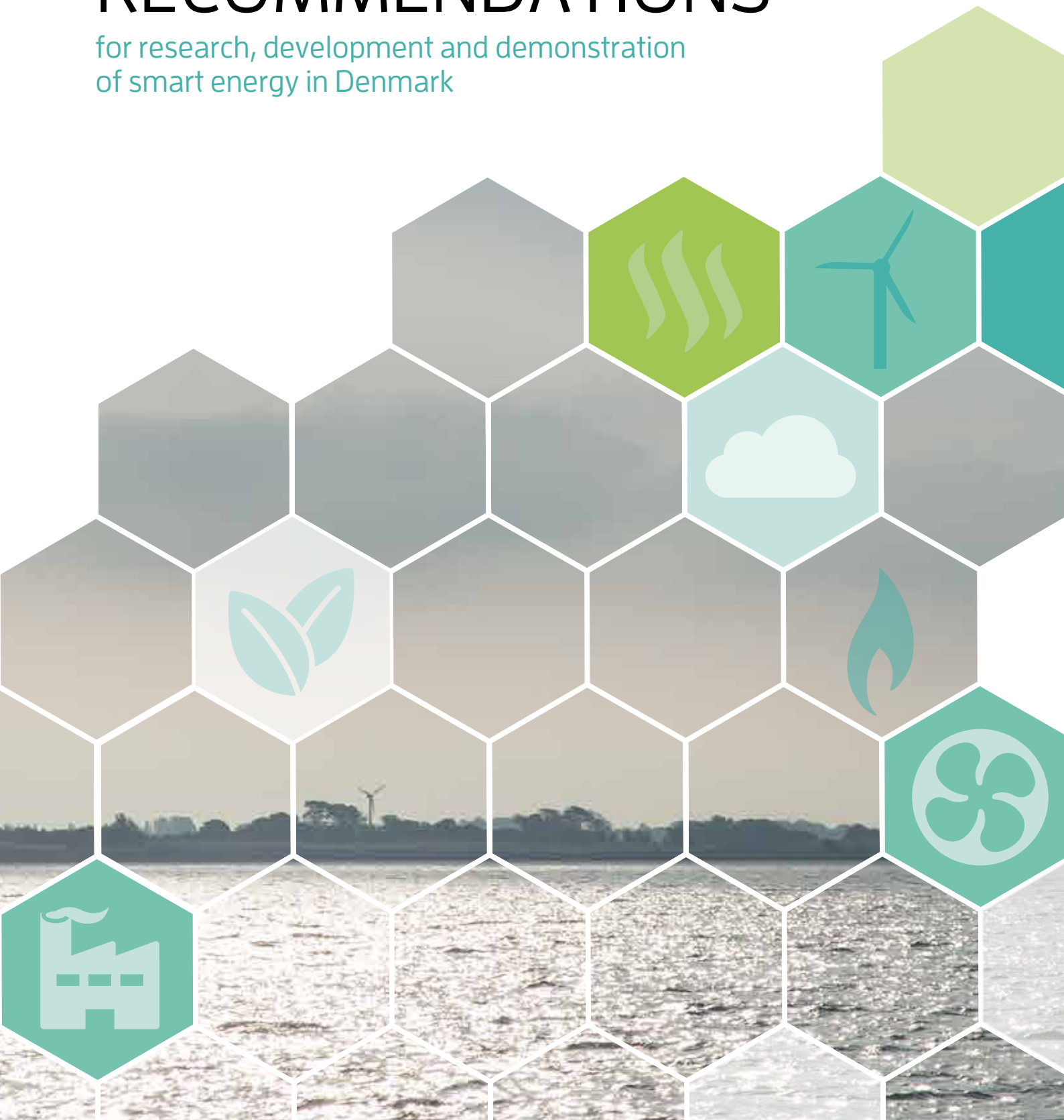
Smart Energy Networks

# STRATEGY & RECOMMENDATIONS

## for research, development and demonstration of smart energy in Denmark



# Definitions

2050 TARGETS
The assumed targets are high security of supply, sustainable solutions and independence from fossil fuels in Denmark by 2050.

STABLE AND ROBUST SYSTEM
The operation of the energy system must be stable at any foreseeable situation and robust to unforeseen situations and development over time (technologies, prices, conditions).

ENERGY SECTORS
Includes supply of electricity, heat, gas and demand in buildings, industry, transport.

INTEGRATION
The integration of the energy system includes I) energy conversion between sectors; 2) multiple energy sources for a given energy service; and 3) integration of markets.

SMART ENERGY
Smart energy contributes to a cost efficient, sustainable and secure energy system, integrating and coordinating the renewable energy generation, the infrastructures and the demand through energy services, active actors and new technologies.

SYSTEM SERVICES
System services are services provided to the system, supporting the stable and robust operation of the system (ancillary services).

ENERGY FLEXIBILITY
Energy flexibility can be provided in either time, space or form, i.e. timeshift of energy flow, shift of energy flow in space, or converting the energy from one form to another.

SOLAR & WIND
The marginal operation cost are negligible for both solar and wind generation.

ENERGY SERVICES
The services requested by the customers. E.g. not heat / cooling, but comfort.

R/D/D
The required main effort is indicated for each recommendation – research (R) / development (D) / demonstration (D).



# RECOMMENDATIONS

If Denmark is to be independent of fossil fuels by 2050, we are facing three main challenges:

- The main energy sources must be wind and solar
- To balance energy production and consumption
- Sustainable solutions for the transportation sector

The decisions we make today in the field of energy are crucial for the opportunities and solutions in the coming decades. This applies mainly to the large, long-term investments in urban planning, buildings and infrastructures, but also to the basic design of the energy system.

Various analyses suggest likely developments of the energy system. Specifically, the critical energy solutions and technologies required to obtain a stable, sustainable, robust and fossil-free energy, system, and when these should be implemented in order to reach the 2050 targets. The time-line (in the middle of the present leaflet) presents crucial targets and decisions on the road to 2050. Common for the suggestions is that more knowledge and further development are required to take qualified decisions. This takes time, and therefore we have to act now!

SHORT TERM
We expect that Denmark will remain energy self-sufficient, but Denmark will also, to a large extent, trade energy with its neighbouring countries. The part of the biomass expected to be used for energy purposes must be prioritized for the transport sector.

The fluctuating energy generation from the solar and wind requires extended flexibility in the energy system. We expect that integration and smart control of the energy system will contribute significantly to the necessary energy flexibility.


We have formulated I5 recommendations for research, development and demonstration (RD&D) of smart energy solutions, which can contribute to the necessary decisions being taken in due time and on a qualified basis.

The recommendations focus on smart energy, especially in terms of the necessary collaboration between sectors, solutions and services. They relate to the Danish energy system. However, we hope that they will inspire an international audience to contribute or to adopt some of them. The recommendations in this leaflet are very concise and are further elaborated on in a background report.

Typically, the implementation of new solutions takes decades, thus the recommended initiatives must be initiated immediately. The weight between research, development and demonstration should depend on their individual stage.

FIVE THEMES
The I5 recommended initiatives are grouped in five general themes:

**Low-hanging fruits**
- Commercial technologies in new roles

**Integration is the key**
- Improved integration of the energy sector

**Varying needs for energy balancing**
- The right consumption at the right time

**Smart methods**
-Planning and operation of smart energy systems

**Smart markets**
-Markets and business models for smart energy

*Low hanging fruits*

# I. Commercial technologies in new roles

Well-known commercial technologies can further be developed with new and extended system and control capabilities, and thereby contribute to the system operation – in addition to their primary functions

**System capabilities**

## #01

**Extended system capabilities to already commercial technologies**

There is a need for developing and demonstrating extended system capabilities, supplementing the primary functions for well-known and commercial technologies.

D D

*For thermal service solutions, their energy exchange with the system can be shifted in time with negligible impact on their primary functions, e.g. heating of hot domestic water.*

**System communication**

## #02

**Communication of system functions for already commercial technologies**

There is a need for solid and cost effective standards, technologies and solutions for communication of system functions between components and the system, as well as for the verification of the provided system services.

D D

*There are many different types of system services, many ways of activating these services, and contribution from many small suppliers. E.g. energy flexibility as a system service can be provided in terms of either immediate power or energy over a given period of time, where both capacities and needs are dynamic.*


**Business models**

## #03

**Business models for supply of system services**

Practical methods for verification and settlement, as well as profitable business models for supply of system services (ancillary services). should be developed. This includes services supplied from many small providers

D D

*To create a better business case, the communication between the energy system and the energy component at the customer premises may be combined with other local monitoring and control functions.*



*Integration is the key*

# 2. Improved integration of the energy sector

There is a need for new components, plants, data exchange and test facilities supporting an improved integration of both the energy system and the energy sectors.


**Energy conversion**

## #04

**Efficient and flexible energy conversion and storage technologies**

There is a need for the development of energy storage and conversion components and plants that are energy and cost efficient, even under dynamic operation in both time and output level.

D D

*Conversion units typically have their highest efficiency at steady and high load, and require many hours in service to be profitable. It is a challenge to obtain high efficiency and a good business case at reduced and dynamic operation of an energy conversion plant.*

**Access to data**

## #05

**Access to data across sectors and actors**

Fast, secure and reliable access to data from all parts of the energy system as well as access to methods for extracting relevant information from large amounts of data are crucial for a smart and optimised operation.

D D

*Access to data is an increasing competitive factor. It is a challenge to make sufficient data accessible in real time for all actors.*

**Energy laboratory**

## #06

**Large scale energy laboratory for smart and integrated energy solutions**

There is a need for a large scale laboratory for testing, development and demonstration of smart and integrated solutions where all concepts, components, conversions, networks, control and business models are tested in joint operation under realistic and complex conditions.

R D D

*With increased integration of the energy system, sectors and markets, the operation becomes extremely complex. The operation of any component will affect the rest of the system and vice versa. Testing the solutions in joint operation and under realistic conditions is crucial.*

*Projection/Forecast*

*Political agreement*

*Necessary actions*

**2016**

**2017**
Large flexible heat pumps (5 MWe) combine district cooling and heating.
*Køleplan Danmark 2016*
*Dansk Fjernvarme, 2015*

**2018**
A gradual implementation of taxes on biomass is necessary and has been acknowledged.
*Brian Vad Mathiesen, AAU*

**2019**
Decentralised combined heat & power plants, based on natural gas, is no longer subsidised.
*Energiforliget, Folketinget, 2012*

**2020**
There is a need to rethink the energy companies energy saving efforts. It's not always rational to save energy.
*Giv energien videre, Dansk Energi, 2016*

**2020**
50 pct. of electricity should come from windpower
*Government, 2012*

**2025**

**2025**
10 years of experience in operation of 40 MWh heat pumps in the district heating are collected from Stockholm.
*Hammarbyverket, Fortum, 2016*

**2025**
Copenhagen becomes first CO2 neutral capital.
*KBH 2025, Københavns Kommune, 2012*

**2030**

**2030**
Heat stored in stones at high temperature (>600 C) is used for long term electricity storage at 50% energy efficiency.
*Allan Schrøder Pedersen (DTU)*

**2030**
30 pct. of district heating comes from large heat pumps and water boilers.
*Anders Dyrelund, Rambøll*

**2030**
75 pct. of district heating is produced from sustainable energy – 10 pct. from solar collectors.
*Energiforsyning 2030, Grøn Energi 2016*

**2030**
One million cars should run on either electricity or hydrogen to reach the EU target.
*Afgifter der forandrer, Klimarådet, 2016*

**2035**

**2035**
3 GW solar power and 4 GW wind power has been installed in Denmark
*IDA's energivision 2050, IDA, 2015*

**2035**
10% of the Danish gas consumption is based on electrolyses and 40% on biomass.
*Energikoncept 2030, Energinet 2015*

**2035**
Large heat pumps with a capacity of 700 MWe are installed in the district heating network.
*IDAs Energivision 2050, IDA*

**2040**

**2040**
Globally 100-300 EJ bio mass is used for energy purposes. Today the global energy consumption in the transportation sector is 100 EJ.
*IPCC - The International Panel on Climate Change*

**2045**

**2045**
Denmark is net importer of natural gas from 2035 and the North Sea is exhausted in 2045-2050.
*Ressourcer og prognoser, Energistvrelsen, 2016*

**2050**

**2050**
The consumption of gas in Denmark is expected to be 75 PJ/year, split equally between bio mass and electrolyzes.
*Energikoncept 2030, Energinet, 2015*

**2050**
Denmark is independent from fossil fuels.
*Folketinget*

# THE ROAD TO 2050

## Decisive choices and necessary development

In 2050 Denmark must be independent of fossil fuels. There is no simple and easy path to reach that goal. There is a variety of approaches that reach the 2050 targets.

Development and implementation of new solutions takes time and that is why it is crucial that we start immediately. A large part of the knowledge and technology that will help us reach the 2050 goal already exist. However, choices must be made. Partial solutions must be developed in time to help us in the green transition and the solutions that we choose must be implemented in large scale in time to make a contribution.

In this Partnership we have made a selection of qualified estimations in terms of both what will happen and what should happen. These predictions and necessary milestones along with political agreements can be seen in above timeline.

ROADMAP >>> 2050

*Varying needs for energy balancing*

# 3. The right consumption at the right time

Mobilising energy flexibility in all steps can contribute to balance consumption and production at any time, any place and for all sectors.

ENERGY FLEXIBLE SOLUTIONS

## #07

**Energy flexibility solutions throughout all sectors**

Cost efficient energy flexibility must be developed in all areas, as well as methods for estimating, aggregating and settling energy flexibility services.

CONSUMER BEHAVIOUR

## #08

**Implementation of energy flexibility**

To develop energy flexible solutions which also works in practice, it is necessary to understand the non-technical factors, such as customer reasoning and behaviour.

DISTRIBUTED PRODUCTION

## #09

**Suitable system solutions for local energy production**

New energy system solutions should be future proofed to make sure they are both suitable and efficient in a substantial distributed energy production.

D D

*If the energy flexibility from many smaller sources should contribute significantly to the system operation, energy flexibility should be incorporated in all parts of the energy system and energy services – including buildings, industry and transportation.*

R R D

*Consumer behaviour is decisive for the realisation of energy flexibility. Many solutions require that the customers, to some extent, are part of the solution.*

R D D

*Energy customers are expected to be both consumers and producers (prosumers) in the future. This provides both new opportunities and challenges in terms of design and operation of the energy system.*

*Smart methods*

# 4. Planning and operation of smart energy systems

The increased integration and complexity of the energy system requires new advanced methods and tools to optimise investments, planning and operation.

SOCIETY LEVEL

## #10

**Optimised investments in energy infrastructures**

In line with an increased integration of the energy system new methods are needed for optimisation in terms of investments and operation of the different energy infrastructures at a society level.

OPERATIONAL PLANNING

## #11

**Methods for operational planning of integrated energy systems**

The increased complexity of the energy system leads to the need for new and supplementary methods and tools for optimised operational planning.

FLUCTUATING PRODUCTION

## #12

**Reliable and cost efficient operation of an energy system with fluctuating production**

New methods and solutions are necessary to secure a steady operation of the integrated energy system in line with an energy production that is increasingly based on fluctuating sources.

R D D

*Conversion between – and integration of – the different energy sectors at all levels affect the distribution of the loads among the energy networks in both time and space. Investments and operation of the grids must be coordinated and optimised.*

R D D

*The increased integration and flexibility of the energy system provides additional options, but results also in a more unpredictable operation of the system. This challenges the operational planning for the sectors and the operators.*

R D D

*More actors and active units are expected. All active units and actors must contribute in a coordinated way to the operation of the overall system. System services must be made available and contribute to a steady operation.*

RECOMMENDATION

# 5. Markets and business models for smart energy

New markets and business models must be developed, supporting and exploiting the new opportunities.

**Market design**

## #13

**Redesign of a future market-based energy system**

It is necessary to redesign the energy markets to make sure they support the development of new technologies and business models.

**Solar and wind**

## #14

**Effective market design for a large share of solar and wind**

Effective markets are vital in an energy system based on a fluctuating energy production with low marginal costs (solar and wind).

**New collaborations**

## #15

**Collaborations and roles to encourage smart solutions**

New collaborations and roles must be developed and tested to encourage development of smart energy solutions.

R D D

*Energy markets are by nature designed to 'yesterday's' technologies and business models. The appropriate energy markets are a premise for developing and implementing the new technologies, solutions and business models.*

R

*The existing market design is not effective at high shares of solar and wind, both characterised by low marginal costs of production. If these units are controlled by market price, all production is stopped simultaneously when the price hits zero.*

R R D

*Going forward, we expect customers to buy energy services rather than energy which will require new actors, new products, new business models and new conditions.*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## METHOD

The recommendations are selected and reasoned by a working group through out a total of six workshops from September 2015 until September 2016. Editorial processing, prioritizing and formulation of the recommendations have been completed by an editorial group and the secretariat of the Partnership.

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Smart Energy Networks

Research, Development and Demonstration

## Partnership for Smart Energy Networks

Smart Energy Networks is Denmark's national public private partnership for Smart Energy with emphasis on the interplay between the electricity system, the gas system, the heating/cooling systems, the energy users and part of the transport system. It acts as catalyst and initiator of a strengthened strategic research, development and demonstration agenda for a smart and integrated energy system that will support initiatives to meet the energy policy goals as well as the creation of attractive and sustainable growth conditions for Danish export and industries.

Smart Energy Networks will initiate analyses and roadmaps to prioritize and specify needs for future RD&D activities in for the short, midterm and long run in order to meet the Danish Energy targets and develop the future Smart Energy system. This work will involve and be made with contributions from relevant stakeholders.

Today the Partnership Smart Energy Networks consists of representatives from industry, universities and knowledge institutions. The partnership is supported by EUDP – Energy Technology Development and Demonstration Program.

EUDP

Energiteknologisk udvikling og demonstration