CATAPULT Energy Systems

An Introduction to Interoperability in the Energy Sector

An Energy Systems Catapult Discussion Paper

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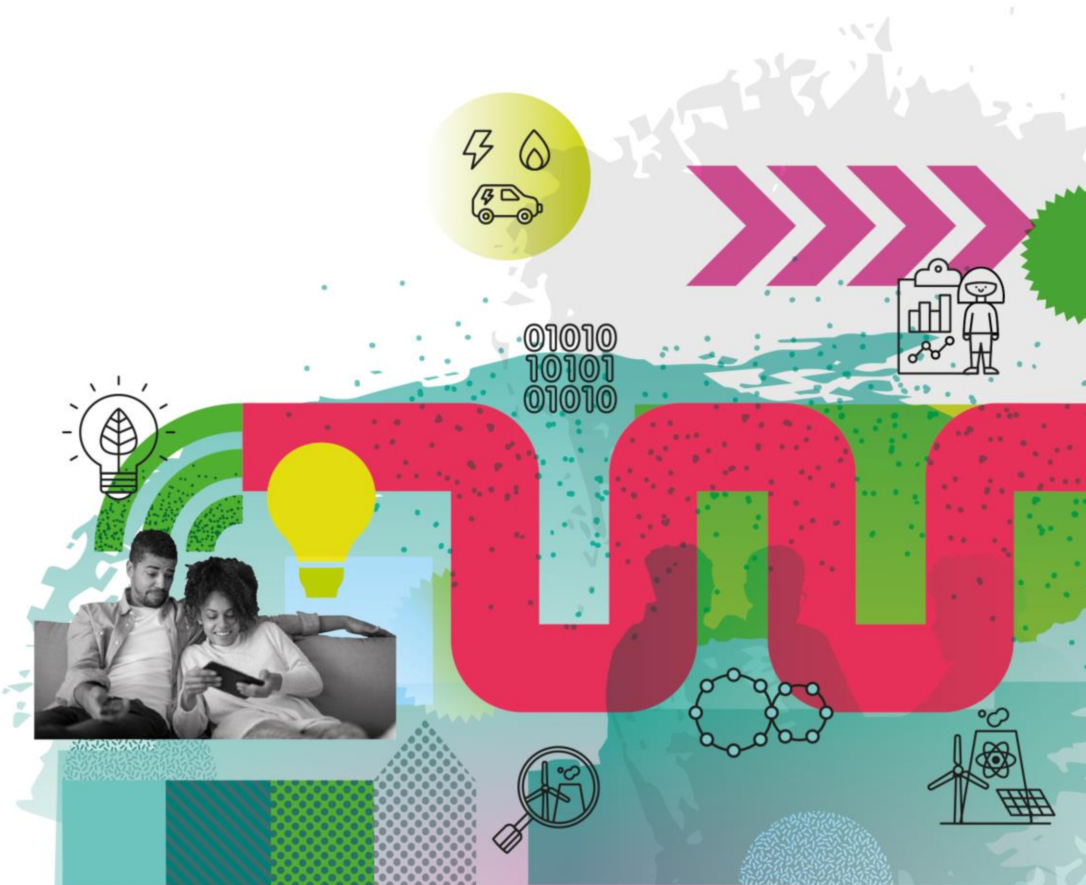
December 2018



Contents

1. About Us 4
2. Executive Summary 5
3. Introduction 6
4. Types of Interoperability 7
5. Case-Study 11
   5.1. Flexibility Case-Study 12
6. Appendices 13
   6.1. Glossary of Terms 13

1. About Us

Energy Systems Catapult is a leading technology and innovation centre set up to help the UK navigate the transformation of our energy system and capture the new commercial opportunities created. Our aims are both informed by and directly support the delivery of the UK's Industrial Strategy, Clean Growth Strategy and the Climate Change Act.

At its heart, our vision is for affordable, secure and clean energy system that works for people, communities and businesses; a system that is enabled and supported by the market to deliver the innovation, products and services required to meet the UK's economic and carbon ambitions, and position UK innovators as leaders on the world stage.

Our mission is to drive innovation and help open-up new markets in the energy system at the pace and scale required to achieve the combined goals of maximising UK productivity and delivering a low carbon energy system.

We will support the UK in becoming a world leader through ongoing collaboration with industry, government and academia to remove barriers to innovation and realise the Government's vision and ultimately meet its legally binding carbon targets.

2. Executive Summary

This paper introduces some of the complex considerations of interoperability within the energy sector(s). This paper is intended to start discussion and debate to refine the thinking. As such it is not consider a final position on the ideas presented. The author welcomes comment via the contact information on the back page.

Interoperability is seen by many in the energy sector(s) as key to unlocking flexibility services. However, the word interoperability is often used narrowly to describe the compatibility between interfacing pieces of technology. For example, when asking, "Is my smart device compatible with my smart-home controller?" we think about whether the device and controller are interoperable. This paper argues interoperability should be considered more broadly. Understanding its wider implications will be essential if the energy system and consumers of energy are to benefit from the potential of digitisation.

Interoperability is the ability of a product or system to cooperate with other products or systems to share resources. The term is suitable for a wide range of uses and this paper explores 19 different types of interoperability within energy sectors.

This report provides clarity on the different uses of the term interoperability, discusses the types of interoperability which must be considered to deliver demand-side flexibility and provides case-studies which illustrate the practical need to consider the different elements in context with each other. Furthermore, evidence for taking a systematic approach for products and services is provided, which highlights the need to think about multiple forms of interoperability simultaneously.

The 19 types of interoperability have been grouped into 6 areas to simplify the debate, however the full descriptions are included in the report since the challenges with each type will need to be considered carefully and may require different approaches to solve. In summary the 6 types are:

1. Consumer Interoperability: ensuring that provisions exist for consumers to switch between both different commercial offers and technology choices.
2. Commercial Interoperability: to ensure that incentives are aligned across the energy system to ensure that value can flow where it needs to, driven by market forces.
3. Data Interoperability: to ease the sharing and portability of data between different systems.
4. Device Interoperability: to ensure that devices are swappable, replaceable and exchangeable as needs change and technologies develop and to allow consumers to make informed choices between open and closed eco-systems.
5. Physical Interoperability: to ensure that end-to-end systems function as changes happen to parts of the system.
6. Vector Interoperability: to ensure that energy provision across gas, electricity, heat, transport fuels etc. are compatible with one-another and that coordination occurs in a timely fashion.

3. Introduction

This paper introduces some of the complex considerations of interoperability within the energy sector(s). This paper is intended to start discussion and debate to refine the thinking. As such it is not consider a final position on the ideas presented. The author welcomes comment via the contact information on the back page.

Interoperability is the ability of a product or system to cooperate with other products or systems to share resources. This is distinct from compatibility which simply means that two products or services can operate in the same environment without adversely affecting the other. As an example; a car, road network and fuel-refilling station are interoperable with each other since they deliver an outcome because they interact successfully. A car and a bicycle could be seen as compatible as they both use the same environment but do not rely on each other for operation.

The advantages, throughout multiple industries, brought by interoperability are numerous but include:

1. Consumers get a better deal by being able to use their products and services in many ways
2. Grid flexibility services can be made to work if interoperable systems can communicate with each other
3. System costs might be reduced by using existing infrastructure in smarter ways

The word interoperability can mean different things to different people. Understanding that there are different uses of the term but being more exacting in how we use it will help ensure that individuals are discussing the same ideas and concepts. The terms presented are an attempt to create a common understanding.

Where possible, the specific terms used in this paper have come from papers and existing literature and every attempt has been made to fit with the most common usage.

There are many types of interoperability which are explored in Table 1. These types have been grouped into 6 groups for clarity which are best explored through the case-study in section 5. Those groups are summarised as Consumer, Commercial, Data, Device, Physical and Vector.

Aside from the different uses of interoperability there are also different depths to consider. Two, widely quoted levels of interoperability are syntactic and semantic. The former refers to the ability to exchange resources or data. For example, computer system A can send the value ‘10’ to computer system B over a specified protocol, e.g. USB. It is received and stored, perhaps, for later use. In semantic interoperability then computer system B is said to understand that ‘10’ means “charge £10 against a certain account number” and can then act on it accordingly. As an example, the phrase “cats pour fantastically” is syntactically valid but makes no semantic sense.

4. Types of Interoperability

Interoperability Type	Interoperability Class	Example Interface Between		Example Description
1	Consumer	Consumer	Domestic Eco-system	The requirement that a consumer is not locked in to one set of devices, services and opportunities after buying into a single platform or eco-system but rather they have a wide range of choices requires that consumers are able to migrate their equipment, assets, data, information and accounts between providers.
2		Consumer	Appliances	Technology choices like heat pumps and heat networks should not have to lock-in consumers for excessive periods. Avoiding lock-in could be through, for example, consideration of consumer interoperability that would ensure there are ways to transfer capital loans or to move amortised value in product so that consumers can move between offerings.
3		Consumer	Service Providers	For example, enabling the ability to be able to move between service providers, taking data, account information and preferences without undue inconvenience.
4	Commercial	Business	Business	The need for one businesses in the supply chain wishing to influence another to be able to form commercial agreements. For example, where an electricity distribution network company wants to influence domestic retailers to enable dynamic pricing (with the aim of influencing time of use pricing) then a means of incentivising behaviour is needed. Commercial interoperability is the idea that businesses motivations should be reflected in cost structures that price and value discovery is truly possible i.e. being able to set the network price to discover whether people are willing to pay for its use at a given time of day rather than avoiding the cost by shifting time of use.
5		Service Provider	Consumer	The notion of providing a service to a customer, guaranteeing outcomes whilst finding a way to improve margins needs commercially interoperable solutions between multiple businesses, aligning business plans with the appropriate financial incentives.
6	Data	Service Providers (ESPs, ESCOs, MaaS providers etc.)	Home Energy Management Systems (e.g. ESC HEMS, Alexa, Overkiz)	The requirement for a third-party to be able communicate with end-devices (to affect real outcomes) through energy management applications regardless of which purchasing choices any consumer has chosen. For example, one consumer uses a brand of heating controller and a connected home device to drive it but wants to offer the flexibility to a 3rd party, who needs to be able to interface with it (and all the other competing market offers).

Interoperability Type	Interoperability Class	Example Interface Between		Example Description
7		Service Providers (ESPs, ESCOs, MaaS providers etc.)	Upstream (e.g. retailers, dist. networks, trans. networks, generators and settlement organisations)	The requirement for data to be communicated and understood between different organisations is paramount. Data interoperability needs to also include access rights, security, privacy considerations, commercial tracking and transacting (if data is paid for). For retailers, settlement agents (and similar) where there may be multiple companies performing similar, or the same roles, then the needs to interoperable such that each agent knows what proportion they are responsible for.
8		Businesses (ESPs, ESCOs, MaaS providers etc.)	Regulator	The ability for data to be archived, reviewed and/or audited by a regulator or, perhaps a consumer protection organisation.
9		Organisation A	Organisation B	The notion that the data belongs to the end user and that interoperability between systems is required to ensure that information, which is useful to those end users is portable such that they benefit from it.
10	Device	Energy System	Appliance	The notion that you can plug your device into a socket with a standard physical interface. For example, connecting a vehicle to charging point.
11		Home Energy Management Systems	Appliances and devices	The expectation that equipment purchased for use in a home can have compatible syntactic and semantic interoperability with other equipment in the home.
12	Physical	Networks	Appliances	The expectation of interoperability between the resource supplied and the equipment consuming. For example, the calorific content of gas consumed by a gas boiler (the implication perhaps being the carbon content) or the frequency and voltage characteristics of electricity reaching a load device and its ability to operate as expected and without damage.

Interoperability Type	Interoperability Class	Example Interface Between		Example Description
13		Flexibility Scheme	Demand-side flexibility (parameters)	The requirement for interoperability between, for example, an electricity network and a provider of flexibility. This is more complex than simply agreeing a number of kWh over a half-hourly window. Electrical loads are not created equal. Some may provide benefits and/or challenges beyond simply kWh. Switch mode power supplies such as those found in many forms of domestic equipment (TVs, laptop chargers, phone chargers, entertainment devices) often have a significant capacitive front end which may offset some inductance and help the system's reactive power position. Pumps (such as those found in white goods and heat pumps etc) are more inductive and skew the reactive power needs in the opposite direction. In sufficient numbers switching them on or off may lead to needing to make additional system interventions with associated costs. Therefore, it is important to understand the interoperability of certain flexibility parameters against the needs of the physical system(s). In conventional generation there is a correlation between what has been traded and what is generated. The output of a conventional thermal plant is often a percentage of the boiler plate rating. In the case of having access to millions of devices (e.g. electric vehicles) there may be a need to aggregate many thousands of devices together but, at some level, each individual item will need to be controlled requiring substantial device interoperability.
14		DSR Scheme A	DSR Scheme B	The need for interoperability between competing schemes. For example, consider the combination of large numbers of smart appliances, BEVs providing V2G services and grid connected battery storage solutions. If each of those technologies is targeting providing the same flexibility service (e.g. frequency response) to the electricity system, then there needs to be some level of co-ordination between them to ensure that they don't all respond simultaneously to an observed condition or parameter. For example, maybe all 3 technologies monitor the frequency of the supply electricity and switch at a certain threshold. We must ensure that they don't all switch at the same time and cause huge swings from over to under supply or vice-versa, leading to extreme systems oscillations.

Interoperability Type	Interoperability Class	Example Interface Between		Example Description
15		Flexibility Scheme	Location	The expectation that issues in one location can be solved by appropriate action in a specific location. Geographical factors are important and for example, utilising an electricity turn-down in demand at one end of the country to alleviate a flow constraint in another area of the country might not be the most effective solution. Alternatively choosing to burn gas in certain areas because the air quality conditions are worse somewhere else might be a socially responsible choice to make.
16	Vector	Gas	Electricity	For example, a reduction in gas pressure in a pipe (perhaps caused by hybrid devices switching vectors suddenly to alleviate a constraint on the electricity network) might be mitigated by reducing gas consumption in a neighbouring area if the systems are interoperable with each other.
17		Electricity	Transport Infrastructure	The need that charging solutions and refuelling solutions are interoperable to ensure that the range (distance) for vehicles is sufficient to meet the requirements of users (including sufficient parking for charging vehicles etc.)
18		Energy	Heat	The notion that different energy vectors have interoperable (related) benefits and challenges for the delivery of heat outcomes.
19		Electricity	Hydrogen	The expectation that hydrogen may be produced using surplus electricity generated from low-carbon sources, normally assumed to be wind requires that sufficient capacity is installed and available and that the systems are interoperable to communicate when there is surplus capacity etc.

Table 1 – Types of Interoperability

5. Case-Study

The case-study below is a simplified, hypothetical example of the provision of flexibility, that is provided by consumers for the benefit of managing network issues and enabled through smart hybrid heat pumps (HHPs).

In the following case-study several definitions are assumed. Firstly, a smart HHP is defined as a heating appliance which is capable of two-way communication and which can respond to an external request to modify its operating behaviour. It can switch between electricity and another fuel source. Secondly, flexibility is defined as the willingness of a consumer to a change an operation of an appliance (which provides the benefit of a change in resource consumption). Such flexibility doesn't have to be encouraged with a financial incentive.

Much of the information in the case study, presented below, is also applicable to other types of smart domestic appliances, including hybrid electric vehicles, provided they are connected to the grid.

5.1. Flexibility Case-Study

Consider the example of a smart HHP ❶ used by a householder in Hockley, a neighbourhood in Birmingham in the West Midlands. Hockley has plenty of headroom and isn't constrained so any local flexibility service ❷ it can provide (usually targeted at reducing network problems) is unlikely to be utilised ❸, under current conditions. The same cannot be said of Portishead, near Bristol, which is heavily constrained, and a flexible device based here may be very lucrative. In Portishead a signal may be sent to request a change in electricity demand (by either reducing demand or switching to another vector ❹) fairly regularly although the primary consideration is that the end-user is getting what they want (heat / comfort / ability to dry clothes etc.) ❺.

However, a national flexibility service, which concentrates on frequency response and/or reducing transmission constraints might use either device dependent on the situation and provided there are no competing offers which can offer the same flexibility at less cost ❻ or provide additional benefits ❼.

An integrated approach ❽ might help deliver the right smart appliances to the right locations to provide the best mutual benefits.

❶ is an example of device interoperability where the smart HHP is a device that needs to talk to other equipment. In this example the smart HHP would need to communicate with a controller either inside the home or externally.

❷ is an example of commercial interoperability where an external party might want to offer something (may or may not be financial) in return for access to the flexibility provided.

❸ is an example of physical interoperability whereby the availability of flexibility doesn't necessarily mean that flexibility is needed or that the type of flexibility offered isn't always appropriate (e.g. long duration reduction in demand to alleviate thermal issues 'vs' short term reduction in active power to manage electricity frequency issues).

It's clear to see that device interoperability enables commercial interoperability and physical interoperability but here ❸ isn't required which calls ❷ into question and means that there is much more to thinking about interoperability than device interoperability alone.

❹ highlights the need for vector interoperability. Large numbers of consumers in an area switching from, say, electricity to gas, needs to be co-ordinated to ensure supplies are in the right places and to avoid problematic pressure drops etc.

❺ illustrates consumer interoperability. Put simply, this simply means that the desire for flexibility is fine but the key is that the outcomes for consumers are met. The points in ❶ to ❸ also illustrate some consumer interoperability in that consumers living in some geographic locations will have unequal access to some flexibility services. Therefore, any sale of a smart appliance where the financial opportunities of providing flexibility is discussed (commercial), must consider the geography of where it will operate and the sorts of flexibility that will be needed (physical).

❻ is another example of commercial interoperability but this time considers competing offers. For example, consider that down the street someone else has some battery storage. This might be offered at a much lower price than the flexibility offered from a smart HHP and therefore would likely be used in preference. There is a physical interoperability ❼ consideration here too which is that use of both the battery and smart HHP simultaneously, might cause physical system problems. It is likely that the controls of systems described in this case study would need to be autonomous (external control would be too slow). Therefore, if both options described here (smart HHP and battery) both responded to a request to modify demand simultaneously then it's possible to go from under-supply to over-supply (or vice-versa) instantly, which would then, presumably, be commanded the other way causing repeated oscillation which could eventually cause system instability and power-cuts.

Finally, ❽, introduces the idea that using better information, enabled through data interoperability can put the right solutions into the right places. Given the complexity described above, multiple pieces of data are needed to be shared with the right parties to drive effective outcomes.

6. Appendices

6.1. Glossary of Terms

Acronym or Term	Definition
BEV	Battery Electric Vehicle (specifically a vehicle which stores electricity and is capable of being plugged in to the electricity system)
V2G	Vehicle to Grid (a vehicle providing power back to the electricity system)
Interoperability	the ability of a product or system to cooperate with other products or systems to share resources
Syntactic Interoperability	Compatibility of language structure e.g. English grammar
Semantic Interoperability	Compatibility of meaning e.g. when you say red, I understand that we're discussing a specific colour.

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Energy Systems Catapult supports innovators in unleashing opportunities from the transition to a clean, intelligent energy system.

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