ENTEC

Energy Transition Expertise Centre

Digitalisation of Energy Flexibility

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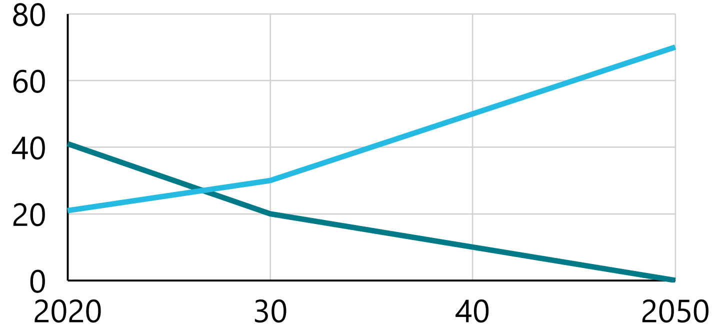
Flexibility requirement in the EU

Net GHG emissions — Electricity share in EU energy consumption — 2020 — 2030/2050

EU power system is evolving rapidly to require more flexibility

Meeting climate neutrality by 2050 will require **increased energy system flexibility**, as a result of increasing share of renewables (RES)

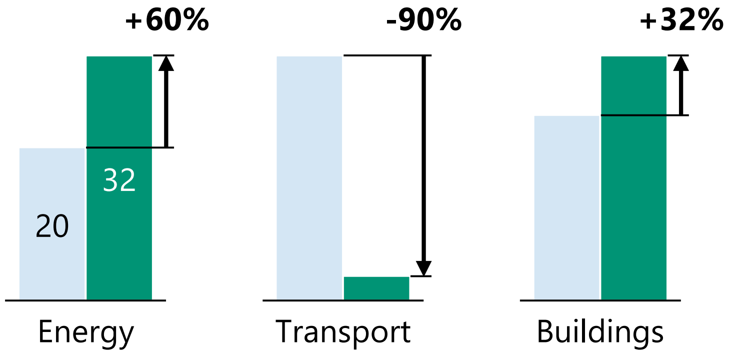
1.5 degree Pathway: Net CO2 equivalent emissions (CO_2 eq., GT) and **Electricity share in EU energy consumption** (%)



EC Green Deal has set ambitious targets which specifically drive flexibility needs

The EC's Green Deal to achieve climate neutrality by 2050 sets ambitious targets in key sectors for energy flexibility control

RES % of EU Energy, 2030 | **GHG emissions, 2050** | **Building energy efficiency, 2030**



Flexibility need can be addressed through digital use cases; part of larger EC ecosystem

Energy storage and DSM flexibility provide opportunities for **optimization made possible through digitalization** however not all solutions will be digital

The overarching Green Deal creates natural links to **DG Mobility and Transport**, **DG Communications** and **EC policy departments**[1]

CEF TRANSPORT

CIVITAS Cleaner and better transport in cities SUITS

Smart Built4EU The European Smart Buildings Community

SMARTER TOGETHER

1. CEF: program on creating high performance interconnected networks in Transport, Energy and Digital Services. SmartBuilt4EU: Smart Building Innovation Platform

Source: McKinsey Global Energy Perspective, EC

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Flexibility solutions comparison

Min TCOO[1], €/kW · Max TCOO, €/kW · Project focus · Min Revenue, €/kW · Max Revenue, €/kW

	Time to deploy	System cost and revenue opportunity 2030	Environmental impact
Digital flexibility solutions	Ramp up to **200+ GW** projected possible by 2030	1 / 60 8 / 68	Limited impact, ranging from software only to minor electric or mechanical parts (e.g., boiler, hot water buffer tank)
Gas power plants	Likely **no significant limitation** to build out given established processes etc.	54 / 57 51 / 71	**~1 GWh** of natural gas burned per 0.6 GWh of flexible generation, generating **345 tons of CO_2**
Electricity storage[3]	**~22 GW** of battery projects estimated by 2030	52 34 / 64	Requires **4.8 tons** of material, thereof **0.11 tons** of lithium, per GWh of capacity
Hydrogen electrolyzer[2]	**40 GW** of capacity announced by EU as an objective for 2030 – competition with industry, mobility applications	15 74	Requires **precious metals** (platinum for electrolyzers)

Based on high level assessment, selected **digital power flexibility solutions can be advantageous or at least on par** with non-digital flexibility options

A high ramp up rate to deployment at scale fast development cycles in digital technology

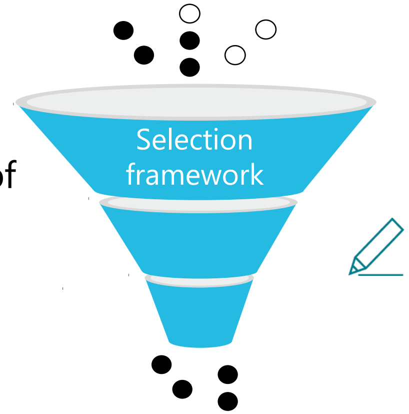
While highly uncertain, cost and **revenue estimates for selected business cases show strong margins** before fees, taxes and other effects

Indicative comparison neglecting additional factors such as availability, flexibility needs addressed (e.g. ancillary services)

1. Total Cost of Ownership
2. TCOO and revenue based on electrolyzer CAPEX for 2030 and projected value of hydrogen. Excludes storage and e.g. fuel cells for grid services
3. Revenue based on wholesale electricity prices

Project Overview

Task 1: Identification of application areas, use cases and business cases



Selection of 15 high impact use cases

Task 1.1

Task 1.2

Detailed analysis of selected use & business cases

Utilize use cases as sounding board

Task 2: Digital infrastructure - enablers

Task 2.1: Flexibility markets and enabling factors

Task 2.2: Governance and enabling framework

The overarching aim of the project is to provide data and expertise driven support for the regulatory process aiming to accelerate integration of digitally enabled flexibility solutions, thereby supporting the EC Green Deal ambition

Incorporate internal and external best practices

Task 3: Status quo and experience

In Member States of EU
In countries beyond EU
In other sectors

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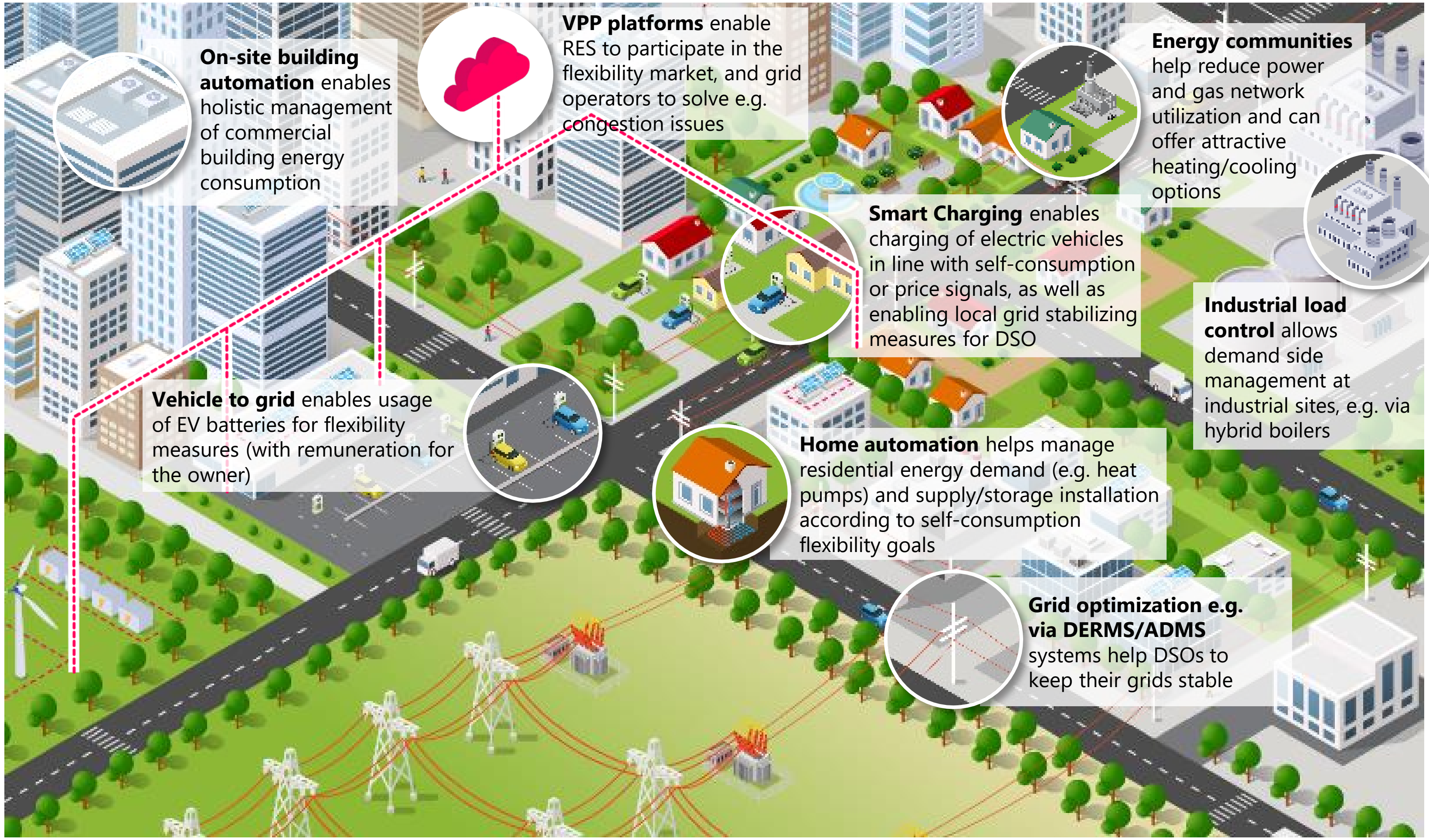
Selected flexibility solutions

Task 1.1	Task 2.1
Task 1.2	Task 2.2
Task 3	



Use cases	Business cases
Grid optimisation	Distributed Energy Resource Mgt Systems (DERMS)
Virtual power plant (VPP) platforms	VPPs for intraday flexibility VPPs for ancillary services VPPs for internal balancing
Energy communities	Energy communities & P2P District heating and cooling
On-site building optimisation	Building Energy Management Systems
Industrial DSR	Industrial load control: hybrid heating
Home automation	Residential heat pumps HEMS and home batteries
EV smart charging	EV: responsive charging EV: self-consumption optimisation
Vehicle to grid	EV: responsive (dis)charging EV: congestion and ancillary services

9 key take aways from this project

Task 1.1	1	Digital flexibility business cases **vary vastly in regards to maturity, size and feasibility**
	2	**Most business cases provide short intraday flexibility**, only one selected business case is able to provide flexibility across a timespan larger than 24 hours
Task 1.2	3	Business cases vary significantly on impact (e.g., amount of flexibility providable, risk profile) and feasibility (e.g. indicative business case viability, technical development status)
	4	The analyzed business cases could – if reaching their full potential – **cover a large percentage or even all identified flexibility requirement** in ancillary services, congestion management and wholesale/spot market
	5	Full build out of the analyzed business cases would **require significant resource investment (~40 bn €) and large scale implementation** in their respective asset base (e.g. industrial complexes, district heating, battery electric vehicles)
Task 2.1	6	**Real time and safe data exchange is an important prerequisite** for most business cases. Several initiatives are trying to facilitate this, e.g. gaia-x – but significant development is still needed to meet needed standards for many business cases
Task 2.2	7	**Regulatory framework should recognize value of flexibility** for renewable integration and promote flexibility readiness. This should focus on reduction of transaction costs for small scale participants and **providing cost-reflective tariffs and incentives**.
	8	The features of flexibility resources need to be considered in the **design of market conditions** by **rethinking market rules according to actual market needs**
Task 3	9	**Positive examples already exist** as first companies start to offer needed services. Learning from their experiences offers further insights into how to support growths in the space by proactively shaping the industry

Business cases potential impact - preliminary

2030 | 2050 | Resource competition

Estimated flexibility potential of business cases (2030 and 2050), GW_{peak}

Wholesale /spot market	EV: responsive charging & discharging	241
	District heating and cooling	170
	VPPs for intraday flexibility	164
	VPPs for internal balancing	Lim. flexibility effect 80
	Industrial load control: hybrid heating	74
	HEMS and home batteries	55
	Energy sharing (+ P2P trading)	46
	BEMS (commercial buildings)	38
	EV: responsive charging	28
	EV: self-consumption optimization	17
	Residential heat pumps	10
	Resource competition	-155
Ancillary services	EV: congestion and ancillary services	154
	VPPs for ancillary services	16
	Resource competition	-110
Congestion management	Industrial load control: hybrid heating	1
	HEMS and home batteries	1
	Resource competition	0
Total		230 (2030) + 600 (2050) = 831

High level roles of flexibility options

Largest potential for **wholesale/ spot market application:**

- Battery electric vehicles (EV)
- VPPs
- District heating and cooling

Largest potential for **ancillary services:**

- Battery electric vehicles (EV)
- VPPs

Largest potential for **congestion management:**

- Industrial load control
- BEMS and HEMS

... due to their spatial distribution in the TSO/DSO grids

Business cases are mapped against a single or multiple flexibility types, but always adding up to 100% of each cases capacity. While business cases may be able to participate in e.g. congestion management and spot market flexibility, it is not possible to participate in multiple markets with the same resource capacity at the same time.

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Task 1.1
Task 1.2
Task 2.1
Task 2.2
Task 3

Example: Use cases for possible EU27 2050 scenario

Scenario description: Meeting EU flexibility demand by 2050

A merit order of flexibility has been constructed for each of the flexibility types

Business cases with decreasing margin were selected until the three flexibility targets for 2050 demand were met or no additional capacity at positive margin is available

Wholesale/intraday spot market: gap of ~45 GW of flexibility to be filled by other, non-digital flexibility sources;

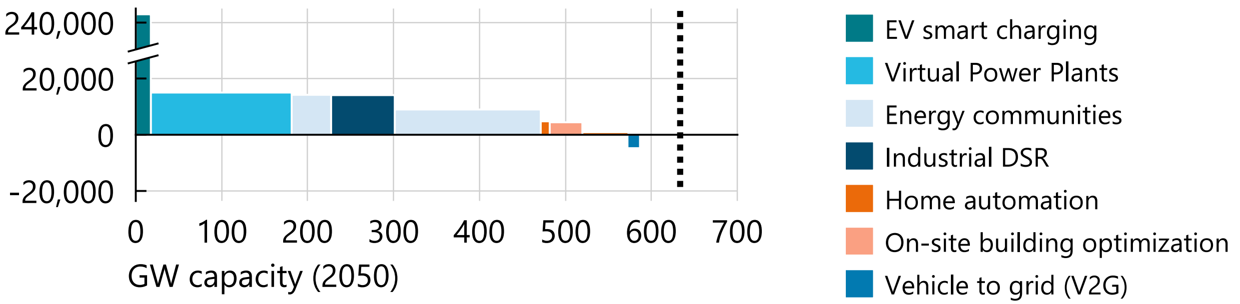
Ancillary services: gap of ~45 GW, with V2G for ancillary services currently projected not profitable

Congestion management: small demand (1 GW) met by spatially distributed flexibility (industrial hybrid heating, BEMS)

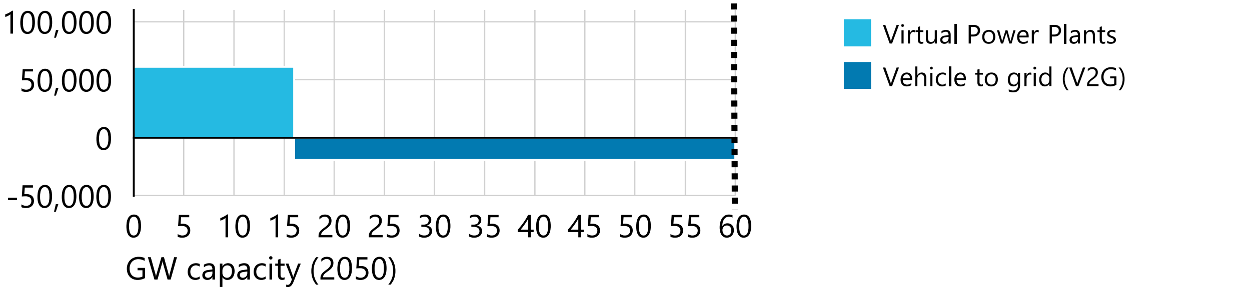
This illustrative example makes at least the following simplifications:

- Margin estimate does not consider fees, taxes and other effects
- Differences in upward/downward demand are not considered
- Maximum shiftable duration of flexibility is not considered, and intraday and interday are not treated separately
- No spatial requirements for congestion management considered
- Non-digital flexibility solutions where not considered

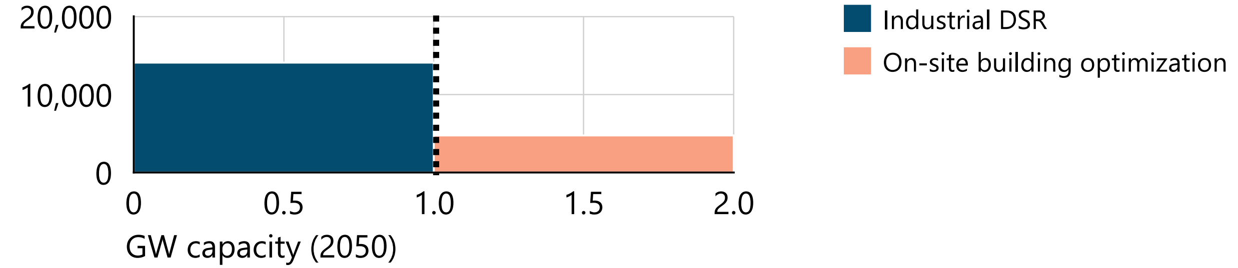
Wholesale/spot market margin merit order[1], EUR/MW-year



Ancillary services margin merit order[1], EUR/MW-year



Congestion management margin merit order[1], EUR/MW-year



1. Capacity from directly competing business cases has been reduced to reflect limited resources e.g. BC 3.1 and BC 4.1 and BC 8.1 and BC 9.1. Most profitable cases have been prioritized for this, so that a higher capacity could be achieved when accepting lower margins

What would it take to implement this scenario?

Task 1.1 | Task 1.2 → Task 2.1 | Task 2.2
Task 3

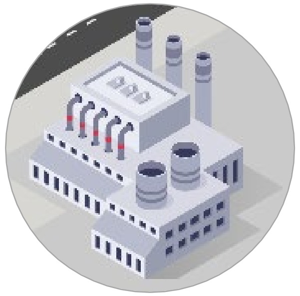
Values are exemplary, non-exhaustive and depend on which business cases prevail

Exemplary changes by 2050

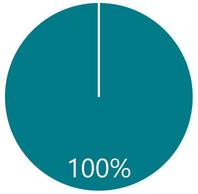
When focusing on digital flexibility

~ 40 Bn EUR capital investment

...specifically targeting flexibility solutions assuming underlying infrastructure (e.g. BEV and dispatchable generation) in place

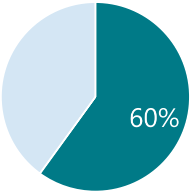


Hybrid heating system upgrade at **3,000 industrial sites** (100% of suitable sites)



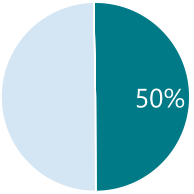
Of industrial sites

165 GW of dispatchable renewable energy sources accumulated in VPPs (~60% of all dispatchable RES[1])



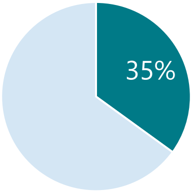
Of dispatchable RES

~ 3,400 district heating networks (170 GW) participating in flexibility markets (50% of all DH networks)



Of district heating networks

~ 59 million BEVs utilizing smart charging and **~ 7 million BEVs participating in V2G activities** (~35% of estimated BEVs)



Of Battery Electric Vehicles

1. Assume 800MW/VPP, 350 VPPs by 2030

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High level summary of use case criticality and readiness with regard to infrastructure and enablers

Task 1.1 | Task 1.2 → Task 2.1 | Task 2.2
Task 3

Infrastructure/enablers criticality[1] and readiness[2]: High, Medium, Low; Criticality / Readiness; Largest gap

Cell values given as Criticality / Readiness.

Use case #	Use case name	Trust	Security and data sovereignty	Ecosystem of data	Standar-dized inter-operability	Value adding apps	Data markets	Key highlights
6	**(DSO) Grid automation/ optimization**	High / Medium	High / Medium	High / Low (largest gap)	High / Low (largest gap)	Medium / Low	Medium / Low	▪ Lack of willingness from DSOs to share data ▪ MV grid operations somewhat digitized, LV grids still paper-based
7	**VPP platforms**	High / Medium	High / Medium	Medium / Medium	Medium / Medium	Medium / Low	Medium / Low	▪ Existing standards to ensure data security and sovereignty, but may need to reduce costs to ensure adoption ▪ No single standard across the EU
8	**Energy communities**	High / Low (largest gap)	High / Medium	Medium / Low	High / Low (largest gap)	Medium / Low	Medium / Low	▪ Energy communities – lack of certification / standardization, with regulation in most MS still in draft form / conceptual stage
9	**On-site building automation/optimization**	High / Low (largest gap)	High / Medium	Medium / Low	High / Low (largest gap)	Medium / Medium	Medium / Low	▪ Limited interoperability for different types of appliances or different OEMs ▪ Unclear data ownership
10	**Industrial load control**	High / Medium	High / Medium	Medium / Low	High / Medium	Medium / Medium	Medium / Low	▪ Lack of standardization across MS ▪ Integration into existing industrial processes could be expensive, specially for SME
11	**Home automation / Residential DSR**	High / Low (largest gap)	High / Medium	Medium / Low	High / Low (largest gap)	Medium / Medium	Medium / Low	▪ Lack of standardization / interoperability for different appliances / OEMs
12	**EV smart charging**	Medium / Low	High / Medium	High / Low (largest gap)	High / Medium	High / Low (largest gap)	Medium / Low	▪ Limited procedures for standardized data sharing (currently based on bilateral agreements) ▪ Data ecosystems very siloed (i.e., with different OEMs, V2G service providers)
13	**Vehicle to grid (V2G)**	High / Low (largest gap)	High / Medium	Medium / Low	High / Low (largest gap)	Medium / Low	Medium / Low	

Improvements required across the board to accelerate adoption of use cases, with special emphasis on improving trust and standardized interoperability, the 2 areas with largest perceived gaps

Source: Expert interviews

1. Criticality - High: Use case / business model's success requires the full application of guidelines; Medium: Use case / business model's success still feasible with partial compliance to the guidelines; Low: Use case / business model's success not hindered by the application of guidelines
2. Criticality - High: Existing solutions (e.g., technology, standards, product) meet full set of guidelines; Medium: Existing solutions (e.g., technology, standards, product) meet some of the guidelines; Low: Existing solutions (e.g., technology, standards, product) in very early stage, do not meet any or most of the guidelines

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Common barriers to flexibility provision and potential options to consider

Barriers	Plausible alternatives to explore
Need for incentives	**Cost-reflective tariffs** for small-scale flexibility resources, a requirement for incentive-based activation of flexibility resources **Grid related incentives** for flexibility usage
External control of demand-side resources	Facilitation of **access to real-time data** (data types, authorization guidance) Enable remote control of assets
Technical requirements of integration	Facilitate availability of cheap and **interoperable metering & control technology**
Market participation/ integration at scale	**Define technical requirements with flexibility resources in mind** (smaller minimum bids, shorter gate closure times, shorter availability periods, comfort needs, production schedules) **Facilitate pre-qualification for groups** instead of individual applications (driving uptake of e.g. storage, heat pumps, electric boilers) **Open the system service markets** to flexibility resources in addition to wholesale Make processes and information flows for the provision of flexibility easy to understand and accessible to small, non-expert parties

Factors that could affect digital businesses for policy makers

Task 1.1 | Task 1.2 → Task 2.1 | Task 2.2 ; Task 3

Policy shapers can influence the development of new digital business models to enable digital business building in energy flexibility

XX Power companies within EU *XX* Power companies outside EU **XX** Companies from other sectors

	From...	To...	Examples from our research
Timing/pace	... engaging with innovators reactively ...	... **assessing impact and risks early** and **continuously evaluating** industry developments ...	Company A, B
Policy design	... fitting new digital business models into existing regulatory frameworks ...	... **designing fit-for-purpose regulatory frameworks** for digitally enabled business models ...	Company A, B, C, D, *E*
Enforcement / public support	... managing enforcement through individual government agencies ...	... leveraging **"whole-of-government" approach and coordination** ...	Company A, **H, I**
International cooperation	... looking at local developments narrowly ...	... **learning from international markets and developments**, and **cooperating with international peers** ...	Company B, C, D

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Consortium

Fraunhofer ISI

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