Sub-task descriptions

Sub-task 1. The power system integration layer

Start	Month 1
End	Month 36
Activity	Evaluate the benefits for the grid of P2P/CSC/TE energy markets. Evaluate the key enablements and constraints arising from existing and likely future power system architectures and technologies.

Proper power system integration is a necessary condition for the success of any new market model. P2P/CSC/TE models provide a range of services to the power system from grid edge balancing to incentivising uptake of Distributed Energy Resources (DERs). Any model that creates more power system problems than it solves is unlikely to be accepted. Understanding the value to the power system is important for finding out both the financial and social value of such models.

Particular challenges arise in understanding the characteristic timescales related to the various forms of grid constraints that peer-to-peer, community self-consumption and transactive energy models can address. These timescales in turn determine the balancing and settlement period needed if the market structure is to provide grid benefits in alleviating these constraints.

Understanding the electro-mechanical grid components governing power flow is essential in designing market mechanisms that provide grid benefits.

This sub-task will assess the evidence on issues including for example:

- Understanding how different configurations of P2P/CSC/TE models create value or challenges for power systems.
- Understanding how the nature and mix of Distributed Energy Resources deployed including generation assets, storage, and controllable demand impacts on the design of local energy markets.
- Understanding the types of controllers and actuators deployed, from grid supply points, through primary and secondary substations, to end use technologies including energy management systems for buildings and vehicles.
- Assessing the power system priorities (local balancing services; decarbonisation of supply; security of supply; increasing system resilience; etc.).
- The treatment of imbalances in day ahead and market closure periods between the P2P/CSC/TE participants and the grid.
- Determining the power-system characteristic time periods of grid constraints – from transformer relaxation, to thermal line limits, to frequency limits and higher harmonic anomalies that may govern the grid benefits of P2P/CSC/TE models settling at different periods. How short does the settlement period need to be to align the transaction layer with the physics of the grid?

Sub-task 2. The hardware, software and data layer

Start	Month 1
End	Month 36
Activity	Evaluating the role of the hardware, software and data ontologies on the functioning of P2P/CSC/TE energy markets. Evaluate the key enablements and constraints arising from existing and likely future ICT solutions.

The digitalisation of the power systems is a necessary condition for successful decentralisation and bidirectional energy flows at the grid edge. Current grid data systems from substation Remote Terminal Units to Supervisory Control and Data Acquisition (SCADA) systems, have not delivered the levels of information needed to understand bidirectional energy flows at the grid edge.

In addition, the data needed to provide market ready evidence of demand response behind the meter in the timescales and with the reliability needed to form the legal basis of contracts on short-term energy markets is frequently lacking in current grid environments. In many countries, deployment of smart-metering infrastructure is insufficiently advanced, and the meters lack the functionality, to support peer-to-peer, community self-consumption and transactive energy trading models.

Recent advances in new ICT technologies such as Internet of Things devices, distributed ledger technologies and the development of hardware crypto-anchors offer new opportunities, but these need careful assessing to understand the constraints they place on development of these new market structures.

This sub-task will assess the evidence on issues including for example:

- Do existing metering assets deployed in countries have the reliability and temporal resolution needed to support peer-to-peer, community self-consumption and transactive energy models.
- Does existing energy ICT support deployment of virtual metering and M&V (measurement and verification) solutions for Distributed Energy Resource authentication including demand reduction.
- How peer-to-peer, community self-consumption and transactive energy models ready are existing types of ICT grid asset hardware including sensors and actuators, dataloggers, and information processing equipment ICT (in addition to standard metering).
- Do the algorithms for controlling devices exist and are they interoperable across the necessary asset classes?
- Do current models used for providing forecasting and counterfactuals of short-term demand and quantification of demand response exist, and if so do they provide the accuracy needed for individual peer-to-peer, community self-consumption and transactive energy trading participants to control storage assets such as behind the meter batteries and vehicle to grid storage?

Sub-task 3. The transaction and markets layer

Start	Month 1
End	Month 36
Activity	Assess the architecture of the transaction layer for recording balancing and settlement of imports and exports. Evaluate the impacts of the design of P2P/CSC/TE energy markets on performance of the system.

Built on top of the ICT layer, the transaction layer allows for functioning markets for balancing and settlement at the grid edge. The design of this layer is central to how P2P/CSC/TE markets function and the social and economic benefits to participants.

Currently, few studies have been conducted on how the design of the market interacts with the physical flow of electromagnetic waves on the grid, and how the response to market signals actuates electromechanical devices control such power flow. The design of markets must take into account these spatial and temporal grid constraints if they are to deliver policy objectives of deferring substantial investment in grid infrastructure renewal.

Market design must also reflect policy priorities on incentivisation of other social goods such as incentivising uptake of renewable generation. Correct market design could provide an alternative to feed-in tariffs to promote uptake of distributed renewables. Market design therefore becomes a key instrument in determining which policy priorities are achieved and much acknowledge that alternative priorities may be conflicting.

An additional consideration is how market design should evolve as the number of participants, and the number of generation and automatable demand side response assets increases during the energy transition. It is likely that initial implementation of peer-to-peer, community self-consumption and transactive energy models will need to deal with small numbers of participants creating problems of illiquid markets. As participant numbers grow, market structure and functionality can change as markets clear more easily and become more efficient. This question of balancing and settlement in an evolving energy transition places particular challenges on transaction layer and market design.

This sub-task will assess the evidence on issues including for example:

- Assessing the architecture of the transaction layer for recording balancing and settlement of imports and exports, including use of distributed ledgers.
- The design of peer-to-peer, community self-consumption and transactive energy models energy markets.
- The implications for balancing and settlement of energy including of different settlement periods and how this alleviates different grid constraints.
- The design of illiquid markets with small numbers of participants and how these should evolve with increasing numbers of actors and assets.
- The design of algorithms for automated trading by participants and the interaction with the evolution of smart contracts on Distributed Ledger systems.

Sub-task 4. The economic and social value layer

Start	Month 1
End	Month 36
Activity	Evaluate the construction of consumer value propositions based on economic and social value. Evaluate how the ‘choice architecture’ of P2P/CSC/TE models impacts on participant engagement and outcomes.

Understanding consumer value(s), both economic and social, is essential to the design of P2P/CSC/TE markets. The design of such values has to be built into the choice architecture of the propositions offered to consumers and will ultimately have a big impact on the popularity and functioning of such markets.

Evidence from existing studies shows that consumers participate in peer-to-peer, community self-consumption and transactive energy trading for a range of reasons in addition to, or sometimes overriding, least cost energy options. Business models vary from efficient market platforms, through corporate social responsibility, to differential pricing for friends and family, to charitable given to support those in energy poverty.

This sub-task will assess the evidence on issues including for example:

- Evaluating the construction of consumer value propositions based on reducing energy price. This includes design of non-punitive market designs that ensure participants cannot be worse off than on a conventional tariff.
- Evaluating social value propositions including psychological values (e.g. autarky) and social (e.g. communitarian and interpersonal) values and their use in business model construction.
- Identifying ways to capture and represent the non-energy social value of P2P/CSC/TE models such as increasing social cohesion; participant desire for autonomy; reducing energy poverty; increasing social capital; etc. This includes identifying what socially valuable options should be designed into the choices presented to participants, e.g. donation of energy to energy poor neighbours, differential pricing for friends and families, options to support local social institutions such as schools, etc.
- Psychological models (the participants’ value proposition), including assessing how does the ‘choice architecture’ of P2P/CSC/TE models impact on participant engagement. This includes how the design of the user interface influences participation.
- Understanding how default settings in interfaces impact on the degree of participation including default settings of pro-economic, pro-social and pro-environmental default values.
- Assessing if social-psychological rewards should be engineered into the design of the system, e.g. social validation for energy trading, etc. This includes application of social norm and other behavioural economic influences.

Sub-task 5. The policy and regulatory layer

Start	Month 1
End	Month 36
Activity	Identify the impact of policy and regulation on the uptake of peer-to-peer and associated models. Identify the key characteristics of the regulatory environment that support or inhibit their implementation

Policy and regulation have been repeatedly identified as some of the limiting factors on the uptake of P2P/CSC/TE models. This work package aims to understand the impact of policy and regulation on the uptake of these models. It will seek to identify the key characteristics of the regulatory environment that support or inhibit their implementation.

This sub-task will assess the evidence on issues including for example:

- What are the key regulatory bodies and regulations that have an impact on the implementation of P2P/CSC/TE models?
- How are relevant areas of regulation structured and how interdependent are they?
- What are the policy objectives that P2P/CSC/TE models could address?
- What are the distributional impacts of implementing P2P/CSC/TE models?
- How are the capital costs of national infrastructure like electricity grids socialised?
- What is the current structure of taxes and charges for use of electricity networks and how does this impact on uptake of P2P/CSC/TE models? (e.g. a charge for use (e.g. kWh/km), a capacity charge (€/annum), or as a social good from general taxation?)

It will seek to address key regulatory questions across multiple sectors such as:

- Energy sector regulation
  - Which elements of regulation need reform? Do they sit with the regulator or the code bodies? Who has the authority to make changes? What are the governance processes for effecting change? Is (the right to) peer-to-peer energy trading and energy self-consumption recognised in energy law? Are prosumers and energy communities legally recognised?
- Data privacy regulation
  - What information about energy use and equipment can be shared publicly? How is pseudonymization treated in data privacy regulation? How technology agnostic is the legislation?
- Consumer regulations
  - How are prosumers treated in consumer law? What protections are given to purchases of energy in P2P schemes? What liabilities should they be exposed to?
- Contract law
  - How does existing contract law impact on use of smart contracts (in the case of blockchain) for energy trading?
- Land-use, planning and property ownership
  - What planning permission is needed to install generation and storage equipment? What is the structure of legal ownership of property and how does this impact on decisions to install equipment in common areas of multi-tenant property?

Sub-task 6: International Comparative Analysis and the Readiness Index (note: no need to actively join this sub-task, as all participants will be contributing to the data analysis)

Start	Month 13
End	Month 33
Activity	Lead on conducting the International Comparative Analysis using Qualitative Comparative Analysis Lead on constructing the Readiness Index

This task aims to synthesize findings from the case studies mentioned above in a methodologically defensible and useful way. The initial intention is to use Qualitative Comparative Analysis. QCA is a method designed to fill the gap between the contextual richness and depth of individual case studies, and the need for general lessons learnt which is traditionally the realm of quantitative survey methods. QCA typically draws general influential factors from the analysis of dozens of individual cases, and allows for wider lessons to be learnt regarding the comparative importance of common contextual factors found in different regulatory or social environments.

QCA has particular advantages in cross-country comparisons because of its ability to treat individual countries holistically as historically, culturally, politically unique entities with meaningful combinations of parts, instead of trying to make these countries fit single models. The researcher is urged not to specify a single causal model that fits the data best, as one usually does with statistical techniques, but instead to determine the number and character of the different causal models that exist among comparable cases.

QCA comes in three primary forms: crisp-set (csQCA); fuzzy-set (fsQCA); and multi-value (mvQCA). Of these, multi-value QCA works best with the number of cases (50-100) anticipated to be collected in this Task. It allows use of multi-state ordinal variables (e.g. high, medium & low) where these values represent the extent to which a single category is present in a given case, not whether a specific category of a condition is present. This provides it with an important advantage over both crisp set (csQCA) and fuzzy set QCA (fsQCA).

The output of the application of mvQCA will be an understanding of the relationships and interdependencies between the power-system, policy and regulatory, social and economic as well as environmental conditions supportive of the uptake of P2P/CSC/TE models in different countries.

Building on the findings from the application of QCA a peer-to-peer and related business models 'Readiness Index' will be constructed. The methods for this are covered in the Research Methods section above. The readiness index will be applied to each Task participating member country across each of the sub-task layers of the technology stack. The result will be a measure of number of changes needed for a country to have the sufficient conditions to implement peer-to-peer, community self-consumption and transactive energy models.

The final research design and analysis of cases will evaluate which combination of these methods provides the most useful evidence to policy makers.