



Recommendations from the CITIES project - Centre for IT-Intelligent Energy Systems

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The CITIES project is a large (budget 75 mill. DKK) strategic research project funded by Innovation Fund Denmark with a project runtime from 2014 to 2020. The research in CITIES focuses on digital methodologies and solutions for smart energy systems to facilitate the green transition to a fossil-free energy system.

39 Danish partners from academia and industry as well as 9 international partner institutions from the EU, Asia, Australia and the USA have investigated all aspects of the energy system and their interactions, including gas, power, district heating/cooling and biomass. The partners developed methods to forecast, control and optimize the integration through the use of advanced IT solutions and suggested new framework conditions and policy measures.

Based on the extensive research conducted, the CITIES partners have the following recommendations in order to achieve the green transition of the energy system.

Energy system operation

→ **Digitalization and data-driven operation of integrated energy systems are key to the green transition.**

Digitalization and data-driven solutions should be prioritized at all aggregation levels of the energy system in order to ensure an efficient and secure operation of the future weather driven low-carbon energy system. Data-driven solutions are needed for providing an efficient integration of the energy systems (power, heat, gas) as well as for the interaction with the water and food sectors.

→ **Spatial-temporal thinking and coherency is important.**

It is important to adopt a spatial-temporal systems-of-systems framework when considering solutions for the future weather-driven energy system. In CITIES, we suggested the Smart-Energy Operating-System (SE-OS) for providing this. The coherence of forecasts, aggregation, models, etc., between all spatial-temporal scales is crucial.

→ **We must prioritize digital and automatic solutions.**

We have demonstrated a large number of opportunities to unlock flexibility and hence to reduce CO₂ drastically by using digital and automatic solutions. Therefore, digitalization can accelerate the green transition through implementation of green digital solutions.

→ **System solutions for sector coupling and Power2X (incl. Power2Heat) should be focused and barriers for those solutions must be eliminated.**

Research results clearly show that the integration of different energy sectors facilitates the flexibility in the energy system, which is crucial for the integration of intermittent renewable energy production from e.g. wind and solar. One example is that excess wind power can be stored as heat in DH systems.

→ **We must consider using virtual storage solutions.**

Integrated and digital operation can lead to (virtual) storage solutions on all relevant time scales from minutes, days to seasons. We can store energy in the thermal mass of buildings, or switch between biogas and power in a dual heat pump in order to use existing gas storages to 'save' green power. Often such virtual storage solutions can be operated without energy losses.

→ **National initiatives for digital and cross-sectorial solutions should be supported and expanded.**

It is essential that cross-sectorial solutions are tested in labs, in living labs and in the field and results are consolidated across projects. It is important that tests are *representative* and *scalable*. Therefore, organizations such as *Uni-Lab.dk*, the national umbrella organisation for Living Labs and Test Labs in Denmark, and *Center Denmark*, the European and National hub for smart and integrated energy systems, should be consolidated and developed further.

Energy system planning

→ **Energy systems planning must be coherent across scales.**

It is important that, e.g., city planning models are linked with regional planning models and Coherency is ensured between the different levels. Short-term flexibility must be properly described in long-term planning models.

→ **Investment models should be developed.**

It would be beneficial to establish new investment models that can facilitate local investments in solutions that can unlock local flexibility, e.g., optimizing local consumption of renewable energy productions. One possibility is the use of auction based methods.

→ **Cities and municipalities should play a major role**

It is important to include cities and municipalities in long-term energy planning to make sure that the municipal initiatives and national plans benefit from each other and do not hinder each other. Furthermore, the local stakeholders are often efficient drivers for the green transition.

→ **Transparency and democracy should be prioritized**

The initiatives taken in long-term planning must be transparent and decisions should be made democratically to ensure the acceptance of the decisions and the best outcome for the society.

→ **Models and methods for planning must be critically assessed. Are sector coupling and flexibility integrated and modelled properly in long-term planning models?**

Energy planning models should incorporate sector coupling between different energy sectors and the flexibility that can be unlocked by sector coupling and digitalization in the energy system. This is crucial to capture the synergy effects and derive results and analyses that show and use the full potential.

Smart Buildings

→ **Designed solutions must respect consumer preferences, e.g., in relation to automatic self-acting solutions.**

To foster the acceptance by consumers, it is essential that consumer preferences are modeled and respected by solutions in smart buildings, in particular, because most users prefer automatic solutions.

→ **Smart controllers should offer users to select preferences regarding energy efficiency, CO₂ efficiency and cost efficiency.**

When designing control solutions the user should be able to provide their preferences, which should take into account the trade-off between energy savings and flexibility, automation and user control, etc.

→ **The design of ICT (information and communications technology) solutions must be robust.**

When designing ICT solutions, there should be a focus on reliability and robustness towards disruptions. For example, the broadcasting of price signals as one-way communication is less prone to disrupted communication than a two-way communication setup.

→ **Buildings should be prepared for energy flexible operation.**

By using thermal mass and other storage possibilities in buildings, time shifts between demand and supply are possible. This adds flexibility to the energy consumption of the building but also the overall energy system, which enables a larger share of renewable energy and avoids unnecessary peaks.

→ **A data-driven alternative to the Smart Readiness Indicator for describing the flexibility must be considered.**

The Smart Readiness Indicator is based on deductive reasoning, and this method does not lead to the actual flexibility. We need a data-driven alternative for a description of flexibility. Furthermore, such an evidence based data-driven approach should be able to automatically calibrate to changes of a building.

→ **Data-driven approaches to energy labelling and energy performance characterization (energy signature) must be adapted**

The energy performance is traditionally given based on deductive methods. This approach is not optimal since deductively provided information about the building, quality of insulation, workman shop, etc. are typically not reflecting reality. Consequently, we need data-driven approaches for energy labelling. The approaches must include self-calibration features such that changes of a building are automatically taken into account. Similarly, we need data-driven methods for providing a more detailed fingerprint or dynamic energy signature of buildings.

→ **Smart buildings shall preferably adopt forecasting.**

In combination with flexible operation, the use of forecasts such as weather or day-ahead demand forecasts allows to optimize the supply of green energy to a building. Instead of following the demand instantaneously as it is traditionally the case, the energy supply can be planned ahead to maximize the use of green energy.

Markets

→ **Coordination of energy markets (heat, gas and electricity) should be further rethought, so they harness flexibility and reward those providing it.**

It is important that also the interplay of the energy markets facilitate sector coupling and flexibility in order to exploit the benefits and synergy effects of an integrated energy system. The market should be set up in a way that actors providing flexibility to the system are rewarded.

→ **Market designs should be thought of in a more flexible manner to allow for a wealth of alternative business models.**

To increase the share of green energy and flexibility, alternative business models such as involving *aggregators* and *energy communities* should be considered. Aggregators consolidate decentralized energy consumers or producers to act on the market on behalf of them including trading the consumers flexibility. Energy communities organize local (often renewable) energy production and consumption to the environmental, economic or social advantage of their members.

→ **Future markets should readily accommodate the uncertainty and variability of renewable energy generation, storage, flexibility and decentralization - this requires new advances in the theory of markets.**

The current energy markets are designed for an energy system where the energy production is scheduled according to the energy demand. This concept must be questioned since with increasing share of intermittent renewable energy production, uncertainty, variability and decentralization is added to the production side. New market concepts have to consider this aspect to improve the overall energy system performance.

→ **New methods for describing the flexibility can be implemented in control solutions as an operational alternative to low level markets.**

We have developed methods for describing the flexibility of e.g. a building or a wastewater treatment plant. These methods can be used to generate price-based control signals for controlling e.g. the peak consumption in DSO areas.

→ **The role of technical aggregators in energy markets should be considered and investigated.**

It has been concluded that the optimal flexibility can be achieved if the aggregators are experts within their field of operation, and for instance it might be advantageous to have experts in wastewater treatment to act as a special aggregator for flexibility related to wastewater treatment.

Policy

→ **We need to use strategic energy planning to aim for emission goals.**

The objective of strategic energy planning is often linked to technical solutions like a certain share of biomass or a number of electric vehicles to reach. Instead the objective should be defined in terms of emission goals, since this allows more flexibility in finding solutions and strategies. Emission calculations have to be standardized. And in order to avoid carbon leakages we need to ensure that the emission calculations are on the same cobber plate (e.g. within the price-zone DK1).

→ **Emission calculations should be linked to the hour and be standardized.**

We need to ensure that emissions are accounted for within the hour and the declaration has to be well defined in relation to Granulated Guarantees of Origin (GGOs), self production, etc. We must avoid carbon leakage between price areas (copper plates).

→ **We must remove barriers for sector coupling and use of waste heat.**

We must ensure that the energy taxes are homogenous and hence that excess heat from some processes can be used, e.g., in district heating, without hitting any barriers.

→ **New dynamic tariff structures should be tested and established.**

New dynamic tariff structures should be developed, tested and established. We need tariffs that are linked to the physics of the system, i.e., the actual load compared to the capacity (kW-related) and to the transport loss (kWh-related). We have suggestions for the design of new tariffs and how the tariffs should be finally tested in test zones (see <https://smart-cities-centre.org/material/> , "Task Force").

→ **New CO₂-related energy taxes need to be established now.**

We need homogenous CO₂-related green taxes as soon as possible to reduce CO₂ emissions. The challenges for the process industry that are connected to this can be converted to "help to self help" by paying into a fund that can finance green initiatives for the industry in collaboration with universities.

→ **Tests of regulatory conditions and solutions should be representative for and scalable to the entire Danish society.**

When new framework conditions and solutions are tested, they should be tested in environments that allow us to make conclusions for the entire Danish society. This could be for example, in defined *test zones* or *living labs* with a representative cross section of the Danish society and building stock. We have suggestions for setups for both thematic and geographical test zones (see <https://smart-cities-centre.org/material/> under "Task Force").

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