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Conceptualising spatial demand flexibility: an introduction

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Abstract

The accelerating transition toward a decentralised, high-renewable energy system is fundamentally changing the relationship between supply, demand, and grid infrastructure. This necessitates moving beyond traditional temporal load shifting to unlock new forms of flexibility that address location-specific challenges. This work introduces and defines Spatial Demand Flexibility (SDF): the intentional and coordinated adjustment of the geographical location where electricity is consumed or stored to resolve localized grid issues, enhance system resilience, and improve overall energy system efficiency and equity.

A clarification worth making is that SDF is not a substitute for temporal shifting, but rather a crucial supplementary mechanism that focuses on where energy is used, and delivers additional value by capitalising on the heterogeneity of energy imbalances across different geographical areas – from adjacent neighbourhoods (Low Voltage) to cross-country regions (Transmission). We establish its critical importance in solving the omnipresent challenge of grid congestion due to overloaded assets and limited transmission capacity issues. SDF effectively acts as a 'virtual wire', enabling non-wired grid balancing alternatives to defer or eliminate costly physical network upgrades by resolving local bottlenecks through load relocation.

We analyse the conditions under which SDF delivers value, highlighting that its benefits must outweigh the cost and inconvenience of implementation and that it is especially valuable when temporal flexibility is unavailable or less efficient. A core tenet is that SDF must not be treated as an isolated resource, as the effectiveness of a spatial demand shift is inextricably linked to the temporal dynamics of demand as well as assets' response time.

From a policy perspective, integrating SDF concepts directly supports UK's transition towards Ofgem's Regional Energy Strategic Plans (RESPs) regime to resolve localised capacity constraints. These plans are meant to guide distribution network investments for 2028-2033. To do so effectively, policy makers must mandate spatial foresight by embedding dynamic analyses of projected energy fluxes across regions into planning frameworks. Moving beyond traditional siloed planning approaches to embrace these spatial flexibility concepts ensures that future developments are strategic and coordinated. Ultimately, this spatial lens is crucial for building resilient, efficient, and equitable infrastructure networks that maximise local economic utility.

Keywords

demand-side flexibility, spatial energy flexibility, energy systems analysis