INDUSTRIAL STRATEGY

UK Research and Innovation

Systems thinking in the energy system

A primer to a complex world

Working document

Delivered by

Catapult Energy Systems

Preface

Systems Thinking is a broad and multi-disciplinary approach to complex problem solving. Energy Systems Catapult believes it is a vital component of the energy revolution because it offers a means to reduce the risk of unintended consequences when we modify things, while simultaneously providing the opportunity to deliver positive changes that satisfy requirements.

This document is the first iteration of what we mean by Systems Thinking and why it is so centrally important to the energy revolution. It is intended to help stakeholders enter a 'Systems Thinking' mindset and be able to communicate in Systems Thinking terms. It is not intended as a methodology or a how-to guide.

This is a working document. Systems Thinking is a broad discipline and the energy system is highly complex, with significant uncertainty about its future direction. It is difficult to predict how stakeholders need assisting materials to be presented, and with that in mind we are sharing this working document to gather feedback so that we may establish a common understanding of Systems Thinking in an energy context. We have also included a working glossary towards the end of the document to help define a standard language that will support and facilitate complex problem solving in the energy revolution.

If you have any comments, please get in touch with us at eris@es.catapult.org.uk.

Introduction

Over the coming decades the UK energy system will need to undergo a challenging transition to meet agreed greenhouse gas emissions reduction targets. The complex nature of the energy system and how its various elements (heat, power, transport) interact mean that simple or gradual solutions won't be sufficient to achieve the required outcomes. Whole System thinking can help us uncover how changes in individual energy system elements, or the relationships between them, will affect wider system behaviour.

Population growth, changing demographics, new and disruptive technologies, and changing patterns of energy use will affect our energy needs – the energy system will need to be flexible, efficient and secure, to respond to future demands whilst meeting carbon targets.

The Energy Revolution

At the end of every pipe, road and wire, sits a consumer. That consumer may be a domestic customer, or a large business. They want the energy system to deliver their needs, but not at just any cost, whether this is financial or perceived environmental expense. If the energy sector doesn't take consumer desires and behaviours into account at the outset of designing the UK's energy future, the system may not perform as expected.

Digitalisation has transformed practically every aspect of life; consider how Amazon, eBay, Google, Facebook, Netflix, iPlayer, Airbnb and Uber have changed shopping, working, relaxing and travel. Yet until now, energy services have remained largely unchanged.

Local markets for supplying energy services, and the increasing ability to understand and respond to consumer needs through digital platforms, are changing the way that people engage with energy.

Electric vehicles, microgeneration, storage and connected homes and businesses offer the opportunity to transform consumers' relationships with the energy system. To enable this positive evolution, legislation and commercial structures will need to adapt.

In a system as complex as the energy system, changes to just one element can have profound effects on others. If changes don't happen with an understanding of the Whole System and how each element interacts, there is increased risk of a costly evolution, an unreliable system, and unsatisfied consumers. By considering the Whole System, opportunities can be created. For example, developments in one area, such as smart meters and their infrastructure, could lead to the ability to offer better consumer services and cost savings.

Systems Thinking can help to grasp and manage complex situations where there are no simple answers and where solutions must be understood in terms of their impacts on the Whole System.

This document introduces Systems Thinking, explores its application in the energy system, and starts to develop a shared language for discussing whole energy system thinking.

Systems Thinking

Systems Thinking is a framework for seeing interrelationships rather than separate things, for seeing patterns rather than static snapshots. It is a set of general principles, spanning fields as diverse as physical and social sciences, engineering and management. *(Senge, Peter M. The Fifth Discipline: the Art and Practice of the Learning Organization. New York :Doubleday/Currency, 1990. Print.)*

Systems Thinking focuses on cyclical understanding rather than linear cause and effect. It can be applied to understand connections between elements, or identify areas to be influenced or changed. When we understand the elements of a system and relationships between them, we can begin to understand how to optimise it.

Systems Thinking requires the 5 C's: curiosity, clarity, compassion, choice, and courage to see a situation fully. Recognising that elements are interrelated and acknowledging that there are often multiple options to solving a problem is important, along with championing interventions that may not be universally popular.

There are well developed techniques that use a systematic approach to complex problem solving and a brief set of definitions are included here.

What is a system?

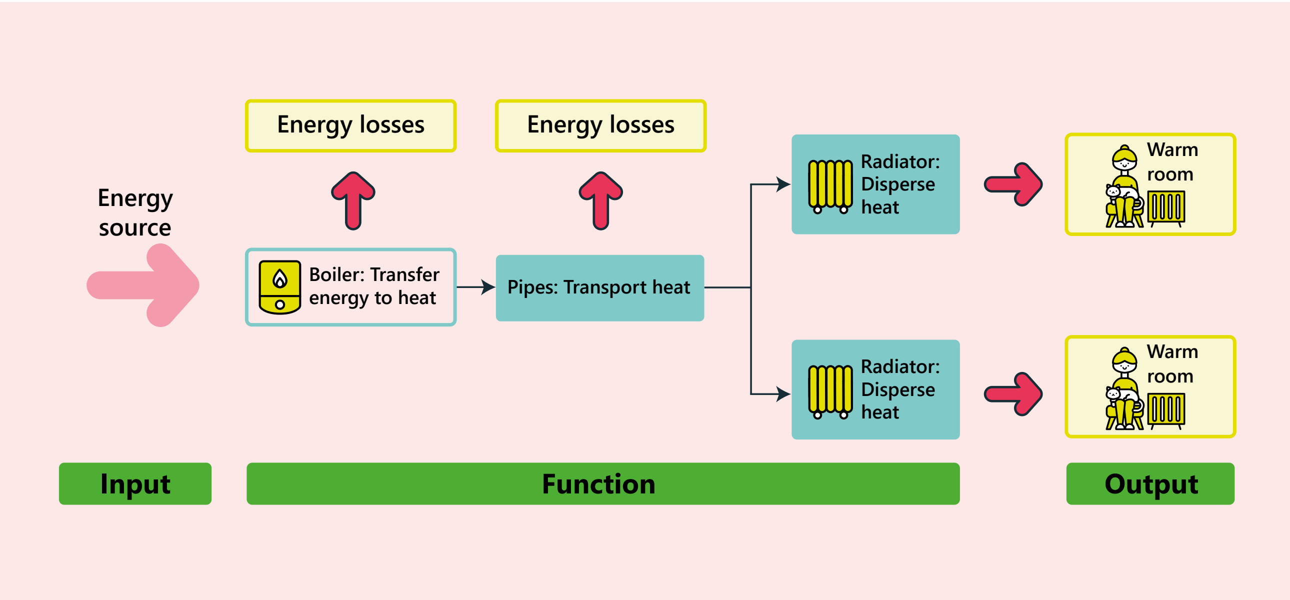
The word 'system' is used in everyday life to describe something that comprises more than one element. Most simply, a system is a collection of different elements that together produce results not obtainable by each element on its own. The elements may represent people, hardware, software, facilities, policies, and documents. True value is created through the relationship between the elements and how they are interconnected. Within a system, there are likely to be multiple actors. An actor is a defined role within the system and may be an individual, an organisation, or a collective entity that gets value from the system in some way.

For example, to provide a warm, comfortable living environment in the UK, a heating system is required. Generally today, this is provided via a boiler that transforms a form of energy into to heat, which is transported to different rooms using pipes, and delivered by radiators, where heat is dispersed. As the system is not 100% efficient there are losses at each stage. The main actors would be the building occupier, the energy providers, and boiler manufactures and maintenance providers.

A system can be described as **complex** if, with the current state of knowledge, it is difficult to reliably predict the system-level outcomes, even if each element is understood.

If a system has many elements, but the outcomes can be reliably predicted, it is described as **complicated**.

The national heating system would be considered complex as it is difficult to predict the exact demands of consumers; what times they require heat, the efficiency of the boiler, and the external temperature for example. The boiler itself, however, could be considered complicated as there are many critical parts that operate together for the overarching purpose of converting stored energy (gas) to heat.



System boundary

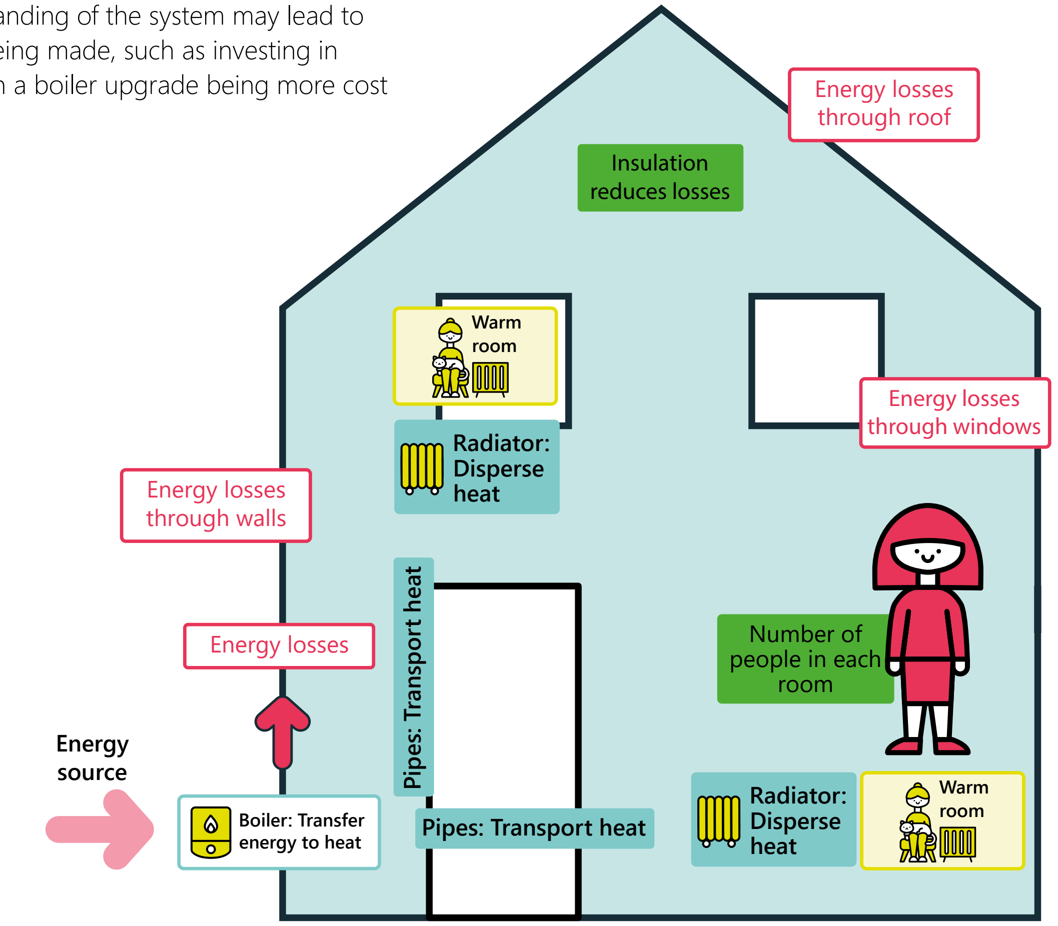
Setting a boundary around the system helps to define what it is, how it is organised and behaves, and how it is controlled. The boundary may (appear to) change depending on the perspective of the system actor and the 'problem' that needs to be solved. The part of the system or boundary that is relevant to the problem to be solved is sometimes referred to as the 'system of interest', and generally sits within a broader complex system.

Using the previous domestic heating example, the system boundary is purely the heating system. This may be an adequate way to consider the system for a plumber to install a new radiator or fix a pipe, for example. As the occupier however, I may want the heating system to maintain the house at a certain internal temperature when I am at home. If we consider the property as the system boundary, other important elements that could affect the internal temperature are also captured, such as insulation, doors and windows. This greater understanding of the system may lead to different decisions being made, such as investing in insulation rather than a boiler upgrade being more cost effective.

System change

Systems are rarely static and when things change, the consequences need to be understood. The better a system is defined and understood, the easier it will be to determine the impact changes may have and successfully manage them.

In our home heating example, the external temperature may change around the house, or the number of people in each room may change, and therefore to keep the internal temperature of a room constant, different levels of heat will be required at different times.



System of systems

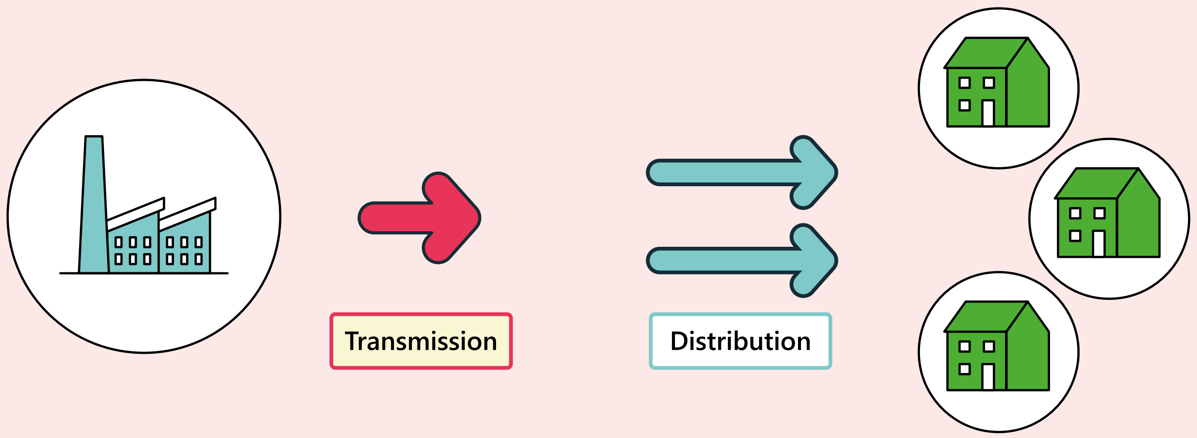
Typically, 'system of systems' applies to large scale inter-disciplinary problems that span multiple, distributed systems:

A system of systems brings together a set of systems for a task that none of the systems can accomplish on its own. Each constituent system keeps its own management, goals, and resources while coordinating within the system of systems and adapting to meet overall goals. (ref ISO/IEC/IEEE 15288 Annex G (ISO, 2015)).

The following characteristics may be useful to decide if a system can be better understood as a system of systems:

- Operational independence: If the system of systems is broken up into its individual systems, each must be able to operate independently
- Managerial independence: The component systems are separately acquired and integrated and continue to operate independently of the system of systems
- Geographical distribution
- Evolutionary development processes

To continue the heating example; in the UK 85% of domestic properties use gas for heating. Gas is extracted, processed, and transported via pipes from distribution and transmission networks at a certain quality, pressure, and flow rate to ensure demand is always met whatever the time of day, and across seasons. At each dwelling the gas is then used to provide heat energy at certain times, depending on the consumer. Each part of the process is managed and owned by a different actor and to some extent can operate independently and therefore could be considered as a system of systems.



Systems engineering

Systems engineering has been widely used across industry: automotive, defence, aerospace, and telecommunications, to name a few examples. It is an interdisciplinary approach and means to enable the realisation of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation, while considering the complete problem and system life cycle.

Systems Engineering integrates multiple disciplines and speciality groups into a team effort forming a structured development process. It should proceed from concept, to production, to operation and considers both the business and technical needs of all consumers with the goal of providing a quality product that meets the user needs over the lifecycle

(ref INCOSE - INCOSE. 2015. Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities, version 4.0. Hoboken, NJ, USA: John Wiley and Sons, Inc, ISBN: 978-1-118-99940-0 or https://www.sebokwiki.org/wiki/INCOSE_Systems_Engineering_Handbook).

Many methods, tools and processes have been developed using this approach to aid problem solving in complex situations.

Systems integration

Systems integration is the process of bringing together different systems and elements into one system, or system of systems, to deliver the overarching purpose. It starts with a big picture perspective of the problem that informs the various high-level requirements of stakeholders.

It can then be taken through into design and development of solutions looking to meet stakeholder requirements, through adopting or adapting existing systems or combining these together with new systems or elements.

Finally, it is taken into system implementation or realisation, enabling the systems and their component elements – new and existing – to be brought together, tested and transitioned into operational use. By considering multiple views, systems integration can help to manage conflicts between certain solutions, in view of the high-level requirements.

For example, for domestic heating, the overarching purpose is to provide a comfortable living environment for the occupier, at an acceptable cost financially and environmentally. As previously shown, this does not only include the heating system and the wider network to deliver the energy source, but also building properties such as insulation, size, number of doors and windows, and the number and type of occupants. We have seen that most houses use gas to supply heating and therefore decarbonising this sector represents a national challenge. Systems integration can be used to identify solutions in a structured way and capture the potential conflicts and opportunities that could arise between the different elements, systems, and actors involved.

System perspective

A perspective is defined as a viewpoint that can change the way the Whole System appears. It is important to consider systems from many perspectives to ensure that solutions or system changes are enduring, transferable and can succeed under a range of conditions. By considering different perspectives of the system, conflicts arising from certain solutions can be identified early and taken into consideration.

In the heating example, the building occupier may want to have choice and control of their own heating system, whereas an energy provider may want to invest in a district heating system as it could reduce their carbon emissions and improve the reliability and security of the network. To make the transition successful, the requirements of both actors need to be understood and managed appropriately.

Systems architecture

Systems architecture is the process of using a structured approach to develop the potential future conditions of a system. It enables the system to be broken down into a number of interacting perspectives such as information, processes, technology, and people. The process can help to translate a system requirement into multiple possible solution options and visualise the potential impacts.

Systems architecture in itself doesn't answer a specific requirement or a question; it provides the blueprint to structure and highlight relevant interfaces that should be considered.

If we applied a system architecture approach to our decarbonising domestic heating example, we could explore a future state where all domestic heating was supplied using an electric heat pump. The architecture model would be developed to include consumer demand, electricity generation technologies, grid capabilities etc. and indicate the changes required for the future system to become reality.

Interoperability

Interoperability is the ability of different elements of a system, or complex system of systems, to work with each other to create an outcome that is greater than the individual operating on its own. Each system can operate independently, and integrate together, in a way that doesn't detrimentally affect the Whole System function.

From a Whole Systems perspective, interoperability between components in the system plays a significant role in ensuring the wider system is flexible, resilient and able to accommodate change in a way that allows easier, more cost-effective integration of new components, without impacting existing system components. One method to facilitate interoperability is through the use of open standards.

Open standards are standards made available to the public and are developed, or approved, and maintained via a collaborative and consensus-driven process. They facilitate interoperability and data exchange among different products or services and are intended for widespread adoption.

Interoperability should be considered across the energy system; from physical elements, components, communication methods, information types, and business models.

For example, if a consumer wants to change their energy supplier because the supplier is offering cheaper rates, a smart meter, and a new app for control, all the elements need to be interoperable between each other, as well as with the wider system. This would include the existing heating system and the device to use the app, and interoperability would ensure the value or benefit to the consumer is achieved.

Interoperability allows device manufactures and energy service providers to develop products and services that are applicable to multiple scenarios, offering consumers a greater level of choice and control over their energy use.

Emergent behaviour

Not all behaviour can be predicted. Emergent behaviour cannot be exhibited through its individual elements, only through the relationships between them. It is important to understand the structure of a system, the elements, and their relationships to be able to manage or control it, however not all emergent behaviour can be predicted. It can also be desirable, or undesirable.

If we continue our smart heating system example, a potential emergent behaviour could be that new business models or markets are developed that provide additional benefits to consumers, enabled by the smart meter. Having a smart meter in the home that can track energy price changes combined with a home hub and devices could lead to many more opportunities. Who could have predicted what new businesses, policies, and consumer behaviours would lead from the development of the internet?

The energy system

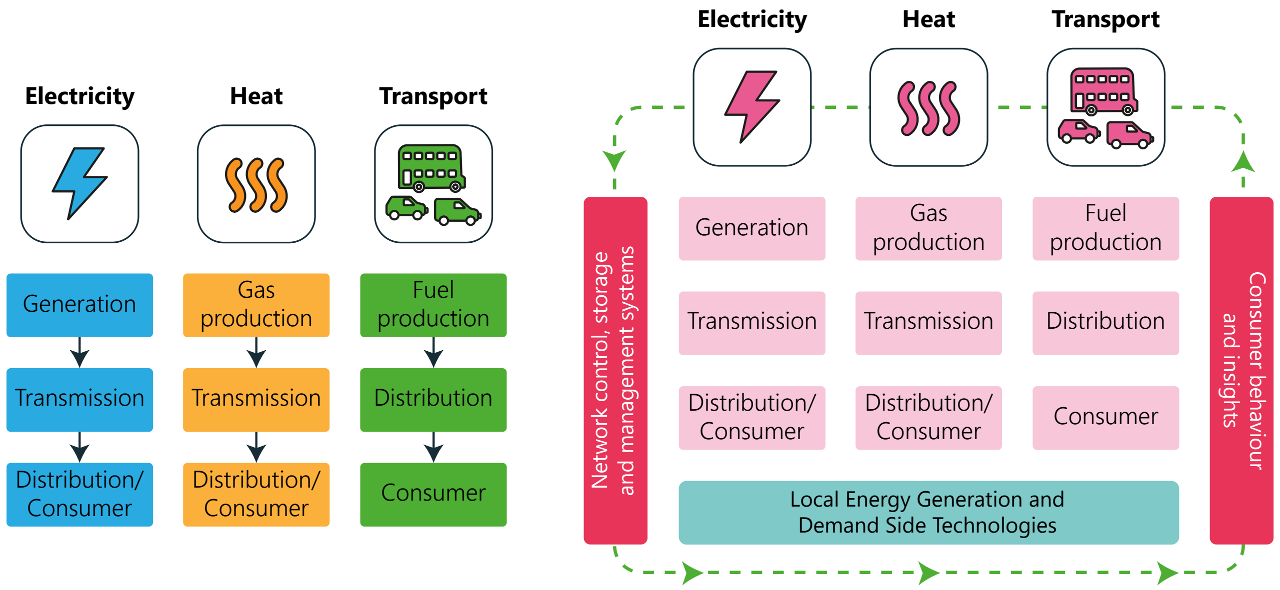
Switching domestic heating from gas to electricity offers one potential solution to decarbonise the heating sector, providing the electricity is generated by low carbon methods. This example demonstrates that it is vital energy vectors are not considered separately when considering how the energy sector can transition to a low carbon system.

The Whole Systems view of the energy system does not just concentrate on generation, networks or services provided to consumers; it is also not simply confined to energy vectors such as electricity or gas, heating, industry or transport. It is all these things and more. Currently, most of the UK's energy is moved around the country, and sometimes beyond, by electricity and gas networks, and the liquid fuel supply system (e.g. petrol and diesel). To achieve the UK's decarbonisation targets, the whole energy system and sector will need to change significantly.

The roles of these networks will inevitably change as the ways energy is provided and consumed evolves and as other networks emerge, including those carrying heat, hydrogen and data. The future of the energy system is likely to be cross-vector (electricity, heat and transport interdependently linked), more distributed (local, regional, national and international networks), flexible (on-demand, service driven) and smart (dynamic, and automatically controlled).

Transformational change is happening at an ever-increasing pace, driven by the need to reduce carbon emissions in the most efficient, cost effective way. There are opportunities in all elements of the energy system, including technologies, capabilities, services, people, policies, regulations, and commercial business models.

Conventional and System Thinking perspective on the energy system



How can Systems Thinking help the energy system?

Systems Thinking offers a structured approach to tackling a complex, but incredibly important challenge. It can uncover how changes in one or more element(s) and the relationships between them will affect system behaviour. This can then be used to inform planning and decision-making to avoid unwanted implications across the system.

Systems Thinking can provide an aid in ensuring that analysis and assessments do not focus too heavily on a single aspect of the system, such as energy supply or consumption. From an innovators perspective, this approach can help identify requirements and opportunities and therefore develop more effective, productive solutions.

Systems Thinking can help promote **optimisation**, that can occur at many points throughout the energy system landscape:

- within a consumer's premises or home
- across transmission, distribution, generation and supply
- in policy, regulation and commercial structures
- in emerging sectors such as electric vehicles

Optimisation may require a reconfiguration of the elements and the relationships between them. By putting consumers at the centre of our thinking about the energy system, rather than regarding them as passive energy users (as has historically been common practice), their very needs and behaviours actively create opportunities to optimise the energy system and provide wider social improvements.

The energy system:	**Systems Thinking can:**
• Is made up of complex socio-technological systems that include people, organisations, politics, products, services, processes, information and regulation	• Highlight interactions across the system
• Increasingly needs to be understood and managed as a system of systems	• Aid understanding of a more complete view of consequences of decisions
• Is planned and operated within a wide range of system time-constants (milliseconds to decades)	• Help establish where best to focus and where the most return on investment can be achieved
• Is faced with a range of drivers for change (e.g. climate change) with multiple competing and interdependent potential solutions and finite investment	• Identify challenges and opportunities that wouldn't otherwise be apparent
• Has loosely defined problems that are always changing	• Help avoid double-counting or under-accounting – costs, CO_2, benefits, etc.

Example: Decarbonising domestic heating

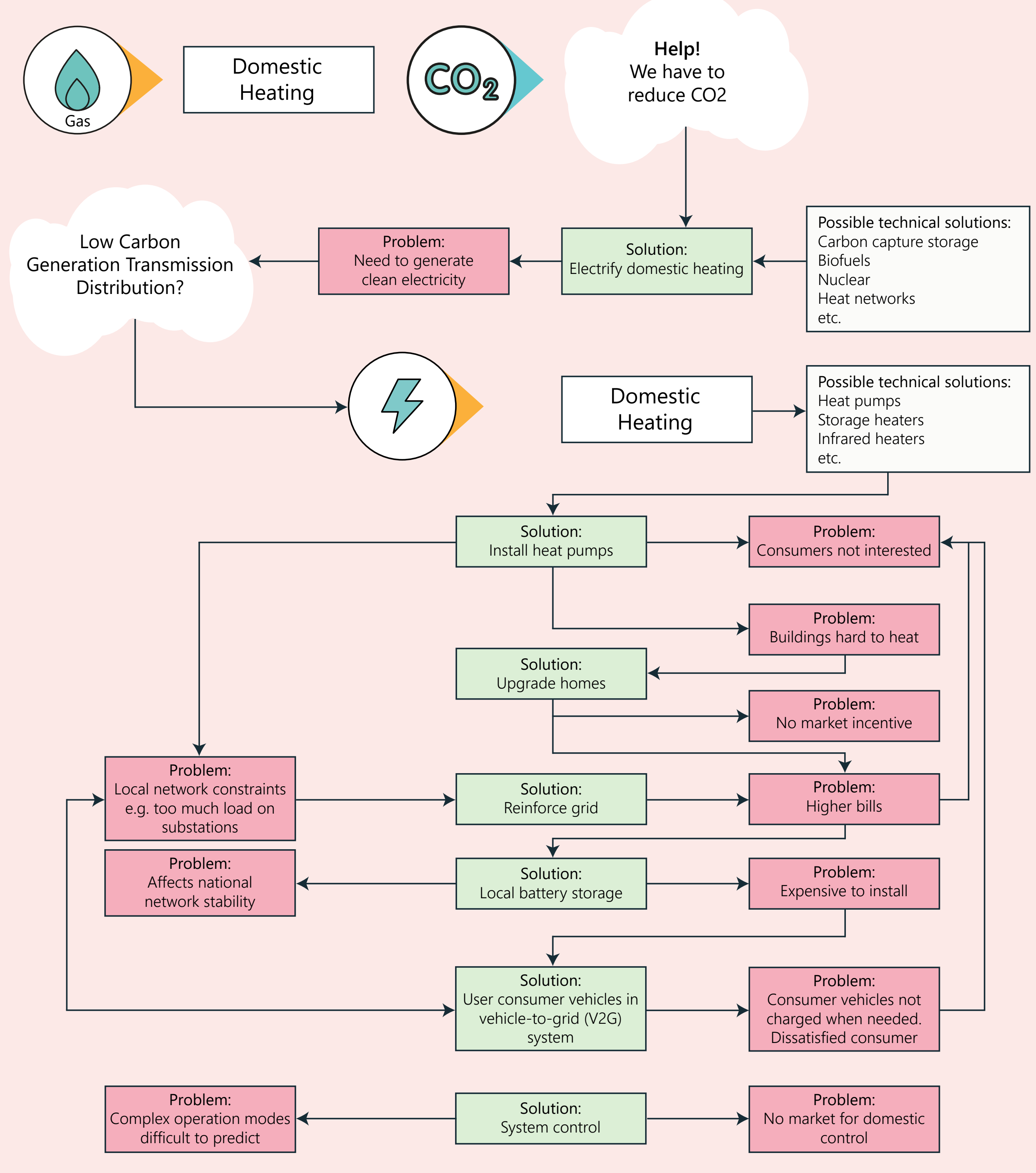
The energy system is a complex system of systems. Each change will prompt a series of reactions in the connected elements. Each solution leads to a new set of problems as the energy system changes to accommodate the solution. Some of these problems could be reframed as opportunities, depending on the further connections and effects.

The following example looks at a possible solution to the problem of decarbonising domestic heat, as introduced in earlier sections. This is not presented as 'the' solution, only as an example of the need for Systems Thinking as we navigate the energy system transformation.

By adopting a Systems Thinking approach, these challenges may converge and enable the discovery of a simpler solution that would not have been apparent if each was considered individually.

It is also important to note that not all end users will have the same values and views on benefits. Consumers need to perceive value to if they are to be encouraged to make a change – whether this is lower costs, improved control and reliability, and/or contributing to reducing carbon emissions. This adds a greater layer of complexity to our domestic heating example.

Example: Energy system problem



Where multiple problems converge, such as disinterested consumeres, there is opportunity to change the relationship between the element (consumers) and the energy system.

Each solution must be considered in terms of all other elements in the system.

A shared language for the whole energy system

The energy system, and how Systems Thinking can help provide structure when considering such a complex entity has been introduced. 'Whole Systems' is an ambiguous term and this section will introduce a set of definitions to explain what we mean by the whole energy system.

The energy system is a complex system of systems and defining its element parts in a consistent and coherent way is useful in supporting systems analysis. For framing a problem, a boundary can be drawn around a specific system of interest to set it within the broader energy system context, encouraging consistency and completeness in the analysis of problems and solutions.

The following definitions and structure are by no means intended to be the authoritative version and aim to act as a 'scaffolding' to discuss elements of the energy system.

The purpose of the Whole System is to provide outcomes that consumers want affordably and reliably, whilst reducing greenhouse gas emissions, in line with the carbon budget.

The boundary is the set of technologies, physical infrastructure, institutions, policies and practices located in and associated with the UK, that enable energy services to be delivered to UK consumers.

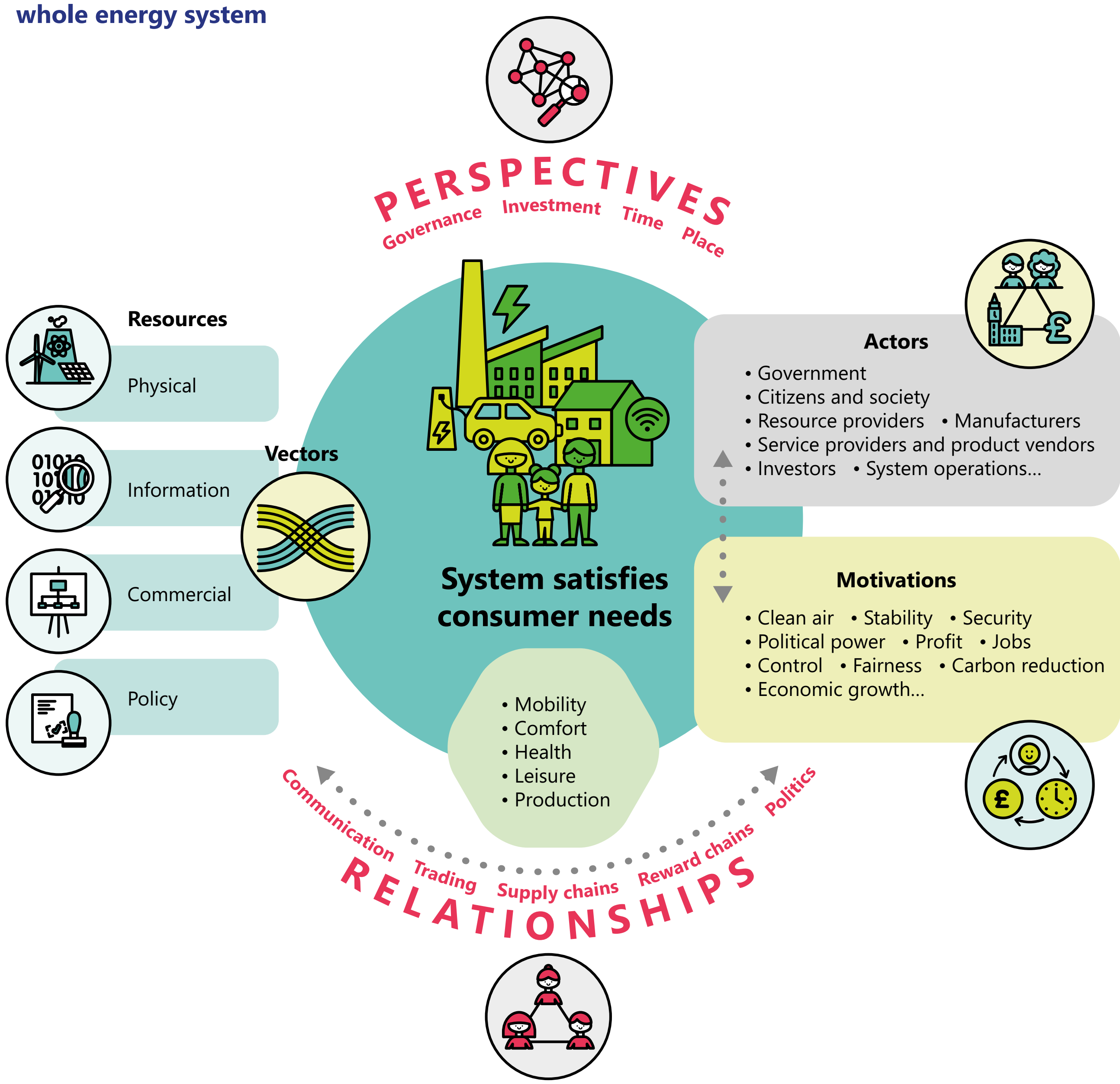
The integration of new approaches in the energy system must meet the following **requirements**:

- **consumer-centric:** the energy system must focus on meeting consumer needs and have an insight into why they use the commodity, as well as what is important to them, such as comfort and convenience
- **societal:** the system must be able to evolve affordably, securely and sustainably
- **physically constrained:** integration must account for the constraints on the system in terms of production, distribution and storage across all energy vectors. This includes the current and future landscape with increased distributed generation, intermittent generation from renewables, and the decarbonisation of transport and heat
- **commercially aligned:** the value chain should be optimised across energy vectors. It must be recognised that different actors will have different motivations, access to relationships, data, and levers of control
- **secure and resilient:** the system must be resilient to systemic failure and should provide stable control

We achieve the purpose by meeting needs, using available resources. Actors are the people, companies, governments and other communities that wish to take or create value within the system. **Actors** have **motivations** to act within the system and use **relationships** between **resources** and **actors** to carry out activities that align with their motivations.

There are several perspectives that are helpful to understand the system:

The ERIS definition of the whole energy system



Consumer needs

Consumers are special actors within the energy system as their needs drive the purpose of the Whole System. Consumers can be individuals, groups or businesses; turning up the heating, driving from A to B, keeping produce chilled across the supply chain. They want the energy system to deliver their needs but not just at any cost to themselves or the environment.

Consumers' needs can be met in many ways, using a range of resources. Needs are interdependent, and satisfying one may impact another, leading to overall consumer dissatisfaction.

The following list is not comprehensive but is indicative of the range of needs that can be included in a system description.

- **Mobility:** This fulfils the end user requirement to move themselves or goods between places. It includes cars, vans, rail, public transport, air and freight. This may be private vehicle ownership, fleets, or services (such as taxis, Uber etc). Electric, hydrogen and hybrid vehicles are of key relevance here, with respect to the transformation of the energy system, due to their multi-vector nature
- **Comfort:** Consumers use energy to maintain a comfortable and safe environment to live and work. This includes thermal comfort through heating and cooling, along with spatial comfort through lighting, safety and ventilation
- **Health:** Consumers require hot water for cleaning, sterilisation and washing. They also require a healthy environment including clean air, water and low impact from noise and light pollution
- **Leisure:** Consumers want entertainment (TV, sports, concerts), holidays and hobbies. These are activities that could be considered non-essential, although an intrinsic part of modern society in the developed world
- **Production:** Industrial consumers manufacture materials and products using energy. This includes industrial processes such as mass food preparation, plastic moulding or car manufacturing

Resources

Resources are used to fulfil consumer needs; they are the toolbox. They include regulatory and commercial arrangements as well as intelligence and physical hardware.

- **Physical:** Physical resources generate, convert, deliver, control and transport energy to consumers safely and reliably. These can be large generators such as power stations or a simple radiator control on a domestic gas boiler heating system. In addition to these primary physical resources, supervisory control and data acquisition (SCADA) systems and voice communications are needed to allow observation and control of delivery
- **Information:** Collecting, processing and making decisions based on data are important parts of the energy system. Control signals and communications also sit under this domain. Appropriate access to data, the connectivity between devices exchanging data and interoperability between infrastructure and vectors, are essential components that underpin Whole System Thinking across planning, forecasting and operational timescales
- **Commercial:** The commercial resource includes the contracts, business models and market arrangements that allow value to be exploited. It is primarily concerned with arrangements between actors and is shaped by policy and regulation. Flows of investment and capital are an important part of the commercial layer as this is often a primary enabling factor to the success of a system approach
- **Policy:** The legal framework within which the energy system exists is made up of primary legislation, secondary legislation and regulations. It also includes the lobbying, consultations and planning processes that inform and provide direction to policy

  Policy and legislation are developed in several ways and are integral in shaping how services can be delivered. Regulations and legislation can be in place to enable technologies, protect consumers, or provide levers of control within the system

  Relaxations of regulations can be made in some cases, such as Ofgem's regulatory sandboxes. These enable innovators to trial innovative business products, services and business models that cannot currently operate under existing regulations.

Vectors

A vector is a means of transferring energy and includes the resources required to generate, store, distribute and convert a fuel to a service, or another vector. Examples include electricity, heat, combustible gases, liquid fuels, electrical storage and transport.

The energy system is multi-vector. Solutions that allow conversion between vectors can provide both flexibility opportunities and challenges to the energy system; for example, using hydrogen to store renewable generated energy to convert back to electricity for charging electric vehicles.

It is important to not get stuck in a single vector perspective as this could rule out potential solutions from a systems point of view, by exploring avenues without the full context or perspective.

Actors and Motivations

Actors are the people, companies, governments and other communities that wish to take or create value within the system. All actors have some value to gain from the system as without value, there is no motivation to act.

The motivations may be for individual gain or as representatives of a wider set of stakeholders. Each actor will have several motivations that they are trying to satisfy, and an optimal solution for the whole system may not be optimal for each of the actors. This is an intrinsic challenge within the energy system. Some motivations could be:

- **fairness** – how equally spread benefits from the system are, how the vulnerable and disempowered are treated within the system?
- **clean air** – how does the system impact the immediate environment?
- **profit** – what is the financial reward?
- **jobs and economic growth** – how can we create jobs and stimulate the economy? e.g. at a local level if you are a council, but across the UK for national government
- **stability** – is the system stable, or does it require continuous intervention?
- **carbon reduction** – an actor may have targets it is obligated to achieve
- **security** – is the system vulnerable to malicious actions, do the control and informational systems have sufficient safeguards?
- **political power** – politics is a very important motivation within the energy system. Most people won't vote for higher bills or an unreliable system. International geopolitics will influence the Whole System

Some examples of actors and their motivations are given below:

National government

- wants to meet international legal targets on carbon reduction
- creates policy, legislation and regulation
- provides governance and frameworks (consumer protection, enabling markets)
- can influence investments and financial flows

Local and regional government

- wants to provide healthy local environment, encourage economic growth and job creation
- takes democratic decisions regarding land use, planning and distribution choices
- delivers services for protection of vulnerable citizens
- looks to improve society in its locality and provides amenities and facilities

Citizens, consumers and society

- want to be comfortable and healthy
- buy products and services
- decide which product and services to accept and prioritise
- shape local and national government policy through elections and representatives

Resource providers, manufacturers, service providers and product vendors

- want to create profit for shareholders
- decide where to develop technology
- offer services to consumers using resources
- agree standards and protocols
- use investment to generate profits

Investors

- want to make a return on investment
- decide how to invest in the energy system, where risks and returns are located
- invest in technologies and systems
- System operators
- want system stability at minimum cost while fulfilling licence terms
- deliver infrastructure for services

Relationships

Relationships represent the connections between actors, resources, and consumers that are used for affected by changes in the system.

- **Communication:** Communication represents protocols and interactions between physical resources, data and consumers. This includes value propositions and their expression to the consumer, and the routes through which actors can share information and insights
- **Trading:** Trading is the exchange of value between actors and different resources. This will use an agreed set of rules, possibly a common platform (such as a commodity exchange) and will often emerge in the form of markets of one form or another
- **Supply Chain:** Supply chain is a system of organisations, people, activities, information, and resources involved in moving and adding value to a product or service from a supplier to the customer
- **Reward Chain:** The reward chain is the expression of the relationships between system resources and actors, providing value by fulfilling a need. This value is not necessarily financial, and each actor will have multiple motivations. For example, to an investor, clean air and health might not be considered of direct financial value. This, however, could lead to reduced demand for health services and therefore reduce indirect costs
- **Politics:** Politics represents a relationship between actors, policy and resources. Politics – both national and international – can influence policy, standards, commercial arrangements and relationships between actors significantly and needs to be considered in any Whole System approach
- **Society:** Society represents the socio-cultural forces that can affect consumers' attitudes, opinions and interests. These in turn impact the shape and make-up of the energy system. Social factors influence who we are as people. They affect how we behave, what we buy, and the policies and legislation that define markets and allow services to be delivered

People's lives and the things we choose to do shape energy demand: the times we get up, how we travel to work or appointments, what we eat and how we spend our free time etc. To think about energy in a sophisticated, holistic way, it is critical that we consider how humans, and the organisations, networks and connections they create, shape energy demand.

Perspectives

A perspective is defined as a viewpoint that can change the way the Whole System appears. It is important to consider systems from many perspectives to ensure they are enduring, transferable, and that potential impacts from changes can be understood.

- **Place:** Place refers to a physical location or set of locations in a certain scale. This could be a building, street, town, city, local authority area, county, nation, or any combination of these areas
- **Time:** Time refers to a specific period and the resolution being examined. Each actor may have a range of time and resolutions that they want to understand. These may be business investment, planning and operation, usage and market settlement, energy supply and demand, and technology development. Very small-time frames may be applicable for operational control and forecasting
- **Investment:** An investment looks at the system from a risk-reward basis. This allows a view of the system to be formed that can determine the most appropriate financial models to help achieve investment objectives. Building a portfolio of investment is of primary importance to those looking at the system though investment perspectives
- **Governance:** Governance is the act of observing how a system changes with different conditions. Viewing the energy system from a governance perspective can expose the underlying structures and patterns that shape the Whole System response to change

  Determining what constitutes the right balance of incentives and rewards is a governance decision and should be informed by a view of the Whole System. The primary outputs from a governance perspective are the strategic objectives of an actor, framed within its mission, values and ethical framework.

Conclusions

This document has introduced Systems Thinking and why it is important when considering changes to the energy system. The ERIS view of the whole energy system has been defined to develop a consistent language in this area. The language and structure proposed are by no means intended to be the authoritative version and are meant to act as a 'scaffolding' to discuss elements of the energy system with a wide range of stakeholders from a diverse range of backgrounds.

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