Digitalisation in Urban Energy Systems

What is digitalisation?

Digitalisation is the transformation of a business or industry by using digital technologies to improve its processes.

How does digitalisation work?

Digital tools can help to integrate and analyze data, underpin more effective and sustainable policymaking and urban planning, provide information and insights, and create benefits for citizens. Especially for urban dense areas, digitalisation can assist to reduce resource demand and improve flexibility to respond to changes.

What is an energy system?

An energy system is a group of things that are used together to produce energy.

What is an urban energy system?

An urban energy system is the combination of the processes for acquiring and utilizing energy to meet the energy service demands of an urban population.

How can digitalisation improve cities?

SECURITY
cameras, smart surveillance

HEALTHCARE
wellbeing, telemedicine, air quality monitoring

ECONOMIC DEVELOP-MENT & HOUSING

ENGAGEMENT &COMMUNITY
local connection platforms

MOBILITY
management, operations, smart traffic

WATER
monitoring, leakage detection

WASTE
optimization of waste collection routes

ENERGY
smart buildings, smart street lighting

Urban Energy Systems for Scalable Cities

An urban energy system represents **all functional processes** related to the **provision and use of energy services for demands from an urban population**. The energy system comprises primary energy supply, conversion, distribution, storage and final use in different sectors (such as buildings and mobility).

It requires an integration of **planning, implementation, operation** and **management** towards an overall sustainable impact, with interactions between a larger number of components and actors.

Prepared by:
Scalable Cities Secretariat

Source:
Digitalisation in Urban Energy Systems. Outlook 2025, 2030 and 2040

European Commission

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The following infographic summarizes the three scenarios and the implications in each sector of **UES** framework. The potential **implications of digitalisation** in urban energy systems are currently **very uncertain** as there are several limitations and barriers in different aspects such as data, coordination and integration within public and private sectors, knowledge, capacity, finance and citizen engagement.

Acronyms:
UES - Urban energy system
RES - Renewable energy sources
SRI - Smart Readiness Indicator
MaaS - Mobility as a service
ESCO - Energy Service Companies
Evs - Electric vehicles
IoT - Internet of Things

	Scenario 1 Slow and reluctant digitalisation of UES	**Scenario 2** Private sector reaps digitalisation benefits	**Scenario 3** Open, trusted, efficient digitalised UES
BUILDINGS DEMAND & SUPPLY SIDE	**Slow digitalisation** due to concerns on data privacy, mistrust on AI, and difficulty of participation in energy markets. **RES** have been adopted but are not being optimised.	Private companies have service contracts in most buildings, and have optimised **efficiency, renewable energy production**, and **flexibility management,** with no upfront costs for building owners.	SRI has triggered investments in **buildings' digitalisation**, adoption of **solutions in renewable energy inte-gration** and **participation** in **energy markets**.
MOBILITY DEMAND SIDE	Traditional **active mobility** (cycling, walking) **car-free zones** are increasingly adopted in cities. **Digitalised mobility** solutions are mostly used for **public transport**.	Cost effective **private MaaS** is displacing public transport. Complex management of urban mobility as the pace of digitalisation within the public sector is comparatively very **slow.**	Cities operate efficient **urban mobility platforms**. Very successful and cost effective **MaaS solutions** have been deployed and are widely in use, together with **multi-modal solutions** for public transport.
INTEGRATED INFRASTRUCTURE	**Slow** penetration of distributed storage and flexibility solutions, and **low participation** of citizens in energy markets.	**ESCOs** and large utilities have control of most of the **UES** through service contracts. They efficiently manage renewables, storage, flexibility assets.	Citizens fully participating in the energy market. **High rate** of distributed RES and storage, 100s GW **flexible capacity** in operation in cities.
CITIZEN ENGAGEMENT	LOW	MEDIUM	HIGH
DATA AVAILABILITY & DATA ACCESS	LOW	MEDIUM	HIGH

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Drivers of renewable energy systems

Feed-in tariffs:
Electric utilities are compelled to pay above-market rates for RE.

Business models:
Investment in RE is encouraged with advantageous models (e.g. tax, regulation, grants, quotas, subsidies, trading).

Recycling:
High improvements in the recycling process have increased the environmental benefits of RE compared to combustion plants.

Decarbonisation:
Energy production through RE has a lower carbon footprint and less impact on climate change.

Long term policies:
Long term strategies help developing sustainable energy systems and encourage research.

Quotas:
Obligation for electricity producers to justify that a determined part comes from renewable sources.

Smart designs:
Smart technologies enable better use of electricity, improving the overall efficiency of RE systems and encouraging development.

Digitalisation:
Provides better control and management that improves the effectiveness of energy systems.

Hybrid systems:
RE systems are often weather relevant. The combination of two sources can compensate for the intermittence and encourage the development of new RE.

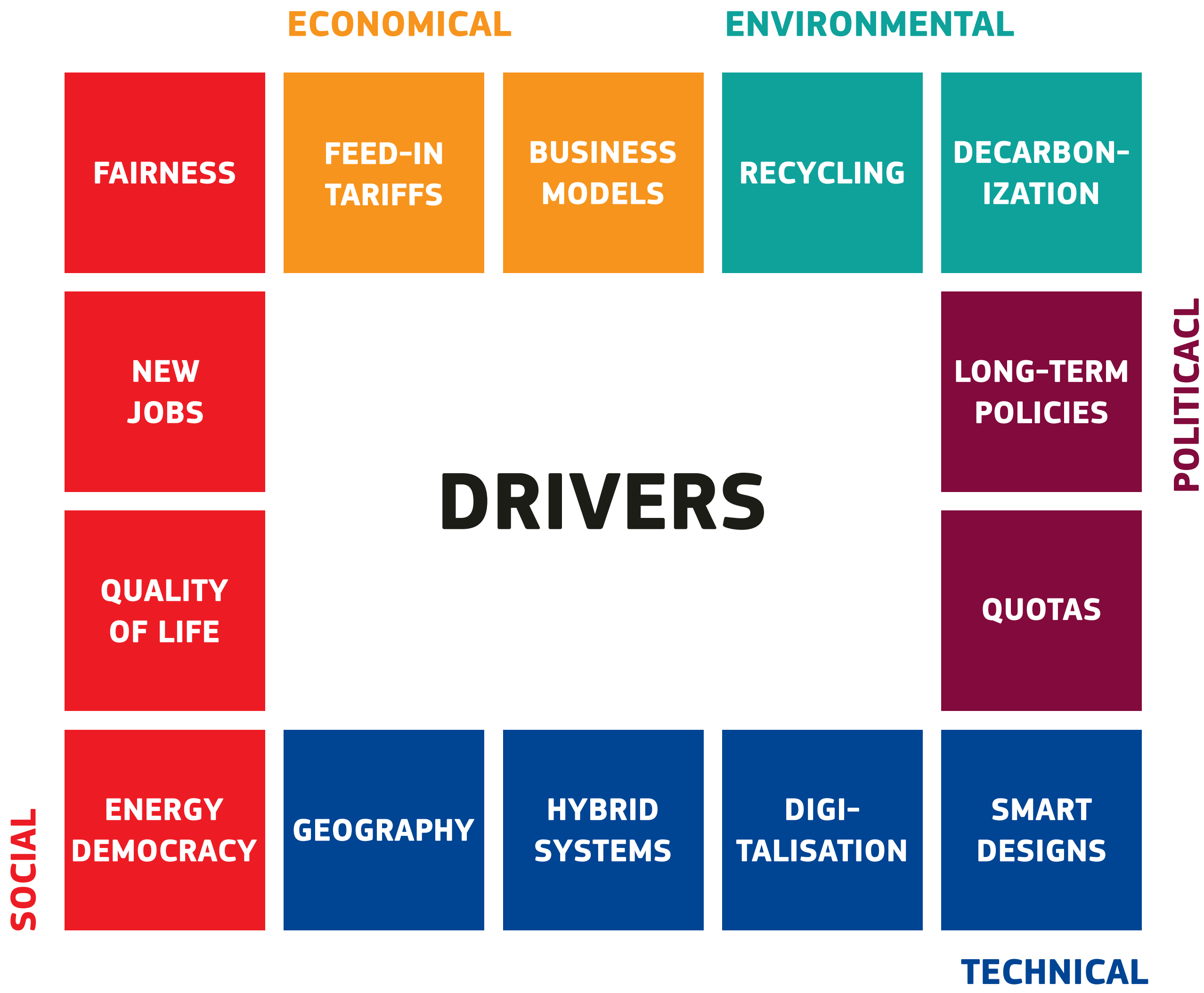
Geography:
Presence of resources (wind, solar, hydro, and geothermal) enables the development of RE production.

Energy democracy:
Request in control of own energy supply and use is increasing.

Quality of life:
A higher life quality generally leads to higher energy needs and its flexibility.

New job opportunities:
RE industry represents new opportunities for jobs leading to a local tax/revenue increase.

Fairness:
Respecting a procedural and distributional justice (fair planning and costs/benefits share) increases social acceptance of RE projects.



Barriers of renewable energy systems

Competitiveness:
Non-renewable resources of energy often present financial advantages that slow down the investments.

Innovation:
Possible new discoveries are breaks to investment in existing RE technologies: a new component or a more optimal way to use an existing one can make past investments useless and considered as wasted.

Materials:
Clean energy technologies, especially wind and solar, increase the mineral demand and the load on extraction mines.

Side-impact:
Implementation of new RE facilities (e.g. hydropower) raises environmental concerns, such as the destruction of ecosystems (flooding).

Leadership:
Lack of motivation from the policy makers to encourage behavioural changes and development of RE systems.

Industry:
Many industries rely on fossil fuels and have a strong influence in the policy making process.

Skills:
The lack of technical skills and qualified manpower slows down the expansion of RE systems.

Curtailment:
RE are not always connected to the grid and the production cannot be used efficiently.

Generation systems:
Existing infrastructures without generation (e.g. dams with no hydropower generation) decreases the part of available sources of RE.

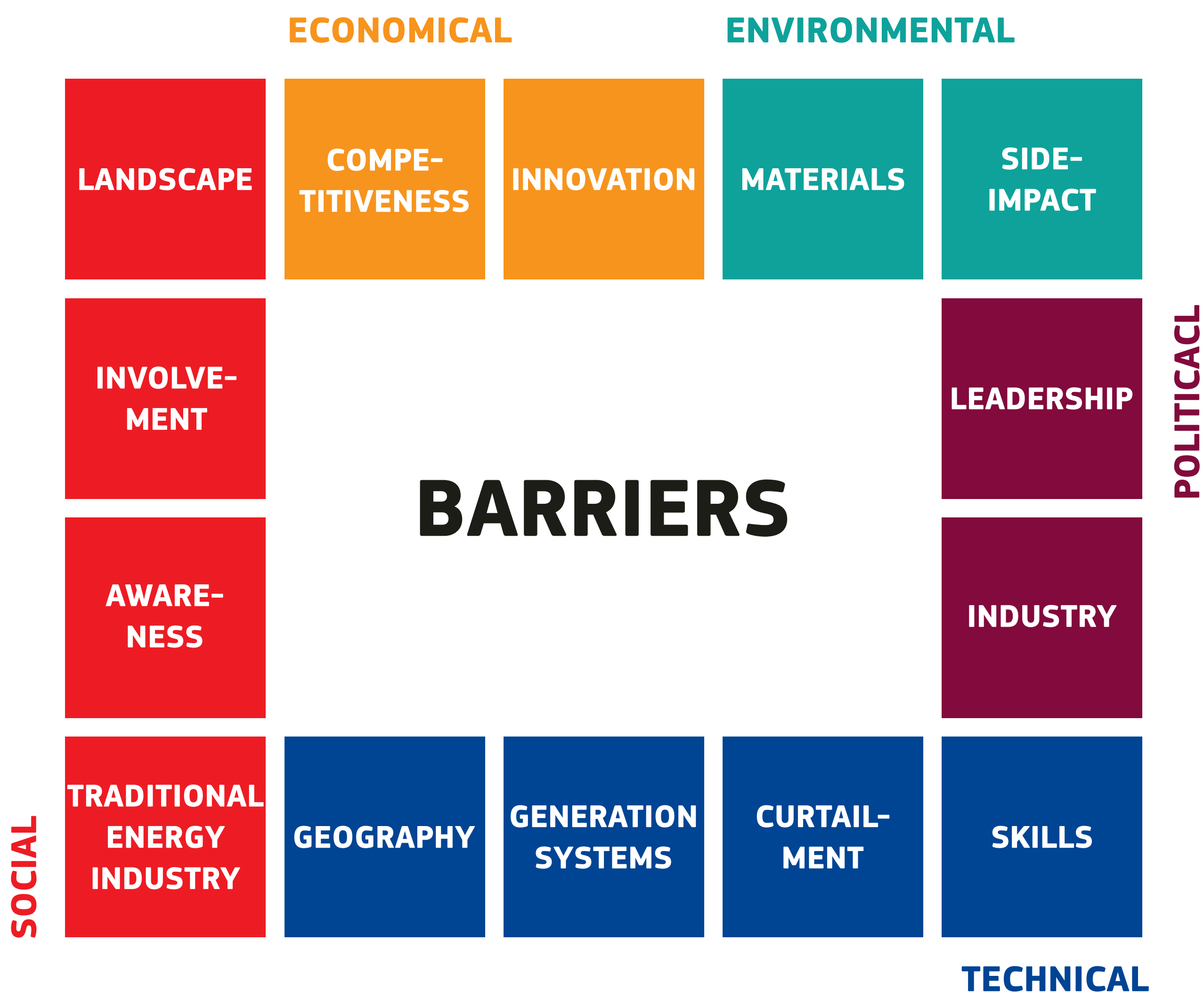
Geography:
Absence of resources (wind, solar, hydro, and geothermal) prevents the development of RE production.

Traditional energy industry:
Fossil-fuel market is often a large part of a country's income. Abandoning it will reduce the associated collected taxes by the government.

Awareness:
End-users do not always have the knowledge of the potential for RE and available financial help.

Involvement:
Lack of data access for the consumers to manage their consumption and the origin of their energy.

Landscape:
Visual impact of RE are often rejected by citizens.



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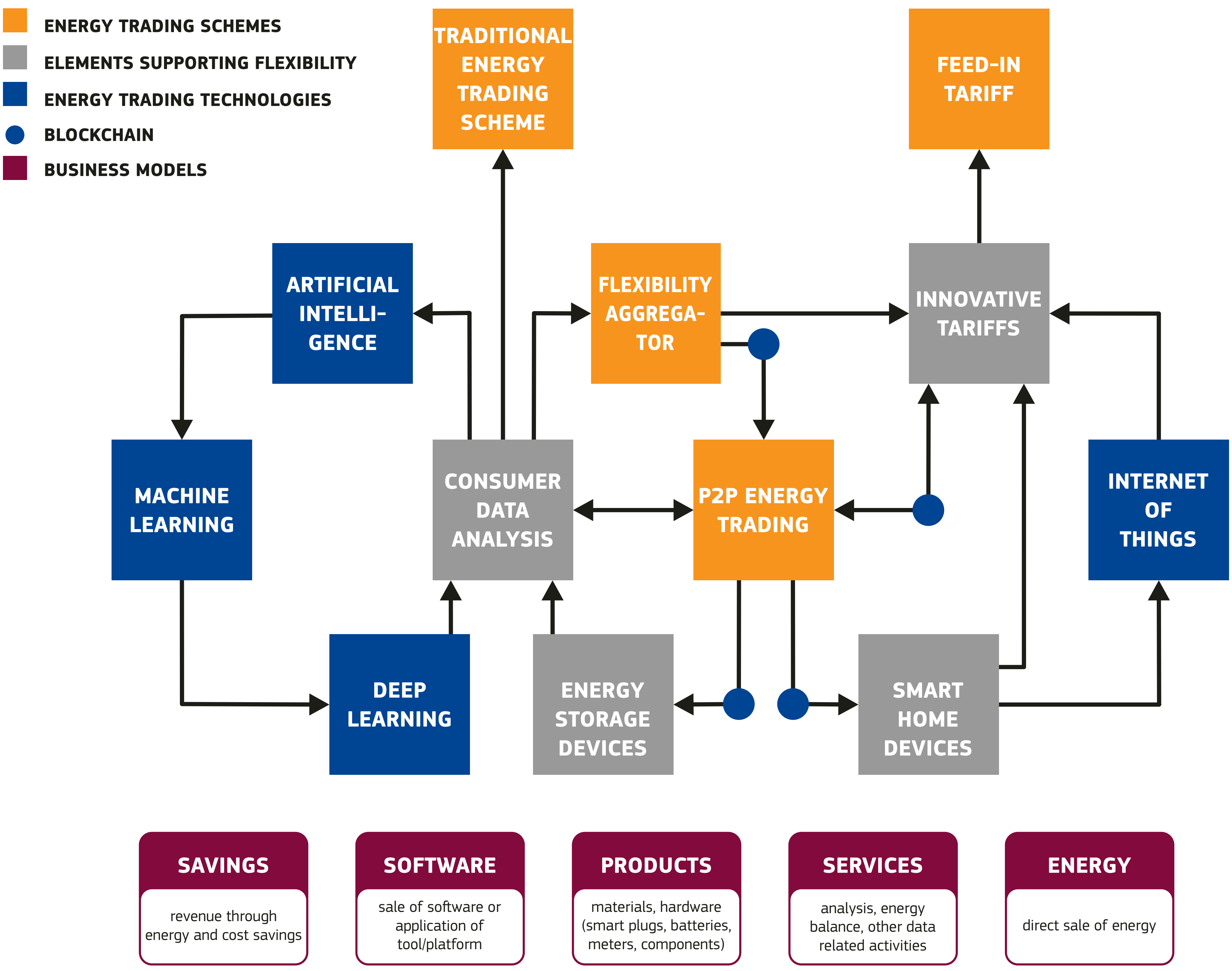
Flexible urban energy market ecosystem



Based on D. W. E. Allen, 2020

ENERGY TRADING SCHEMES

Traditional energy trading scheme
Bilateral contracts
Hour (or day) ahead markets
Ancillary services markets
Capacity markets

Feed-in-Tariffs (FITs)
paid for electricity generated from renewable sources fed back into the electricity grid. It removes the need for the prosumer to actively 'trade' their electricity because they are offered a fixed price for it which does not vary in time or with network conditions.

Flexibility aggregator
Offers flexibility to balance energy markets or to a grid operator, and meanwhile stimulate investment, innovation and improve customer choices. When the flexibility is activated, the aggregator receives revenue from the provided flexibility service. The aggregator redistributes some of the revenue in the form of a premium to the flexible prosumers.

Peer-to-Peer (P2P) trading
Producers can also be consumers and the energy produced by one prosumer (function as both producer and consumer) can be shared with another prosumer. Some P2P energy markets are designed with **blockchain** where all transactions will be validated by every node of the network and stored permanently without the involvement of a central authority. Smart **energy contracts** are available through the integration of blockchain with energy trading.

P2P energy trading can bring additional flexibility to the system in the energy market by:

- Innovative tariffs
- Smart home devices
- Energy storage technologies
- Consumer data collection and forecasting using machine learning
- Connection with flexibility aggregator

TECHNOLOGIES FOR BUSINESS MODELS

	USES	ENABLERS	BARRIERS
Intelligence AI, Machine learning deep learning	• Carbon management • Energy efficiency • EVs management • Grids services • Platforms & P2P • Smart metering	• Large amount of available data and algorithm • Complexity in energy system • Optimising resource utilisation	• Existing market mechanism • Depend on data resource • Lack of previous experience
Blockchain Distributed ledger	• Carbon management • Energy efficiency • EVs management • Grids services • Platforms & P2P • Smart metering	• Tedious trading process • Need in increasing trading efficiency • Trading from a centralized to decentralised one • Reducing financial burdens • Engage market participants • Build trust among prosumers	• Slow transaction due to proof of concept • Lack of regulations • Energy-intensive computation • Lack of previous experience • Conflicts of interest of established trading schemes • Challenge in local energy market
IoT Integrate smart appliances for energy services	• Energy efficiency • EVs management • Grids services • Platforms & P2P	• Engage market participants • Demand response • Improving grid service • Collection of data	• Relying on sensors • Limited by data interpretation • Lack of guidance for use engagement

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Recommendations for 2025, 2030 and 2040

TARGET LEVELS
- EU level
- National level
- City level

2025

DATA
- Develop the legal and strategic framework for data storage, usage access, sharing and security.
- Strengthen support from public authorities.
- Promote data-sharing tools and platforms across different stages for cities.

COORDINATION
- Develop communities of practice.
- Set up a core unit in local government to oversee the overall development to identify potential synergy and facilitate coordination.
- Engage local stakeholders in digitalisation of urban energy systems, through various ways, such as workshops, popular science, exhibitions etc.

CAPACITY
- Extend opportunities for knowledge exchange through existing initiatives, such as IEA, Cost Actions, JPI Urban Europe, etc..
- Increase investment from public sector in capacity building.
- Increase level of energy literacy & consciousness among citizens.

FINANCING
- Enable participation of P-P sectors and citizens in interventions with clear financial benefits.
- Stimulate P-P partnerships, mainly in investment on RE systems.
- Enhance the awareness among citizens of possible financing/ subsidy mechanisms.
- Reduce burdens by regulating the opportunities for P2P energy trading.

DIGITALISATION
- Strengthen the application of cyber security frameworks and guidelines.
- Digitalize the energy system infrastructure in different sectors, promote the development of digital twin.
- Promote wide application of urban energy system modeling.
- Ensure transparency to citizens about the values from sharing data.

2030

DATA
- Accelerate data communication by improving data transmission infrastructure.
- Strengthen transparency in use of data.
- Ensure the achievement of open application programming interfaces (API).
- Promote requirements for improving interoperability.

COORDINATION
- Create cross-cutting networks for co-creation.
- Build up special purpose vehicle.

CAPACITY
- Develop new initiatives to attract capacity and skills.
- Develop training and upscaling programmes.

FINANCING
- Encourage development of new business models.
- Introduce training to develop bankable projects.
- Clear financial guidance for prioritization of interventions and optimized use of resources.
- Ensure fair contracting to public / private companies.

DIGITALISATION
- Promotion of green IoT design, eco-labelling.
- Strengthen digitalisation on the energy service and promote the development of second layer of digital twin.
- Build low-threshold solutions and develop step-by-step digitalisation guidelines for different stakeholders.

2040

DATA
- Optimize urban energy system using large sets of data, and strengthen 3rd layer of digital twin for cities' operation and management.

COORDINATION
- Develop coordination framework across city levels and departments.
- Encourage trustworthy / neutral actor to coordinate.

CAPACITY
- Extend training and upscaling programmes in different levels of education system.
- "Enlightened" municipalities to take the lead and update HR/training systems.

FINANCING
- Redirect funding and develop dedicated financing vehicles.
- De-risk investments or reduce cash flow needs for faster transformation.
- Support the development of new instrument, such as green bonds.

DIGITALISATION
- Build capacity anddevelop inclusive policies.
- Ensure just, fair transition and profit sharing.
- Digitalise UES as a whole.
- Align with EU standards and roadmaps on digitalisation, push vendor-independent solutions for easier integration, scale up.

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