Publishable summary

1. Introduction and objectives

To achieve low energy or even energy neutral districts, the share of renewable energy must increase drastically over present levels. However, accommodating a large supplier of renewable energy, such as a wind farm, in the existing energy infrastructure is hampered by the fluctuating character of the energy supply with the result that renewable energy supply is either too large or too small to cover the instantaneous demand. Both smart energy management systems and energy storage are essential to meet this challenge.

The objective of the E-hub project is to maximise the amount of renewable energy in a district by matching energy demand and supply, by shifting the demand of heat pumps, refrigerators or washing machines. Excess renewable heat can be stored in distributed buffers, advanced Thermo-Chemical Materials (TCM) or boreholes. An important element is the acceptance of such an advanced energy system by energy suppliers and users alike. Therefore, developing new business models and service concepts that are attractive to all stakeholders is crucial.

The E-hub energy system will be demonstrated in the district of Tweewaters in Leuven, Belgium. In addition, four scenario studies will be carried out to assess the feasibility of an E-hub type of system in the districts of Amsterdam (NL), Freiburg (D), Bergamo (It) and Dalian (China).

2. Overview of the project and results obtained so far.

WP1 on System Definition and **WP2 on Energy Conversion & Storage** have been finished in the first period. In the next phases of the project, we are using the results of these work packages, in particular the methodology for determining the most suitable equipment for energy generation and distribution and the measurements on energy generating equipment such as CHP's (Combined Heat and Power plants) based on an Internal combustion Engine (ICE) and a micro turbine.

An overview of the remaining tasks in the E-hub project is given in *Figure 1*. The elements in the different boxes are discussed below.

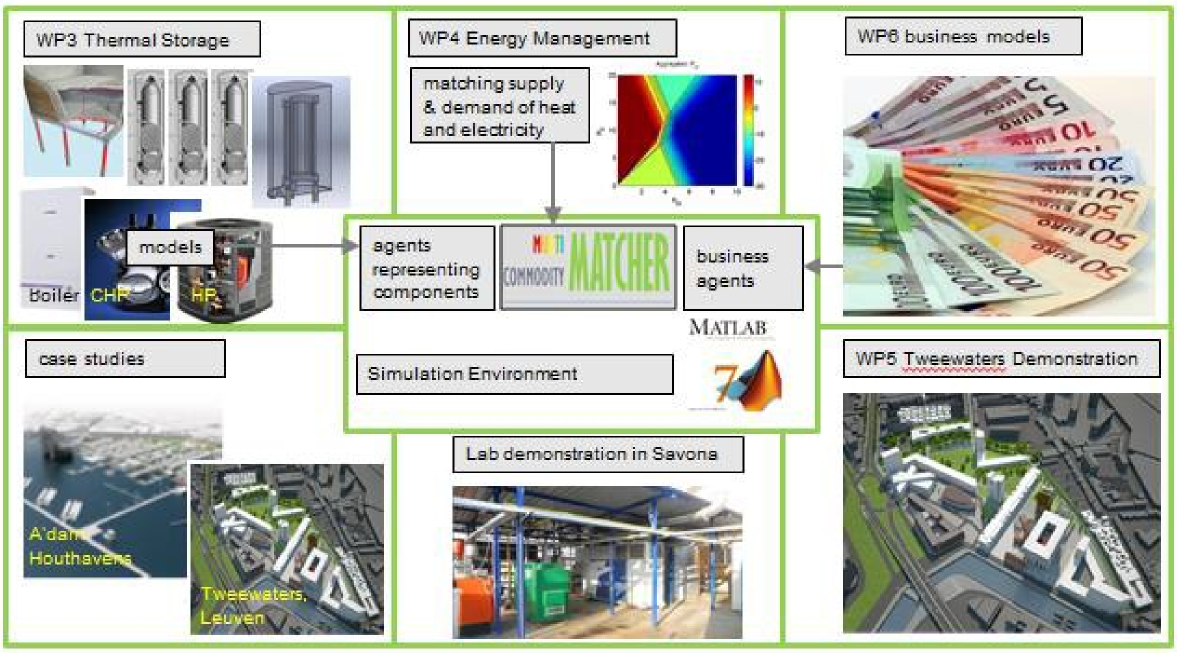

Figure 1: overview of the remaining tasks in the E-hub project.

Thermal storage, developed in **WP3** is an important component in the matching of supply and demand of thermal energy. Thermo-active foundations are being developed as low temperature heat storage. They can be combined with road thermal collectors to restore the heat balance of the soil over a summer+ winter period.

In the work on thermo-active foundations, a number of promising innovations, such as the use of thermally enhanced concrete have been analysed, using calibrated high detail 3D models. The work on the optimisations of the road thermal collector (structural and thermal) aims to increase the outlet water temperature. The higher the temperature level, the higher the efficiency of the total energy system. The work focussed on minimising the depth of the pipes in the road without compromising the structural stability of the road (*Figure 2*).

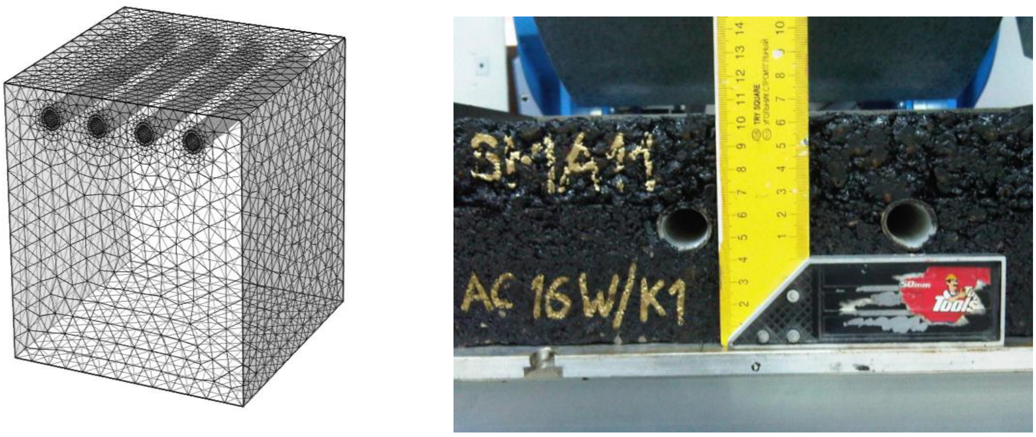

Figure 2: finite elements model of pipes in asphalt and result of structural tests carried out at Mostostal.

TNO and ECN are developing Thermal storage components based on Thermo Chemical Materials (TCM's). VITO is investigating different heat charging strategies for water based vessels in a district heating grid fed by a CHP. Pictures of the test rigs are shown in *Figure 3*.

Figure 3: 14 kWh TCM reactor at ECN (left), 3 kWh TCM reactor at TNO (middle) and test rig with water vessels in the lab of VITO (right).

VITO has also carried out a study to determine the State of Charge (SoC) of a water based storage vessel with a minimum number of temperature sensors. TPG has done a similar study using a different approach.

In addition, a number of (Matlab) models were made of heat and electricity generating equipment such as a CHP, boiler and heat pump. A dedicated piece of software called an agent will allow communication between each model and the control algorithm.

The pivotal work package is **WP4 on Energy Management**, where a Multi Commodity Matcher (MCM) control algorithm was developed that allows to simultaneously match supply and demand of electricity and heat**.** Where transfer of electrical energy from supplier to consumer can be considered (near) instantaneous and with minor energy losses, the transfer of heat must take place by transporting water through pipes, involving a delay between production and consumption of heat and giving rise to thermal losses.

A running version of the simulation tool is available, illustrated by the simple configuration in *Figure 4*. It consists of a house with a CHP and a smart white good appliance but with an otherwise 'uncontrollable' energy demand for space heating, electricity and DHW (Domestic Hot Water). The house has a solar thermal collector on its roof and it is connected to the electricity grid, which is fed by an 'uncontrollable' producer of renewable energy (wind farm). The right figure shows how supply and demand of *electricity* are very nearly balanced (the red line varies slightly around zero).

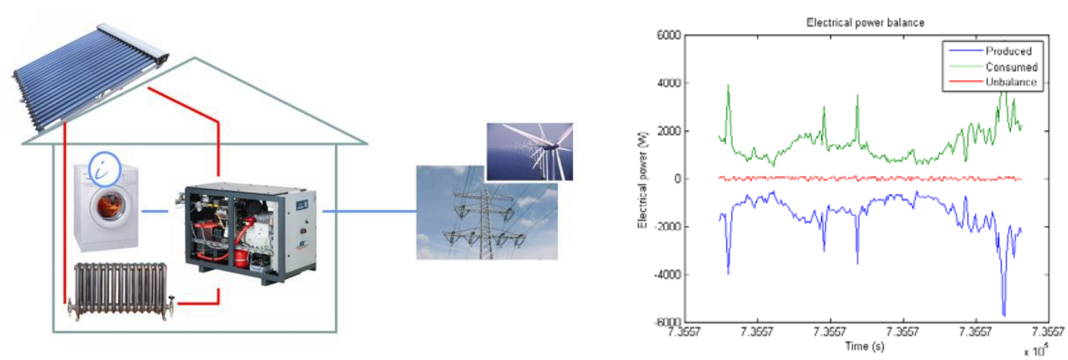

Figure 4: Simple configuration consisting of a house connected to the grid and electricity balance.

WP6 on business models will supply business models /service models to allow specific optimisations for the Energy Management System. For instance, the system could minimise the energy bill for the benefit of end users or shave peaks or reduce imbalance for the benefit of the DSO (Distribution System Operator). These business models will interact with the Energy Management System through so-called business agents.

Another task in WP6 focuses on the interaction between energy efficiency projects and investors. A report was produced providing short practical guidelines targeted to individual/households, public buildings' owners, commercial/industrial buildings' owners and project developers.

The simulation environment will be used in three types of applications. The **first** is the simulation of the *case studies* of Amsterdam, Freiburg, Bergamo, Tweewaters and Dalian, allowing a virtual demonstration of the Energy Management System. Currently the partners are building their districts, using a Graphical User Interface.

The **second** application is the demonstration of the Energy Management System in practice in the *lab demonstration* at the laboratory of TPG and benchmarked against the ECoMP optimisation software from TPG.

In the lab demo, three heat producing units can be made to feed a ‘virtual’ mini district: a micro Turbine with a thermal/electrical output of 160/100 kW could feed e.g. a 30-apartment residential building or an office building, an ICE with thermal/electrical output of 40/20 kW could feed an 8-apartment building and a biomass fired boiler a 6-apartment building.

The **third** application is in **WP5 Demonstration**, where the energy management system (electricity only) will be applied in a *full scale demonstration* in the district of Tweewaters, Leuven in Belgium.

The construction of the Tweewaters building ‘Balk van Beel’ has been completed (see *Figure 5* below). A MultiCommodity Gateway for the agent based control system was installed in each unit of the building (106 dwellings and 9 commercial units).

Figure 5: Pictures of the north side (left) and south side (right) of the ‘Balk van Beel’

A partnership between Ertzberg (as developer of the quarter and of the smart control of energy), Dalkia (as the energy producer) and Eandis (as the distribution system operator for heat and electricity) will be officially ratified in December 2013. The Balk van Beel was awarded the BREEAM ‘Outstanding’ certificate and the building received the 2013 BRE award.

In **WP7 Dissemination**, a website was made (http://www.e-hub.org/), containing a public part as well as a restricted part the latter serving as a database for all project related documents. The website, shown in *Figure 6*, is regularly updated.

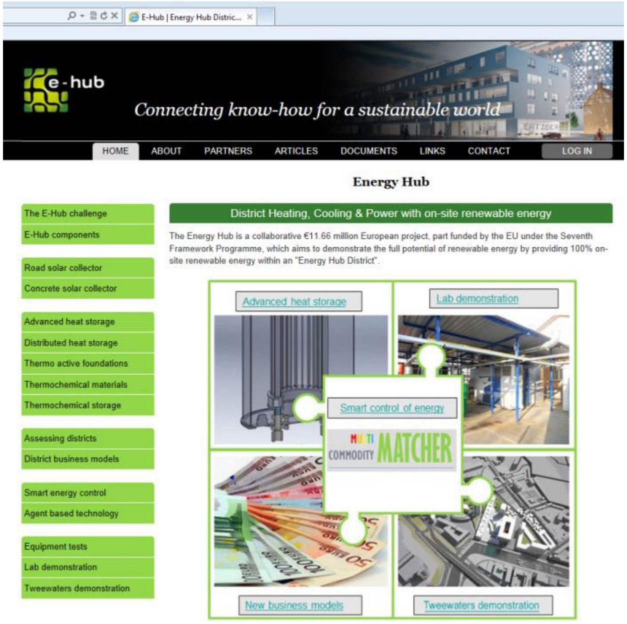

Figure 6: Home page of the public part of the website.

The website underwent a major update in March 2013 to improve the presentation of e-hub's aims and achievements, to revise the underlying html code to make the site respond more quickly and to achieve page 1 returns for many more key phrases in Google searches. The site now also adapts its presentation to suit small screens used on mobile devices.

As a result, the E-hub website is much more visible, doubling the numbers of unique visitors (~550/month, mainly from the UK, Netherlands, Belgium, Spain and the USA) and it scores well in Google searches for a large number of key phrases related to smart grids and thermal storage.

It the first three years of the project, 26 scientific papers were submitted for presentations at (future) national and international conferences, and 2 lectures were given on the application of smart energy systems.

TNO is actively involved in the foundation of the 'Flexible Power Alliance' with stakeholders in an attempt to set the Powermatcher and MultiCommodity Matcher as the standard for smart control in smart grids.

3. Impact

Due to finite stocks of fossil fuels and an increasing demand for energy, in the long run, energy prices will inevitably rise. Considering also increasing public awareness of the effects of greenhouse gas emissions and stricter regulation on the matter, future energy supply systems will change considerably.

The share of renewable energy from wind, biomass and solar energy is expected to grow substantially. Application of short term and long term energy buffers and intelligent energy management systems are essential to match demand and supply of energy to deal with the fluctuating nature of renewable energy supply.

Energy, being an increasingly scarce commodity, is expected to be subject to a price differentiation which will replace the flat rate in use today. Energy will be more expensive in times of shortages of supply and cheaper in times of abundant supply. Powermatcher ® and MultiCommodity Matcher software, the latter developed in the E-hub project, use a pricing mechanism - presently using artificial prices - to match the supply and demand of energy. These control algorithms are therefore well prepared for future price differentiation mechanisms.

More information can be found on the project public website http://www.e-hub.org/.