

Demonstrating cost-effective low energy buildings – Results from the EU CONCERTO project Class1

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ABSTRACT

The Class1 project commenced in 2007 and involves 5 countries: Denmark, Estonia, France, Italy and Romania. Originally, app. 400 dwellings were to be designed and constructed as "low-energy class 1" houses according to requirements set by the Municipality of Egedal/Denmark. This means that the energy consumption is 50 % below the existing energy regulations. 65 dwellings and a about 30 single family houses have been constructed. The Concerto community also includes a kindergarten (completed) and an elderly centre (almost completed). Currently, because of the financial crisis, only about 200 new dwellings will be constructed. Therefore, a contingency plan (plan B) has been developed – replacing some of the new dwellings with renovation of public buildings.

The CLASS 1 project uses the requirements for low-energy buildings to drive the technological development of different key building components/technologies: windows, slab and foundation insulation systems, bio-mass gasification, local district heating distribution networks, ventilation heat recovery combined with heat-pumps and BEMS.

Furthermore, it demonstrates the benefits of ultra-low energy buildings integrated with biomass- and solar heating energy supply.

The paper describes the status of the project - results and developments carried out.

1. INTRODUCTION

The municipality of Egedal decided in 2006 to strengthen the energy requirements for a new settlement to be erected in the municipality. During the years 2007-2011 a total of 442 dwellings was to be designed and constructed with a heating demand corresponding to the new Danish low-energy standard referred to as "low-energy class 1" in a new settlement called Stenløse Syd. This means that the energy consumption will be 50 % below the new energy regulations. 65 dwellings were to be designed and constructed with a yearly heating demand of 15 kWh/m². Furthermore the Concerto community will include a kindergarten and an activity centre for elderly people.

The Class 1 project will use this strengthening of the energy requirements to boost the development of 6 selected key technologies/building components: slab and foundation insulation, window frames, mechanical ventilation with heat-recovery combined with heat-pumps, biomass-CHP, heat distribution for local district heating and user-friendly building energy management systems. Furthermore, the economic and environmental benefits of ultra-low energy buildings integrated with biomass-CHP and solar heating based renewable energy supply is to be shown. The demonstration project is supported by specific design guidelines developed within the project, covering Indoor Environmental Quality (IEQ) and energy savings as well as requirements for monitoring and evaluation. The project also covers activities dealing with town planning and regulatory means and has eco-labelling as a cross cutting activity to increase the general awareness of ecological issues. The training activities defined in the project are targeted towards the technical personnel of the local authori-

ties, the builders and the users in the associated municipalities. Finally, the dissemination activities will primarily focus on the associated observer municipalities in Estonia, France, Italy and Romania supported by the organisations around them. Secondly, the dissemination will be directed towards existing networks of cities and municipalities and thirdly towards the public in general.

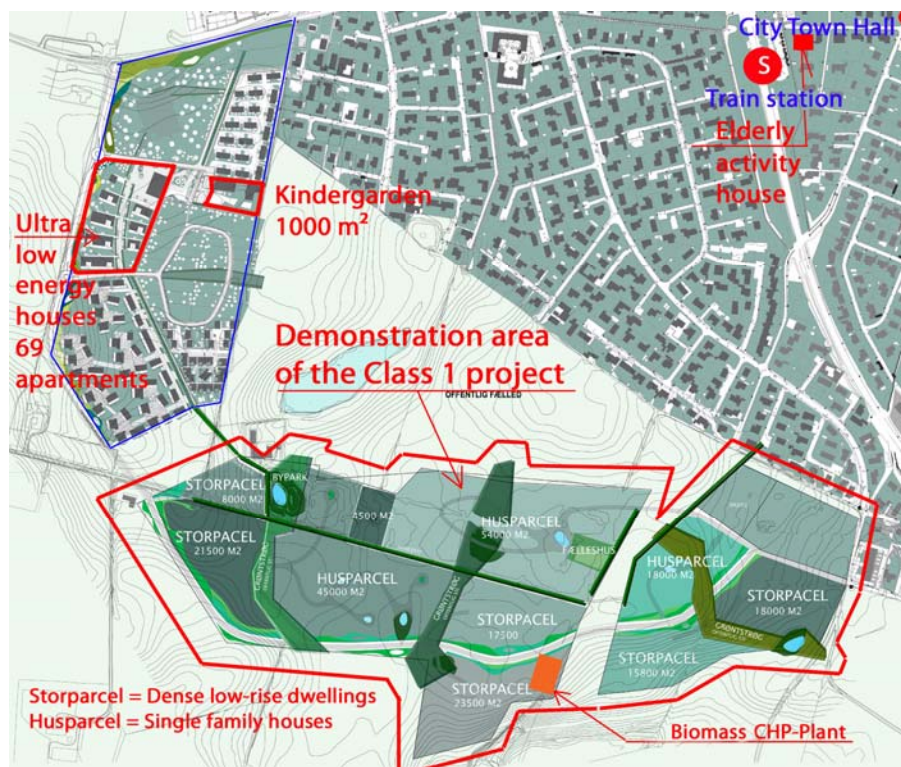


Figure 1. Overview of the Stenløse Syd settlement.

The influence of the financial crisis resulted in a slow-down in the selling and development of construction sites at Stenløse South – especially for dense-low rise housing. It is now expected that the total number of dwellings to be built within the project time schedule will be reduced from 511 to 258. A contingency plan (referred to as “Plan B”) has therefore been developed. In short the contingency plan increases the CONCERTO community to include the existing part of Stenløse City, where public buildings (a town hall, a school, a sports hall and six kindergartens and other institutions) are to be renovated to reach the current Danish energy requirements for new buildings. Besides the district heating network will be extended to reach this existing part of Stenløse. The district heating network will be based on “load sharing” from a number of different CO₂-friendly or -neutral technologies – bio-mass CHP, bio-mass heating, large heat pumps (may utilise excess electricity from the many wind turbines in Denmark) and large solar heating plants. The Class1 project is acting as a lever to push the renovation of the public buildings and to enter into the path towards a CO₂-neutral district heating network for all of Stenløse.

Energy classes in Denmark

The Danish Building Regulation (BR) defines a building's energy consumption in relation to a so-called energy frame. For dwellings the energy frame includes heating, hot water and electricity used for pumps and ventilators, which are part of the heating and ventilation system and for institution and offices also electricity for lighting is included. If the calculation shows a cooling need this will be added as well, even if there is no cooling system installed. In the energy frame may be included production of heat and electricity with solar energy - solar thermal and solar cells. The calculation of the

energy frame of a building is conducted according to "SBI-Guidelines 213" from the Danish Building research institute. The calculation takes into account the sun, personal production of heat and the buildings heat accumulative properties. Calculation is done using the tool Be06 (or other tools with the same kernel). It is a method based on monthly energy balances using monthly averaged weather data.

A dwelling, which meets the energy requirements, must be shown by the Be06 calculations to meet the building requirements expressed in the following formula:

Energy frame = $70+2200/A$ in kWh/m²/year, where A is the heated floor area.

With in the Danish Building Regulation two low energy classes have been defined. The definitions refer to the energy frame definition. The two classes are called low energy class 2 and low energy class 1, respectively. Where low energy class 1 refers to the strongest requirements.

Low energy class 2

A dwelling can be classified as a low energy class 2 house if the needed energy for heating, ventilation, "cooling" and hot water use (as defined in the energy frame) does not exceed $50+1600/A$ in kWh/m²/year, where A is the heated floor area.

Low energy class 1

A dwelling can be classified as a low energy class 1 house if the needed energy for heating, ventilation, "cooling" and hot water use (as defined in the energy frame) does not exceed $35+1100/A$ in kWh/m²/year, where A is the heated floor area.

Passive house

The so-called "Passive house" - concept has achieved widespread use in several countries in Europe. The term passive refers to the overall idea that the houses do not need a conventional heating system. The complete definition and much more about passive houses can be found at <http://www.passivhus.dk/>. The key technical requirements are:

- Net space heating demand: Below 15 kWh per year per m² net area
- Total primary energy: Below 120 kWh per year per m² net area
- Infiltration: Air change rate below 0.60 h⁻¹ by pressure test with 50 Pa.

2. PROJECT OBJECTIVES

There are five scientific, technical and "political" objectives of the Class 1 project:

2.1. Optimise the integration of low-energy building technologies with supply (renewable and conventional) and distribution (heating and electricity) technologies

The heating season is reduced considerably when houses are designed for ultralow-energy use. The supply from a solar heating plant with seasonal storage is very difficult to achieve for a whole settlement in a cost-efficient way when some of these single-family houses are geographically "spread" over a larger area. *The original idea of the Class 1 project was to combine district heating from a biomass CHP plant and a central solar heating plant for the new dense, low-rise housing projects with heat-pump heating of the single-family houses, but currently the demonstration project is been changed to cover also some existing municipal buildings and to have them covered by the biomass CHP and the solar plants. The objectives are to:*

- Illustrate that a local distribution network can still be a viable option even when supplying ul-

tralow-energy houses.

- Integrate and use the solar heating system storage tank(s) as buffer tanks for the CHP-produced heating.
- Demonstrate how this integrated supply system can be monitored and controlled by an advanced, yet easy to use, BEMS.

2.2. Advance selected technologies within the 3 areas: low-energy building, renewable energy supply and distribution

Six technologies that are crucial for the overall goals of achieving ultralow energy houses with a high proportion of renewable energy supply integrated in the supply system have been selected for further development in the project. The six technologies are:

- Windows.
- Foundation and floor slab insulation.
- A biomass plant CHP plant
- Low-loss cost-efficient piping system for local district heating distribution systems.
- Integrated heat-recovery and heat-pump system.
- Advanced user-oriented BEMS

2.3. Improve the design, checking and verification procedures

Stipulating and checking special energy requirements to a certain neighbourhood is not an easy task. In many MS, the implementation of the Directive on Energy Performance in Buildings (EPBD) introduces new, stringent requirements to the energy performance of buildings or at least new requirements for showing how to comply with the existing requirements. To handle these new provisions in practice requires a certain set of procedures. Based on lessons learned, it is the objective of the Class 1 project to develop procedures that are both useful when a local authority decides to introduce tougher energy requirements (as is the case with Stenløse community) as well as for the general handling of the practical implications of the local implementation of the EPBD.

2.4. Integrate the European eco-label in the building projects (houses and components)

This objective addresses specifically the environmental considerations which concern the selection of products for the project and reducing the environmental impact of these products by incorporating the EU eco-label in the project.

In this objective, the EU eco-label will be incorporated in the various stages of the project from design and planning to construction and management.

The EU eco-label will be integrated through contractors and community officials so that the final users of the settlement (the residents) will be ensured a supply of less environmentally damaging products and knowledge to understand the EU eco-label, Paxevanos, and Mørck (2009).

2.5. Demonstrate large-scale implementation close to market technical and economic conditions

The implementation of new, tougher requirements is always met with scepticism from the building market professionals. Architects, contractors and manufacturers see things from different perspectives and they are instinctively almost always against new requirements.

To convince these groups and to pave the way for forthcoming tougher general energy requirements in the building regulations, it is imperative to demonstrate in a large scale and close-to-normal (business as usual) situation that the design and construction of ultralow-energy houses with a high degree of renewable energy supply is indeed a viable option.

In conclusion the objective is to pave the way for a faster introduction of the demonstrated ultralow-energy building technologies and the integrated renewable energy supply – in this case the biomass CHP plants in combination with solar heating systems.

3. SPECIFIC DESIGN GUIDELINES FOR STENLOESE SYD

A set of guidelines for designing low-energy houses and a suitable heating system is presented in a report (Citterio et al., 2008). The definition of low energy houses is bound to be dependent on the country and climate, which it concerns. These guidelines have been developed for the Danish conditions and it should be noted that appropriate measures have to be taken if they are transferred to other countries. Generally, a low energy house is a house that uses considerably less energy to maintain comfort conditions than a house built according to the standard that is current practice at the location in question.

The guideline report is divided in chapters concerning the thermal envelope planning and design phase, the air tightness, the indoor environmental quality, the thermal comfort, the day lighting and visual comfort and finally the user influence on the energy performance.

Shown below are some examples of good thermal envelope technology solutions, but the guidelines also show examples of unnecessary insulation.

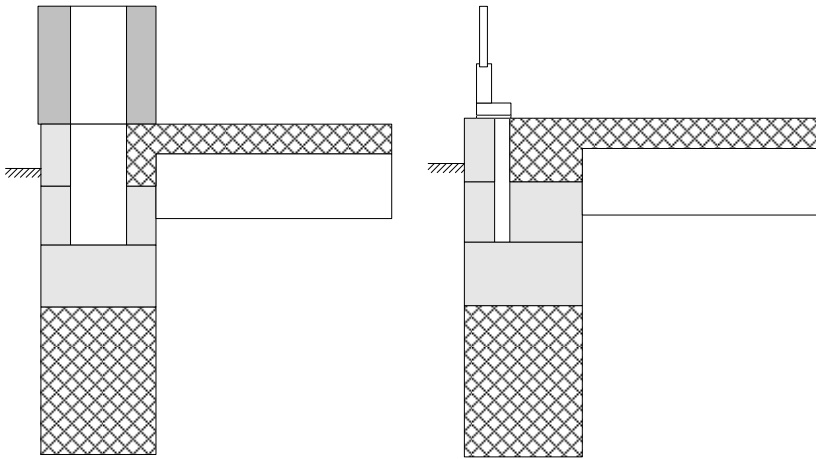


Figure 2. Sections of a joint between the outer wall/foundation/slab-on-ground respectively door/foundation/slab-on-ground

The insulation in the outer wall continues into the foundation. Both solutions are in terms of thermal technology good as the thermal bridges are reduced heavily because of the big insulation in the foundation. The contractors have paid much attention to minimizing the thermal bridges in the foundations.

Examples of unnecessary insulation

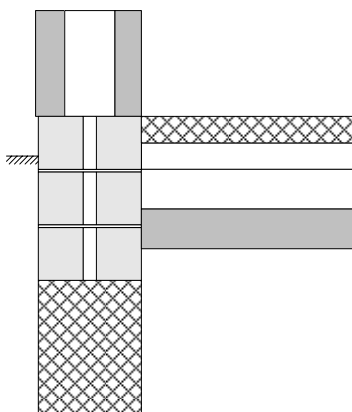


Figure 3. Section of a joint between the outer wall/foundation/slab-on-ground with three insulated lightweight concrete blocks in the foundation

Detailed analyses of different foundation have shown that it has no meaning to use an insulated third course and this can be replaced by a cheaper massive block.

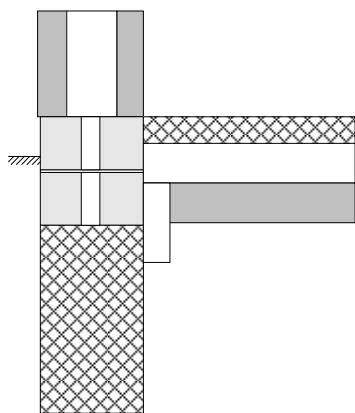


Figure 4. Section of a joint between the outer wall/foundation/slab-on-ground with vertical insulation inside of the foundation

Detailed analyses have shown that on well insulated foundations the inside vertical insulation has a very small influence on the linear loss coefficient.

Airtightness

There is a direct connection between the airtightness of a building and the energy consumption. Furthermore, the airtightness has a big effect on the indoor climate. There should be a certain ventilation rate in a building, but it is crucial to be able to control, where the air enters and where it exits. When the air leaks through openings e.g. at windows and assemblies, it can create a draught, which lowers the indoor air comfort level. At the same time moisture begins to form in the construction when cold and warm air meet. Condensation in the construction constitutes a risk of mould growth and results in poor indoor climate.

Experience shows that leaks are often found at installations, assemblies and transitions between outer walls, floors, roofs, windows and doors. Problems often occur when there is a change of construction material or change from one building part to another. If the building has to be airtight, it is necessary incorporate airtightness right from the start of the project. A well organized design of the location of the vapour barrier and the principle for its unbroken continuity should be decided at the planning stage and should be clearly and unambiguously stated in the design material.

The advantages of building airtight can be summarized as follows:

- Energy saving
- Prevention of moisture damage
- Improved indoor climate (no draught/draught along the floor)
- Improved air quality (control of ventilation etc.)
- Improved sound insulation as direct airborne sound is discontinued.

The rules for airtightness in the Danish Building Regulations

New buildings should be airtight. Under normal conditions the demand for air change per hour for dwellings is 0.5 h^{-1} corresponding to 0.33 l/s m^2 with a room height of 2.4 m. In normal buildings, the demand for air change through openings in the thermal envelope should not exceed 1.5 l/s m^2 heated floor area at a pressure test of 50 Pa (average excess pressure and depression of the building). This corresponds to an infiltration rate of 0.13 l/s m^2 at normal pressure.

The local authorities can demand that a Blower-Door test should be made before issuing a permit to use the building. In a conventional building, it is permitted that approximately 1/3 of the air

change takes place through infiltration.

4. STATUS OG WORK

The municipality of Egedal has advertised the construction sites at the new settlement area Stenloese Syd for sale with special energy requirements for all buildings to be built according to the Danish low-energy standard class 1 or better. Furthermore, the usage of solar energy for hot water preparation and heat pumps for heating in the single-family houses is required.

During the first year of the project, the municipality itself constructed a kindergarten in compliance with the above restrictions and a social housing association (KAB - Copenhagen Social Housing association) has completed an ultralow-energy house project – comprising 65 dwellings. Besides, the construction of the senior citizens centre and 30 single-family houses have commenced.

The photos below present an overview of the Stenloese Syd settlement from the air.



Figure 5. Photo of the Stenloese Syd settlement.

4.1 *The demonstration buildings*

The Class 1 project encompasses 5 different types of building demonstration projects:

- 65 ultralow-energy social housing units – the KAB social housing project
- A kindergarten
- A centre for senior citizens
- About 90 single-family houses
- 4 dense low-rise building areas

Of these targets, the first two have been met, the third is almost finished and about 30 single-family houses have been built. The first of the 4 plots for low-rise housing areas have been sold and a project is being developed.

The KAB social housing project

The project comprises 65 dwellings in two sizes: 82 and 110 m². The houses are built as row-houses and the construction is prefabricated room-size elements – meaning that each apartment consists of two elements put together at the building site. Thus construction time at the site is very short. The dwellings have been designed for a net heating load of 15 kWh/m²/y. This is well below the Danish low-energy class 1 standard which generally leads to net heating loads of about 25 kWh/m²/y. The first year's measurement shows a heating load of about 20 kWh/m²/y, which is probably due to leakage on the assembling lines. This is being mended in the last months of 2009. The dwellings are primarily heated by the ventilation air from a mechanical ventilation system with heat recovery. One-two radiators have been mounted to ensure that heating can maintain comfort temperatures in very

cold winters. The houses are to be supplied with heat from the district heating network fed by the planned biomass CHP plant and a central solar heating system (also part of the Class1 CONCERTO project).



Figure 6. Photo of the KAB-ultralow-energy housing project.

The kindergarten

The new kindergarten for the Stenløse South area has been designed for low energy class 1 according to the Danish Building Regulations. The kindergarten has two heat pumps in series for space heating and one separate heat pump for hot water heating. Space heating is a floor heating system and it is striking to observe the very low temperatures were needed to heat the kindergarten – even in winter months. A mechanical ventilation system with heat recovery ensures good quality indoor air.



Figure 7. Photo of the kindergarten.

The centre for senior citizens people

An activity centre for designed for elderly people of the municipality and allowing them to relax with hobbies and other indoor activities. The centre has been designed for low energy class 1 and a net heating load lower than expected for this class. It is also heated by a heat pump and has mechanical ventilation with heat recovery. The construction principle is steel plates buried about 1 m in the ground and then insulated on both sides, reaching very low U-values with no thermal bridges.



Figure 8. Photo of the centre for senior citizens – under construction.

Single-family houses

About 30 single-family houses have been constructed or are under construction. They are all designed for low energy class 1 standard according to the Danish Building Regulations. They have a minimum of 3 m² thermal solar collector and are heated by individual heat pumps.



Figure 9. Photo of two single-family houses.

Intelligent building control

All the buildings of the Class 1 project will be monitored and controlled by an advanced BESM. The system will be targeted at users enabling them to monitor and control their own comfort and energy consumption. The system will be internet-based to reduce costs and enable residents to use their own computers for direct access to all data related to their own home and to comparative data from the other households. This will e.g. enable them to compare their own energy use with the average of all similar households. The users will have a number of different options, e.g. to set up a vacation period, where temperatures can be kept lower. If they return home earlier than expected, they can turn on the heat from an internet café anywhere in the world. The system will also hold a budget for the energy consumption and therefore allow the residents to compare their actual use with the budget.

4.2 Evaluation of user preferences

One part of the demonstration activities deals with the evaluation of the user preferences to improve targeting of future buyers/builders of low-energy houses. During the first 12 months of the project the methodology was determined and the initial interviews carried out, Quitzau, Munthe-Kaas, Hoffmann and Elle (2009).

The project in Stenløse South has been ground breaking for Danish low-energy building projects. Though hampered by the financial crisis, the project has shown that it is possible for a municipality to promote low-energy building on market terms. The project is important as a showcase for low energy buildings in various ways. Firstly, it is an example of proactive municipal involvement in environmental issues, secondly it is an example of how low-energy dwellings do not have to compromise when it comes to comfort and thirdly it has given important experiences with user preferences and

the role of the building industry. Finally, it has contributed to develop the competences of building industry.

The project is to be viewed as a success as it has documented it possible to promote low-energy dwellings for ordinary people on market terms. The newcomers, clients as well as tenants, seem to be perfectly ordinary inhabitants in those types of dwellings. Their main motivations for moving to the area, was the price and location and the possibility to live in a newly built home. It is also worth to mentioning that a great deal of the newcomers has moved primarily because they were obliged to, for example by a divorce, or because of dissatisfaction with their former dwelling. It is evident that environmental standards by themselves will hardly work as a motivating factor for the main part of clients or tenants outside the greenest segment. Even though it is generally viewed as a positive asset of a dwelling, the low-energy aspect does not seem to have been the main priority for any significant part of the population of Stenløse Syd. From other research on moving habits and dwelling preferences, we see that moving mainly has to do with changes in the life of the individual or family, which makes the current dwelling inadequate. The choice of a new dwelling is also dependent on several factors, such as economy, location and transportation, before people consider the environmental profile.

However, though not the main driver, it is worth mentioning that a big majority of the respondents in this survey seems to like the idea of municipal environmental involvement. Generally, low-energy dwellings and environmentally sound projects are viewed as positive.

Legislative measures seem to be an effective way to ensure a more environmentally sound building industry as the client/industry relation seems to create deadlocks where neither part is willing to take the initiative to innovate voluntarily when it does not seem economically profitable. As new opportunities emerge - it is now possible to include environmental demands in local planning - it is much easier for municipalities to stipulate low energy requirements through legislation, though it still requires quite a lot of work to manage the developmental processes as neither clients nor industry have much experience with low-energy requirements.

On one hand, it is problematic that the newcomers to Stenløse Syd did not choose the area because of the environmental profile, as it makes it difficult to sell new building projects with energy efficiency as an argument. On the other hand, it seems that the newcomers to Stenløse Syd are perfectly ordinary people and the project thus documents that it is possible to work with low-energy building projects on market terms.

4.3 The development of products

During the first 12 months period the development work for the windows - Haulrik and Mørck (2008) and the heat recovery heat pump system - Svendsen and Mørck (2008) have been completed and a considerable part of the development work for the district heating network innovation and the bio-mass CHP-plant have been undertaken.

4.4 Training activities

Training of the technical personnel of the local authorities and building promoters and builders has been planned for the four associated municipalities in France, Italy, Estonia and Romania. Training material has been developed by the training work package leader, ICIE in sets – a PowerPoint presentation to be translated into each language and a hand-out in English. The first training event took place in Odobesti in Romania in May 2010 and was characterised as very successful. To summarize the following observations were made:

- The participants from the public administration appreciated the basic information from Deliverable 28 (the training material)
- The builders and promoters were very interested by the 5 examples and concrete results from Denmark (also in the training material)

- The event has created a communication window between the two categories of actors and a base to launch private - public partnerships.

4.5 Participant list

The main part of the project is carried out in Denmark and the 4 associated MS receive the results and lessons learned and convey and implement them in their national municipalities. The table below lists the participants of the Class 1 project.

Table 1. Participant list.

Municipality of Egedal	Denmark
Cenergia Energy Consultants	Denmark
Danish Building Research Institute, Aalborg University	Denmark
Dept. of Civil Engineering, Tech. Univ. of DK	Denmark
PRO TEC Windows A/S	Denmark
Dansk Leca A/S	Denmark
BioSynergi Proces ApS	Denmark
Genvex A/S	Denmark
Logstor A/S	Denmark
Electronic Housekeeper A/S	Denmark
IB Aksiaal OÜ	Estonia
Valga Town Government	Estonia
Ente per le Nuove Tecnologie l'Energia e l'Ambiente	Italy
I Istituto Cooperativo per l'Innovazione	Italy
Commune di Bologna	Italy
Sustainable Urban Development European Network	France
Municipality of Begles	France
Association of the Local Development Promoters	Romania
Municipality of Odobești	Romania

5. CONCLUSIONS

In the coming months (the project runs for 60 months) the next demonstration buildings are to be completed, the biomass CHP plant combined with a large array of solar collectors is to be implemented and the monitoring initiated. The users will be followed and assisted and the lessons learned will be documented. Also the development of the next 4 key technologies will be completed. The next two training events will be carried out in spring 2011 and further dissemination will be carried out. One possible development is that one or more of the associated communities will also begin the implementation of new CONCERTO demonstration projects.

It is expected that the experiences, lessons learned and R&D carried out as part of the Class 1 project will pave the way for the development, design and construction of sustainable, low or zero CO₂-emission communities in the future. A guideline activity was to review existing design guidelines in the participating MS. The aim of this investigation was to evaluate the cross applicability of existing guidelines in participating MS and how they fit with national implementations of the Directive on Energy Performance of Buildings. The first step was to do a survey on the existence and the contents of national or local guidelines in the participating MS: Denmark, Estonia, France, Italy and Romania, (Castellazzi, Citterio, Mørck, Thomsen, Kase, Charlot-Valdieu, and Balica, (2009).

The conclusions are that in general the Danish guidelines have been evaluated to have a good applicability in all the other MS. The summer conditioning with absorbing cooling systems (from Ital-

ian guidelines) have been considered to be not applicable in Denmark and Estonia. This can be explained by the facts that in Estonia and in Denmark there is a low solar radiation and a low summer cooling demand, but in France (not in the metropolitan area), solar cooling should have a good potential and is being developed.

The items that had a consensus from all experts were the following:

- Building envelope and thermal insulation
- High-efficiency boilers
- High-efficiency air-conditioning systems
- Thermostats and radiator valves to prevent overheating
- Cooling demand assessment
- Lighting systems efficiency standards and control systems
- Water accounting and water saving
- Low temperature floor heating systems
- High-efficiency heat pumps
- Design process check.

All the guidelines proposed by the Danish, Italian and Romanian experts fit with the national implementation of EPBD in their respective MS, Castellazzi et al., (2009). In general, there seems to be a lack of up-to-date design guidelines for dwellings of different categories. With present low-energy requirements and wishes for sustainable buildings the guidelines developed 10 or more years back are outdated.

The Danish Energy Research Programme is also supporting the project.

Further information about the Class1 project is to be found on the project website: www.class1.dk

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