EDRC
Energy Demand Research Centre

Demand Flexibility Certificates

Increasing the Visibility of Demand Flexibility through Certification

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Executive Summary

This report introduces the concept of Demand Flexibility Certificates and lays the methodological foundations for establishing a Demand Flexibility rating system, with a focus on buildings – a sector anticipated to have the most numerous potential Flexibility Providers.

Up until now, the Demand Flexibility potential of the buildings sector has been largely untapped. This can be attributed in great measure to the lack of robust frameworks that allow for producing reliable and consistent estimates of the Demand Flexibility potentials afforded by individual assets at the household, dwelling or building level.

Flexible demand response, or Demand Flexibility for short, refers to the ability to produce a deliberate change in demand, in response to any request or incentive, or as previously agreed upon. As improvements are made in the ability to harness Demand Flexibility – that is, increase or decrease demand as needed to alleviate system stress – the need for network upgrades and additional generation capacity decreases.

An essential prerequisite to the use of Demand Flexibility as a reliable system-wide resource, is the ability to provide accurate measurements of the existing Demand Flexibility potentials, and the traded volumes of Demand Flexibility services in everyday market operations.

The need for accurate and robust methodologies to appraise Demand Flexibility is far from limited to the validation of what is exchanged and delivered through the Flexibility market. At the most basic level, if we are to ensure that Flexibility market operation can reach near-optimal levels, it becomes essential to be able to provide *ex-ante* appraisals of the Demand Flexibility potential of a diverse number of assets and Flexibility providers.

Producing estimates for the Demand Flexibility harnessing potential every time we need to determine the amount of Demand Flexibility we can call upon would be at best impractical, and at worst unattainable. Therefore, a key goal in the efforts to characterise the Demand Flexibility potentials would be to condense the wealth of information and layers of complexity that need to be dealt with while producing such estimates into an easy-to-read and -interpret **Demand Flexibility Certificate** (DFC).

The Demand Flexibility Certificate is the result of the systematic appraisal of the different components that contribute to the overall ability to increase, decrease, and shift demand loads from within the building envelope.

In essence, a building's Demand Flexibility Certificate would become a currency of sorts, which would allow both prospective Flexibility Providers and Flexibility users to quickly and reliably assess the value that an asset could offer.

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The Demand Flexibility Certificate would prove highly advantageous as it would serve three main purposes.

Firstly, a robust and reliable framework would allow for identifying opportunities to improve Demand Flexibility potential of individual assets/providers. Having a clear idea of both what is available and what is achievable is a necessary first step when it comes to engaging in Demand Flexibility provision. Therefore, any prospective Demand Flexibility provider would be better suited to do so if guidelines and frameworks exist that allow for a systematic analysis of the Flexibility potential of one or a combination of assets.

Secondly, a solid foundational mapping of the asset-level Flexibility potential would provide reliable pictures of both the current state of and prospects for Demand Flexibility harnessing potential at the local, regional and national levels. In the first instance, this can inform system planning and management decisions in relation to network reinforcement needs and temporary buffering opportunities.

Thirdly, a clear idea of the extent to which existing Demand Flexibility potential can be harnessed at the local, regional and national levels would provide clear indications of where investment is needed the most in order to further unlock and boost Demand Flexibility potential, particularly in locations and regions where network constraints are most problematic and network reinforcements are too difficult or too costly to provide. Whenever it is determined that the need for network reinforcements is imminent, this can also help in identifying the network sectors which should top the list of priorities.

The report is organised as follows.

Section 1 sets the scene by providing an overview of Flexibility. It defines what Flexibility is; why it is so important; and its role as a grid resource. It introduces frameworks and mechanisms which need to be put in place so that Demand Flexibility can be readily harnessed and delivered as a system-wide resource, including infrastructure and technology systems; market rules and legal frameworks; and coordination platforms. For instance, Section 1.4 outlines some of the pre-requisites to harnessing the Demand Flexibility potential that have been or are being developed. However, it also highlights the gap that the Demand Flexibility Certification Framework put forward in this report is trying to address.

Section 2 discusses Demand Flexibility. It describes the stages at which quantifications are needed; how to estimate harnessing potential; baselining methodologies and validation of Flexibility delivery.

Section 3 introduces Demand Flexibility Certification, and makes the case for a common framework to characterise Flexibility assets and providers; explains how Demand Flexibility Certificates could draw on the Energy Performance Certification experience by discussing methodological similarities and requirements.

Section 4 presents the Demand Flexibility rating methodology in terms of data prerequisites and metrics, and details the Flexibility Rating Procedure. Capturing the complex dynamics involved in estimating a building's Demand

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Flexibility potential would be difficult using a tiered rating framework such as the one used for EPC ratings. Thus, in order to better capture this complexity, we implement a grid rating framework that rates the Demand Flexibility potential across two key dimensions: Magnitude and Quality. The rating framework is limited to two dimensions primarily with the aim of providing an overview with enough nuance, but at the same time, avoiding unnecessary complexity when it comes to interpreting the ratings of particular buildings or assets. Further details on the Demand Flexibility Certificates' rating procedure can be found in Section 4.3, along with an illustrative example of the way in which the information produced by the Demand Flexibility Rating procedure could be summarised in the form of an officially-issued Demand Flexibility Certificate.

Section 5 discusses applications and use cases. It discusses who would benefit directly from these certificates; and other potential use cases such as RIIO and Nodal pricing reform.

Throughout the report, relevant terms are capitalised for added emphasis, and working definitions for them can be found in the Glossary.

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1 Background: Flexibility Overview

1.1 What is Flexibility?

Energy systems need to constantly match supply and demand in order to ensure the safe and adequate operation of the system as a whole. The process through which this happens is what is commonly referred to as System Balancing. Thus, when we talk about Flexibility in the context of energy systems, we refer to the overall ability to adjust supply and/or demand to achieve and maintain system balance.

To ensure the most efficient operation, the system needs to balance the supply and demand over different timescales; from seconds to hours, days and across seasons. Likewise, distinctions can be made between the types and amounts of Flexibility required at each timescale. In the case of Power Systems, this constant balancing needs to happen in real time, and supply and demand need to be matched almost exactly in order to keep system voltages and frequencies stable.

Historically, system operation has been **demand-driven**. That is, system Flexibility has predominantly stemmed from the **supply side**, where generation output has been ramped up or down to match demand. In future, however, the decarbonisation of the energy systems will see an increase in the volumes of weather-dependent generation, along with a decrease in the volumes of flexible generation. This means that the current System Balancing paradigm will need to change, and **demand** will have to become **more flexible** in order to be able to shift in time and/or space to make the most effective use of available generation and network capacities.

The sources of Demand Flexibility are varied, and include flexible Demand Response, direct electricity storage (i.e. electric batteries), multi-vector energy storage systems such as Power-to-Gas (P2G), pumped hydro, and optimised combinations of these in so-called Virtual Power Plants (VPPs). All of these, when aggregated together, and coordinated with Power System operation, help to effectively handle the (sometimes unforeseen) variation in available power generation.

1.2 Why is Flexibility so important?

Flexibility is widely considered as a crucial component in the transition to net zero. This is because, as we move towards net zero, system operation will have to deal with increasingly larger shares of renewables, as well as increasingly smaller shares of dispatchable generation assets such as gas-fired power plants. Therefore, much higher levels of Flexibility will be needed in order to balance supply and demand in an efficient and (cost-)effective manner.

Reaching net zero can be achieved through a number of paths, therefore, there is a certain degree of uncertainty as to what exactly a net zero energy system will look like. However, some guiding tenets have been emerging along the way, so we can expect a number of things as the transition progresses. For instance, across most net zero scenarios, an overall increase in electricity

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demand loads is expected due to the large-scale electrification of transport and heating.

The net zero targets we are aiming for are ambitious, and the envisaged changes will no doubt be challenging. However, these changes also bring about opportunities to rethink the way our energy systems operate, and to find ways to take full advantage of existing generation and network capacities by leveraging distributed Flexibility assets. For instance, the electrification of transport will entail larger shares of Electric Vehicles (EVs) which could help in supporting System Balancing through smart charging schedules that allow for absorbing the oversupply of renewable generation rather than curtailing it, or through Vehicle-to-Grid (V2G) programmes that allow for reducing demand during peak periods to alleviate stress and congestion on local networks and the system as a whole.

Demand Flexibility, therefore, will be increasingly important as we move towards net zero as it is precisely the level of Flexibility what will determine to a large extent both our ability to take advantage of these opportunities, and the rate of progress of wider decarbonisation of the energy systems.

National Grid ESO's report on Future Energy Scenarios of 2023 estimated that, by 2040, flexible Demand Response from residential, commercial and industrial sectors could provide between 6-12 GW of Demand Flexibility. By 2050, it is envisaged that between 10-12 GW of Demand Flexibility could be harnessed from the residential sector alone[1].

1.3 The role of Demand Flexibility as a grid resource

A detailed understanding of the demand loads likely to be experienced, as well as their implications, have always been essential prerequisites for the purposes of system planning and operation. The concept of peak demand in particular has been central to these purposes as both generation and network capacities have traditionally been sized in accordance with the peak demand likely to be experienced.

Currently, peak demand is commonly associated with a winter weekday evening, where system stress is at its highest. Thus, the idea of peak demand has traditionally evoked negative connotations. As we transition to a net zero economy, the concept of peak electricity demand and how it affects system planning and operation will also change.

System stress will no longer be solely driven by those periods where either generation or network capacity (or both) are approaching their (upper) limits. Increasingly, it will also be driven by periods where surplus generation is experienced, be it due to an unforeseen increase in generation output or an unforeseen decrease in demand loads.

[1] National Grid ESO, Future Energy Scenarios 2023, https://www.nationalgrideso.com/future-energy/future-energy-scenarios/documents

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Flexible demand response, or Demand Flexibility for short, refers to the ability to produce a deliberate change in demand, in response to any request or incentive, or as previously agreed upon. As improvements are made in the ability to increase or decrease demand as needed to alleviate system stress by absorbing surplus generation or avoid exceeding network capacity, the need for network upgrades and additional generation capacity decreases.[2,3,4]

The increasing uptake of distributed Demand Flexibility assets such as dedicated storage systems, EVs, smart appliances, heat pumps, among others, means that the potential for Demand Flexibility to contribute towards System Balancing efforts will be on a par with traditional sources of supply-side Flexibility.

As more energy end-uses are electrified, larger amounts of short-term Demand Flexibility will be needed to ensure that demand can match available supply over the course of any given day.

Recent developments in new sources of Demand Flexibility bring even more opportunities for demand to play a more active role in the balancing of the system.
For instance, large-scale deployments of Power-to-Gas (P2G) facilities – to produce either hydrogen through electrolysis or methane through methanation – will increase our ability to shift demand over longer timescales. This includes absorbing excess wind and solar produced during the day to power our needs during the evenings, but also taking advantage of the summer sun and breeze to power our needs throughout the winter months.

In the longer term, network reinforcements and generation capacity increases are likely to be unavoidable. However, a supply-led system balancing paradigm, where Demand Flexibility allows for making adjustments to the amounts of energy used or stored, will ensure that investment into such system upgrades can be strategically targeted to keep the transition to net zero on track, and hopefully even accelerate it.

[2] Lund, P. D., Lindgren, J., Mikkola, J., & Salpakari, J. (2015). Review of energy system flexibility measures to enable high levels of variable renewable electricity. *Renewable and sustainable energy reviews*, *45*, 785-807. https://doi.org/10.1016/j.rser.2015.01.057
[3] Cochran, J., Miller, M., Zinaman, O., Milligan, M., Arent, D., Palmintier, B., ... & Soonee, S. K. (2014). *Flexibility in 21st century power systems* (No. NREL/TP-6A20-61721). National Renewable Energy Lab. (NREL), Golden, CO (United States). https://doi.org/10.2172/1130630
[4] Grunewald, P., & Diakonova, M. (2018). Flexibility, dynamism and diversity in energy supply and demand: A critical review. *Energy Research & Social Science*, *38*, 58-66. https://doi.org/10.1016/j.erss.2018.01.014

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1.4 Harnessing Demand Flexibility

Numerous sources of Demand Flexibility have been identified to date, and many more are being actively developed and deployed.[5]

While this process of identifying and integrating all the potential sources of Flexibility is a necessary step, it is only the first one out of the several steps that need to be taken before Demand Flexibility can be readily harnessed and delivered as a system-wide resource.

Up until recently, the primary sources of system Flexibility were on the supply side, which meant that most mechanisms for harnessing said Flexibility have been tailored to them. The Capacity Markets developed in the UK and elsewhere are examples of such mechanisms to trigger Flexibility on the supply side. This means that, at present, it is relatively straightforward to control supply levels by ramping generation output up or down, as and when needed.

In order to be able to harness Demand Flexibility effectively, similar frameworks and mechanisms need to be put in place.

1.4.1 Infrastructure and technology systems

From the most practical point of view, Demand Flexibility harnessing can only be achieved so long as the necessary infrastructure and technology systems have been deployed and are operational on a sufficiently large scale. This concerns a number of programmes and initiatives such as the Smart Meter rollout programme and the creation of the Data Communications Company (DCC) in the UK.

Behind the meter – that is, on the consumer's end – flexible Demand Response can be enabled through either Automated or Manual systems, or a combination of both.
The scope of Automated Demand Response systems ranges from whole-building management systems which decide on the best way to respond to any requests or external signals, to specific load controls. These, in turn, can be divided into:

- **Direct Load Control**, which allows DNOs[6] or ESOs[7] to remotely ramp-up/down particular demand loads, or
- **Dynamic Demand Control**, which allows particular loads to respond to changes in frequency resulting from grid imbalances.

Manual Demand Response control comprises the responses elicited by signals or communicates from System Operators, aggregators, or utilities that rely on direct customer involvement in the decisions regarding which demand loads to

[5] Cruz, M. R., Fitiwi, D. Z., Santos, S. F., & Catalão, J. P. (2018). A comprehensive survey of flexibility options for supporting the low-carbon energy future. *Renewable and Sustainable Energy Reviews*, *97*, 338-353. https://doi.org/10.1016/j.rser.2018.08.028
[6] DNO: Distribution Network Operator
[7] ESO: Electricity System Operator

increase/decrease, how much and for how long. These can be broadly divided into two categories:

- **Change in Behaviour**, which refers to those instances where individual members of households or organisations modify their behaviour in response to the signals or incentives applicable at the time, in order to shift their typical demand loads or reduce their overall consumption. For example, the Demand Flexibility Service is a programme which was active during the winter of 2022-2023 and engaged 1.6 million households and businesses, resulting in a collective reduction of 3,300 megawatt-hours (MWh) of electricity.
- **Change in Processes**, which refers to those instances where relevant Flexibility Providers (usually businesses or organisations) make adjustments to their daily processes (e.g. energy-intensive manufacturing activities) to shift the associated demand loads or reduce their overall consumption. For example, pulp and paper manufacturing have autonomous, discrete, production processes that can be shifted to other times of day or to different days.

1.4.2 Market rules and legal frameworks

Putting in place such enabling infrastructure and technology systems is only the starting point, however. Once the communication channels are open, the appropriate signals and messages need to be created and sent across. This is where the creation of new Demand Flexibility Market rules, as well as policy and legal frameworks comes into place.

Current market provisions and policy frameworks allow for the creation of two broad types of contractual arrangements between System Operators and Flexibility Providers. Given their terms, these contractual categories can be denominated as **Explicit** and **Implicit**.

Explicit Demand Flexibility contracts comprise the kind of contractual arrangements made between System Operators and Flexibility Providers to secure **Manifest Flexibility Potentials**. These contracts are meant to ensure, on the one hand, the provision of Demand Flexibility as and when needed by System Operators, and on the other, the fair and prompt compensation of Flexibility Providers for supporting System Balancing and Congestion Management tasks.

Implicit Demand Flexibility contracts comprise the kind of contractual arrangements aimed at enabling the harnessing of **Latent Flexibility Potentials**. These contracts outline the terms based on which the target Flexibility Providers would be compensated should they ***choose*** to engage in the intended Demand Response, and/or penalised if they do not.

As is pointed out in the two preceding paragraphs, a distinction is made between the two broad types of Demand Flexibility that can be harnessed depending on the type of source.

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Flexibility Providers can have a number of devices, buildings or other assets at their disposal, and the extent to which the demand loads associated with particular sources can be increased/decreased, how fast, and for how long is what we refer to as the Flexibility Potential.

The term **Manifest Flexibility Potential** refers to the Demand Flexibility harnessing that has been agreed upon through one or more procurement contracts which clearly outline the terms and conditions under which the target Flexibility Providers need to deliver said Flexibility, as well as the level of compensation that will be received in exchange. This type of Flexibility mostly stems from large consumers (e.g. industrial and commercial), or Demand Flexibility aggregators.

The term **Latent Flexibility Potential** refers to the Demand Flexibility that ***could*** be harnessed through external signals such as pricing incentives or carbon intensity warnings, but the target Flexibility Providers have ***no obligation*** to deliver. This type of Flexibility mostly stems from the residential sector, and has been typically harnessed through Time-of-Use tariffs (e.g. Economy 7).

The relationship between the concepts outlined above are summarised in Table 1.

Table 1 - Summary of the relationship between contractual arrangements and types of Flexibility harnessed through them.

Type of Contract	**Type of Flexibility**	**Key Characteristics**
Explicit	Manifest Potential	• Considered a dispatchable Flexibility resource as it is deemed more reliable and predictable. • Procurement is market-based. • Allows for longer-term planning in the support of system balancing and congestion management tasks due to the nature of the procurement contracts.
Implicit	Latent Potential	• Typically associated with higher levels of uncertainty. • Procurement is supplier-based. • Currently seen as short-term (same-day, next-day) support only, mostly due to the lack of experience in handling complexity of harnessing, as well as limited scope of market and policy frameworks.

1.4.3 Coordination platforms

In order to realise the delivery of Demand Flexibility potentials, several distributed assets need to be coordinated for their Flexibility to be delivered in a timely and reliable manner. For this reason, it is necessary to create adequate platforms where Demand Flexibility potentials can be traded efficiently, and agreements can be made regarding the conditions under which said Demand Flexibility needs to be delivered.

In essence, these coordination platforms are meant to facilitate the existing Demand Flexibility markets, and allow system operators and regulators to provide signals to direct investment to areas where it is most needed. These platforms also help in clarifying both the buyers' needs and purchasing intentions, and the incentives or compensation levels that Flexibility asset owners can expect to receive by making their assets available and selling their Flexibility.

As the development of Demand Flexibility markets progresses, different, more specialised types of platforms, as well as the different types of corresponding participants have been emerging. Tables 2 and 3 below summarise the key platforms and players in the current markets.

Table 2 - Key types of coordinating platforms for Demand Flexibility harnessing.

Type of platform	Key purposes
General coordination	• Sign-posting and facilitating data flows • Harmonising standards and operation principles
Procurement	• Establishing links between Flexibility providers and purchasers • Communicating Flexibility requirements and availabilities
Dispatch and Control	• Coordination of dispatch signals to distributed assets • Notification of asset dispatch • Verification of asset dispatch
Transaction Settlement	• Validation of Flexibility delivery against scheduled transactions • Settlement of transactions

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Table 3 - Key participants in Demand Flexibility trading.

Type of participant	**Key roles**
Consumers	This participant category comprises individual consumers who can interact with the Demand Flexibility markets either through direct participation, an aggregator, or their energy supplier. Participants in this category mostly contribute towards the Latent Flexibility potentials, harnessed primarily through price signals such as Time-of-use tariffs.
Prosumers	This participant category comprises those consumers who also have distributed generation assets at their disposal. Participants in this category mostly contribute towards Manifest Flexibility potentials, and interact with the markets through the creation of Explicit Demand Flexibility contracts.
Distributed Energy Resources (DER)	Participants in this category correspond to entities that control DER assets but do not fall into the previous two categories. The asset classes at their disposal can include generation or storage resources connected at the Distribution network level.
Aggregators	This participant category comprises those entities who task themselves with pooling a number of participants that fall into the previous three categories in order to allow them to collectively interact with the Flexibility markets.
Distribution Network Operators (DNOs)	This participant category comprises those entities in charge of local network balancing. They can transact in most types of coordination platforms in order to access Demand Flexibility services from a number of asset classes ranging from large DER assets to aggregated residential Demand Flexibility.
Electricity System Operator (ESO)	This participant category comprises those entities in charge of system-wide balancing. They can transact in the same platforms as the DNOs. However, depending on the market arrangements, they could be in competition with these for the same Demand Flexibility available at any given time. When cases such as these arise, closer coordination between the ESO and DNOs is required in order to handle the System Balancing tasks in the most (cost-)effective and efficient way possible.

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In the UK, examples of this kind of coordinating platforms include the Demand Flexibility Service, an easy-onboarding procurement platform which allowed for the first time residential, industrial and commercial consumers alike to actively participate in the grid balancing tasks and be compensated for flexing their demand for electricity on a voluntary basis.

Essential to the operation of these platforms, as well as to the use of Demand Flexibility as a reliable system-wide resource, is the ability to provide accurate measurements of the existing Demand Flexibility potentials, and the traded volumes of Demand Flexibility services in everyday market operations.

The following section dives deeper into the challenges associated with achieving this.

2 Quantifying Demand Flexibility

2.1 Stages at which quantifications are needed

As part of everyday system operation, it is necessary to determine the availability of all system balancing resources that system operators can call upon if/when needed.
This information, in turn, allows system operators to make informed decisions regarding the most effective way to make use of such resources in order to keep system stability high and operational costs low.

Decisions made in this regard are then formalised through procurement contracts for the different resources needed to support system balancing operations at any given time.

Demand Flexibility is among these resources, and one that is increasingly sought after due to is cost-effective nature.

Based on the overall processes described in the preceding paragraph, we can identify three primary stages at which Demand Flexibility would need to be quantified in order to support effective system operation. These stages are summarised below in Table 4.

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Table 4 – System resource assessment process: stages at which Demand Flexibility quantifications are needed.

Operational need	Harnessing potential	Transaction settlement
• System operators make decisions regarding the assets or resources that can/should be mobilised in order to alleviate stress and keep system in balance. • Based on expected generation and/or demand patterns, volumes of Demand Flexibility likely to be needed are estimated.	• Flexibility providers or asset operators make judgements as to the extent to which they will/might be able to either reduce, increase, or shift demand away from periods of system stress. • Flexibility providers willing to engage in system balancing tasks through existing Demand Flexibility markets make their Flexibility offerings public. They can then trade these either directly or through a third-party (e.g. aggregators). • Aggregate volumes of available Demand Flexibility can then be called upon by system operators should these be needed.	• Procurement contracts are established between Flexibility providers and system operators. These contracts outline the terms under which Demand Flexibility needs to be delivered, as well as the compensations in return. • Discrepancies may arise between total volumes of purchased and delivered Demand Flexibility. These can be due to either overprovisioning or underdelivering. In any case, revised assessments of realised Demand Flexibility against traded volumes need to be made so that the corresponding transactions can be settled.

2.2 Estimating harnessing potential

Unlike generation or storage assets which have nominal/rated capacities that are mostly fixed, Demand Flexibility potentials are rather more like moving targets. This is due to the fact that demand loads change in line with natural and/or institutional rhythms, and so does the extent to which they can be flexible.

For instance, seasonal changes in daylight hours and temperature have a significant impact on overall demand loads. Likewise, institutional rhythms such as the typical weekday/weekend split or the typical working hours, are a primary determinant of the changes in demand observed over the course of a day or week across the residential, commercial and industrial sectors.

At its core, estimating Demand Flexibility harnessing potential is very simple: all there is to do is adding or subtracting individual loads to arrive at the total

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requirements or savings. In practice, however, producing any reasonably accurate estimate involves facing a number of challenges. The level of complexity is determined by the key considerations made when it comes to estimating the Flexibility potential, as well as by the relevance to the everyday operation of the system.

Three key distinctions can be made in terms of both the approaches to and applications of the quantification of Demand Flexibility harnessing potentials. These are further described below in Table 5.

Table 5 - Approaches to quantification of Demand Flexibility harnessing potential.

Basis for Quantification	**Key elements and considerations**	**Applications**
Theoretical potential	• This can be broadly considered as the absolute upper bound estimate. • Corresponds essentially to the sum of all existing flexible loads, under the assumption that they are entirely controllable. • While a useful figure, over-reliance on this estimate can be misleading as this corresponds to an 'ideal case' scenario.	• The primary applications of this kind of estimates are in the longer-term planning for system provisioning.
Technical potential	• This corresponds to all those flexible loads with a proven ability to engage in Demand Response events. • Primarily comprises those loads/assets behind Demand Management systems; these can be either automatically or manually operated. • In addition to the magnitude of demand loads, this also takes account of the 'controllability' of such loads. That is, it provides additional information about likely availability and response durations. • In the context of system operational purposes, this can be considered as the practical upper bound of available Flexibility.	• The primary applications for this kind of estimates include Demand Flexibility market development and investment signalling.

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Feasible potential	• This corresponds to a large extent to the Manifest Flexibility Potential, but may also include very-short-term estimates of Latent Flexibility Potential likely to be deliverable. • Comprises those Demand Loads/Flexibility Assets that are both technically enabled and commercially available to participate in Demand Response events. • This is arguably the most important estimate, as it is what determines the extent to which System Operators can rely on Demand Flexibility harnessing as a system balancing resource in their everyday operations.	• The primary applications for this kind of estimates are directly relevant to the everyday operation of both Demand Flexibility markets and System Balancing mechanisms.

As with any quantification exercise, it is necessary to determine not only the scale (i.e. units [kW, kWh]) that will be used for the quantification, but also the reference point(s) against which any increases or decreases in demand (flexibility) will be measured. This is what is commonly referred to as the Baseline.

Conceptually, the Baseline can be understood as the typical or expected demand profile, which comprises both the magnitudes and timings of the demand loads experienced over the course of a day.

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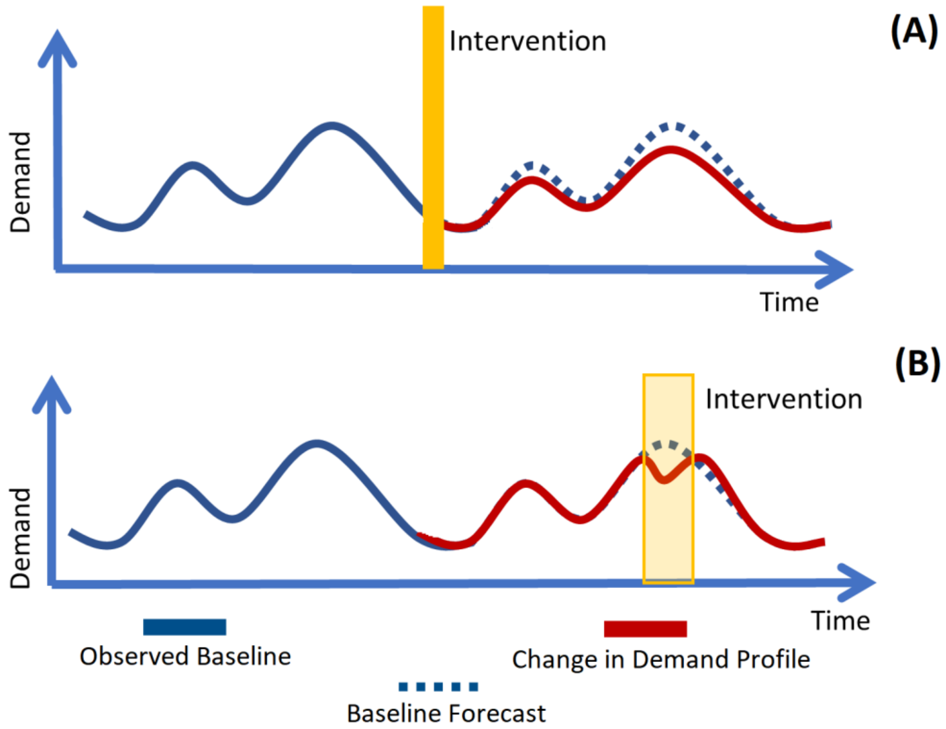

Figure 1 - Illustrative examples of intervention-driven changes in Demand Profiles relative to the Baseline Demand. (A) Overall demand reduction observed after the intervention is enforced. (B) Temporal Demand Load Shifting is observed during the period in which the intervention is enforced.

The Baseline itself needs to be quantified as well, and this is a fundamental initial step towards any Demand Flexibility quantification effort.

Depending on the kind of estimate that is sought (theoretical, technical, feasible), the methodology that is best suited will vary. Likewise, depending on the type of loads and/or Flexibility assets that will be accounted for, some methodologies will be better suited than others. Regardless of any particular circumstances, producing an accurate estimate for the Baseline demand loads is essential.

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2.3 Baselining methodologies

Currently, there are a number of methods in use which provide different tools and abilities to estimate Demand Load Baselines. A summary of the categories in which these can be broadly grouped is shown below in Figure 2.

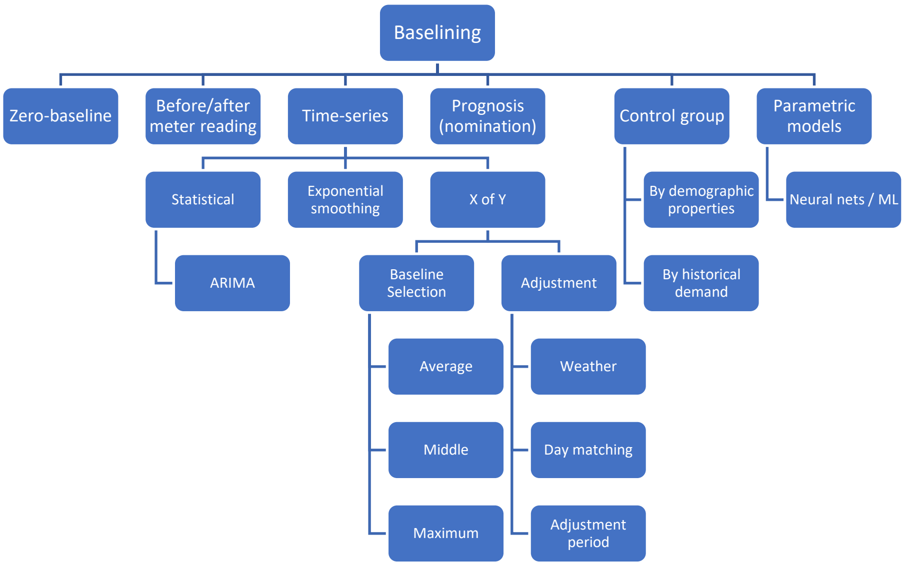

Figure 2 - Overview of baselining methodologies categories.

Each category is relevant and applicable to different circumstances. In some cases, a number of them can be applied to the same Baselining problem as there is considerable overlap in their scope and data requirements. However, for the sake of clarity, further descriptions of the general processes involved in each of them are provided below.

- **Zero-baseline** – This type of methodology is usually applied to generation or storage DER assets. This is primarily due to the fact that any potential Flexibility provision is determined by the rated capacities of the assets in question. That is, the output capacity of a generation asset, as well as the input/output capacity of a storage asset are constant for all intents and purposes. Therefore, any time the assets are unavailable, their baseline will always be zero.
- **Before/After Meter reading** – This type of methodology is commonly applied when it comes to quantifying the Demand Flexibility delivered by continuously operating Demand Response assets/providers with short notification timeframes for the delivery of Flexibility services (e.g. frequency response). In essence, this methodology consists in establishing a very-short-term historical baseline of an asset's input/output in order to validate any potential responses to a given Demand Flexibility event.
- **Time-series modelling** – This type of methodology consists in using longer-term historical time-series data, in order to establish an asset's typical/expected baseline. The time-series analysis typically revolves around demand and weather data with a view to identifying any trends

and/or patterns. A relatively common approach, primarily due to its simplicity, is the "**X** out of **Y**" method. This method consists in taking **X** samples (e.g. days) out of the total **Y** samples available in order to determine the most likely outcome. The total number of available samples (**Y**) typically corresponds to a set of qualifying time-series samples (e.g. daily profiles) which are meant to be illustrative of the typical asset behaviour prior to a given Demand Flexibility event. Another, more robust approach which also aims to leverage the statistical strength of historical data consists in building regression time-series models such as **ARIMA** (Autoregressive Integrated Moving Average) models.

- **Prognosis / nomination** – This type of methodology is commonly applied when the availability of historical empirical data is too limited to implement statistical methods, but is likely enough to make educated inferences with a reasonable degree of confidence regarding the likely outcomes of Demand Flexibility events from different asset classes. Prognostic/nomination models, therefore, consist in choosing what will be considered as the typical/expected asset behaviour, which will then serve as the reference point for any responses to Demand Flexibility events.
- **Control group** – This type of methodology has been commonly applied when it comes to establishing the baseline behaviour of small Demand Flexibility providers, which mostly include residential consumers. The method consists in segregating the consumer base on the basis of socio-demographic and/or demand profiles, in order to determine what constitutes the typical behaviour of a given group/consumer type. This group baseline is then used as the reference point against which any individual Flexibility provider's responses are measured and verified.[8]
- **Parametric modelling** – This type of methodology encompasses methods such as Machine Learning (ML). When available, huge quantities of historical empirical data are classified based on certain key parameters (hence parametric modelling), and are then fed to ML algorithms in the hope that said algorithms will accurately map the relationships between the parameters of interest and what corresponds to the typical or expected behaviour of different Demand Flexibility asset classes. The implementation of such methods can be done based solely on historical demand data, or supplemented by relevant external variables such as indoor/outdoor temperatures. The obtained baselines are then used as the reference point to assess any potential responses to Demand Flexibility events.

[8] A. Rajabi, L. Li, J. Zhang and J. Zhu, "Aggregation of small loads for demand response programs — Implementation and challenges: A review," 2017 IEEE International Conference on Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), 2017, pp. 1-6, https://doi.org/10.1109/EEEIC.2017.7977631

2.4 Validation of Flexibility delivery

Baselining is closely linked to the processes for validating the delivery of Demand Flexibility services, as the magnitude of any Flexible Demand Response will necessarily be determined based on the changes in demand relative to the typical or expected behaviour (i.e. the Baseline).

The specifics of the processes for validating Demand Flexibility delivery will vary depending on the particular context, e.g. type of Flexibility provider, type of service offered, scale of provision. However, they can generally be broken down into four key stages:

- Defining the type of Demand Flexibility service, as well as the type of provider.
- Determining the **magnitude** and **quality** of service expected, as agreed through the corresponding procurement contracts.
- Verifying the delivery of services through the direct comparison of the observed demand against the estimated Baseline. Within-day and/or half-hourly adjustments might be required depending on the relevant timescales for service provision.
- Reporting on the assessment of service delivery, which involves notifying both the Flexibility provider and the Flexibility user of the results of the verification process.

The Demand Flexibility validation processes are very important as they are essential to an effective market operation. This is what ensures that Flexibility Providers are getting adequate compensation for their services, and that Flexibility users are able to rely upon them.

For the validation processes to be as effective as possible, it is necessary to continually monitor and revise the following factors:

- The accuracy and reliability of any measuring systems in place, as the quality of the available data will only be as good as what the measuring system allows for.
- The representativeness of the Baseline demand estimates, as these should be relevant enough to the type of provider and service, and representative enough of the demand that was likely to be observed should the service delivery had not occurred.
- The robustness of the verification process, as this process should be transparent and auditable to foster trust between Demand Flexibility market participants.

The need for accurate and robust methodologies to appraise Demand Flexibility is far from limited to the validation of what is exchanged and delivered through the Flexibility market. At the most basic level, if we are to ensure that Flexibility market operation can reach near-optimal levels, it becomes essential to be able to provide *ex-ante* appraisals of the Demand Flexibility potential of a diverse number of assets and Flexibility providers.

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In what follows, we introduce the concept of Demand Flexibility Certification and provide the foundations for the implementation of a Demand Flexibility Rating framework for what is envisaged to become the most numerous sector of prospective Flexibility Providers: residential buildings.

3 Introducing Demand Flexibility Certification

3.1 The case for a common framework to characterise Flexibility assets and providers

Up until now, the Demand Flexibility potential of the buildings sector has been a largely untapped resource. This can be attributed in great measure to the lack of robust frameworks that allow for producing reliable and consistent estimates of the Flexibility potentials afforded by individual assets at the household, dwelling or building level.

Having the ability to produce such estimates would prove highly advantageous as it would serve three main purposes.

Firstly, a robust and reliable framework would allow for identifying opportunities to improve Demand Flexibility potential of individual assets/providers. Having a clear idea of both what is available and what is achievable is a necessary first step when it comes to engaging in Demand Flexibility provision (see Table 4). Therefore, any prospective Demand Flexibility provider would be better suited to do so if guidelines and frameworks exist that allow for a systematic analysis of the Flexibility potential of one or a combination of assets.

Secondly, a solid foundational mapping of the asset-level Flexibility potential would provide reliable pictures of both the current state of and prospects for Demand Flexibility harnessing potential at the local, regional and national levels. In the first instance, this can inform system planning and management decisions in relation to network reinforcement needs and temporary buffering opportunities.

Thirdly, a clear idea of the extent to which existing Demand Flexibility potential can be harnessed at the local, regional and national levels would provide clear indications of where investment is needed the most in order to further unlock and boost Demand Flexibility potential, particularly in locations and regions where network constraints are most problematic and network reinforcements are too difficult or too costly to provide. Whenever it is determined that the need for network reinforcements is imminent, this can also help in identifying the network sectors which should top the list of priorities.

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3.2 Demand Flexibility Certificates

Producing estimates for the Demand Flexibility harnessing potential every time we need to determine the amount of Demand Flexibility we can call upon would be at best impractical, and at worst unattainable. Therefore, a key goal in these efforts to characterise the Demand Flexibility potentials would be to condense the wealth of information and layers of complexity that need to be dealt with while producing such estimates into an easy-to-read and -interpret **Demand Flexibility Certificate** (DFC).[9]

In essence, a building's Demand Flexibility Certificate would become a currency of sorts, which would allow both prospective Flexibility Providers and Flexibility users to quickly and reliably assess the value that an asset could offer. This would, in turn, be reflected in a Demand Flexibility market that is able to operate in a more efficient manner.

Producing such a certificate may appear as an endeavour too challenging to embark upon, or to complete fast enough. However, substantial relevant experience and capacity exist that could help streamline the processes involved.

3.3 Drawing on the Energy Performance Certification experience

In the UK, the concept of Energy Performance Certification was first introduced 20 years ago, when the EU Energy Performance of Buildings Directive (EPBD) became European Law in January 2003 with the key objective of reducing the amount of energy used in buildings, while also improving their overall energy efficiency through cost effective measures.[10]

The EPBD set out standards for the design and construction of buildings, as well as requirements for the building's energy performance ratings to be readily available and easily understood. Based on the standards and requirements of the EPBD, the UK government introduced the Energy Performance Certificates (EPCs) in 2007 across England and Wales, where they became a mandatory part of the Home Information Pack which was meant to be supplied to people intending to buy large residential properties (4+ bedrooms). The requirements to provide an EPC when a building was being sold or rented then gradually extended to all residential and commercial properties. The EPC has since become an integral part of UK legislation concerning any new building or major renovation projects.

The introduction of the EPCs has undoubtedly been instrumental in raising awareness about the importance of energy efficiency and promoting the overall enhancement of the UK building fabric. In addition, the certificates also provide potential property renters/buyers with an insight into how much they are likely to spend on energy bills, as well as how much they could save if they were to

[9] See Section 5.3 for an illustrative example of an officially-issued Demand Flexibility Certificate.

[10] EU Energy Performance of Buildings Directive, Official Journal of the European Communities (2003), p. 65-71, http://data.europa.eu/eli/dir/2002/91/oj

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make recommended energy efficiency improvements. Governments are also increasingly using EPCs as the basis for developing energy efficiency targets and policies, while businesses are beginning to use them to measure their performance against others in their sector.

Determining the Energy Performance Rating of a building involves complex calculations. However, thanks to the support for the Energy Performance Certification programme, the gathering and processing of the information required to produce the performance ratings can be done relatively quickly. For the purposes of standardisation, the energy ratings are adjusted for building's floor area so that it is independent of size for a given type of building. The rating is also meant to be independent of the number of building occupiers.

The factors and processes required to produce the Energy Performance ratings of dwellings are detailed in what is referred to as the Standard Assessment Procedure (SAP).[11] The SAP is the official methodology employed by the government to provide accurate assessments of the energy performance. The SAP was developed by the Building Research Establishment (BRE), and is based on the BRE Domestic Energy Model (BREDEM), which provides a framework for calculating the energy consumption of dwellings. SAP works by assessing how much energy a dwelling is likely to consume when delivering a determined level of comfort and service provision, and is based on standardised assumptions about occupancy and behaviour patterns.

The latest version of this methodology – SAP11 – will come into force in 2025.[12] The version currently in force – SAP 10.2 – is the latest revision which was released in April 2023. The scope of the SAP procedure is detailed in the documentation report published by BRE.[13]

The experience developed up to this point, both in terms of data collection and rating procedures for estimating the energy performance of buildings has great transferability potential when it comes to the implementation of a Demand Flexibility Rating framework. In theory, this means that transitioning from an Energy Performance Rating procedure to a Demand Flexibility Rating one, would be much easier and faster to achieve. In practice, however, there are fundamental differences in the way the calculations are performed, and the ratings are assigned.

The following section elaborates further on the overlaps between the existing Energy Performance rating and a hypothetical Demand Flexibility rating procedure.

[11] Standard Assessment Procedure - https://www.gov.uk/guidance/standard-assessment-procedure
[12] Future developments – SAP11 - https://www.gov.uk/guidance/standard-assessment-procedure#future-developments---sap-11
[13] The Government's Standard Assessment Procedure for Energy Rating of Dwellings - Version 10.2 - https://bregroup.com/sap/sap10

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3.4 Methodological similarities and requirements

SAP is a data-intensive assessment procedure which involves a comprehensive analysis of the factors that affect a building's energy efficiency. The primary objective of SAP's methodology is to integrate a number of components into a single final rating that reflects the overall energy performance of the building in question.

According to the documentation for the SAP version currently in force[14], energy performance ratings are calculated based on the following relevant factors:

- Dwelling dimensions
- Ventilation rate
- Heat transmission
- Domestic hot water
- Internal gains
- Solar gains and utilisation factor
- Mean internal temperature
- Climatic data
- Space heating requirements
- Space cooling requirements
- Fabric energy efficiency
- Total energy use and fuel costs

When it comes to estimating the Demand Flexibility potential that a building could afford, its energy performance will necessarily have an impact on it. This essentially means that all the factors listed above will feed into the Demand Flexibility calculations. However, a 'translation layer' will have to be implemented in order to be able to determine the impact of these factors on the intra-day variations in demand loads that are typical of the building in question.

In addition, the Demand Flexibility potential is also largely dependent on other factors such as:

- Rated power consumption of flexible demand loads present
- Rated capacity of physical storage devices
- Thermal inertia of the building
- Systems and infrastructure(s) in place for demand management

Ultimately, however, the primary aim will be to condense the wealth of information related to each of the relevant factors into a single rating that summarises the Demand Flexibility potential.

[14] The Government's Standard Assessment Procedure for Energy Rating of Dwellings - https://bregroup.com/sap/sap10

4 A Demand Flexibility Rating Methodology

4.1 Overview

The rating of the Demand Flexibility potential must be based on a systematic appraisal of the different components that contribute to the overall ability to increase, decrease, and shift demand loads from within the building envelope.

To this end, it is useful to make a distinction between the three broader categories towards which each one of the components might contribute:

- **Basal Flexibility** – This constitutes the Demand Flexibility potential that is directly related to the physical properties and energy performance of the building fabric itself. This is primarily determined by the extent to which we can leverage the thermal inertia of the building to support Demand Management.
- **Heating/Cooling Flexibility** – This constitutes the Demand Flexibility potential that can be directly harnessed from the central heating/cooling systems, as well as any coupled heat stores. Both the magnitude and the quality of the Demand Flexibility that can be harnessed will depend on the properties of the heating/cooling systems.
- **Additional technology-enabled Flexibility** – This encompasses any other sources of Flexibility that could be harnessed through any existing Demand Management systems. Examples of the flexible loads that could contribute towards this include Smart EV charging, and energy-intensive appliance scheduling.

Given the classification of the types of Demand Flexibility harnessing potential put forward in Section 3.2 (see Table 5), the Demand Flexibility potential reflected by the three broader categories listed above correspond to a combination of theoretical and technical harnessing potentials. We envisage that readily available Demand Flexibility Certificates will play a catalytic role in unlocking the feasible harnessing potential of buildings' Demand Flexibility.

4.2 Data prerequisites and metrics

The table below provides examples of the components that contribute towards a building's overall Demand Flexibility potential, as well as the metrics that are better suited to their analysis, and the data required in order to assess their corresponding contribution.

Table 6 - Summary of Demand Flexibility Certificate rating components and metrics used to assess them.

	Rating Component	Metrics [units]	Data requirements
Basal Flexibility	Building cool-down profile	Temperature drop rate [-ΔT/h]	• Half-hourly internal temperature records under passive cooling conditions • Half-hourly gas & electricity consumption records for relevant period
	Internal temperature recovery	Temperature recovery rate [degrees/min]	• Minutely internal temperature records under active heating and cooling conditions • Minutely gas & electricity consumption records for relevant period
Heating/cooling Flexibility	Heating/cooling system performance	Coefficient of Performance [ΔQ/kWh]	• Minutely records of heat supplied/extracted during periods of operation • Minutely records of energy consumed during relevant periods
	Heating/cooling system power ratings*	Power draw [kW]	• Theoretical power drawn during periods of operation • Empirical power drawn during periods of operation
	Thermal stores' performance	Storage capacity [kWh/kg] Heat loss rate [kWh/min]	• Theoretical rated capacity and heat loss • Empirical effective capacity and heat loss
Technology-enabled Flexibility	Power ratings of managed demand loads	Power draw [kW]	• Theoretical power drawn during periods of operation • Empirical power drawn during periods of operation
	Dedicated electric storage performance	Storage capacity [kWh] Charge/discharge rate [C-rate] Degradation rate [% capacity loss/cycle]	• Theoretical rated capacity and charge/discharge rate • Empirical rated capacity and charge/discharge rate • Theoretical degradation rates from same or similar storage technology

* It is assumed that these are electric power ratings.

4.3 Flexibility Rating Procedure

The primary aim of the Flexibility Rating Procedure (FRAP) consists in providing an informative summary of the Demand Flexibility potential that can realistically be harnessed. Each one of the components that contribute towards the overall Demand Flexibility potential is characterised through the relevant metrics identified in the previous section. Based on this characterisation, as well as any relevant contextual data, the Demand Flexibility potential is then mapped across the following dimensions:

Upper & Lower bounds of Demand Flexibility potential – as their name suggests, these provide an insight into the minimum and maximum Demand Flexibility that could be provided during a given response event.

Response rate – this refers to the total Demand Flexibility that could be provided over a given period of time.

Frequency – this refers to the frequency with which a building might be able to take part in any response events, primarily throughout the same day.

Duration – as the name indicates, this corresponds to the overall duration of any response. Acknowledging the fact that this is not a fixed value, this rating would be derived based on the range of durations any potential responses.

Notice period required – this refers to the agility of the responses, which depends on how far in advance the providers need to be notified in order to elicit a response (i.e. hours, days, weeks)

Passive/active source ratio – this attempts to summarise the degree of control over the elements involved in providing a Demand Flexibility in a given response event.

Manual/automated control – this is merely a binary rating to indicate the presence of any automated control systems that could be leveraged in order to provide Demand Flexibility.

Preconditioning – this refers to how readily available is the Demand Flexibility, based on whether certain conditions need to be met in order to be able to provide said Flexibility, or whether responses can be elicited at any moment.

Top 3 Flexibility sources/flexible energy end-uses – in addition to the overall upper and lower bounds, we anticipate that an insight into the biggest individual loads that make up the total Demand Flexibility potential will also be of relevance to providers, aggregators and users.

Each of these dimensions is scored based on a pre-defined scale, and weighted based on the extent to which they have an impact on the provision of Demand Flexibility services, where higher scores reflect better quality and suitability. Providing a detailed description of the calculations that form part of the overall rating procedure is beyond the scope of this report. However, it is the subject of ongoing work, and a detailed report with the documentation for the FRAP methodology will follow shortly.

Capturing the complex dynamics involved in estimating Demand Flexibility potential would be difficult using a tiered rating framework as the one used for EPC ratings. Thus, in order to better capture this complexity, we implement a grid rating framework that rates the Demand Flexibility potential across two key dimensions: **Magnitude** and **Quality**.

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The rating framework is limited to two dimensions primarily with the aim of providing an overview with enough nuance, but at the same time, avoiding unnecessary complexity when it comes to interpreting the ratings of particular buildings or assets.

The **Nominal** rating corresponds to the range within which the overall Demand Flexibility potential falls into (i.e. Magnitude of demand increase/decrease [kW]). The **Quality** rating, on the other hand, provides an indication of how readily the Demand Flexibility potential can be harnessed, and is a function of important factors for Demand Flexibility provision such as how often, how fast, and for how long can the flexible demand responses be delivered (i.e. response rate [kW/second], frequency [events/day], and duration [minutes]).

Figure 3 below provides a visual representation of the way in which the underlying dimensions of the Demand Flexibility potential feed into the rating grid dimensions.

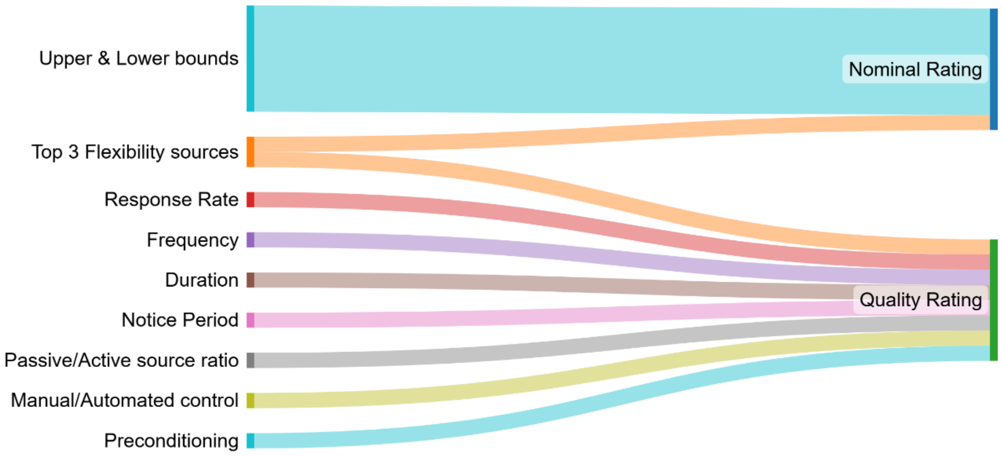

Figure 3 - Visual representation of how the underlying dimensions of the Demand Flexibility potential are colapsed into the Nominal and Quality ratings used in the Demand Flexibility Certificates rating framework.

Table 7 below provides a visual representation of the proposed Demand Flexibility rating grid to be used as part of the rating framework, and Figure 3 provides an illustrative example of the way in which the information produced by the Demand Flexibility Rating procedure could be summarised in the form of an officially-issued Demand Flexibility Certificate (DFC).

To account for the fact that the most significant demand loads are likely to change with the seasons, it is envisaged that the summary offered in the DFC would include two overall ratings: one for **summer**, one for **winter**. Additionally, the certificate provides further information about the most significant loads likely to be engaged in Demand Flexibility provision, along with other key information such as the frequency with which the building is able to respond to Demand Flexibility events.

It should be emphasised the role of the DFC as a summary of the rating. As the DFC mock-up in Figure 3 shows, it is envisaged that this summary would be complemented by a **digital detailed breakdown** of the relevant components that make up the overall Demand Flexibility ratings indicated in the DFC, as well as a monthly breakdown of the changes in rating likely to be observed over the course of a year. DFC's detailed breakdown is intended to be more than just a digital version of the DFC itself. Rather, its digital nature would allow for a seamless integration into external frameworks for the purposes of, for instance, building performance modelling, Demand Flexibility forecasting, and Flexibility Market operation.

The data provided as part of this complementary detailed breakdown are intended to offer a more comprehensive picture of the range of services the building/asset would be able to deliver, which is relevant to any potential aggregators or Flexibility users looking to make use of the Flexibility being offered. A more detailed discussion of the range of applications and use cases for the Demand Flexibility Certificates is offered in the following section.

Table 7 - Demand Flexibility rating grid.

		Quality rating											
		1		2		3		4		5		6	
Nominal rating	A	A	1	A	2	A	3	A	4	A	5	A	6
	B	B	1	B	2	B	3	B	4	B	5	B	6
	C	C	1	C	2	C	3	C	4	C	5	C	6
	D	D	1	D	2	D	3	D	4	D	5	D	6
	E	E	1	E	2	E	3	E	4	E	5	E	6
	F	F	1	F	2	F	3	F	4	F	5	F	6

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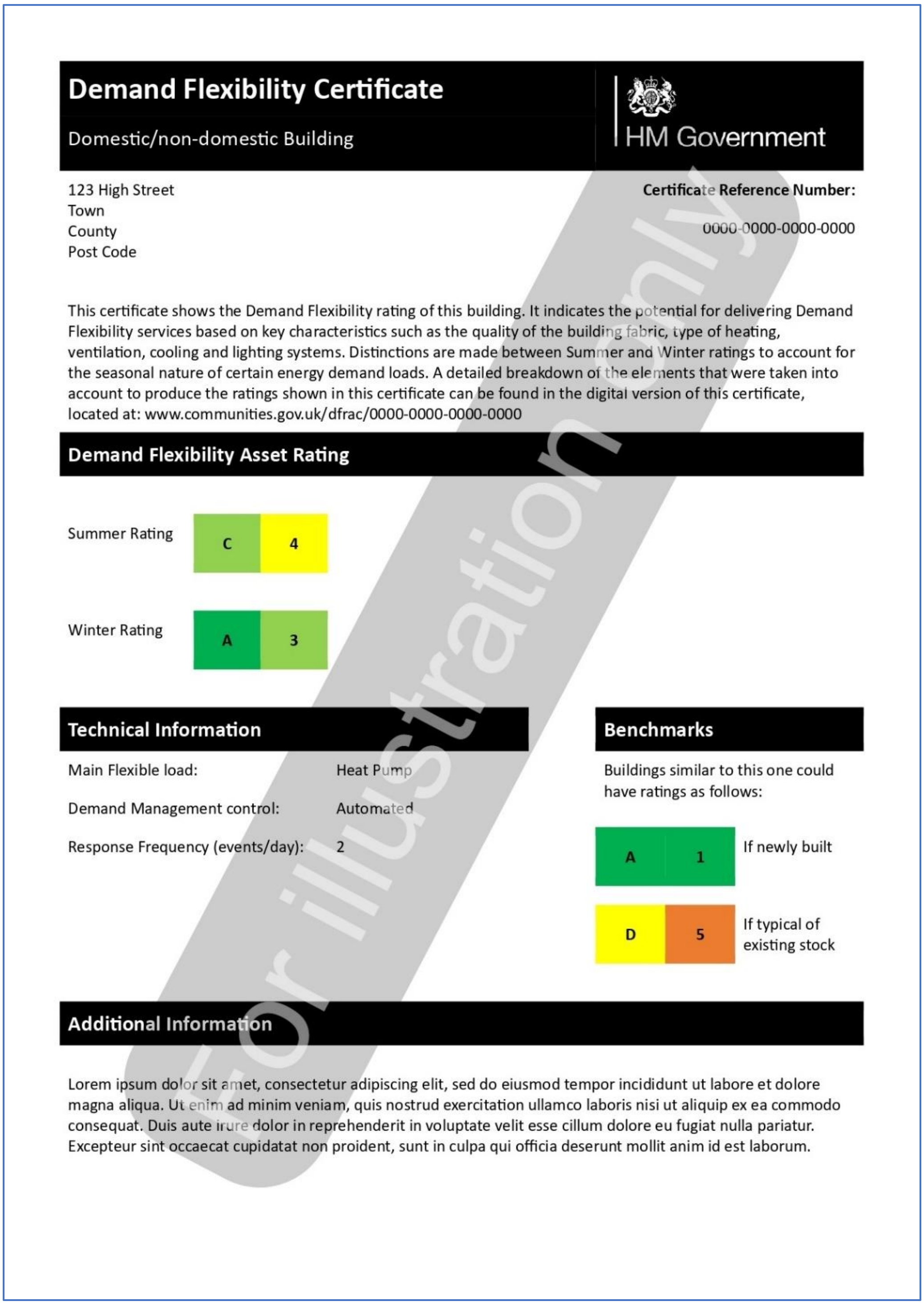

Demand Flexibility Certificate

Domestic/non-domestic Building

HM Government

123 High Street
Town
County
Post Code

Certificate Reference Number:

0000-0000-0000-0000

This certificate shows the Demand Flexibility rating of this building. It indicates the potential for delivering Demand Flexibility services based on key characteristics such as the quality of the building fabric, type of heating, ventilation, cooling and lighting systems. Distinctions are made between Summer and Winter ratings to account for the seasonal nature of certain energy demand loads. A detailed breakdown of the elements that were taken into account to produce the ratings shown in this certificate can be found in the digital version of this certificate, located at: www.communities.gov.uk/dfrac/0000-0000-0000-0000

Demand Flexibility Asset Rating

Summer Rating	C	4
Winter Rating	A	3

Technical Information

Main Flexible load:	Heat Pump
Demand Management control:	Automated
Response Frequency (events/day):	2

Benchmarks

Buildings similar to this one could have ratings as follows:

A	1	If newly built
D	5	If typical of existing stock

Additional Information

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

For illustration only

Figure 4 - Demand Flexibility Certificate mock-up.

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5 Applications and Use Cases

5.1 Who would benefit directly from these certificates?

We envisage a number of potential applications of the proposed Demand Flexibility Certificates across the Energy System participants. Table 8 below summarises them. Additionally, we provide a quick reference to the areas of scope for the Demand Flexibility Certificate in Box 1.

Table 8 - Demand Flexibility Certificate applications per Energy System participant.

Primary Beneficiaries	**DFC Applications**
Energy end-users	• Informing property buying/leasing decision making • Providing leverage for securing supply deals in the market and access to new Flexibility-based products • Understanding value of Flexibility and options available for decarbonisation of their properties and operations
Suppliers / Aggregators	• Quick assessment of potential Flexibility value per site • Quick estimation of aggregated potential at the area level • Providing input to differed supply services (including Time of Use tariffs, dynamic, smart meter-enabled tariffs* and X-as-a-Service products) offering based on potential supplier-consumer mutual benefit
ESO	• Quick(er) way to estimate short, mid, long-term Flexibility potentials • Providing input to Flexibility maps and Future Energy Scenarios • Providing input to live procurement on Constraint Managed Zones
DSO	• Aiding in planning for network reinforcement • Quick aggregated potential at the area level for business plans (e.g. RIIO submission) • Providing input to DSO Flexibility services, including Constraint Management Zones, operational windows and locational data • Enhance Distribution Future Energy Scenarios and tracking their implementation at the street level • Informing network modelling with asset register and network utilisation • Settlement of transactions

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Local Authorities	• Local area energy planning assistance – identification of weak/strong areas, areas in need of further investment • Informing decarbonisation pathways and tracking of delivery of Net Zero commitments • Informing local initiatives for alleviating fuel poverty • Potential assistance to Energy Community Aggregator Service

* Voluntary half-hourly settlement is now available, and some energy suppliers have begun offering dynamic, smart meter enabled tariffs.

Box 1 - Demand Flexibility Certificate: areas of scope.

The certificate will:	• Estimate the Flexibility potential of individual buildings • Identify opportunities to improve the Demand Flexibility potential of individual buildings • Provide input to detailed mapping of Demand Flexibility potential at the local, regional and national levels
The certificate will not:	• Generate new data which was not previously available • Create Flexibility *per se* • Make buildings more flexible • Reduce energy bills *per se* • Resolve energy poverty

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5.2 Other potential use cases

5.2.1 RIIO

Since 2013, Ofgem has set price controls for the companies that operate the gas and electricity networks in Great Britain by setting Revenue using Incentives to deliver Innovation and Outputs (RIIO).

Thus far, RIIO has played a pivotal role in catalysing the growth of local Flexibility markets for Distribution System Operators (DSOs). As part of their future RIIO business plan submission, DSOs may make use of the Flexibility Certificates in order to encompass specific activities or 'baseline expectations' that Ofgem will evaluate their performance on throughout the price control period, including:

- Streamlining the efficient dispatch of distribution Flexibility services based on baseline information from the Flexibility Certificate
- Collaborating and engaging with third-party platform providers, which can access and integrate with additional data the information contained in Flexibility Certificates; and
- Identifying the optimal blend of market durations and contract lengths, aligning with network requirements.

5.2.2 Nodal pricing reform

Ongoing market reform considers nodal pricing structures. Nodal pricing involves establishing energy prices for various points on the transmission grid, known as nodes. As a result, the price at each node would represent the specific value of energy at that location.

A Flexibility Certificate can improve price signals in electricity markets by enhancing the baseline information.

First, A Flexibility Certificate systematically assesses various components contributing to the ability to modify electricity demand within a building's envelope. By understanding the Flexibility potential within a specific location, electricity market operators can have a more precise grasp of how demand can be increased, decreased, or shifted. This granular understanding enables market operators to create more accurate price signals that reflect the real-time and location-specific conditions of the Power System.

Second, as the Flexibility Certificate provides insights into the potential for demand modification within a building, market operators can dynamically adjust price signals to incentivise consumers to either increase, decrease, or shift their electricity consumption based on the current system status. For instance, during peak demand periods or when there is a surplus of renewable energy, the certificate can inform the market to send signals encouraging load reduction or load-shifting.

Third, the Certificate's assessment of building-level Flexibility considers time and location, enabling electricity markets to generate location-specific price

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signals. This is particularly beneficial in grids with localised congestion or varying distributed generation, where price signals can differ from one area to another. The certificate allows market operators to tailor price signals to each location's unique characteristics.

Acknowledgements and Future outlook

The research underpinning this report has been initially developed as part of the Centre for Research into Energy Demand Solutions (CREDS) project on Measuring Flexibility. CREDS is funded by UK Research and Innovation, Grant agreement number EP/R035288/1

This work is being further developed as part of the EDRC Flexibility Theme. EDRC is funded by UK Research and Innovation, Grant agreement number EP/Y010078/1

Initial results on the Demand Flexibility Certificate were presented as part of a CREDS/BEIS Joint Expert Workshop on Heating Flexibility Metrics on 9 May 2022.

The need for the standardisation of metrics and procedures on Demand Flexibility is becoming evident, so it is only natural that multiple groups/institutions are converging towards similar goals.

In preparation for the transition to an energy system where Demand Flexibility plays a central role in the operation of the system itself, as well as the markets that enable it, Ofgem is developing governance strategies for the provision of the overarching Flexibility Digital Infrastructure which will address some of the current market failures in relation to the Flexibility data exchanges, and the implementation of standards for data and metrics, as well as supporting a coordinated approach to market access and operations.

In their open letter to the ENA Open Networks Project[15], they have emphasised the importance of and urgency of Flexibility enablers delivery, which includes the development of adequate standardisation frameworks.

At the time of writing the report we have become aware that others are working on a similar concept.

We will continue to work on further developing our proposed framework, as well as investigating the barriers and opportunities for implementation, and we will welcome any opportunities to collaborate with those who might be working to develop similar concepts, or who have an interest in this area.

[15] Ofgem's Open Letter to the Energy Networks Association's Open Networks Project - https://www.ofgem.gov.uk/publications/open-letter-open-networks-project

Glossary

Baselining – refers to the estimation of what corresponds to a ‘typical’ day, or ‘normal’ behaviour, when it comes to the levels of demand over a given period of time.

Capacity Market – refers to the set of mechanisms introduced by the UK government to manage security of electricity supply and safeguard against the possibility of future blackouts. Participants in this market are paid to ensure they are available to respond when there is a high risk that a System Stress Event could occur.

Congestion Management – refers to the coordination of both demand and supply management so as to ensure that the power flowing through the grid at any given time does not exceed the rated capacity of transmission and distribution lines.

Demand Flexibility – refers to the ability to produce a deliberate change in demand, in response to any request or incentive, or as previously agreed upon.

Demand Response – is a change in demand loads elicited by previous commitments, direct requests, or other incentives.

Explicit Demand Flexibility Contracts – refers to the kind of contractual arrangements made between System Operators and Flexibility Providers to secure Manifest Flexibility Potentials. These contracts are meant to ensure, on the one hand, the provision of Demand Flexibility as and when needed by System Operators, and on the other, the fair and prompt compensation of Flexibility Providers for supporting System Balancing and Congestion Management tasks.

Flexibility Potential – refers to the extent to which the demand loads associated with particular devices, buildings or other assets at the Flexibility Providers’ disposal can be increased/decreased, how fast, and for how long.

Flexibility Providers – refers to the entities that are willing, able, and responsible for the provision of Demand Flexibility.

Implicit Demand Flexibility Contracts – refers to the kind of contractual arrangements aimed at enabling the harnessing of Latent Flexibility Potentials. These contracts outline the terms based on which the target Flexibility Providers would be compensated should they ***choose*** to engage in the intended Demand Response, and/or penalised if they do not.

Latent Flexibility Potential – refers to the Demand Flexibility that ***could*** be harnessed through external signals such as pricing incentives or carbon intensity warnings, but the target Flexibility Providers have ***no obligation***

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to deliver. Mostly stemming from the residential sector, and harnessed through Time-of-Use tariffs.

Manifest Flexibility Potential – refers to the Demand Flexibility harnessing that has been agreed upon through one or more procurement contracts which clearly outline the terms and conditions under which the Flexibility Providers need to deliver said Flexibility. Mostly stemming from large consumers (e.g. industrial and commercial), or Demand Flexibility aggregators.

Power Systems – refers to the set of tangible and intangible infrastructures that allow for the transmission of electric power from the point of generation to the end-users.

System Balancing – refers to the real-time matching of supply and demand in order to ensure the adequate functioning of the Power System as a whole.

System Operators – are the entities in charge of ensuring that adequate System Balancing and Congestion Management tasks are carried out in a timely and adequate manner.

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About EDRC

The Energy Demand Research Centre (EDRC) undertakes research for an affordable and secure low energy future. Our interdisciplinary research programme identifies evidence-based energy demand reductions for a sustainable and more equitable future. We work closely with partners from policy, industry, civil society and academia.

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