic Digestion

Share and connect	Create and cope	Big and smart
• AD becomes a flexible technology for nutrient management, organic waste management and in some areas, energy generation. • Local stakeholders buy into AD and it becomes an area ripe for community investment. Today's commercial plants open community share schemes. • In other cases, small specialised plants provide communities with bespoke resource management solutions where digestate, bio-gas and biofuels are used locally to meet specific needs. • Decisions on planning, siting and dispute resolution take place in community interest groups.	• Growth in UK farming increases demand for digestate, and with increased fuel costs AD is a valuable source of biomaterials. • AD sees rapid innovation to enhance the production and usability of non-energy outputs. • Small scale AD is common in both rural and urban areas. Households and businesses use AD to turn inedible food waste directly from into growing material and energy. • Largescale AD is used to process inedible organic wastes from the agri-food system to produce biomaterials, fuel, chemicals, digestate and gas.	• AD is *the* route for processing inedible organic wastes. • Large indoor farms have AD built in and bio-refineries produce energy, biomaterials, chemicals, and pharmaceuticals from hybridised feedstocks. • Public services (hospitals, universities etc. have smaller digesters on-site). • The delivery of digestate to soils is optimised for example using regulatory mechanisms and automated technologies. • AD is not typically used to produce electricity but gas supplied to grid.

Insect Proteins

Share and connect	Create and cope	Big and smart
• Insect farms provide a local source of protein and their production makes use of organic wastes and heat from local production (including AD). • Insects are another option in the 'grow your own' market. Alongside fruit and veg, insect farms are commonly found in allotments and in community gardens. These insects are either eaten by growers, or used as feed for their chickens. • Community owned insect farms are also common with people buying into larger, more efficient production processes.	• Insects are now commonly used as animal feed, and are starting to feature in the food market. In some locations wild catch supplements farmed stock. • Household insect farms are common, and entrepreneurs have designed 'coffee-pod-style' starter kits integrated with smart-home technologies. • Insect farming also occurs on larger scales to produce animal feed, helping make the UK's agricultural sector less reliant on imports from overseas. • Food courts provide outlets to experiment with food, including new insect products.	• Small numbers of large businesses dominate the insect market. These are new entrants (or new to protein market) with automated production lines and high levels of innovation. • Production is localised, but standardised with verified breeds, breeding systems and trade practices. • Insects are used as feed for livestock and pets, or as an enriching agent in products for people replacing meat either directly, or as padding in meat products.

Redistribution of surplus food

Share and connect	Create and cope	Big and smart
• Edible food waste is avoided by greater sharing of produce and meals, resulting from the expanded use of apps like Olio, supper clubs and community fridges. These low tech solutions help to improve social relationships in communities and neighbourhoods. • New SME's and community enterprises appear, producing secondary products from food waste reclaimed from within production processes or retail (e.g. like Toast Ale and ChicP). • Restaurants and eateries vary their menus, working closely with suppliers to accommodate produce when it is available.	• The volume of edible food waste reduces out of necessity. The risks of food scarcity are evident, prices are high and people's tolerance to produce with low aesthetic qualities has increased. • Reappearance of traditional skills (e.g. bottling, canning and storing) allows people to prolong the life of seasonal produce, manage gluts and make use of damaged produce. • More dining-out makes edible wastes easier to use and inedible wastes easier to collect. • Inedible wastes are a valuable source of nutrients and composted or used for AD.	• Overproduction is lessened by smart stock management that allow retailers to prepare for gaps and gluts, and farmers to adapt to changes in demand. • Smart packaging senses food deterioration, reducing waste in shops and homes. • The rise in convenience food increases end-of night surplus and it is now common that eateries offer food cheap or free at closing time. Various apps have appeared to locate and advertise these foods. • Inedible wastes are disposed of directly to a centralised organic waste management system (e.g. via macerators).

Key Challenges

The latter part of the workshop was spent identifying the key challenges the different scenarios posed for the water-energy-food nexus and for nexus-innovations. We then began to unravel the changes in policy, business, society and technology that would be required to support effective up-scaling of nexus innovations under different circumstances. Though different changes were seen to be required to support innovation in different scenarios, there was also overlap. The following provide the headline findings:

- All scenarios have consequences for how money circulates in society and for employment prospects. Supporting effective up-scaling of today's nexus-innovations was seen to require careful consideration of social justice, vulnerable people and overall prosperity.

- Investment was recognised as both a precondition to nexus-innovations' success, and a potential barrier to upscaling. For example, discussions highlighted how an investment culture that supports social enterprise and small-scale business would support both AD and insect farming in Share and Connect, while divestment from existing incumbents that do not fit with this scenario would create space for community ownership models. These discussions highlight that it is not only investment that is important, but also divestment.

- Similarly discussions highlighted how regulatory frameworks, research funding and legal systems must change, both to support desirable innovations and to obstruct those that do not fit with a sustainable future. In other words, the scenarios highlight a need to constrain options along the innovation pathway, if a particular desired transition end-point, as opposed to a more unsustainable transition, is to materialise.

- Various discussions highlighted the importance of recognising the differentiated needs of regions, communities and businesses in the UK. Understanding the specific needs that people have might enable a more effective matching of nexus-solutions. This underlines the importance of local context and devolved governance.

- In several instances discussions highlighted how new technical solutions, and the optimisation of existing technologies, would alone be insufficient to bring about the visions for nexus-innovations described. Instead there is a need for better understanding of the application of technologies, and the social and political changes required to enable them to function effectively, and without disadvantaging parts of society.

- Specific key areas that were identified as having potential to facilitate change include:
    - Increased data collection, collation and sharing;
    - Greater dialogue across sectors and between different actors within sectors;
    - More outward looking and longer-time horizon forward looking policies;
    - Identification of key skills people and associated training to allow people to participate in sustainable transitions (e.g. producing food or energy, designing technologies, or financing systems they support).

Further findings from both morning and afternoon sessions will be published in due course, following further analysis. Wherever possible these will be made available through open access publications.

Next Steps

Stepping Up is an ongoing project. Bringing together an interdisciplinary team with expertise across water, food and energy nexus, Stepping Up looks to improve our understanding of both positive and negative impacts of scaling up nexus-innovations. We combine quantitative and qualitative methods, and this research is just one part of expansive programme of research designed to understand the processes of up-scaling nexus-innovations.

Next steps:

- **Decision support tool:** Building on the discussions from this workshop, and on indights derived from the ABM researchers from Abertay University are developing a tool to support effective decision making in the water-energy-food nexus. Workshops to support the development of this tool will be hosted early in 2018.

- **Game Jam:** In February 2018 researchers from Abertay University will use the Stepping Up scenarios to develop educational games around the Water/Energy/Food nexus.

Papers and reports

Several papers, blogs and reports from the *Stepping Up* project team are available online, and more are in the pipeline:

- Larkin, A and Varga, L (2016) contribution to POSTNote on the water-energy-food nexus Published by POST - Parliamentary Office of Science and Technology December, 2016
- Hoolohan et al. (2018) Engaging stakeholders in research to address water-energy-food (WEF) nexus challenges. *Sustainability Science.*
- Hoolohan, C., Soutar, I., and Suckling, J. Druckman, A., Larkin, A., and McLachlan, C. (forthcoming) Stepping-Up innovations in the water-energy-food nexus: A case study of Anaerobic Digestion in the UK.
- Falconer, R., et al. (forthcoming) Toward a Hybrid Agent-Based Decision-Making Model for Assessing the Impact of Innovations on the WEF nexus.
- Five fallacies of innovation and what they mean for the nexus. Soutar, I. (Sept. 2017): http://bit.ly/2i5MudF
- What does the future hold for AD? A summary of two recent workshops. Soutar, I. (Aug. 2017): http://bit.ly/2AnIuxD
- Diversity and complexity at the nexus: Reflections from China. Soutar, I. (Aug. 2017): http://bit.ly/2j7ymS1

To keep in touch:

For updates, please see our website: http://steppingupnexus.org.uk/
or follow us on twitter: @steppingupmcr

Workshop- The water-energy-food nexus in 2050: challenges and opportunities for innovation
18th October 2017, Lloyd's Register, London

Delegate List

First name	Surname	Organisation
Corin	Bell	Real Junk Food Project
Martin	Bowman	Feedback Global
Angie	Bywater	Methanogen / BBSRC
Vincent	Doumeizel	Lloyd's Register
Mark	Driscoll	Forum for the Future
Ruth	Falconer	Abertay University
Paula	Forbes	Abertay University
Daniel	Gilmour	Abertay University
Julie	Hill	WRAP
Claire	Hoolohan	Tyndall Centre, The University of Manchester
Nick	Hughes	WWF
Alexander	Lamond	Bug Bakes
Alice	Larkin	Tyndall Centre, The University of Manchester
Freya	Lemon	Michelmores
Carly	McLachlan	Tyndall Centre, The University of Manchester
Thomas	Minter	Malaby Biogas
Douglas	Moore	Monkfield Nutrition
Chris	Noyce	ADBA
Rachel	O'Connor	Michelmores
Maria	Parisi	Jamie Oliver Food Foundation
Simon	Pickard	Integrated Dynamic Automated Solutions
Amrita	Sidhu	Tyndall Centre, The University of Manchester
Julie	Smith	Countryside and Community Research Institute, University of Gloucestershire
Iain	Soutar	University of Exeter
James	Suckling	University of Surrey
Diego	Vega	Community by Design
Kim	Wakelam	FareShare
Chris	Walsh	Kindling Trust
Keiran	Whitaker	Entocycle
Sarah	Wynn	ADAS
Rokiah	Yaman	Community by Design

big'n'smart

Coordinated climate change action reduces impacts on water, energy and food

Strategic alliances with businesses in countries such as Germany and Japan support investment in large infrastructural projects and attracts associated skills, practices and technologies into the UK. Extensive upgrades in energy and water networks, as well as transport and housing, deliver efficiency improvements. Parallel advances in mobile technologies, data collection and remote control change the face of production and service provision. Decision-making is expert-led but the results work well for the majority of UK citizens. Despite being committed to limiting climate change to 2 degrees, the time taken to deliver the UK's 'big fixes' means that the possibility of meeting Paris climate change targets has passed.

SOCIETY & ECONOMY

In this data driven society, real time usage data, accurate weather forecasting and supply chain information allow sophisticated demand management throughout the public and private sector. Robotics, remote control and automation are extensively applied in all industries.

Working patterns have changed and 9-to-5's are no longer common. For some, ICT enables flexible home working. For others, gowth in manufacturing and construction increase employment in these sectors, and shift work is the new normal.

Landfill has dramatically declined. Organic waste is used in bioenergy and fertiliser production, and a second-hand materials market reduces non-organic waste. A materials registry enables secondary markets, scrappage schemes encourage timely recycling and 'material mining' is a profitable industry.

ENERGY

Fossil fuel energy has declined, thanks to government-led investment in large-scale renewables and strategic development of nuclear and bioenergy. Biofuels replace natural gas and transport fuels, though demand is lessened by extensive electrification.

World leading high-speed ground transport connects UK cities with fast, frequent services, reducing road journeys and making domestic flights redundant. Freight is moved by train and ship, using old rail networks and new ports. All remaining HGVs are biofuelled.

Housing reforms have vastly reduced domestic energy demand; improving insulation, glazing and heating as well as introducing 'smart' appliances and demand-side tech. New homes mimic Japanese 'pods' and German eco-homes.

Rising industrial energy demand, a result of growth in domestic engineering, construction, and agriculture, is met by renewables and heat networks.

WATER

Summer droughts are typical and prolonged, particularly in the south. A national water network has emerged as a result of mergers and connections designed to secure supplies.

Cross-sectoral mergers enable the provision of multi-utility services such as the 'One Bill' but also enable innovation, such as water reclamation for agriculture and industry, and energy from organic wastes.

People are increasingly ill-acquainted with local water sources and rising costs strengthen consumers' sense of entitlement, so it is difficult to balance complaints whilst also protecting local rivers.

Water demand is rising and supply-side innovations are sought to bring new resources online. Housing upgrades offer opportunities for dual-water systems and coastal desalination supplies water for industrial demand.

FOOD

Climate change benefits British agriculture, and domestic production is booming. Large-scale commercial farms dominate and with regulation prioritising efficient, transparent production, indoor climate-controlled farming is common.

Extensive deployment of robotics and remote sensing support intensive agricultural practices, and agricultural land cover is reduced. Some reforestation has occurred to provide wood for construction and export.

Convenience is king. Takeaways and meals-on-the-go are common while 'shakes, meal pills, and other super-processed products offer quick sustenance. When people cook, they favour meal kits and ready-meals, delivered to their doors by one of the Big 5 retailers.

The average diet is a fusion of British, Asian and German foods, with specialities available in fast food outlets & vending machines. This means lower meat consumption, particularly of red meat and more effective use of animal products.

create'n'cope

Turbulent times spark a lively patchwork of experiments in service provision

Climate impacts are felt sooner and more strongly than expected, at least in some areas of the UK. Under-investment in efforts to adapt and mitigate earlier in the century mean that centralised infrastructure now struggles to maintain the services that consumers have come to expect. However, insecurity prompts innovation and carves out considerable space for new entrants to supply energy, food and water services to consumers. Organisations both large and small, experiment with novel on-site solutions to manage supplies while the national Government increases the flow of funding to Local Authorities who, along with other investors, support creative thinkers in identifying social enterprise opportunities and business ventures.

SOCIETY & ECONOMY

Demand for chemicals rises as a result of efforts to manage and live with drought (e.g. to produce measures to reduce evapotranspiration and allow waterless cleaning).

Demand for low-wash textiles with improved thermal properties boosts the UK textile industry, particularly in the north.

Rising transport costs drive innovation in virtual reality and teleconferencing tech for business, education and leisure. It's now uncommon to travel far. Warmer weather supports a surge in domestic tourism, creating valuable jobs as other industries decline.

Waste management is a precious source of materials and employment. Recovery, collection and processing occur at various scales, organised by a variety of organisations. Edible wastes are a thing of the past, and inedible organic waste streams are processed for animal feed and bioenergy.

ENERGY

Centralised development of renewables slowed after 2017 and aspirations for the nuclear sector never materialised. Some large power stations still source biomass for electricity, but new entrepreneurial ventures emerge to replace disrupted services, including local energy systems in some areas.

Warm weather makes air conditioning popular, but frequent blackouts cause people to find creative ways of heating and cooling, like insulating homes, high-tech mechanical devices and using communal facilities.

Conventional fuels remain common but climate levies and global supply challenges drastically increase prices and few people now own cars. Localised trials in freight and public transport deliver some success, e.g. biofuels provide a valuable fuel for ships importing waste.

Rising industrial energy demand, a result of growth in chemicals, textile and agricultural sectors, is met by onsite renewable energy production and heat networks.

WATER

Early forecasts underestimated today's challenges. Summer droughts are now normal and supply interruptions are common in many areas. Floods are also a problem, causing catastrophic failure to local supplies, if only short-term. Water quality suffers as a result of both.

These challenges prompt innovation in water services, funded through public and private investment. 'Pop up' water service providers such as waterless laundrettes, capitalising on the opportunity created by disruption.

Water demand peaked earlier in the century, as people tried to maintain gardens and homes. As supplies became less predictable, new patterns of water use arose, and demand is now lower.

Decentralised rain- and grey-water systems are widespread, providing non-potable water at various scales. Sustainable Drainage Systems (SUDs) are widely implemented as a combined flood alleviation and water storage technique.

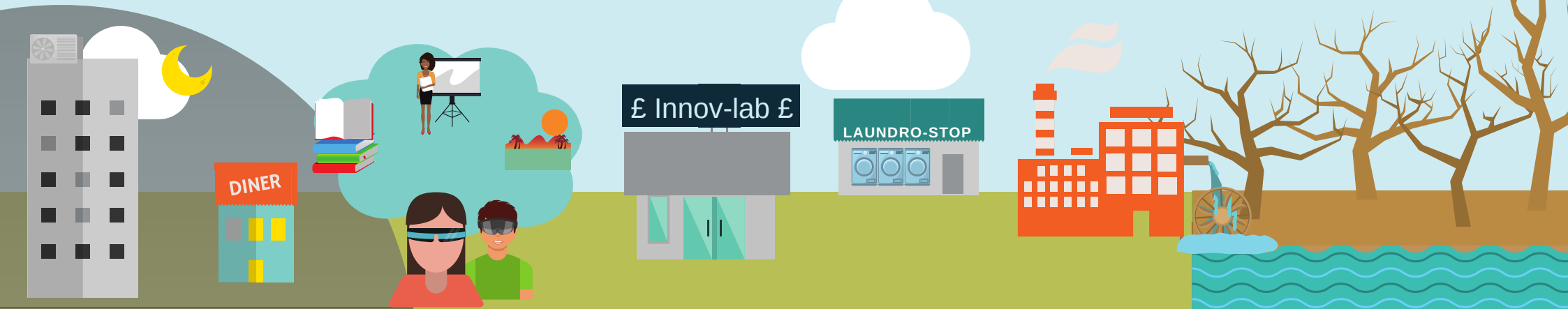
FOOD

The prices and availability of overseas produce is unpredictable, and efforts to secure food supplies boost UK farming. Food typically travels less than 50 miles farm to fork.

Expensive energy and frequent blackouts mean food courts and diners are popular places to spend an evening, catering for consumers with simple, cost effective meals.

Collaboration between farmers and food providers has reinvented British cuisine, with local specialities reflecting new growing conditions. Favourites include Oswestry olive tapenade and Carlisle Chardonnay.

Agricultural production diversifies as farmers invest in biochemical and energy production for supplementary income. Nevertheless, climate change creates challenges and closed-loop indoor practices are common. Even so, food is costly and vulnerable to shocks, so choice is reduced. Many people rely on government subsidised nutraceuticals for basic sustenance.



share'n'connect

Accessible technology and social networks enable decentralised climate action.

Extensive climate action, in-line with the Paris Agreement, prompts changes in water, energy and food systems. Individuals, communities, and small businesses lead social and technological experimentation, designing context-specific solutions to meet local challenges. Centralised planning and big business help roll-out mature innovations, though with high levels of collaboration and a cultural patience for uncertainty. Agility, diversity, and adaptation are the dominant characteristics of this society, with different 'solutions' springing up in different places, depending on specific local needs and opportunities. However collaboration aids the diffusion of innovation and avoids any duplication of effort.

SOCIETY & ECONOMY

International trade is low, due to the growth in UK production systems and low rates of material consumption. The decline in freight complements large efficiency gains, and bio-electric ferries and wind-assisted container vessels are common alongside electric vehicles.

Most people work 20-25 hours a week, allowing time for community enterprise, entrepreneurial activity and leisure. Novel funding platforms support small-scale enterprise; and kick-starters and crowd funding are common mechanisms for people, businesses and governments to invest in new technology and service systems.

This is a sharing society, allowing the exchange of knowledge, skills and stuff. Self-employment is common, and office spaces are filled with people working for similar sectors, rather than single businesses, enabling rapid cross-fertilisation of ideas and strong community relations. Skills marketplaces are now the most common way to source employment.

ENERGY

Domestic energy demand is low and daily 'peaks' are dispersed, a result of changed lifestyles and large efficiency gains. The 'digital generation' drive experimentation in domestic control and micro-generation, supported by affordable tech. Open-home schemes facilitate skill sharing.

Travel patterns are dominated by infrequent, short journeys by bike, e-bike and electric-car. Car clubs are common and public transport is extensive, efficient and well used. People favour long, slow holidays rather than short breaks and though bio-fuelled flights are available, they're very expensive.

Supply is diverse and mostly decarbonised, with extensive deployment of renewables (including micro- and community generation), and some nuclear. Extensive electrification is well catered for by an expanded electricity network, and heat networks are common at all scales. Biogas provides for off-grid heat and cooking needs, and biomass is used for high-grade industrial applications.

WATER

Citizen participation in decision-making alters the social and political discourse around water. Fresh water is highly valued and though national infrastructure persists, decentralised systems are also common.

Demand is declining, fewer cars mean less washing and less formal working arrangements reduce the frequency of showering and laundry.

Extensive changes to the built environment are visible, with fewer impervious surfaces and more water butts, soak-aways and ponds. The quality of rivers, beaches and water bodies is improving and supports a growing outdoor leisure industry.

Extensive, well networked citizen science projects increase participation in water management. Widgets and apps make flows of water visible, and peoples understanding of water has grown. This complements changing patterns of use, but means people expect utility companies to deliver sustainable water services.

FOOD

Consumers' trust in short supply chains and rising transport costs have resulted in the localisation of production. Co-ops, markets, independent retailers and small farms are thriving. Organic wastes are processed locally to produce heat, water and fertiliser.

Affordable tech allows extensive participation in agriculture. Small-scale growing on ex-industrial land deploys off-the-shelf micro- and modular technologies to maximise efficiency. Big agriculture has declined and farmers are now investors, consultants and collaborators, as well as diversifying into energy, forestry, and other integrated production techniques.

Social networking apps enable the exchange of seeds, plants, produce and skills. They've also changed how people eat; meals are shared in supper clubs, chefs connect directly to offer batch cooking, meal prep and catering.

Diets vary depending on local growing conditions, but are typically high in home-grown grains &veg.