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

Impacts of technology packages

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

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 Gorenske Javni Zavod - LEAG (Slovenia).

1 Purpose

This report presents the impact assessment results of the district technology packages described in “New solutions for technology packages at district level”.

When aiming at optimal energy-system design at district level, the refurbishment of buildings and sustainable energy supply are two essential parts, which should be considered with the help of balanced, cost-optimal, environmental and social-responsible design approach. Analysis of energy demands of districts and the availability of renewable energy sources form the baseline for optimal energy supply design. Sustainable energy supply requires utilization of local RES systems in sustainable manner to increase the level of energy self-supply.

The technology packages are divided into two main groups: with centralised or decentralised energy supply, The refurbishment of building stock in different technology packages was assumed to be on the level of national minimum or on nearly zero energy level. The technology packages were derived from the list of the suitable technologies for different types of districts as presented in “New solutions for technology packages at district level”. The technology packages combine the suitable energy (heat, electricity, and gas) 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. All technology packages were assessed in terms of the impact on greenhouse gas (GHG) emissions and impact on energy matching.

The authors of the report are Tarja Häkkinen, Jari Shemeikka and Jaakko Ketomäki, VTT.

2 Background

MODER Deliverable 2.3 New solutions for technology packages at district level proposed 18 different packages for district level refurbishment. This study assesses the impacts of these technology packages.

Deliverable 2.3 described the Technology packages for refurbishment considering the potential of energy-efficient and nearly zero energy refurbishment of buildings together with meaningful and effective use of local renewable energy sources (RES) systems.

Aiming at optimal energy-system design at district level, building refurbishment and sustainable energy supply are two essential parts, which should be considered with the help of balanced cost-optimal, environmental and social-responsible design approach. Analysis of energy demands of districts and the availability of renewable energy sources form the 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.

As described in Deliverable 2.3, the technology packages are divided into two main groups: with centralised or decentralised energy supply, whereby building stock can be refurbished to national minimum or to nearly zero energy building level. In the proposed technology packages, these two stages of building refurbishment are taken into account:

Standard building refurbishment encompasses:

- Envelope - energy efficient renovation of each building component with the U-value nationally required in case of major renovations.
- 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, operability, energy-system-responsiveness and ability for renewable energy uptake were combined in a meaningful way. Deliverable 2.3 derived technologies packages from the list of the suitable technologies for different types of districts as presented in Deliverable 2.2 Availability and suitability of technologies. 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.

All technology packages were assessed in terms of the impact on greenhouse gas (GHG) emissions and impact on energy matching. These aspects were chosen as the most important aspects in accordance with the district level indicators presented in Deliverable 2.2.

The impacts were assessed by expert assessment. The following experts represented three viewpoints completing each other:

- Jari Shemeikka – nZEB refurbishment, energy efficiency, district level energy efficiency
- Jaakko Ketomäki – energy efficiency, electrical engineering and lighting
- Tarja Häkkinen – greenhouse gas emissions and sustainability indicators

In order to enable the comparison of different packages with each other, the first package was defined as the baseline. Values 0 and 0 were given for both impact indicators (GWP and Energy matching). All other packages were compared to the baseline. In the case of more positive impact, the impacts was characterised with the help of +, ++ or +++. In the case of less positive impact compared to the baseline, the impacts were assessed by minuses (1 – 3 minuses).

The results are shown in Table 1. The summary of results is presented in Table 2.

Table 1. Assessment results of the impacts of 18 district level refurbishment packages.

	GWP		Energy-matching	
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.)	District level energy demand and correspondingly GWP decrease because of standard level refurbishment of buildings. GWP also deceases because of (partial) change of fossil fuel boiler to wood biomass boiler. GWP may also slightly decrease because of weather forecast control.	0	Heat load peaks can be somewhat decreased with the help of thermal energy systems. The package does not affect power load peaks.	0

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP decrease because of standard level refurbishment of buildings. GWP deceases also because of CHP compared to separate plants for heat and power. GWP may also slightly decrease because of weather forecast control.	+ Assuming that electricity in Package 1 is supplied with the help of separate fossil fuel power plants.	Heat load peaks can be somewhat decreased with the help of thermal energy systems. The demand for external grid electricity decreases because of local CHP. However, the effect on power load peaks cannot be assessed without further information.	0

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP decrease because of standard level refurbishment of buildings. GWP deceases also because of CHP compared to separate plants for heat and power. GWP may also slightly decrease because of weather forecast control. GWP decreases because of PV systems and batteries. GWP also slightly decreases because of smart meters, thermostats and lighting control.	+	The demand for external grid electricity decreases because of local CHP. The batteries decrease the district level power peaks. (Net metering helps to make PV installations profitable).	+

	GWP		Energy-matching	
Package 4 - Advanced refurbishment with centralised heat supply: wood biomass CHP & central heat storage Advanced building refurbishment 1 Heat supply: • District local heating system with wood biomass CHP 2 Thermal energy storage: • District centralised, demand peaks control, supply (heating and DHW) through local grid 3 Control system: • Local district energy supply management system (SCADA, automatization, weather forecast control, etc.) 4 Electricity supply: • District centralised by CHP	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. GWP deceases significantly also because of CHP compared to separate plants for heat and power and because of wood biomass. GWP may also slightly decrease because of weather forecast control, smart meters, thermostats and lighting control.	++	The demand for external grid electricity decreases because of local CHP. District level heat load peaks decrease because centralised thermal energy storage.	+

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. Primary energy use and GWP decrease because of geothermal heat pumps compared to fossil fuel based district heat. However, the pumps increase the use of electricity. Thus the GWP of electricity is essential. GWP may also slightly decrease because of weather forecast control, smart meters, thermostats and lighting control. PV power plants decrease the demand for grid electricity. However, the significance of this may be smaller than the increase of electricity because of the heat pumps.	+	The batteries decrease the district level power peaks. However, its meaning may be relatively low because of the use of electricity by heat pumps (Net metering helps to make PV installations profitable).	+

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. Primary energy use and GWP decrease because of geothermal heat pumps compared to fossil fuel based district heat. However, the pumps increase the use of electricity. Thus the GWP of electricity supply is essential. Cooling slightly increases the use of electricity (Assuming that there was no cooling before renovation). GWP may also slightly decrease because of weather forecast control, smart meters, thermostats and lighting control. PV power plants decrease the demand for grid electricity. However, the significance of this may be smaller than the increase of electricity because of the heat pumps.	++	The batteries decrease the district level power peaks. However, its meaning may be relatively low because of the use of electricity by heat pumps (Net metering helps to make PV installations profitable).	+

	GWP		Energy-matching	
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)	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. Primary energy use and GWP decrease because of geothermal heat pumps compared to fossil fuel based district heat. However, the pumps increase the use of electricity. Thus the GWP of electricity supply is essential. Compared to Package 5, the electricity demand of pumps is lower because of solar thermal plant support during summer. GWP may also slightly decrease because of weather forecast control, smart meters, thermostats and lighting control. PV power plants decrease the demand for grid electricity. However, the significance of this may be smaller than the increase of electricity because of the heat pumps.	++	The batteries decrease the district level power peaks. However, its meaning may be relatively low because of the use of electricity by heat pumps (Net metering helps to make PV installations profitable). Demand response supports the stability of the public electricity grid and decreases power peaks. District level heat load peaks decrease because centralised thermal energy storage.	++

	GWP		Energy-matching	
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)	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. GWP deceases significantly also because of CHP compared to separate plants for heat and power and because of waste biomass. GWP may also slightly decrease because of management systems.	++	District level heat load peaks decrease because centralised thermal energy storage. The heat load peaks of the centralised system may decrease because of the distributed building level heating systems connected to the local energy supply system. The demand for external grid electricity decreases because of local CHP.	+

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. GWP deceases significantly also because of CHP compared to separate plants for heat and power and because of wood biomass. GWP may also slightly decrease because of management systems. GWP decreases because of PV systems and batteries. GWP also slightly decreases because of smart meters, thermostats and lighting control.	+++	The demand for external grid electricity decreases because of local CHP. The batteries decrease the district level power peaks. (Net metering helps to make PV installations profitable). District level heat load peaks decrease because centralised thermal energy storage.	++

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP decrease because of standard level refurbishment of buildings. GWP deceases also because of CHP compared to separate plants for heat and power. The additional effect of wood boilers on GWP is positive but small. GWP also slightly decreases because of management and control systems.	+	District level heat load peaks decrease because centralised thermal energy storage and building level DHW storages. The demand for external grid electricity decreases because of local CHP.	+

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. GWP deceases also because of CHP compared to separate plants for heat and power. The additional effect of heat pumps on GWP is positive but small. GWP also slightly decreases because of management and control systems.	++	District level heat load peaks decrease because centralised thermal energy storage and building level DHW storages. The demand for external grid electricity decreases because of local CHP.	+

	GWP		Energy-matching	
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)	District level energy demand and correspondingly GWP decrease because of standard level refurbishment of buildings. GWP deceases also because of CHP compared to separate plants for heat and power. Biogas solution may also decrease GWP (depending on the source of biogas). GWP also slightly decreases because of management and control systems.	+	District level heat load peaks decrease because centralised thermal energy and biogas storage. The demand for external grid electricity decreases because of local CHP. The batteries decrease the district level power peaks. Demand response supports the stability of the public electricity grid and decreases power peaks. Demand response and the biogas storage support the stability of the national gas network.	+

	GWP		Energy-matching	
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)	District level energy demand and correspondingly GWP decrease because of standard level refurbishment of buildings. GWP decreases because of wood boilers (compared to fossil fuel based boilers) (However, small-scale building-level wood boilers increase particle emissions).	0	No impact on heat load peaks as there is no district level network. No effect on power peaks.	0

	GWP		Energy-matching	
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)	District level energy demand and correspondingly GWP decrease because of standard level refurbishment of buildings. GWP decreases with the help of heat pumps (compared to fossil fuel based boiler). However, the GWP of electricity is essential because the electricity demand increases.	+	Power peaks increase because of the electricity use of heat pumps. No effect on heat load peaks (as there is no network).	-

	GWP		Energy-matching	
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.)	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. GWP decreases with the help of heat pumps (compared to fossil fuel based boiler). However, the GWP of electricity is essential because the electricity demand increases. GWP may also slightly decrease because of control systems.	++ (assuming clean electricity)	Power peaks increase because of the electricity use of heat pumps. No effect on heat load peaks (as there is no network).	-

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. GWP decreases with the help of heat pumps (compared to fossil fuel based boiler). However, the GWP of electricity is essential because the electricity demand increases. GWP decreases because of PV systems and batteries. GWP also slightly decreases because of smart meters, thermostats and lighting control. (In addition, GWP of mobility decreases because of charging for electric cars).	++ (assuming clean electricity)	Heat pumps increase powers peaks. However, the building level batteries and electric car batteries decrease the district level power peaks. Demand response supports the stability of the public electricity grid and decreases power peaks.	0

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. GWP decreases with the help of heat pumps (compared to fossil fuel based boiler). However, the GWP of electricity is essential because the electricity demand increases. Cooling with the help of geothermal energy causes less GHGs compared to traditional split cooling system. GWP decreases because of PV systems and batteries. GWP also slightly decreases because of smart meters, thermostats and lighting control.	++ (assuming clean electricity)	Heat pumps increase powers peaks. However, the building level batteries and electric car batteries decrease the district level power peaks. Direct heat exchange connection to the ground source cooling is beneficial in terms of peak loads. However, its significance is low. Demand response supports the stability of the public electricity grid and decreases power peaks.	0

	GWP		Energy-matching	
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	District level energy demand and correspondingly GWP significantly decrease because of advanced building refurbishment. GWP decreases with the help of heat pumps (compared to fossil fuel based boiler). As the electricity is based on wind energy, its GWP is very low..	+++	The combination of heat pumps and wind energy is optimal because of variable renewable production and controllable load. However, larger heat storages (also for space heating) would still improve the overall system. Building level batteries and electric car batteries decrease the district level power peaks.	+++

Table 2. summary of the assessment results

		GWP	Energy-matching
Package 1	Standard refurbishment with centralised heat supply: wood biomass boiler	0	0
Package 2	Standard refurbishment with centralised heat supply: gas CHP		0
Package 3	Standard refurbishment with centralised heat supply: gas CHP & PV power plant	+	+
Package 4	Advanced refurbishment with centralised heat supply: wood biomass CHP & central heat storage	++	+
Package 5	Advanced refurbishment with centralised heat supply: geothermal heat pumps & PV power plants	+	+
Package 6	Advanced refurbishment with centralised heat supply: geothermal heat pumps & PV power plants – heating and cooling	++	+
Package 7	Advanced refurbishment with centralised heat supply: geothermal heat pumps & solar thermal & central heat storage & PV power plant	++	++
Package 8	Advanced refurbishment with centralised heat supply: waste biomass CHP & central heat storage & integration	++	+
Package 9	Advanced refurbishment with centralised heat supply: wood biomass CHP & central heat storage & PV power plant	+++	++
Package 10	Standard refurbishment with centralised heat supply: integration of individual wood boilers & gas CHP & central heat storage	+	+
Package 11	Advanced refurbishment with centralised heat supply: integration of individual geothermal heat pumps & gas CHP & central heat storage	++	+
Package 12	Standard refurbishment with centralised heat & biogas supply: biogas CHP plant & central biogas storage & gas peak boiler & central heat storage	+	+
Package 13	Standard refurbishment with decentralised heat supply: individual wood boilers	0	0
Package 14	Standard refurbishment with decentralised heat supply: heat pump - a/w	+	-
Package 15	Advanced refurbishment with decentralised heat supply: heat pump - geothermal	++	-
Package 16	Advanced refurbishment with decentralised heat supply: heat pump – geothermal & PV power plants & district electricity supply local grid centralised	++	0
Package 17	Advanced refurbishment with decentralised heat supply: heat pump – geothermal – heating and cooling & PV power plants & district electricity supply local grid centralised	++	0
Package 18	Advanced refurbishment with decentralised heat supply: heat pump – geothermal & wind mill (or small hydro, if available)	+++	+++

Impact assessment of technology packages