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Grant Agreement No: 680447

Project acronym: MODER

Project title: Mobilization of innovative design tools for refurbishing of buildings at district level

Funding scheme: Innovation Action

Starting date of project: 1st September 2015

Duration: 36 months

D2.3 – New solutions for technology packages at district level

Due date of deliverable: 31.12.2016
Actual submission date: 13.3.2017
Revised document submission date: 21.6.2017

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 680447

WP 2 **Leader: ZRMK**
Task 2.3 **Leader: ZRMK**

Dissemination Level		
PU/CO	Public / Confidential, only for members of the consortium (including the Commission Services)	PU – The content of the deliverable will be published as a conference paper or journal article

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 680447

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Version	Description	Lead author	Date
0.1	draft	ZRMK	29.12.2016
0.2	Draft final	ZRMK + all	1.3.2017
0.3	Final	ZRMK + all	13.3.2017
0.4	Update	ZRMK + all	18.4.2017
1.0	Revised version	ZRMK + all	15.6.2017

Acknowledgements

The work presented in this document has been conducted in the context of Horizon 2020 programme of the European community project MODER (n° 680447). MODER is a 36-month project that started in September 2015 and is funded by the European Commission as well as by the industrial and research partners. Their support is gratefully appreciated.

The partners in the project are:

- Sweco Finland Ltd. (Finland)
- VTT Technical Research Centre of Finland Ltd.(Finland)
- Fraunhofer Gesellschaft zur Forderung der Angewandten Forschung EV - Fraunhofer Institute for Building Physics IBP (Germany)
- Siemens AG (Germany)
- REM PRO SIA (Latvia)
- Stichtung W/E Adviseurs Duurzaam Bouwen - W/E Consultants Sustainable Building (The Netherlands)
- Ertex Solartechnik GmbH (Austria)
- Gradbeni Institut, ZRMK DOO – GI ZRMK (Slovenia)
- Finnenergia Oy (Finland)
- Lokalna Energetska Agencija Gorenjske Javni Zavod – LEAG (Slovenia)

1 Introduction

1.1 Publishable summary

For energy efficient refurbishment at district level, four aspects have to be observed.

- The local district energy systems due to their size operate with higher efficiencies than systems per building.
- For distribution of energy at district level an efficient infrastructure must be present.
- Technologies for distributed RES on building level needs smart balancing with district networks to overcome seasonal imbalances.
- To attract users a legal framework (power tariff system etc.), rising awareness and new business models have to be developed.

To meet occupant needs and reduce primary energy consumption, energy efficiency technologies can be used in residential, public and commercial buildings for both new construction and retrofits. Goal of project MODER is to encourage district refurbishments, and to reach nZEB standards. In order to reach this goal, we have to include measures that have to be done on individual buildings (insulation, ventilation, shading systems…), and measures that can be done on a district level (heating, cooling, energy production, optimization of energy storage and usage).

There are many different systems and technologies that need to be used in refurbishment of individual buildings and whole districts in order to reach nZEB goal. Before we even start with the refurbishment we must know end user, grid operator and energy provider's requirements that need to be fulfilled. Those requirements can vary according to country or municipality legislation.

This document is based on:

- A study of new requirements for technology packages on district level,
- expanding technologies for nZEB refurbishment from a building level on the district level,
- identifying end users, grid operators and energy sources requirements across Central and Northern Europe countries with a goal of minimization of non-renewable energy consumption,
- the analysis of availability and suitability of technologies for district refurbishment; like electricity and biogas generation technologies, storage solutions, smart metering and smart grids.

Initially, in D2.1 up-to-date information on the requirements for buildings and districts was collected from stakeholders and summarized in conclusions of requirements for technology packages at district and building level for nearly-zero-energy building refurbishment. In D2.2 the availability of technologies was studied, its suitability in different conditions was presented, combinations, advantages and problems of technologies were investigated.

This deliverable D2.3 presents new solutions for technology packages at district level, that were built on the identified requirements for technology packages at a district level and on the list of technologies. Setting of nZEB targets in buildings refurbishment enabled also a number of new technologies applicable at a district level to take a lead role.

New solutions for technology packages in this report are developed for some typical districts (urban, sub-urban and rural), the districts are additionally diversified with regard to climate, specifics in current typology of building stock and its energy saving potential as well as existing energy supply solutions, renewable energy sources and smart-readiness. In final steps of the developing the new packages of technologies in D2.3 also some new elements were considered defined in a set of proposed EC regulation of the "winter package" Clean Energy for All Europeans. The last revision of the deliverable D2.3 was updated with additional focus on building smartness, heat storages, dynamic operability, responsive systems, smart meters and other technologies, also prioritized in a recent study of BPIE on smartness-ready of EU built environment. New packages of measures are prepared.

By new solutions in technology packages we are targeting modern technical systems for the rational use of energy (RUE) and utilization of renewable energy sources (RES) on a district level. We analysed and pointed out the criteria that need to be fulfilled in order to successfully install devices that enable refurbishment of buildings and districts in a nZEB manner, from different points of view (end users, grid and energy sources operators).

1.2 Purpose and target group

The purpose of the work in WP2 leading to creation of this deliverable was to:

- To search up-to-date information, summarise, make conclusions of technology packages at district and building level for nearly-zero-energy building refurbishment
- To summarise the availability, suitability in different conditions, combinations, advantages and problems of technologies
- To develop improvements and integrated technology packages suitable for refurbishment at district level

The first target group is the MODER consortium. The main purpose is to review existing information on energy-efficient refurbishment at district level and organise it to be used as guidelines for development of IT tools in work packages 3, 4 and 5.

1.3 Relation to other tasks/deliverables

Identification of technology packages in WP2 is closely connected with WP 3. Information and solutions from WP2 will be used in WP 3 and later on in the project and district refurbishments in various cities and conditions. The following figure presents the relationships of the work-packages:

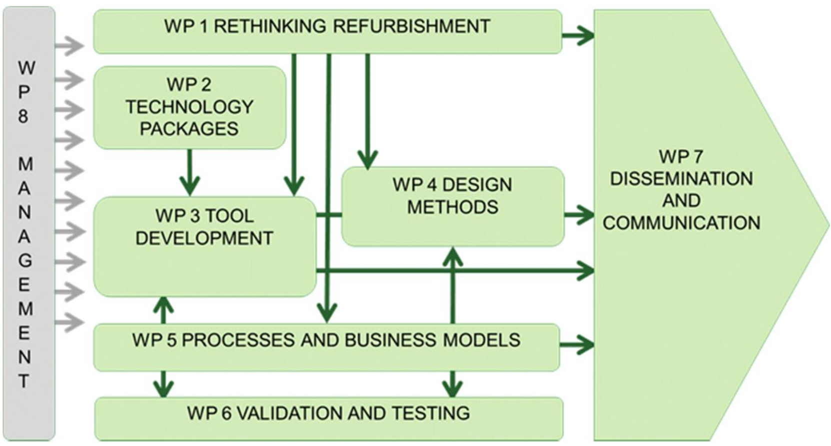

Figure 1 – Relationship of the work with other parts of the project

1.4 Terminology and definitions

BPIE	Building Energy Performance Institute
CHP	Combined heat and power plant
COP	Coefficient Of Performance (heat pumps)
DC	District cooling
DH	District heating
DH/C	District heating and cooling
EE	Energy Efficiency
EPBD	Energy Performance of Buildings Directive
GHG	Greenhouse gas
HVAC	Heating, ventilation, and air conditioning
IT, ICT	Information (and Communication) Technology
nZEB	Nearly zero energy building
NZEBR	Nearly zero energy building refurbishment
RES	Renewable energy sources
RUE	Rational use of energy

2 Starting point and methodology

2.1 Starting point

New possible improvements and new combinations for refurbishment packages were developed to address current problems of ineffective utilisation of refurbishment benefits on district level and/or ineffective use of local RES systems as well as the challenge of nearly zero energy building renovation. In the deliverable (D2.1 'New requirements for technology packages at district level') the requirements for using refurbishment measures on district level were compiled and presented. New requirements were grouped to those applied at the building level and specially those on the district level. They were also described from the viewpoint of end users, grid operators and energy source operators.

New solutions should enable the efficient operation of buildings as part of the district energy system with ability to adapt the building's energy demand according to availability or time dependant cost-efficiency. The characteristics of new solutions/technologies were collected in the deliverable D2.2 'Availability and suitability of technologies'.

New solution packages will consider building technological and HVAC technological solutions, monitoring and automation technologies and ICT solutions, energy efficient production, distribution and transformation, renewable energy technologies with focus on locally distributed energy systems. Because with holistic design new connections between distributed RES systems and demand side are considered to allow the optimal (balanced) selection of energy production and transfer through energy distribution system. The study of new solutions packages started from the evidenced requirements (in D2.1) and possible technologies (presented in D2.2).

2.2 Methodology

The Task 2.3 is developing new technology packages for nZEB refurbishment at a district level.

A technology package is subject to a number of boundary conditions, such as type of a district, age, maintenance and renovation level, climatic and geographical conditions, availability of energy sources, societal facts (fuel poverty, employment rate, market development, economic stability, strategic targets in the area).

The work programme clearly justified the importance and benefits of widening the EPBD concept of nZEB renovation at a building level to a holistic refurbishment at a district level. The concept of nZEB renovation of districts takes advantage of a combination of building and HVAC technologies, monitoring and automation technologies and ICT solutions, energy efficient and/or RES based production of heat and electricity on-site or near-by, as well as energy efficient distribution and transformation.

A holistic technology package should be based on a comprehensive design process and at the same time it should generate benefits from the proactive relations between demand and supply side. The MODER technology packages for renovation at a district level thus address:

- different RES technologies,
- common RES solutions combined with storage systems at neighbourhood or district level,

- different energy system choices with consideration of mitigation of mismatch or non-simultaneity between local production and consumption and peak power demand,
- better involvement of owners and users in decision making.

Following to the experiences with the implementation of nZEB principle in practice (gained since EPBD in 2010) the Commission is proposed (in November 2016) changes to EPBD in the frame of *Clean Energy for all Europeans* set of regulation (winter package). According to this proposal buildings should be

- »smart, by encouraging the use of ICT and modern technologies, including building automation and charging infrastructure for electric vehicles, to ensure buildings operate efficiently«[1].

Consequently, the main thesis at preparation of "New solutions for technology packages at district level" is that:

- "the nZEB refurbishment at a district level is feasible if the buildings and the district is also »smart-ready«".

Smartness indicator is also a new proposed indicator in the amended EPBD and it is supposed to reflect the capability of building(s) and users to interact with the energy networks and thus optimize the operation of the whole system.

BPIE[2] investigated smart-readiness in EU member states in a recent study "Is Europe ready for the smart buildings revolution? [3]", where they initially prepared and overview of how smart the wider built environment is as this is a precondition for the buildings and districts to become nZEB. The smart-readiness was evaluated around "five pillars of a smart built environment" from energy efficient buildings and their dynamic operability to the interaction of buildings with networks and grids, and the maximum uptake of RES. Based on that four key indicators of smart readiness of the built environment were pinpointed:

- energy performance of the building stock,
- deployment of smart meters,
- share of RES and
- demand response availability.

In this deliverable the refurbishment technologies (at a building level, at the energy demand and supply side) are thus structured into groups according to "five pillars of a smart built environment« in BPIE study.

To present *New solutions for technology packages* for nZEB district renovation first **typical / sample districts** are defined, and the **Pros and Cons of a typical district** for its transformation into nZEB district are described. Description of Pros and Cons follows the above mentioned pillars for future nZEB and smart districts.

Three types of districts are considered: urban, suburban and rural.

[1] http://europa.eu/rapid/press-release_MEMO-16-3986_en.htm
[2] http://bpie.eu/about/
[3] http://bpie.eu/publication/is-europe-ready-for-the-smart-buildings-revolution/

In the Tables 1-3 the expected boundary conditions and potentials for transformation of a district into a nZEB one are described.

Then the technologies based on the overview from Task 2.2 and the conclusions of BPIE study on Smart-readiness are listed for future grouping into *New technology packages*.

The combination of technologies applicable at a building and district level depends on

- **the type of the district**, basically diversified into urban, suburban and rural (however in each group more specific settlement types can be defined, i.e. suburban – new satellite sleeping areas or old suburban areas integrated into the city);
- **existing energy supply concept** (with consideration of strategic goals in the region / country) and **RES availability** in the area;
- **climatic conditions** (Central and Eastern European continental climate, North European cold climate and not considered in MODER – South European – Mediterranean climate)

3 Typical districts

3.1 Urban district

  

An "Urban district" is characterized with

- Building stock

(still mainly residential, but high level of commercial, tertiary and public buildings, relatively old buildings, renovation level is average, maintenance is level high, potential for transformation is average (building stock structure))

- Population (density is high, age is in average, employment rate, fuel poverty likelihood is highest of three cases)
- Economy (highest level of companies at the district, a lot of working places, highest incomes)
- Geography and climate (size of a district can vary, urban, coverage of RES depend of location)
- RES in the area (coverage of RES depend of local sources and location, forest less possible in the vacancy, best potential in sun and geothermal)
- Energy & ICT infrastructure (energy networks, smart metering, internet is on high level, where not, it has best chances to develop fastest)

Table 1. Pros and Cons for transformation of an urban district into a nZEB district – based on boundary conditions and technology up-take opportunities.

PROS	**CONS**
RES opportunity: solar energy, RES in district heating system, heat pumps CHP opportunity: wood, waste, gas (in district heating systems due to high density population) PV opportunity: high (priority to place PV on roofs) Smart metering deployment (big potential), for heat and electricity supervision and optimization	Energy refurbishment of thermal envelopes may be subject to architectural and building heritage restrictions Final energy use usually exceeds renewable energy sources available on site. The share of electricity in final energy use is high.

Energy storage: thermal storage is common at a building level (in building fabrics); thermal storage deployment in district heating systems Electricity storage: batteries (buildings, electric vehicles – big density) Very good internet connection (readiness for "smart operation")	Heterogeneous population could result in higher degree of fuel poverty. RES restrictions: decentralized use of biomass, wind mills, biogas Dynamic pricing is not yet common for buildings and households

3.2 Suburban district



A "Sub-urban district" is characterized with

- Building stock (mainly residential, low level of commercial, tertiary and public buildings, relatively new buildings, maintenance level is high, potential for transformation in smart district is high)
- Population (density is high, age is in average, employment rate is high, fuel poverty likelihood is low)
- Economy (highest level of companies at the district, employment rate is high, high incomes)
- Geography and climate (size of a district can vary, urban, coverage of RES is less restricted than in urban district, but still not abundant, depend of location)
- RES in the area (coverage of RES depend of local sources and location, forest possible, but limited)
- Energy & ICT infrastructure (relatively new buildings, energy networks, smart metering, internet is on high level, where not, it has best chances to develop fastest)

Table 2. Pros and Cons for transformation of a suburban district into a nZEB district – based on boundary conditions and technology up-take opportunities.

PROS	CONS
Energy refurbishment of thermal envelopes – less restrictive conditions, typical solutions for particular building types are applicable or many buildings are recently built.	RES restrictions: decentralized use of biomass, wind mills, biogas Dynamic pricing is not yet common for

Renewable energy sources available on site could match the final energy use in the area. The share of electricity in final energy use is relatively low, as the dwelling are prevailing type of buildings, the share of commercial and tertiary buildings is lower comparing to urban settlements. Prevailing middle class population and thus less fuel poverty risk. RES opportunity: solar energy, RES in district heating system, heat pumps, decentralized use of biomass, wind mills, biogas CHP opportunity: wood, waste, gas (in district heating systems due to high density population) PV opportunity: high (priority to place PV on roofs) Smart metering deployment (big potential), for heat and electricity supervision and optimization Energy storage: thermal storage is common at a building level (in building fabrics); thermal storage deployment in district heating systems Electricity storage: batteries (buildings, electric vehicles – big density) Good internet connection	buildings and households

3.3 Rural district



A “Rural district” is characterized with

- Building stock

  (residential, no commercial, tertiary and public buildings, relatively old buildings, maintenance level is low, potential for transformation to smart district is average, mainly because of low population and houses density)

- Population (density is low, age of population is highest of three analysed cases, employment rate is low, fuel poverty likelihood is low (abundance of natural sources))
- Economy (rare companies at the district, employment rate is low, mostly self-employment, low incomes)
- Geography and climate (size of a district can vary, usually larger than other two cases, coverage of RES is good, depend on location)
- RES in the area (abundance of RES of various sources (wood, plant residues, animal waste,…anyway, depend on location)
- Energy & ICT infrastructure (relatively low density, old infrastructure hinder development of energy networks and deployment of smart metering, internet infrastructure is on lowest level of three, largest potential, but with highest effort)

Table 3. Pros and Cons for transformation of a rural district into a nZEB district – based on boundary conditions and technology up-take opportunities.

PROS	**CONS**
Energy refurbishment of thermal envelopes easily achievable Renewable energy sources available on site exceed the final energy use in the area. The share of electricity in final energy use is between urban and suburban district, mainly due to the agricultural activities and crafts operation in the area. Natural resources are easily accessible therefore; the fuel poverty can be easily mitigated. RES opportunity: solar energy, RES in district heating system (micro) Energy storage: thermal storage is common at a building level (in building fabrics) Acceptable internet connection	low density of population prevents utilisation of some technologies (i.e. large CHP) PV opportunity: low (less buildings to place PV panels) HP opportunity: low, because of abundance of other (cheaper) RES Smart metering deployment (low potential), for heat and electricity supervision and optimization Dynamic pricing is not yet common for buildings and households Electricity storage: batteries (buildings, electric vehicles – low capacity)

4 Baselines of technology packages at a district level

Technology packages for refurbishment were determined on the basis of importance and feasibility to address challenges of nearly zero energy building renovation, together with meaningful and effective use of local renewable energy sources (RES) systems.

Aiming at optimal energy-system design at district level, buildings refurbishment and sustainable energy supply are two inherent parts, which should be considered in holistic balanced cost-optimal, environmental-friendly and social-responsible design approach. Analysis of what energy demands of district are, and what energy (RES, existing systems) sources are available on or nearby district area, is baseline for optimal energy supply design. Sustainable energy supply requires utilization of local RES and systems in sustainable manner to increase the level of energy self-supply.

4.1 District vs building

The main differences between nZEB building and nZEB (smart) district are not so much in refurbishment benefits potential of the buildings, but in possibilities to use some innovative technologies for RES utilization, which are not suitable for single houses, mainly because they are too complicated technically, too costly and are too down-sized to be able to show their energy efficiency.

Another important reason is that some renewables are not constant and stable energy source and are much more efficient in combination with other energy sources. Integration of more RES in one energy supply system enables compensation of shortcomings of the single sources.

4.2 Centralised vs decentralised energy supply

Centralized is a preferred mode of energy supply of buildings in the district:

- Local district heating system,
- Local distribution system for electricity,
- Local gas distribution system, ...

because of:

- increased possibility of the RES technologies integration into the local centralized systems for supplying buildings with energy,
- new heat and electricity storage possibilities,
- adaptation - not just of the supply system to the buildings, but also the buildings to the supply system, and
- possibility of a (local) centralised continuous monitoring and optimization of system parameters during operation,

however it does not preclude individual energy systems in some cases:

- Sometimes, in districts with lower heat demand density the heat losses of the local district heating system can prevail over the technical excellence of the production source

- Better investment and/or operating conditions of the financial operation of individual systems

The energy supply system is in transition from the conventional - centralised, national system towards the increasingly decentralised systems with a variable architecture, where buildings are becoming active players.

A harmonised combination of improving the building envelope and switch to demand responsive technologies would be the most appropriate and viable solution, whereby the increased interaction with the supply grid should be taken into account.

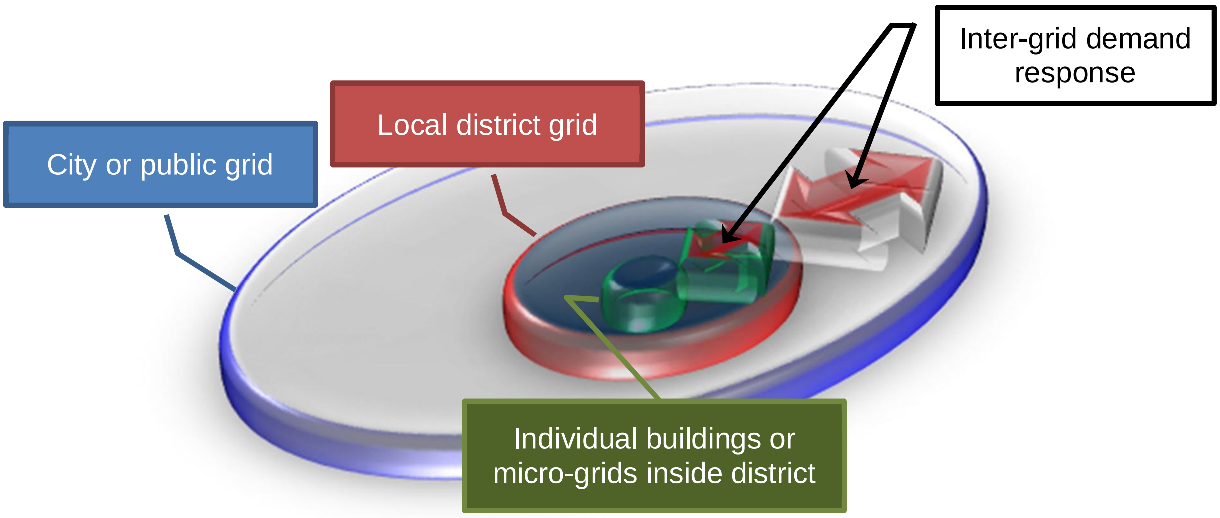

Figure 1: Internal and external connection of local district energy supply systems

With the increasing importance of renewable electricity and its transportation between Member States, an electrification of the market seems to have preference over gasification. Natural gas demand is declining, but on the other hand the existing infrastructure could serve for other energy carriers such as syngas, biogas and methane from organic matter gasification processes (syngas methanisation).

Large-scale renewable energy systems are easily integrated in district energy supply, are more efficient and can easily be controlled based on energy demand and local grid quality. Trade-off the small-scale building-related renewable technologies (heat pumps, biomass boilers or solar thermal applications) is that they are more accessible for end-users and can have an important impact on improving the energy performance of a district.

An individual building power and heat storage is usually feasible for shorter durations. District-scale centralised storage is more appropriate for longer storage durations such as seasonable storage and provides advantages for local grid-related operations and economic feasibility.

Using the existing infrastructure, aggregation of a large number of decentralised storage facilities, such as hot water tanks, air conditioning, hot tubs, is another, in many cases cheaper option than implementing supply or grid-side district centralised storage solutions. Individual battery storage is still not the most economical option today, but through the benefits of experience and scale, the situation for the combination of PV systems and power storage is expected to be changed soon. It seems that especially plug-in electric vehicles could play an important role as a district decentralised power storage system.

4.3 Interactive adaptation between district buildings and local energy supply system

Buildings have substantial potential for energy demand reduction. In districts, the building gain interactivity with the local energy supply system(s) and have important role in power-supply-system stability by providing renewable electricity production, storage and demand response.

A district as a conglomerate of buildings is a source of flexible energy demand and storage, providing distribution and transmission system operators with the services they need to balance available supply and manage power quality at all times.

Instead of steering the supply side with power generation to balance the grid, demand response steers the power demand of energy consumers using price signals. Demand response of a district can be provided by district-centralised monitoring and optimization system balancing the local energy sources supply and energy consumption within the district, employing different technologies or strategies to achieve shifts in demand. Different strategies can be used simultaneously or in combination, as reducing or interrupting consumption temporarily, shifting consumption to other time periods, temporarily using district-only local generation, using the district storage capacities, etc. During periods of excess local energy production, district storage facilities may absorb this energy.

In a district, demand response could be enabled by district-centralised energy management systems through the various supervision and control systems in buildings, for example smart meters, smart thermostats, lighting controls and other load-control technology. Heat pumps, being energy efficient and deploying high share of RES, have become very important in demand-response systems because home heating is responsible for the highest use of residential energy.

4.4 RES utilisation for sustainable district energy supply

Supplying buildings with energy that meets the criteria nZEB regarding the RES share in a cost-effective manner is possible with the use of systems that include following (not necessary comprehensive) list:

- Local district heating system (for all buildings in district), which is autonomous, but (if applicable) connected to the city district heating system in order to facilitate demand response and use two-way storage possibilities
- Biomass cogeneration system as a production source for local district heating system and distribution system for electricity and/or local gas distribution system
- Individual biomass boilers, mainly in suburban and rural districts with low energy demand density
- Solar collectors (as a complementary measure)
- Photovoltaic power plants for electricity self-supply.

All these systems are potential candidates for integration into the district energy supply system, together with potential storage facilities.

4.5 District energy storage technologies

Energy storage technologies are used to rapidly adapt to operating loads of the district, absorb or release energy when needed, or convert a specific final energy into another form of energy. Common technologies are:

- co-generation technologies for electricity and thermal systems;
- systems absorbing power from the grid through heat pumps and storing it as heat in excess-generation periods;
- absorption technologies for heating and cooling
- electrical and thermal storage capacities used in peak-demand periods.

On the level of individual buildings, power and heat storage is feasible for shorter durations. Longer storage duration has to be approached on a centralised district level. Domestic hot water storage is a well-known technology, often combined with solar thermal panels, as well as the utilisation of the building mass (walls and ceilings) as a storage capacity. By using heat storage, buildings in a district connected to local district heating system can support demand response approach – by cutting the heat-load peak, allowing the district-heating supplier to avoid running the peak-load boilers.

The home battery-storage is useful if there are blackouts, but more important is that this type of storage enables to time-shift demand to off-peak times and reduce demand during peak periods in district. Flattening demand curves, especially peaks, is very advantageous for proper stabilisation of local district electricity supply grid and demand response inside the district as well as district-to-public grid demand response.

Because of the higher number of plug-in electric cars in the district, they might take over the same role in the future to be charged when wholesale electricity prices are low or RES electricity production is abundant to avoid times when energy resources are scarce and prices are high. In addition, electric vehicles might be able to provide energy back to the grid during the peak-demand periods.

4.6 Technology packages for urban district

Table 4. Urban district with existing energy supply grids - recommended technology packages for conversion to smart district

nZEB & Smart ready district	URBAN DISTRICT - conversion to nZEB Smart urban district		
List of Technologies	Scenario 1a (mild climate, local grids)	Scenario 2a (warm climate, local grids)	Scenario 3a (cold climate, local grids)
Efficient and healthy buildings			
refurbishment of building thermal envelope	x	x	xx
shading	x	xx	x
ventilation with heat recovery	x	xx	xx
cooling		x	
Dynamic operability			
local district energy supply management system (SCADA, automatization, weather forecast control, etc.)	xx	xx	xx
simultaneity of energy consumption- appliances in buildings	x	x	x
simultaneity of energy consumption – buildings in district	x	xx	xx
building energy management system (smart meters, smart thermostats, lighting controls, etc.)	xx	xx	xx
Energy-system-responsive buildings			
thermal energy storage – building individual	x	x	x
thermal energy storage - district supply local grid centralised	x		xx
electricity storage - building individual, battery	xx	xx	x
electricity energy storage - district supply local grid centralised (biogas, syngas)	xx	xx	x
electric cars	xx	xx	x
filling stations for electric vehicles	x	x	x
interoperability between buildings and supply systems – demand response (local or public (electricity) grid)	xx	xx	xx
Ability for renewable energy uptake			
PV power plants - on-site; self-supply with smart metering	xx	xx	x
solar thermal - on-site	x	xx	
heat pump - a/w	xx	xx	x
heat pump - w/w	x		xx
heat pump - geothermal	x		xx
wood biomass boilers			
CHP wood-to-energy (local district heating production source)	xx		xx
CHP waste-to-energy (local district heating production source)	xx	x	xx
wind mills			
small hydro			
solar cooling	x	xx	
integration potential of on-site systems into local district energy supply system	xx	xx	xx

Table 5. Urban district with no energy supply grids available - recommended technology packages for conversion to smart district

nZEB & Smart ready district	URBAN DISTRICT - conversion to nZEB Smart urban district

List of Technologies	Scenario 1b (mild climate, no local grids)	Scenario 2b (warm climate, no local grids)	Scenario 3b (cold climate, no local grids)
Efficient and healthy buildings			
refurbishment of building thermal envelope	x	x	xx
shading	x	xx	x
ventilation with heat recovery	x	xx	xx
cooling	x	x	
Dynamic operability			
local district energy supply management system (SCADA, automatization, weather forecast control, etc.)			
simultaneity of energy consumption- appliances in buildings	x	xx	xx
simultaneity of energy consumption – buildings in district			
building energy management system (smart meters, smart thermostats, lighting controls, etc.)	xx	xx	xx
Energy-system-responsive buildings			
thermal energy storage – building individual	x	x	xx
thermal energy storage - district supply local grid centralised			
electricity storage - building individual, battery	xx	xx	x
electricity energy storage - district supply local grid centralised (biogas, syngas)			
electric cars	x	x	x
filling stations for electric vehicles	x	x	x
interoperability between buildings and supply systems – demand response (local or public (electricity) grid)	xx	xx	x
Ability for renewable energy uptake			
PV power plants - on-site; self-supply with smart metering	xx	xx	x
solar thermal - on-site	x	xx	
heat pump - a/w	x	xx	x
heat pump - w/w	x		xx
heat pump - geothermal	xx		xx
wood biomass boilers	x		xx
CHP wood-to-energy (local district heating production source)			
CHP waste-to-energy (local district heating production source)			
wind mills			
small hydro			
solar cooling	x	xx	
integration potential of on-site systems into local district energy supply system			

In urban districts, energy demand is high and influenced not only by residential, but also with high share of commercial buildings.

There is the highest, but relatively even energy demand.

The density of electric cars is the highest of three districts.

In the group »*Efficient and healthy buildings*«, refurbishment of building thermal envelope, shading and ventilation with heat recovery is important, no matter in what climate the location of district is. In colder climate, the refurbishment of the building envelope has highest priority, as well as ventilation with heat recovery, while shading is more important in warmer climate.

"*Dynamic operability*" group of technologies refers to building management system with emphasis on the simultaneity of energy consumption and deployment of smart metering. In district with high density and local grids, simultaneity of energy consumption **among** buildings is more important than simultaneity of energy consumption **in** the buildings, especially from the management of the district supply system point of view. Smart metering is prerequisite for smart district transformation and is important in all districts and climates.

"*Energy-system-responsive buildings*" group of technologies deals with potential of integration of various (non-constant) RES with capability of buildings to adapt on possibilities of energy supply system. Here, the paramount is "accumulation" and "integration". In urban districts, there is highest possibility that there exist district energy supply systems. Where not, demand response can be implemented at least through the interoperability between buildings and public (electricity) grid. In colder climate, electricity grid is less strained as heating is usually provided from other renewable sources, while demand for cooling is not so pronounced.

With no local heating grids, only feasible way for thermal energy storage is by individual heat storage tanks. On the other way, and this is most likely in urban districts, the district supply local grid enables centralised thermal energy storage, which allow for different and also innovative ways to storage and integrate various sources into supply system and harmonize with needs of buildings. On the other side, dense population hinders use of some technologies, like biogas production, waste-to-energy transformation systems, and wood biomass boilers, as long the climate is not too cold.

"Ability for renewable energy uptake" group of technologies is oriented into selection of most effective combination of RES technologies and boundary conditions of use them in various environments. Again, starting point was that there is highest possibility of district energy systems existence, therefore these technologies were introduced, which show the most effectiveness for integration. For example, in urban districts it is more effective to use solar thermal as a district heating system support than as an individual building system, especially when we consider finite roof area of the building in the district, which is usually (dependent on location) more efficient utilized by PV solar power plants.

It is highly improbable to find possibilities for wind or hydro power plants implementation in as dense populated area as is urban district.

Heat pumps represent the most sustainable way for heating and cooling of the buildings, if there is no local district heating system available. They use a high share of renewable sources at operation, which depends on the quality of the heat pump (Coefficient Of Performance - COP), renewable source it uses, and the share of renewable electricity in public or local district power supply grid (EE), as shown in Figure 2.

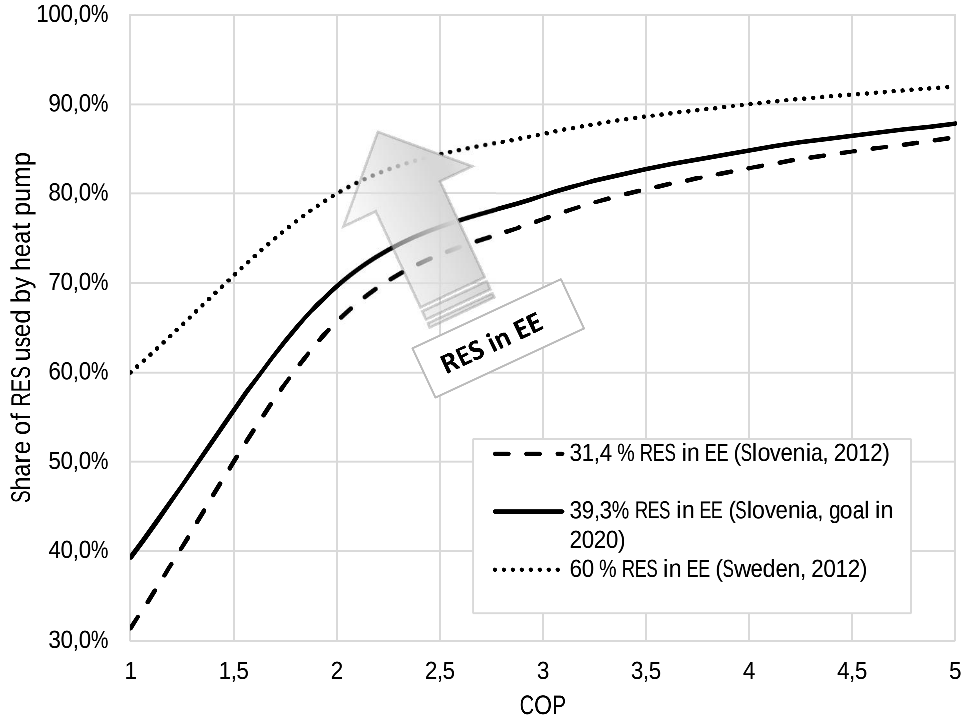

Figure 2: Impact of COP on the share of RES utilized by heat pump, operating at different share of renewable electricity in power supply grid (EE)

Heat pumps, which use air as a renewable source (a/w), have higher COP in milder and warm climate, anyway in general it must be considered, that in high concentration these type of heat pumps may be too loud considering the quality of life in condense populated areas. Nevertheless, heat pump integration into district heating system can be implemented efficiently and non-intrusive for inhabitants.

CHP – cogeneration system in combination with district energy supply system is advisable sustainable energy supply system in all districts with high enough population density. Waste as a fuel for CHP should be utilized with utmost care with clean, state-of the art technologies (plasma gasification, fluidised bed gasification, catalytic depolymerisation,…) to deter public opinion conflict. In mild climates, economic efficiency should be checked carefully because the density of the energy supply is the paramount of the economic sustainability of the district energy supply systems.

In any case and climate, typical characteristics of urban districts give them the best possibilities to develop the building – systems – grid integration potential and to utilize all advantages of demand response concept for energy supply and energy market mutual optimization.

4.7 Technology packages for suburban district

Table 6. Suburban district with existing energy supply grids - recommended technology packages for conversion to smart district

nZEB & Smart ready district	SUBURBAN DISTRICT - conversion to nZEB Smart suburban district		
List of Technologies	Scenario 1a (mild climate, local grids)	Scenario 2a (warm climate, local grids)	Scenario 3a (cold climate, local grids)
Efficient and healthy buildings			
refurbishment of building thermal envelope	x	x	x
shading	x	xx	x
ventilation with heat recovery	x	x	x
Dynamic operability			
local district energy supply management system (SCADA, automatization, weather forecast control, etc.)	xx	xx	xx
simultaneity of energy consumption- appliances in buildings			
simultaneity of energy consumption – buildings in district	xx	xx	xx
building energy management system (smart meters, smart thermostats, lighting controls, etc.)	xx	xx	xx
Energy-system-responsive buildings			
thermal energy storage – building individual			
thermal energy storage - district supply local grid centralised	xx	x	xx
electricity storage - building individual, battery	xx	xx	x
electricity energy storage - district supply local grid centralised (biogas, syngas)	xx	xx	xx
electric cars	xx	xx	xx
filling stations for electric vehicles	xx	xx	xx
interoperability between buildings and supply systems – demand response (local or public (electricity) grid)	xx	xx	xx
Ability for renewable energy uptake			
PV power plants - on-site; self-supply with smart metering	xx	xx	x
solar thermal - on-site			
heat pump - a/w	xx	xx	x
heat pump - w/w	x	x	xx
heat pump - geothermal	x	x	xx
wood biomass boilers			
CHP wood-to-energy (local district heating production source)	x		xx
CHP waste-to-energy (local district heating production source)	xx	xx	xx
wind mills			
small hydro			
solar cooling	xx	xx	
integration potential of on-site systems into local district energy supply system	xx	xx	xx

Table 7. Suburban district with no energy supply grids available - recommended technology packages for conversion to smart district

nZEB & Smart ready district	SUBURBAN DISTRICT - conversion to nZEB

MODER

List of Technologies	Smart suburban district Scenario 1b (mild climate, no local grids)	Scenario 2b (warm climate, no local grids)	Scenario 3b (cold climate, no local grids)
Efficient and healthy buildings			
refurbishment of building thermal envelope	x	x	x
shading	x	xx	x
ventilation with heat recovery	x	x	x
Dynamic operability			
local district energy supply management system (SCADA, automatization, weather forecast control, etc.)			
simultaneity of energy consumption- appliances in buildings	xx	xx	xx
simultaneity of energy consumption – buildings in district			
building energy management system (smart meters, smart thermostats, lighting controls, etc.)	xx	xx	xx
Energy-system-responsive buildings			
thermal energy storage – building individual	xx	x	xx
thermal energy storage - district supply local grid centralised			
electricity storage - building individual, battery	xx	xx	xx
electricity energy storage - district supply local grid centralised (biogas, syngas)			
electric cars	xx	xx	xx
filling stations for electric vehicles	xx	xx	xx
interoperability between buildings and supply systems – demand response (local or public (electricity) grid)	xx	xx	xx
Ability for renewable energy uptake			
PV power plants - on-site; self-supply with smart metering	xx	xx	x
solar thermal - on-site	xx	xx	
heat pump - a/w	xx	xx	x
heat pump - w/w	xx	x	xx
heat pump - geothermal	xx	x	xx
wood biomass boilers			
CHP wood-to-energy (local district heating production source)			
CHP waste-to-energy (local district heating production source)			
wind mills			
small hydro			
solar cooling	xx	xx	
integration potential of on-site systems into local district energy supply system			

In suburban districts, energy demand is more uneven than in urban districts, as they consisted almost exclusively from residential buildings with part of the day elsewhere employed inhabitants.

The density of electric cars is relatively high, but they are almost all there only through the night. They can be used as a storage units for electricity, but loaded elsewhere – mainly on employer parking lots.

In the group »*Efficient and healthy buildings*«, refurbishment of building thermal envelope, typically there is not much potential for improvement, as the buildings are relatively new and the maintenance of them is good. Nevertheless, it is always good to revise in warm climate, if the window shading is appropriate.

"*Dynamic operability*" group of technologies is important in suburban districts because of uneven energy demand characteristics. In district with high density and local grids, but so much uneven energy demand, simultaneity of energy consumption **in** the buildings is more important than simultaneity of energy consumption **among** buildings for demand response optimisation. Smart metering is prerequisite for smart district transformation and is important in all districts and climates.

"*Energy-system-responsive buildings*" group of technologies have large potential in suburban districts with high share of modern and well equipped buildings with state-of-the-art energy & ICT infrastructure. In this way, accumulation, integration and adaptation of the energy system can be performed with less funds and faster. As in urban districts, also in suburban districts in cold climate, the electricity grid is less strained as heating is usually provided from other renewable sources, while demand for cooling is not so pronounced.

"Ability for renewable energy uptake" group of technologies is oriented into selection of most effective combination of RES technologies. Coverage of RES is less restricted than in urban districts, but still not abundant and depend on local sources and location. Heat pumps are the most sustainable heating/cooling system, if there is no local district heating system available. CHP (wood or waste) is preferred production source for local district heating system, if it exists.

Similar as urban district, suburban districts also have many possible ways to develop the building – systems – grid integration potential and to utilize all advantages of demand response concept for energy supply and energy market mutual optimization, as long the uneven energy demand characteristics is taken into account.

4.8 Technology packages for rural district

Table 8. Rural district with existing energy supply grids - recommended technology packages for conversion to smart district

nZEB & Smart ready district	RURAL DISTRICT - conversion to nZEB Smart rural district		
List of Technologies	Scenario 1a (mild climate, local grids)	Scenario 2a (warm climate, local grids)	Scenario 3a (cold climate, local grids)
Efficient and healthy buildings			
refurbishment of building thermal envelope	xx	xx	xx
shading	xx	xx	x
ventilation with heat recovery	xx	xx	xx
Dynamic operability			
local district energy supply management system (SCADA, automatization, weather forecast control, etc.)	x	x	x
simultaneity of energy consumption- appliances in buildings	x	x	x
simultaneity of energy consumption – buildings in district		x	
building energy management system (smart meters, smart thermostats, lighting controls, etc.)	xx	xx	xx
Energy-system-responsive buildings			
thermal energy storage – building individual	x	x	x
thermal energy storage - district supply local grid centralised	xx	x	xx
electricity storage - building individual, battery	xx	xx	xx
electricity energy storage - district supply local grid centralised (biogas, syngas)	x		xx
electric cars			
filling stations for electric vehicles	x	x	x
interoperability between buildings and supply systems – demand response (local or public (electricity) grid)	xx	xx	xx
Ability for renewable energy uptake			
PV power plants - on-site; self-supply with smart metering	xx	xx	x
solar thermal - on-site	xx	xx	x
heat pump - a/w	x	x	
heat pump - w/w	x	x	x
heat pump - geothermal	x	x	x
wood biomass boilers	xx	xx	xx
CHP wood-to-energy (local district heating production source)	xx	x	xx
CHP waste-to-energy (local district heating production source)	xx	xx	xx
wind mills	x	x	x
small hydro	x	x	x
solar cooling		x	
integration potential of on-site systems into local district energy supply system	x	x	x

Table 9. Rural district with no energy supply grids available - recommended technology packages for conversion to smart district

nZEB & Smart ready district	RURAL DISTRICT - conversion to nZEB

List of Technologies	Smart rural district Scenario 1b (mild climate, no local grids)	Scenario 2b (warm climate, no local grids)	Scenario 3b (cold climate, no local grids)
Efficient and healthy buildings			
refurbishment of building thermal envelope	xx	xx	xx
shading	xx	xx	x
ventilation with heat recovery	xx	xx	xx
Dynamic operability			
local district energy supply management system (SCADA, automatization, weather forecast control, etc.)			
simultaneity of energy consumption- appliances in buildings	x	x	x
simultaneity of energy consumption – buildings in district		x	
building energy management system (smart meters, smart thermostats, lighting controls, etc.)	xx	xx	xx
Energy-system-responsive buildings			
thermal energy storage – building individual	xx	x	xx
thermal energy storage - district supply local grid centralised			x
electricity storage - building individual, battery	xx	xx	xx
electricity energy storage - district supply local grid centralised (biogas, syngas)	x		xx
electric cars			
filling stations for electric vehicles	x	x	x
interoperability between buildings and supply systems – demand response (local or public (electricity) grid)	xx	xx	xx
Ability for renewable energy uptake			
PV power plants - on-site; self-supply with smart metering	xx	xx	x
solar thermal - on-site		xx	
heat pump - a/w	xx	xx	x
heat pump - w/w	xx	x	xx
heat pump - geothermal	xx	x	xx
wood biomass boilers	xx	xx	xx
CHP wood-to-energy (local district heating production source)			
CHP waste-to-energy (local district heating production source)			
wind mills	x	x	x
small hydro	x	x	x
solar cooling			
integration potential of on-site systems into local district energy supply system			

The third typical districts group, the rural districts, is characterised by low population and buildings density, mainly poorly maintained residential buildings with possible production activity (agriculture, crafts, self-employment), lowest employment rate of three districts type and abundance of RES of various sources.

In rural districts, energy demand per area is the lowest, but relatively even.

The density of electric cars is low and cannot be considered as important storage capacity for electricity.

In the group »*Efficient and healthy buildings*«, refurbishment of building thermal envelope has huge potential on improving the energy efficiency. Implementation of proper insulation and ventilation systems can vastly contribute to better healthy living condition.

"*Dynamic operability*" group of technologies is important in rural districts, especially simultaneity in optimisation of energy consumption in the buildings. Simultaneity of energy consumption among buildings has less effect, as there are not many feasible opportunities for local district energy supply systems, except of micro systems connecting few buildings. Old infrastructure hinder development of energy networks and deployment of smart metering, internet infrastructure is on the lowest level of three.

"*Energy-system-responsive buildings*" group of technologies in rural districts relies primarily on individual systems for heat and electricity storage. Demand response optimisation is mainly oriented to electricity public grid via the smart metering and control of appliances.

"Ability for renewable energy uptake" is the group of technologies, where rural districts can find most promising options for transformation into nZEB smart districts. Abundance of RES of various sources (wood, plant residues, animal waste, etc.) enables economically efficient utilization of sustainable energy for fulfilling the energy demand of buildings, however mostly by individual systems. In case there is enough heat demand that CHP is economically feasible for micro local district heating system, also the level of electricity self-supply can be high enough for demand response consideration.

Rural districts have the most diverse conditions for development into smart districts. From the RES point of view, they have huge potential, but with highest effort, considering the typical buildings and infrastructure conditions.

5 New solutions for technology packages at a district level

The technology packages were discussed between GI ZRMK and Fraunhofer IBP (leaders of tasks T2.3 and T3.3, respectively) and proceeded to the partners for further discussion. The technology packages were designed with gradually increased novelties and innovativeness, but remained practical and reasonably feasible. Nevertheless, the packages shall be reviewed by the case study planners. They should check whether one or more packages can be helpful in their situation and whether an additional package might support them in the use of the MODER D-ECA tool.

The technology packages are divided into two main groups: with centralised or decentralised energy supply, whereby building stock can be optional rehabilitated to national minimum, or to nearly zero energy building requirements. In the proposed technology packages, these two stages of building refurbishment considering envelope, shading and ventilation are provided as standard and advanced building refurbishment options.

Standard building refurbishment encompasses:

- Envelope - energy efficient renovation of each building component with the U-value nationally required in case of major renovations.

  It is suggested that in the standard refurbishment stage the cellar ceiling, cellar walls and basement slab are not treated and additionally insulated as these interventions most often exceed simple thermal renovation of the envelope. U-values have to meet national demands.

- Shading - external shading system to prevent overheating
- Ventilation - window opening / Mechanical ventilation

  Minimum requirements between window ventilation, exhaust ventilation system and ventilation system without heat recovery have to be defined by the national experts.

Advanced building refurbishment encompasses:

- Envelope - energy efficient renovation of each building component following the nZEB requirements.
- Shading - external shading system to prevent overheating
- Ventilation - mechanical ventilation with heat recovery.

  Minimum requirements between mechanical ventilation with 60%, 75% and 85% heat recovery have to be defined by the national experts.

Considering these two building thermal refurbishment stages, dynamic operability, energy-system-responsiveness and ability for renewable energy uptake were meaningful combined. Technologies considered in the packages are derived from the list of the suitable technologies sets for different types of districts in Chapter 4. The technology packages combine the suitable energy (heat, electricity) supply and storage systems, the energy management and control approaches, and the systems for RES utilisation with increased complexity and integration of the energy supply systems.

5.1 Centralised heat supply

5.1.1 Package 1 - Standard refurbishment with centralised heat supply: wood biomass boiler

1. Standard building refurbishment

2. Heat supply:
   - District local heating system with wood biomass boiler
3. Thermal energy storage:
   - Building individual, for domestic hot water (DHW)
4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)

5.1.2 Package 2 - Standard refurbishment with centralised heat supply: gas CHP

1. Standard building refurbishment

2. Heat supply:
   - District local heating system with gas CHP and peak boiler
3. Thermal energy storage:
   - Building individual, for domestic hot water (DHW)
4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
5. Electricity supply:
   - District centralised by CHP

5.1.3 Package 3 - Standard refurbishment with centralised heat supply: gas CHP & PV power plant

1. Standard building refurbishment

2. Heat supply:
   - District local heating system with gas CHP and peak boiler
3. Thermal energy storage:

- Building individual, for domestic hot water (DHW)

4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
   - Building energy management system (smart meters, smart thermostats, lighting controls, etc.)
5. Electricity supply:
   - PV power plant – on buildings
   - District centralised by CHP
6. Electricity storage:
   - building individual, battery
   - into the public grid over the net metering

5.1.4 Package 4 - Advanced refurbishment with centralised heat supply: wood biomass CHP & central heat storage

1. Advanced building refurbishment

2. Heat supply:
   - District local heating system with wood biomass CHP
3. Thermal energy storage:
   - District centralised, demand peaks control, supply (heating and DHW) through local grid
4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
5. Electricity supply:
   - District centralised by CHP

5.1.5 Package 5 - Advanced refurbishment with centralised heat supply: geothermal heat pumps & PV power plants

1. Advanced building refurbishment

2. Heat supply:
   - District local heating system with geothermal heat pumps
3. Thermal energy storage:
   - Building individual, for domestic hot water (DHW)

4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
   - Building energy management system (smart meters, smart thermostats, lighting controls, etc.)
5. Electricity supply:
   - PV power plant – on buildings
6. Electricity storage:
   - building individual, battery
   - into the public (local) grid over the net metering

5.1.6 Package 6 - Advanced refurbishment with centralised heat supply: geothermal heat pumps & PV power plants – heating and cooling

1. Advanced building refurbishment

2. Heat supply:
   - District local heating system with geothermal heat pumps (winter, urban districts)
   - District local cooling system with geothermal heat pumps (summer, urban districts)
3. Thermal energy storage:
   - Building individual, for domestic hot water (DHW)
4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
   - Building energy management system (smart meters, smart thermostats, lighting controls, etc.)
5. Electricity supply:
   - PV power plant – on buildings
6. Electricity storage:
   - building individual, battery
   - into the public (local) grid over the net metering

5.1.7 Package 7 - Advanced refurbishment with centralised heat supply: geothermal heat pumps & solar thermal & central heat storage & PV power plant

1. Advanced building refurbishment

2. Heat supply:

- District local heating system with geothermal heat pumps and solar thermal plant support

3. Thermal energy storage:
   - District centralised, demand peaks control, supply (heating and DHW) through local grid
4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
   - Building energy management system (smart meters, smart thermostats, lighting controls, etc.)
   - Control on simultaneity of energy consumption of the buildings in district
5. Electricity supply:
   - PV power plant – on buildings
6. Electricity storage:
   - building individual, battery
   - into the public (local) grid over the net metering
7. Interoperability between buildings and supply systems
   - demand response (local or public (electricity) grid)

5.1.8 Package 8 - Advanced refurbishment with centralised heat supply: waste biomass CHP & central heat storage & integration

1. Advanced building refurbishment

2. Heat supply:
   - District local heating system with waste biomass CHP
   - Air/water or geothermal heat pumps (electrically driven) - building individual (multi-flat houses, commercial buildings)
3. Thermal energy storage:
   - District centralised, demand peaks control, supply (heating and DHW) through local grid
4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
5. Electricity supply:
   - District centralised by CHP
6. Integration:

- Integration of building individual heating systems into local district energy supply system (in case of individual systems (multi-flat houses, commercial buildings) surplus heat production with good efficiency)

5.1.9 Package 9 - Advanced refurbishment with centralised heat supply: wood biomass CHP & central heat storage & PV power plant

1. Advanced building refurbishment

2. Heat supply:
   - District local heating system with wood biomass CHP
3. Thermal energy storage:
   - District centralised, demand peaks control, supply (heating and DHW) through local grid
4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
   - Building energy management system (smart meters, smart thermostats, lighting controls, etc.)
5. Electricity supply:
   - PV power plant – on buildings
   - District centralised by CHP
6. Electricity storage:
   - Building individual, battery
   - Into the public grid over the net metering

5.1.10 Package 10 - Standard refurbishment with centralised heat supply: integration of individual wood boilers & gas CHP & central heat storage

1. Standard building refurbishment

2. Heat supply:
   - Wood boilers of individual buildings feeds excess heat into district heating system
   - Gas CHP
3. Thermal energy storage:
   - District centralised, demand peaks control
   - Building individual for domestic hot water (DHW)
4. Control system:

- Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)

5. Electricity supply:
   - District centralised by CHP
6. Integration:
   - Integration of building individual (multi-flat buildings, commercial buildings, etc.)heating systems into local district energy supply system

5.1.11 Package 11 - Advanced refurbishment with centralised heat supply: integration of individual geothermal heat pumps & gas CHP & central heat storage

1. Advanced building refurbishment

2. Heat supply:
   - Geothermal heat pumps of individual buildings feeds excess heat into district heating system
   - Gas CHP
3. Thermal energy storage:
   - District centralised, demand peaks control
   - Building individual for domestic hot water (DHW)
4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
5. Electricity supply:
   - District centralised by CHP
6. Integration:
   - Integration of building individual heating systems into local district energy supply system

5.1.12 Package 12 - Standard refurbishment with centralised heat & biogas supply: biogas CHP plant & central biogas storage & gas peak boiler & central heat storage

1. Standard building refurbishment

2. Heat supply:
   - District local heating system –biogas CHP and gas peak boiler
   - District local biogas grid for individual buildings boilers
3. Thermal energy storage:

   - District centralised, demand peaks control
   - Biogas district centralised supply, domestic use, demand peaks control
4. Control system:
   - Local district energy supply management system (SCADA, automatization, weather forecast control, etc.)
   - Building energy management system (smart meters, smart thermostats, lighting controls, etc.)
5. Electricity supply:
   - District centralised by biogas CHP
6. Integration:
   - Integration of building individual heating systems into local district energy supply system
7. Electricity storage:
   - Building individual, battery
   - Biogas district centralised storage and use for power generation
8. Interoperability between buildings and supply systems
   - demand response (local or public electricity grid)
   - demand response (local or public gas/biogas grid)

5.2 Decentralised heat supply

5.2.1 Package 13 - Standard refurbishment with decentralised heat supply: individual wood boilers

1. Standard building refurbishment

2. Heat supply:
   - Wood boilers - building individual
3. Thermal energy storage:
   - Building individual, for domestic hot water (DHW)

5.2.2 Package 14 - Standard refurbishment with decentralised heat supply: heat pump - a/w

1. Standard building refurbishment

2. Heat supply:

- Air/water heat pumps (electrically driven) - building individual

3. Thermal energy storage:
   - Building individual, for domestic hot water (DHW)

5.2.3 Package 15 - Advanced refurbishment with decentralised heat supply: heat pump - geothermal

1. Advanced building refurbishment

2. Heat supply:
   - Geothermal (ground/water) heat pumps (electrically driven) - building individual
3. Thermal energy storage:
   - Building individual, for domestic hot water (DHW)
4. Control system:
   - Building energy management system (smart meters, smart thermostats, lighting controls, etc.)

5.2.4 Package 16 - Advanced refurbishment with decentralised heat supply: heat pump – geothermal & PV power plants & district electricity supply local grid centralised

1. Advanced building refurbishment

2. Heat supply:
   - Geothermal (ground/water) heat pumps (electrically driven) - building individual
3. Thermal energy storage:
   - Building individual, for domestic hot water (DHW)
4. Control system:
   - Building energy management system (smart meters, smart thermostats, lighting controls, etc.)
   - Interoperability between buildings and electric supply system – demand response
5. Electricity supply:
   - PV power plant – on buildings
   - District supply local grid centralised
6. Electricity storage:
   - Building individual, battery
   - Electric vechiles - filling stations

- Surplus of the district supply local grid stored into the public grid - net metering

5.2.5 Package 17 - Advanced refurbishment with decentralised heat supply: heat pump – geothermal – heating and cooling & PV power plants & district electricity supply local grid centralised

1. Advanced building refurbishment

2. Heat supply:
    - Geothermal (ground/water) heat pumps (electrically driven) - building individual, convectors or ground/air system, heating in winter, cooling in summer
3. Thermal energy storage:
    - Building individual, for domestic hot water (DHW) – in connection with geothermal heat pump, or separate air/water heat pump
4. Control system:
    - Building energy management system (smart meters, smart thermostats, lighting controls, etc.)
    - Interoperability between buildings and electric supply system – demand response
5. Electricity supply:
    - PV power plant – on buildings
    - District supply local grid centralised
6. Electricity storage:
    - Building individual, battery
    - Electric vehicles - filling stations
    - Surplus of the district supply local grid stored into the public grid - net metering

5.2.6 Package 18 - Advanced refurbishment with decentralised heat supply: heat pump – geothermal & wind mill (or small hydro, if available)

1. Advanced building refurbishment

2. Heat supply:
    - Geothermal (ground/water) or water/water heat pumps (electrically driven) - building individual
3. Thermal energy storage:
    - Building individual, for domestic hot water (DHW)
4. Control system:

- Building energy management system (smart meters, smart thermostats, lighting controls, etc.)

5. Electricity supply:
   - District centralised by wind mill (or small hydro)
6. Electricity storage:
   - Building individual, battery
   - Electric vehicles - filling stations
   - Surplus of the district supply local grid stored into the public grid - net metering

5.3 Addition comments on the technology packages

The availability of a DHW storage is dependent on the type of system that is chosen for DHW. It can be a decentralised system (i.e. continuous flow heater), a fresh water station or a centralised (building central) system either separated or in combination with the heating system. Additionally a thermal storage can be used in the building in case of a non-inverter heat pump as a heat buffer storage.

There is provided optional storage of district central generated electricity (i.e. CHP) in a battery in the so-called e-node, and in batteries within the buildings (in off peak time (low tariff) to prevent net export to public grid). What is generated on the building can be stored at the building.

Albeit there is no standardised calculation method, we proposed local district heat supply management (SCADA, automatization including weather forecast data), combined with district heating dynamic model. It requires monitoring of the supply and prediction of the demand and could considerably decrease the district heating system losses.

The same shortcoming relates to interoperability between buildings and supply systems, i.e. demand response. Its main benefit is to synchronise the timing of the consumption, lower the peak demands and thus more RES energy could be used, and could reduce the energy consumption to some extent. However, the calculation method is not standardised and it requires at least hourly resolution model.

The central thermal energy storage is offered as a “daily” buffer storage to reduce the peaks (and this is implemented for all DHU types as a standard) and a bigger “seasonal” thermal storage to transfer excess energy (solar or waste heat) from one month to the other.

Proposed packages are the starting point to packages, which will be integrated into the MODER D-ECA tool. The D-ECA tool can adapt the packages so that they could be tested with simulations on provided case studies within the MODER project – probably not all of them but by all means those which are applicable for the specific analyzed case.

6 Conclusions

New technology packages for nZEB refurbishment at a district level elaborated in this report cover three types of districts; each district exhibits specific opportunities (PROs) for installation of technologies for nZEB renovation at a district level and each has some disadvantages (CONs) that either prevent or hinder the application of some of technologies.

The list of technologies, which were used for creation of new solutions for technology packages, was structured according to the four core pillars of “building-smartness[4]”:

- **Efficient and healthy buildings**: refurbishment of building thermal envelope, shading, ventilation with heat recovery
- **Dynamic operability**: local district energy supply management system (SCADA, automatization, weather forecast control, etc.), simultaneity of energy consumption-appliances in buildings, simultaneity of energy consumption – buildings in district, building energy management system (smart meters, smart thermostats, lighting controls, etc.)
- **Energy-system-responsive buildings**: thermal energy storage – building individual; thermal energy storage - district supply local grid centralised; electricity storage - building individual, battery; electricity energy storage - district supply local grid centralised (biogas, syngas); electric cars; filling stations for electric vehicles; interoperability between buildings and supply systems – demand response (local or public (electricity) grid)
- **Ability for renewable energy uptake**: PV power plants - on-site; self-supply with smart metering, solar thermal - on-site; heat pump - a/w; heat pump - w/w; heat pump – geothermal; wood biomass boilers; CHP wood-to-energy (local district heating production source); CHP waste-to-energy (local district heating production source); wind mills, small hydro; solar cooling; integration potential of on-site systems into local district energy supply system.

New solutions for technology packages are composed based on the list of technologies and presented in a number of Scenarios (3 x 2 x 3):

- where the typical districts (typical urban, sub-urban and rural) are defined and
- additionally diversified with regard to availability of local grid and
- different climate (mild, warm, cold).

The prerequisites for each scenario covered also the status of existing building stock and energy supply conditions (grid, RES).

New solutions for technology packages cover thus altogether 18 scenarios describing opportunities and/or potentials for the implementation of particular technologies or smart solutions for nZEB refurbishment at a district level.

Future development will make EU countries and buildings more and more smart-ready, i.e. heat storages, dynamic operability, responsive systems, smart meters and other relevant technologies will be widely in place and will facilitate nZEB renovation at district level. Currently, according to the above mentioned study of BPIE, countries like Finland and the Netherlands are front-runners in

[4] Is Europe ready for the smart buildings revolution?, BPIE, 2017

assuring the proper (technical, ICT, legal, financial) framework for nZEB renovation at a district level; Austria and Germany are the “followers”, while Latvia and Slovenia are reported to be “cautious adopters” (with less developed built environment for nZEB renovation at a district level).

The answer on question: "How smart can be districts in energy supply?" might be: "Very smart."

Rapid development of technologies, especially RES ones, provides huge and new possibilities of meaningful:

- integration in the local district centralized systems for energy supply,
- storage of heat and electricity,
- adaptation - not just of the supply system to the buildings, but also of buildings to the system, and
- continuous monitoring and optimization of system parameters during operation,

if only the planners and the decision-makers will be smart enough (smart-ready) to use these options in sustainable manner.

For faster implementation of “new solutions of technology packages at district level” an effective institutional infrastructure should be established in the country in order to support the nZEB renovation at district level (may support development of new financing and social models for renovation, go beyond technical), while local authorities should aim to have respective strategies, targets as well as policies, financing instruments in place for successful implementation of new solutions at district level.

References

1. D2.1 New requirements for technology packages at district level, H2020 MODER, LEAG

2. D2.2 Availability and suitability of technologies H2020 MODER, Ertex-Solar

3. Is Europe ready for the smart buildings revolution?, Maarten De Groote, Jonathan Volt, Frances Bean, BPIE, February 2017. (http://bpie.eu/publication/is-europe-ready-for-the-smart-buildings-revolution/ (retrieved: 16 February, 2017))

4. The active role of buildings in a transforming energy market, BPIE, 2015

5. http://www.buildup.eu/en/topics/nearly-zero-energy-buildings. MEnS project webinar series. Energy initiatives at community level: small to big European towns implementing integrated solutions at city level (http://www.buildup.eu/en/events/mens-project-webinar-series-energy-initiatives-community-level-small-big-european-towns-0?gid=50726) (retrieved: 28 February, 2017)

6. RAP. Demand Response as a Power System Resource. 2013

7. http://www.buildup.eu/en/events/nearly-zero-energy-buildings-net-zero-energy-districts-lessons-learnt-existing-projects-eusew (retrieved: 27 December, 2016)

8. http://www.eusew.eu/energy-infrastructure-boost-renewables (retrieved: 29 February, 2017)

9. GJERKEŠ, Henrik, ŠIJANEC-ZAVRL, Marjana, STEGNAR, Gašper. Heat pumps and cost optimal building performance. V: Proceedings, 2nd Annual International Interdisciplinary Conference, AIIC 2014, Azores Islands, Portugal, 2014

10. GJERKEŠ, Henrik, STEGNAR, Gašper, ŠIJANEC-ZAVRL, Marjana. The potential of heat pumps in sustainable building. Engineering - development and innovations for new employments 2014: proceedings of the 4th AMES International Conference, Ljubljana, Slovenia, 2015