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The nexus of energy sufficiency, prosumerism, and flexibility: a framework for equitable energy transition

COLLECTION: CONSUMPTION, BEHAVIOUR AND ATTITUDES

PEER-REVIEWED PAPER

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ABSTRACT

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There is broad consensus that future energy systems must be climate-neutral, affordable, resilient, and universally accessible. Energy efficiency improvements and renewable energy deployment, while essential, are insufficient to achieve the scale and pace of demand reduction required by the Paris Agreement. Energy sufficiency, defined as limiting energy use to levels compatible with well-being and planetary boundaries, must complement efficiency and renewables. Sufficiency explicitly addresses absolute consumption levels rather than relative intensity improvements, while allowing increased energy access for underserved populations, thereby linking decarbonisation with equity objectives.

Closely related, energy justice provides a normative framework to ensure fair distribution of benefits and burdens, recognition of diverse needs and identities, and inclusive participation in energy system transformation. Technological advances in renewable generation, storage, and digitalisation have simultaneously enabled energy prosumerism and demand-side flexibility. Prosumers actively participate in energy production and consumption; demand-side flexibility provides the system balancing essential for integrating variable renewable energy. These developments can enhance system resilience, democratise energy governance, and reduce system costs, but without appropriate policies and market designs, risk reinforcing socio-economic inequalities by privileging households with greater access to capital, technology, and information.

This paper examines the interactions, synergies, and trade-offs between energy sufficiency, demand flexibility, and prosumerism, and assesses how these concepts can be aligned with energy justice principles. Applying a structured conceptual review methodology, synthesising peer-reviewed literature, EU policy analysis, and case evidence, the paper proposes an integrated nexus framework and identifies the policy, regulatory, and market conditions necessary to support a fair, smart, and democratic energy system.

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INTRODUCTION: BEYOND EFFICIENCY

The transition toward sustainable energy systems requires a fundamental rethinking of how energy is produced, distributed, and consumed. Traditionally, energy systems have been characterised by centralised production, passive consumption, and a primary focus on supply expansion to meet growing demand. However, increasing concerns about climate change, resource depletion, and energy security have catalysed a paradigm shift toward more decentralised, participatory, and adaptive energy models (Brisbois, 2020).

The traditional decarbonisation discourse has long been dominated by energy efficiency, the technical improvement of the ratio between energy output and input and by renewable energy supply expansion. However, the rebound effect (the Jevons Paradox) often offsets efficiency gains through increased consumption, meaning that improved energy intensity does not necessarily translate into reduced absolute energy demand (Ruzzenenti and Bertoldi, 2017; Sorrell and Dimitropoulos, 2008). Sorrell et al. (2020) review extensive empirical evidence showing that direct and indirect rebound effects can erode 10–60% of projected efficiency savings depending on sector and context, while Spangenberg and Lorek (2019) argue that without structural behavioural constraints, efficiency policies systematically underperform their projected targets.

This paper argues that addressing these limitations requires a conceptual and policy move beyond efficiency alone toward a holistic triad of complementary demand-side strategies. Energy sufficiency, defined as "a strategy aiming at limiting and reducing the input of technically supplied energy towards a sustainable level" (Thomas et al., 2019), addresses the absolute scale of energy consumption (Bertoldi, 2022). Energy prosumerism, the active participation of citizens in energy production, storage, and trading through distributed technologies, restructures the ownership and governance of energy systems (Parag and Sovacool, 2016; Korsnes et al., 2024). Demand-side flexibility – the capacity to adjust the timing and magnitude of energy consumption in response to system signals – enables the dynamic integration of variable renewable energy (Powells and Fell, 2019). These three concepts are not selected arbitrarily: together, they address the three core dimensions of the demand-side challenge – how much energy is consumed, who controls it, and when it is used. As Section 3 elaborates, they also exhibit strong interdependencies: sufficiency reduces the scale of prosumer investment required, prosumers provide the distributed assets enabling flexibility, and flexibility optimises the performance and economic viability of prosumer systems, creating a mutually reinforcing nexus.

Importantly, these interactions only deliver equitable outcomes when embedded within a justice-oriented framework. Energy justice, encompassing distributional, recognition, and procedural dimensions (Jenkins et al., 2018), provides the normative foundation that transforms a technical nexus into an instrument of social equity. Flexibility mechanisms, for instance, carry significant technical potential for grid balancing, but without justice safeguards, they can transfer energy management burdens disproportionately onto vulnerable households. The justice dimension is not an afterthought but a constitutive element of the nexus: a framework that advances sufficiency, flexibility and prosumerism without equity safeguards risks reinforcing existing inequalities rather than addressing them. This paper explores how and under what conditions these three pillars can be aligned with justice principles to support a fair, effective, and democratically governed energy transition.

Importantly, the present analysis explicitly excludes the notion of household or community energy self-sufficiency, the concept of producing enough energy to match one's own consumption, which, while related, involves distinct technical and policy considerations beyond the scope of this paper. The focus here is on sufficiency as a demand-reduction strategy, on prosumerism as a form of active participation in distributed energy systems, and on flexibility as the systemic enabler of decentralised energy system, connecting these dimensions within a justice-oriented framework.

This paper proceeds as follows. Section 2 elaborates the conceptual foundations and definitions of each pillar, establishing a common analytical vocabulary. Section 3 examines their bilateral and trilateral interactions and systemic implications, supported by a conceptual framework table (Table 1). Section 4 discusses the equity and justice dimensions underpinning the nexus. Section 5 reviews integrated policy frameworks and real-world examples. Section 6 identifies challenges and limitations, and Section 7 concludes with evidence-grounded policy

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recommendations. The methodology underpinning the analysis is a structured conceptual review: peer-reviewed literature published primarily between 2015 and 2024 was selected through systematic searches of Scopus and Web of Science using the terms 'energy sufficiency', 'prosumerism', 'demand-side flexibility', and 'energy justice', supplemented by analysis of key EU policy documents and grey literature.

CONCEPTUALISING THE TRIAD

ENERGY SUFFICIENCY: REDEFINING DEMAND

Energy sufficiency refers to the deliberate limitation and reduction of energy consumption through behavioural, social, and structural changes, such that energy use remains within levels compatible with both human well-being and planetary ecological limits (Darby and Fawcett, 2018; Gossen and Lorek, 2021). Unlike energy efficiency, which focuses on using less energy to deliver the same level of service, sufficiency questions and potentially reduces the demand for services in the first place – particularly when those services exceed what is necessary for well-being (Fawcett and Darby, 2019). As Sachs observed, "while efficiency is about doing things right, sufficiency is about doing the right things" (Sachs, 1999). Thomas et al. (2019) define energy sufficiency as "a strategy aiming at limiting and reducing the input of technically supplied energy towards a sustainable level," while Sorrell et al. (2020) extend this to encompass "a level of energy service consumption that is consistent with equity, well-being and environmental limits."

Within this framework, sufficiency addresses absolute consumption levels rather than relative efficiency improvements (Bertoldi, 2022). It represents a cap on consumption through changes in infrastructure (e.g., smaller living spaces, efficient urban planning), technology (e.g., mandatory limits on appliance performance regardless of size, through mechanisms such as the EU Ecodesign Directive), and social practices (e.g., shared mobility, reduced business travel). By lowering overall energy demand, sufficiency reduces the scale of the decarbonisation challenge: a system with lower demand requires fewer renewable generation assets, less grid expansion, and reduced storage capacity. Samadi et al. (2017) estimate that lifestyle-sufficiency measures could contribute 10–30% of the demand reduction needed for deep decarbonisation in European energy scenarios – a contribution comparable in magnitude to many supply-side investments. Zell-Ziegler et al. (2021), reviewing 18 European National Energy and Climate Plans, find that sufficiency receives marginal attention relative to its potential, underscoring a significant policy implementation gap.

Crucially, sufficiency must be distinguished from energy deprivation. Fawcett and Darby (2019) introduce the concepts of "need" and "want", underscoring the importance of guaranteeing minimum energy access, meeting basic needs, while limiting excessive consumption beyond what is required for well-being Baumgartner et al., 2022). This framing resonates with Doughnut Economics (Raworth, 2017), ensuring that sufficiency policies address overconsumption in affluent contexts while expanding access in energy-poor communities. In practice, this means that well-designed sufficiency policy must be differentiated: it imposes constraints on high-consumption households while simultaneously investing in access for those currently in energy poverty.

ENERGY PROSUMERISM: FROM PASSIVE CONSUMPTION TO ACTIVE PARTICIPATION

The concept of energy prosumerism – referring to actors who simultaneously consume and produce energy – has gained significant traction alongside the diffusion of decentralised renewable technologies. First introduced by Toffler (1980) to describe a return to production for personal use, the concept has been extended by Parag and Sovacool (2016) to encompass situations where "energy customers actively manage their own consumption and production of energy." In legislative terms, the EU's Renewable Energy Directive (RED III, 2023) and the Internal Electricity Market Directive (2024) have formalised the categories of "active consumers," "renewable energy communities" (RECs), and "citizen energy communities" (CECs), providing institutional grounding for collective prosumer initiatives.

Korsnes et al. (2024) propose a sociotechnical typology of energy prosumerism along three interrelated dimensions: degree of technological engagement (ranging from low-tech to high-tech), ownership structures (from open-access and common-public to private), and forms of participation (from decentred and emergent to dominant). This typology is analytically useful

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because it makes explicit that prosumerism is not a homogeneous phenomenon. A community solar cooperative with open ownership and emergent participatory governance is qualitatively different – in its sufficiency and justice implications – from a high-income household with rooftop photovoltaics, an electric vehicle, and AI-managed home storage. The latter configuration may generate rebound effects and reinforce existing inequalities, whereas the former is more likely to align with sufficiency and justice principles.

The narrative review conducted by Campos et al. (2024), covering over 200 prosumer studies, confirms that while prosumer research has grown substantially since 2016, inclusivity and sufficiency have not been consistent cross-cutting concerns. Exceptions are found in research on "energy commons" and grassroots innovations: indigenous off-grid communities in Canada, low-tech eco-villages, and cooperative models such as SomEnergia in Spain and Ecopower in Belgium. These cases demonstrate that prosumer initiatives are more likely to advance sufficiency, inclusivity, and equity when grounded in collaborative, sharing-based, and democratically governed arrangements. Burke and Stephens (2018; 2017) further emphasise that energy democracy, the active participation of citizens in ownership, governance, and decision-making over energy systems, is a prerequisite for prosumerism to realise its equity potential. Szulecki (2018) argues that energy democracy should be understood as a framework for transforming energy systems toward greater citizen participation, civic ownership, and democratic governance, where prosumers play a central role in decentralized and socially just energy transitions.

DEMAND-SIDE FLEXIBILITY: THE SYNCHRONICITY ENABLER

Demand-side flexibility (DSF) refers to the capacity of consumers and prosumers to adjust the timing and magnitude of their energy consumption in response to external signals such as dynamic prices, grid frequency, or system operator requests (Powells and Fell, 2019). In power systems characterised by high shares of variable renewable energy (VRE), flexibility is the essential mechanism that maintains supply-demand balance and prevents grid instability. Flexibility can be provided through demand response (explicit or implicit), distributed energy storage, electric vehicles operating in vehicle-to-grid (V2G) mode, sector coupling (e.g., power-to-heat), and smart home energy management systems (Lund et al, 2015).

Within the nexus, flexibility serves as the "glue" that enables sufficiency and prosumerism to function coherently within the broader energy system. At the technical level, flexibility includes short-term balancing services (frequency regulation, operating reserves), medium-term load shifting (time-of-use response), and long-term demand modulation (seasonal storage, efficiency-driven load reduction) (Göransson, 2023). These different temporal dimensions interact with prosumerism and sufficiency in distinct ways: short-term balancing is primarily a prosumer-technology interaction, while long-term modulation is predominantly a sufficiency effect. It is also important to distinguish between energy consumption (total energy used) and energy demand (instantaneous or peak power demand), as flexibility primarily addresses the latter, while sufficiency addresses both.

Prosumers equipped with storage, smart appliances, and electric vehicles can shift consumption to periods of high renewable generation or low demand, providing distributed flexibility services. Aggregators and virtual power plants (VPPs) can coordinate these dispersed resources, transforming them into grid-relevant assets. Sufficiency measures, in turn, permanently reduce the total load and smooth demand profiles over longer time horizons, diminishing the magnitude of flexibility interventions required and making system balancing more tractable (Morstyn et al., 2018). Powells and Fell (2019) introduce the concept of "flexibility capital", the technical, financial, and temporal resources enabling flexible behaviour, and "flexibility justice", the principle that the distribution of flexibility burdens and opportunities must be equitable. This framing is central to understanding how the technical potential of flexibility is translated – or not – into socially equitable outcomes.

INTERACTIONS, SYNERGIES, AND TRADE-OFFS

The sufficiency-prosumerism-flexibility nexus is not merely a collection of three parallel strategies. The three pillars exhibit bilateral synergies, trilateral interactions, and genuine trade-offs that must be understood and managed through policy. Table 1 provides a structured overview of these interdependencies.

DIMENSION	ENERGY SUFFICIENCY	PROSUMERISM	DEMAND FLEXIBILITY	JUSTICE IMPLICATION
Primary mechanism	Reduce absolute demand	Distributed generation & active participation	Shift timing/magnitude of consumption	Access & capabilities
Key enablers	Regulation, social norms, urban planning	Distributed renewables, storage, cooperatives	Smart meters, aggregators, VPPs, V2G	Inclusive design & safeguards
Risk without justice lens	Energy poverty deepened if poorly targeted	Rebound effects; widening inequality	Flexibility burden on vulnerable households	Distributional harm
Synergy with others	Reduces scale of prosumer & flexibility need	Provides distributed flexibility assets	Enables sustainable prosumer revenue streams	Mutual reinforcement when aligned
Policy levers	Progressive tariffs, building codes, Ecodesign	RECs/CECs, virtual net metering, one-stop shops	ToU pricing, social tariffs, aggregation frameworks	Co-design, governance, equity audits

Table 1 The Sufficiency–Prosumerism–Flexibility Nexus: Key Dimensions and Interactions.

Source: the author, synthesised from Korsnes et al. (2024); Powells and Fell (2019); Bertoldi (2022).

SUFFICIENCY AND PROSUMERISM

Sufficiency and prosumerism interact through mutually reinforcing behavioural and technical dynamics. Energy sufficiency enhances the economic viability of prosumer systems by reducing overall energy demand, thereby increasing the proportion of energy needs that can be met through local generation. A household that has already reduced consumption through sufficiency measures – such as downsized appliances or reduced indoor temperatures – requires a smaller photovoltaic system to cover its remaining needs, lowering capital costs and improving financial attractiveness for lower-income households (Korsnes et al., 2024).

Conversely, engagement in prosumer activities can catalyse sufficiency-oriented behaviours. Prosumers, by gaining direct awareness of their energy production and consumption patterns through real-time monitoring and smart meter feedback, tend to develop greater energy consciousness and intrinsically motivated reductions in consumption (Korsnes et al., 2024; Labanca and Bertoldi, 2018). Labanca and Bertoldi (2018) emphasise that social practice theories predict that such feedback loops are most durable when embedded in collective and community settings rather than individual behavioural nudges. However, this positive loop is not automatic: high-tech prosumer arrangements can generate rebound effects if the perception of producing "green" energy encourages overall consumption growth. Sorrell et al. (2020) document this moral licensing dynamic in several empirical studies. Managing this tension requires combining technical prosumer support with sufficiency-oriented pricing and regulatory frameworks.

PROSUMERISM AND FLEXIBILITY

Prosumers are structurally well-positioned to provide flexibility services due to their access to distributed generation, storage, and flexible loads. At the individual level, a prosumer with rooftop PV and battery storage can shift excess midday solar generation to the evening peak, providing implicit flexibility to the local distribution network. At the collective level, aggregators and virtual power plants can pool the flexibility of multiple small-scale resources, households, electric vehicles, small businesses, and offer it as a service to wholesale or ancillary markets (Parag and Sovacool, 2016).

However, this synergy raises important equity concerns. The capacity to be flexible is conditioned by socio-technical factors including housing type, working routines, household composition, wealth, and digital literacy (Powells and Fell, 2019; Campos et al., 2024). Flexibility market participation tends to favour households that are already affluent and technologically equipped, those owning electric vehicles, home batteries, or smart appliances. Korsnes and Throndsen (2021) demonstrate how prosumer pilot projects in Norway pre-figured solutions appealing predominantly to high-income households, raising concrete concerns about "flexibility justice".

Beyond purely monetary or market-based solutions, non-monetary pathways to inclusive flexibility exist. Community energy cooperatives can aggregate flexibility from low-income households through shared storage assets, distributing revenues democratically without requiring individual capital expenditure (Burke and Stephens, 2018). Time-banking schemes

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and community benefit funds can reward flexible behaviour with in-kind services or community goods rather than financial payments. Lorek and Spangenberg (2019) identify social innovation in housing, including co-housing, communal energy management, and shared appliance libraries, as non-market pathways through which flexibility and sufficiency can be jointly advanced by households that lack individual financial capital. Policymakers must therefore ensure that flexibility mechanisms include safeguards for vulnerable consumers and create multiple, differentiated pathways for inclusive participation.

FLEXIBILITY AND SUFFICIENCY

Flexibility and sufficiency are mutually reinforcing in their contributions to system efficiency and resilience, but operate on different time scales that must be explicitly distinguished. Sufficiency primarily reduces permanent baseline demand – lowering the overall scale of the energy system needed – while flexibility primarily addresses the temporal distribution of residual demand, enabling smarter use of available (especially renewable) energy.

By permanently reducing peak demand and smoothing load profiles, sufficiency diminishes the magnitude of flexibility interventions required to balance the grid. Conversely, flexibility mechanisms can complement sufficiency by enabling smarter use of available energy, minimising curtailment of renewable generation, and reducing the need for expensive peaking infrastructure. The combination creates a virtuous cycle: a sufficiency-reduced, flexibility-optimised system requires less total investment and operates with greater renewable penetration.

For low-income or energy-poor households, however, forced flexibility through dynamic pricing, where heating or other essential loads must be curtailed during high price periods, can generate discomfort, health risks, or forced energy poverty. This tension underscores the importance of designing flexibility mechanisms with robust social safeguards, including baseline consumption protections, social tariffs, and explicit exclusions of life-critical loads from demand-response mandates. Heindl and Kanschik (2016) provide a normative framework for distinguishing between "voluntary" and "forced" sufficiency, arguing that the former is consistent with individual liberties while the latter requires explicit distributional compensation.

ENERGY JUSTICE: THE NORMATIVE FOUNDATION

The nexus of sufficiency, prosumerism, and flexibility cannot be assessed solely on technical or economic grounds. Energy justice provides an essential normative framework, encompassing three interconnected dimensions: distributional justice, recognition justice, and procedural justice (Jenkins et al., 2018; Korsnes et al., 2024). These dimensions are not merely theoretical: they provide the analytical criteria against which specific policies, market designs, and prosumer arrangements can be evaluated. Figure 1 provides a structured overview of these interdependencies.

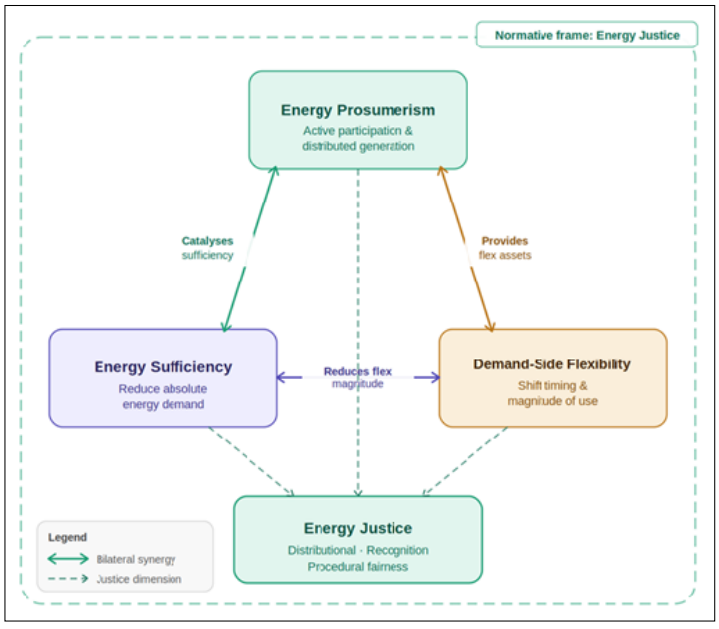

Figure 1 Integrated conceptual nexus framework of sufficiency, flexibility and energy justice.

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DISTRIBUTIONAL JUSTICE

Distributional justice concerns the fair allocation of the costs and benefits of energy transitions across households and communities (Jenkins et al., 2016). Within the sufficiency–prosumerism–flexibility nexus, prosumer benefits such as reduced energy bills, self-generation revenues, and flexibility payments may disproportionately accrue to higher-income households with access to capital, home ownership, and enabling technologies unless targeted equity measures are implemented (Milčiuvienė et al., 2019). Meanwhile, the remaining fixed costs of grid infrastructure may be disproportionately borne by those who cannot participate, creating what analysts term a "utility death spiral" (Borenstein, 2016): as prosumers defect from grid-dependent consumption, fixed network costs are increasingly concentrated on remaining, typically lower-income, ratepayers, raising prices and accelerating further defection in a regressive feedback loop.

Sufficiency policies that impose consumption limits without compensatory mechanisms risk falling disproportionately on vulnerable households, who may already live in energy poverty. Bertoldi (2022) notes that high energy prices tend to reduce consumption particularly in less affluent households, requiring careful attention to distributional impacts and the potential use of revenue recycling from carbon taxes or energy levies to support lower-income groups. Empirically, Zell-Ziegler et al. (2021) find that the distributional effects of sufficiency policies remain underanalysed in European climate planning, constituting a significant gap that policymakers must address proactively.

RECOGNITION JUSTICE

Recognition justice requires acknowledging the differentiated capacities and vulnerabilities of households participating in flexibility markets and demand response schemes. Dynamic pricing and flexibility mechanisms may disadvantage households with inflexible energy needs – including medically dependent residents, elderly populations, or inadequately insulated homes, unless appropriate safeguards, exemptions, and minimum service protections are implemented (Winther & Sundet, 2023; Dudka et al., 2026). For such households, demand response and dynamic pricing represent not an opportunity but a risk that must be actively managed through regulatory exemptions and guaranteed minimum service levels.

Recognition justice also requires attention to gender dimensions. Research has shown that women tend to bear a disproportionate burden of household energy management and are systematically underrepresented in prosumer and cooperative governance structures (Campos et al., 2024). Energy poverty itself has documented gender dimensions, with single-parent households – predominantly female-headed – exhibiting particularly high vulnerability across European member states (European Commission, 2023). Policies promoting prosumerism and flexibility must therefore ensure that women and other marginalised groups are actively included in energy community governance, cooperative decision-making, and the design of flexibility programmes.

PROCEDURAL JUSTICE

Procedural justice concerns the fairness and inclusiveness of decision-making processes governing the energy transition. Chilvers et al. (2018) introduce the "ecologies of participation" framework – an analytical concept describing the diverse, overlapping, and often informal modes of citizen engagement in socio-technical change, including activism, community energy groups, speculative design, and lived experiments, arguing that dominant, centralised participation modes tend to foreclose more decentred and emergent forms of engagement that are often more aligned with sufficiency and justice principles.

Korsnes et al. (2024), drawing on this framework in the context of prosumerism, demonstrate that utility-driven prosumer markets consistently favour dominant and formalised participation modes, typically the high-tech, private-ownership configurations least likely to advance sufficiency or justice. Genuinely procedurally just energy prosumer initiatives require mechanisms for meaningful stakeholder participation, transparent access to information, and the capacity of citizens, not merely consumers, to shape project design and governance. Practically, this includes technical assistance grants for low-income neighbourhoods to form energy cooperatives, co-design processes for demand-response programmes that centre the experiences of energy-poor households, and democratic governance structures within energy communities analogous to cooperative law principles.

POLICY FRAMEWORKS FOR AN INTEGRATED NEXUS

The effective realisation of the sufficiency-prosumerism-flexibility nexus depends on coherent and mutually reinforcing policy frameworks operating across regulatory, economic, and informational domains. Integrated National Energy and Climate Plans (NECPs) should reflect the complementarity of these three dimensions rather than treating them as isolated interventions. Zell-Ziegler et al. (2021) find that, among 18 European NECPs, sufficiency receives significantly less attention than efficiency and renewables, suggesting a systemic gap in current national planning frameworks.

POLICIES FOR ENERGY SUFFICIENCY

Bertoldi (2022) reviews a range of policy instruments capable of advancing energy sufficiency, noting that traditional energy efficiency policies, appliance standards, building codes, energy labelling, are necessary but insufficient to reach the EU energy and climate targets. Policies explicitly targeting sufficiency must move from voluntary behaviour change to structural interventions (Thomas at el., 2019). These include: progressive building codes and property taxes that penalise excessive floor area while incentivising renovation; enhanced Ecodesign Directive requirements mandating "sufficiency by design" for appliances and equipment; urban planning transitions toward compact, mixed-use "fifteen-minute cities" that structurally reduce the energy necessity of private motorised mobility; and progressive energy tariffs or personal carbon allowances (Fuso Nerini et al., 2021) that create financial signals discouraging excess consumption while protecting minimum access.

Information and awareness campaigns, while often limited in their standalone effects, can be effective when they engage social norms, personalise energy information, and provide targeted feedback embedded in broader structural and social contexts (Bertoldi, 2022; Labanca and Bertoldi, 2018). Energy savings feed-in tariffs and Pay for Performances schemes, rewarding households for metered energy savings rather than only for technology investments, represent an innovative instrument that incentivises both efficiency and conservation (Bertoldi et al., 2013). In all cases, equity implications must be assessed carefully, with revenues from carbon taxes or levies recycled to support lower-income groups.

POLICIES FOR PROSUMERISM

Effective prosumer policies require supportive regulatory frameworks that enable distributed energy participation while safeguarding inclusion. Key instruments include: legal recognition and simplified administrative procedures for RECs and CECs as mandated by the EU RED III and the Internal Electricity Market Directive; virtual net metering schemes allowing tenants in multi-family buildings and social housing to benefit from collectively owned renewables; one-stop shops providing technical, legal, and financial guidance for energy communities; and inclusive financing mechanisms, grants, cooperative funding models, participatory budgets, PACE schemes, that lower barriers for low-income households (Hanke & Lowitzsch, 2020; Sokołowski, 2020; Horstink et al., 2021).

The EU's Fit for 55 Package, RepowerEU, and the Affordable Energy Action Plan provide important legislative foundations, defining energy communities as entities generating environmental, economic, and social benefits for their members rather than pursuing profit maximisation. However, as Campos et al. (2024) note, significant implementation gaps remain, particularly regarding practical guidance for addressing energy poverty through community prosumer initiatives. The SomEnergia cooperative in Spain and the Ecopower cooperative in Belgium demonstrate that community-governed, open-membership models can achieve both high renewable penetration and inclusive participation when supported by appropriate regulatory and financing conditions. Policymakers should systematically document and disseminate lessons from such cooperative models to support replication.

POLICIES FOR FLEXIBILITY

Flexibility policies must create market designs that value distributed demand-side resources while preventing the exclusion of vulnerable consumers. Dynamic time-of-use (ToU) tariffs and real-time pricing can incentivise flexible behaviour, but must be coupled with social tariff

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protections and baseline guarantees for those who cannot or should not adjust their energy use. Regulatory frameworks enabling aggregators to represent small-scale flexibility by pooling prosumers, electric vehicles, and flexible industrial loads as collective grid services, are essential to unlock the full potential of distributed flexibility at scale (Parag and Sovacool, 2016).

Investment in digital infrastructure, smart meters, interoperability standards, data access frameworks, is a prerequisite for flexibility at scale, but must be deployed in ways that preserve consumer privacy and prevent market concentration. Network tariff reform is also needed to ensure that distributed generation and flexible loads are fairly compensated and that grid costs are equitably distributed across all consumer categories, avoiding the regressive "death spiral" dynamic for households unable to participate in prosumer or flexibility markets (Borenstein, 2016). Flexibility mechanisms should also include non-monetary participation pathways, community shared storage, cooperative aggregation, in-kind benefit schemes, to ensure that low-income households can contribute to and benefit from system flexibility without requiring upfront capital.

INTEGRATING THE POLICY APPROACHES

The integration of sufficiency, prosumerism, and flexibility policies requires moving beyond siloed sectoral instruments toward systemic policy packages. Combining sufficiency measures with dynamic pricing encourages both reduced and more flexible consumption simultaneously. Supporting prosumers with storage technologies enhances their ability to provide flexibility services while also reducing their exposure to price volatility. Progressive building codes align with the investment logic of community prosumer initiatives by ensuring that new buildings are designed for minimal energy demand and active grid participation from the outset.

An integrated approach also guards against unintended consequences. Promoting prosumerism without addressing sufficiency risks rebound effects where increased self-generation encourages higher total consumption (Sorrell et al., 2020). Flexibility policies relying solely on price signals may disadvantage consumers without the means or freedom to respond (Powells and Fell, 2019). The policy architecture must therefore simultaneously embed minimum and maximum consumption bounds, value flexibility services from distributed actors, support inclusive and collective prosumer models, and ensure participatory governance of the energy transition. Regulators and policymakers should conduct explicit equity audits of any proposed nexus policy package, assessing distributional, recognition, and procedural justice implications before implementation.

CHALLENGES AND LIMITATIONS

Despite the conceptual coherence and policy appeal of the nexus framework, several challenges constrain its realisation in practice. These challenges span behavioural, structural, technological, and political economy dimensions.

Behavioural resistance to sufficiency remains a significant barrier. Cultural norms, consumption habits, and economic incentives often favour higher energy use, and information instruments alone are insufficient without structural and financial complements (Bertoldi, 2022; Spangenberg and Lorek, 2019). Sufficiency policies that are perceived as restrictive may face political resistance, as illustrated by the "yellow vest" protests in France triggered in part by fuel tax increases (Douenne and Fabre, 2022), particularly where equity and co-benefit narratives are absent or poorly communicated.

Geographic and socioeconomic constraints on prosumer participation represent a fundamental equity challenge. Citizens in rented accommodation, multi-family buildings, or areas with inadequate grid infrastructure face structural barriers to prosumer engagement. The development of distributed prosumer-based smart energy systems remains nascent across much of the Global South, where basic grid stability and digital infrastructure are prerequisites requiring major investment before distributed prosumer models can be viable at scale (Campos et al., 2024). Leapfrogging strategies, e.g. deploying distributed renewable systems ahead of centralised grid expansion, offer opportunities but require careful governance design to avoid replicating the exclusionary dynamics observed in high-income prosumer markets.

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Technological and infrastructural requirements pose further challenges. Implementing flexibility at scale demands advanced digital systems, cybersecurity measures, and interoperability standards. Ensuring that digitalisation does not generate new forms of exclusion, through complexity, data asymmetries, or algorithmic management that removes consumer agency, requires careful regulatory design. The ecological footprint of digital infrastructure itself must also be considered: the energy and resource demands of information and communication technologies (including AI-managed smart home systems and VPPs) can partially offset the sufficiency gains they enable, raising questions about systemic rebound at the infrastructure level.

Finally, the political economy of incumbency poses a structural challenge. Centralised energy utilities, fossil fuel interests, and established market actors may resist the transition toward distributed, sufficiency-oriented energy systems. Overcoming this resistance requires sustained political commitment, multi-level governance coordination, and alliances between civil society, municipalities, cooperatives, and progressive businesses, precisely the "decentred and diverse" forms of participation that Chilvers et al. (2018) identify as both essential and systematically undervalued in dominant energy governance frameworks.

CONCLUSIONS AND POLICY RECOMMENDATIONS

The nexus of energy sufficiency, prosumerism, and demand-side flexibility constitutes a coherent and evidence-supported framework for reimagining energy systems in the context of decarbonisation, equity, and democratic participation. Unlike approaches relying solely on efficiency improvements or renewable energy supply expansion, this framework addresses the systemic drivers of energy demand, the ownership and governance structures of distributed energy, and the dynamic management of supply-demand balance, all within a justice-oriented perspective.

The structured conceptual review conducted in this paper yields five evidence-grounded conclusions, each carrying specific policy implications.

CONCLUSION 1: THE THREE PILLARS ARE INTERDEPENDENT, NOT PARALLEL

Sufficiency, prosumerism, and flexibility form a genuinely integrated nexus: sufficiency reduces the scale of prosumer investment required; prosumers provide the distributed assets enabling flexibility; and flexibility optimises the performance and economic viability of prosumer systems. This interdependence means that policies targeting one pillar in isolation risk undermining the other, promoting prosumerism without sufficiency risks rebound; pricing-based flexibility without prosumer capacity may exclude low-income households; and sufficiency alone cannot deliver system balancing. Integrated policy packages explicitly designed to activate all three pillars simultaneously are essential.

CONCLUSION 2: ENERGY JUSTICE IS A CONSTITUTIVE, NOT SUPPLEMENTARY, ELEMENT OF THE FRAMEWORK

All three pillars generate significant distributional, recognition, and procedural justice challenges when deployed without explicit equity design. The risk of a "utility death spiral" from prosumer defection, the disproportionate flexibility burden on vulnerable households, and the underrepresentation of women and marginalised groups in prosumer governance are not peripheral concerns but central challenges that determine whether the nexus advances or undermines a just energy transition. Justice impact assessments should be mandatory components of nexus policy design.

CONCLUSION 3: SUFFICIENCY MUST BE ELEVATED FROM VOLUNTARY ASPIRATION TO STRUCTURAL POLICY OBJECTIVE

The evidence base from Samadi et al. (2017) on scenario contributions, to Zell-Ziegler et al. (2021) on NECP gaps, to Sorrell et al. (2020) on rebound limits to efficiency, consistently demonstrates that voluntary sufficiency approaches are insufficient. Structural interventions are required: progressive building standards; urban planning for low-energy mobility; product regulations mandating sufficiency by design through enhanced Ecodesign requirements; and

economic instruments, including progressive tariffs and personal carbon allowances, that discourage excess consumption while protecting minimum access standards for all households. Revenues from such instruments should be explicitly earmarked for supporting low-income households.

CONCLUSION 4: PROSUMER POLICY MUST BE EXPLICITLY DESIGNED FOR INCLUSION

Regulatory frameworks for RECs and CECs must go beyond enabling legislation to provide active support: one-stop shops, inclusive financing, virtual net metering for renters, and measurable targets for the participation of low-income and vulnerable households. Cooperative and commons-based models, with democratic governance and shared ownership arrangements, warrant explicit policy prioritisation over high-tech, privately-owned prosumer configurations. The EU's legislative framework – RED III, the Internal Electricity Market Directive, the Affordable Energy Action Plan – provides the necessary foundations; the critical gap is implementation, particularly in translating enabling legislation into accessible support mechanisms for low-income communities.

CONCLUSION 5: FLEXIBILITY MARKETS MUST INCORPORATE JUSTICE SAFEGUARDS FROM THE OUTSET

Dynamic pricing must be paired with social tariffs and baseline consumption protections. Life-critical loads must be explicitly excluded from demand-response mandates. Aggregation frameworks should enable small-scale and low-income participants to access flexibility markets on fair terms, including through community cooperatives and non-monetary participation pathways. Network tariff design must prevent the inequitable concentration of grid costs on those unable to participate in distributed energy. Regulators should monitor flexibility market outcomes for distributional effects and intervene proactively when regressive patterns emerge.

Collectively, these conclusions point toward an energy governance paradigm that is simultaneously technically sophisticated and socially just. Realising the nexus vision requires not only technological innovation and regulatory reform but also cultural, institutional, and political transformation: placing energy for well-being within ecological limits at the heart of twenty-first-century energy policy.s

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **PowerPoint Slides.** PowerPoint Slides relating to this article. URI: https://eceeeproceedings.org/articles/135/files/6a54c555399b2.pptx

COMPETING INTERESTS

The author has no competing interests to declare.

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