EU 7th Framework Programme – EeB-ENERGY

School of the Future

Towards Zero Emission
with High Performance Indoor Environment

Project number: 260102

PROJECT FINAL REPORT

Grant Agreement number:	260102
Project acronym:	School of the Future
Project title:	School of the Future - Towards Zero Emission with High Performance Indoor Environment
Funding scheme:	Collaborative project
Period covered:	**from** 01/02/11 **to** 31/01/16
Name, title and organisation of the scientific representative of the project's coordinator:	Hans Erhorn Fraunhofer Institute for Building Physics
Tel:	+49-711-9703380
Fax:	+49-711-9703399
E-mail:	hans.erhorn@ibp.fraunhofer.de
Project website address:	www.school-of-the-future.eu

CONTENT

1. FINAL PUBLISHABLE SUMMARY REPORT

1.1. EXECUTIVE SUMMARY

The aim of the "School of the Future" project (www.school-of-the-future.eu) was to design, demonstrate, evaluate and communicate shining examples of how to reach the future high-performance building level. School buildings and their primary users, namely pupils - the next generation - were in the focus of the project. Both, the energy and indoor environment performance of 4 demonstration buildings in 4 European countries and climates have been greatly improved due to holistic retrofits of the building envelope, the service systems, the integration of renewables and building management systems. The results and the accompanying research and dissemination efforts to support other actors dealing with building retrofits shall lead to a multiplied impact on other schools and on the residential sector, since the pupils act as communicators to their families. The user behaviour and the awareness of energy efficiency and indoor environment were improved due to tailored training sessions.

Nearly zero emission or nearly zero energy buildings are a main goal in various country roadmaps for 2020. The demonstration buildings that were part of this project have not completely reached this level, though, as the aim of the call was cost efficiency and multiplication potential. The retrofit concepts, however, resulted in buildings with far lower energy consumption than in regular retrofits with high indoor environment quality - thus leading the way towards zero emission. They can be considered as schools of the future. Results from national examples of zero emission schools completed the information used for developing the deliverables such as guidelines, information tools, publications and a community at the EU BUILD UP portal.

The project was based on a close connection between demonstration, research and industry which was being represented by the "Design Advice and Evaluation Group". The idea of the proposal was introduced at the E2B association brokerage event and met with high interest which resulted in the establishment of a consortium including well-known partners from the building industry.

1.2. SUMMARY DESCRIPTION OF PROJECT CONTEXT AND OBJECTIVES

1.2.1. Why schools as show cases?

Social values are strongly formed by public models. This is also valid for buildings. It is easier to gain people's attention for the need to significantly raise the quantity and quality of energy efficient retrofits in Europe when they realise that the public authorities address this area in an exemplary and brilliant way. It is therefore

particularly important to demonstrate exemplary solutions at frequently used public buildings like schools. The use of public buildings as frontrunners will help to increase the market penetration of high performance retrofit approaches. In the framework of a European sustainable development the energy demand of educational buildings has to be fulfilled by taking energy efficient measures and by using renewable energy sources. The 100% carbon free school building has to become the standard of the future.

The particular and unique feature that distinguishes the retrofit of schools is the possibility of including students in the retrofit process. This provides the opportunity of an enormous knowledge multiplication, as on the one hand the pupils transfer the knowledge to their parents and on the other hand they will become the decision makers of tomorrow. Europe depends on providing high quality education for its future generations. However, studies such as the PISA study on pupils' performance have shown that other countries have caught up and even overtaken most of the European countries concerning the educational quality. As studies have proven that the indoor environmental quality is strongly linked to the performance of work, for adults but also for students, the improvement of indoor air quality, acoustic, lighting and thermal comfort is one of the main aims of school retrofit. The general aim of energy consumption reduction and replacement of fossil energy sources has to be realised at the same time. This is a big challenge that was to be met in the School of the Future project.

1.2.2. Concept of the project

The concept of the School of the Future project consisted of 3 main parts:

1. Design, demonstration and evaluation of highly energy efficient retrofitting of schools in 4 different European countries with differing climates
2. Development of guidelines and tools – building upon existing knowledge and tools – applicable throughout the EU countries
3. Dissemination of results, guidelines and tools – also including training activities

The **design, demonstration and evaluation** of the school retrofits were tackling two major challenges at the same time: energy saving and indoor environment quality.

The demonstration buildings within the project have not completely reached the level of zero energy as the aim of the call is cost efficiency and multiplication potential. The retrofit concepts, however, resulted in buildings that use significantly less energy than after regular retrofits ensuring high indoor environment quality - thus leading the way towards zero emission. They can be considered as schools of the future.

As an example, there are more than 40,000 school buildings in Germany. Most of them are awaiting retrofitting. Retrofitting is not only intended to improve the energy efficiency but also to improve indoor environmental conditions for pupils and

teachers. As most of German schools are not equipped with mechanical ventilation systems, natural ventilation controlled by the occupants opening the windows is the main way to maintain healthy and comfortable conditions in the classrooms. Recent experiments have shown that poor indoor environmental quality (IEQ) in office buildings can reduce the performance of office work by adults. It is thus reasonable to suspect that poor IEQ can also negatively affect the performance of schoolwork by children. While it is well documented that IEQ in schools is both inadequate and frequently much worse than in office buildings, new studies (carried out at the Technical University of Denmark for example) investigated whether IEQ can affect the performance of schoolwork by children. The results indicated that doubling the outdoor air supply rate would improve the average performance of schoolwork by about 15%.

The **development of guidelines and tools** built upon existing knowledge and further developed already available instruments in order to cover both qualities, the energy efficiency and the indoor environment. The guidelines and tools are applicable throughout the EU countries. The guidelines will address the following subjects:

- Building construction elements
- Building service systems
- Improved indoor environment quality
- Solution sets for zero emission/zero energy schools

Two types of simple to use tools were further developed: one which focuses on the presentation of information such as case studies and retrofit technologies, that also contains the guidelines and a benchmark system for average and best practice energy performance data, and one that allows an energy performance assessment of school buildings with and without retrofit measures. The main target groups of the information tool are public authorities and other types of planners. The calculation tool enables different user groups including students to perform a simple assessment of the energy quality of school buildings.

The **dissemination of the project results** and the deliverables was realised through the project website (www.school-of-the-future.eu) and the use of existing, already proven dissemination channels that allow for a multiplication of the impact compared to a single approach by the project. Examples for this are: “Industry” dissemination via the communication channels of the national and international industry associations, sessions and presentations at major conferences and articles in technical journals in the relevant areas and the use of the EU platform for energy efficiency in buildings “BUILD UP” (www.buildup.eu). Here the project submitted its results and deliverables as news, publications, tools and cases. A community “School of the Future” was started that enables discussions and gathers targeted information on energy efficient school buildings with high indoor comfort.

The **training activities** supported the energy saving retrofits by providing the building users (students, teachers/office workers and care-takers) with information on how to correctly use the building and the integrated technologies so that further energy use reduction can be achieved.

1.2.3. Objectives of the project

The objectives of the School of the Future project can be summarised as follows:

- Increasing people's awareness to save energy by exemplary realisations of highly energy efficient retrofit projects of school buildings that lead the way to carbon free approaches with at the same time high performance indoor environment. The success of the retrofits were to be measured by the realisation of the following goals:
    - Reduction of the total energy use > factor 3, verified through monitoring
    - Reduction of the heating energy use > 75 %, verified through monitoring
- Improvement of the indoor environment quality (air, daylight, acoustic, thermal comfort) with impact on the pupils' performance analysed by short-term measurements and questionnaires
- Demonstration that such big energy savings can be achieved with limited additional costs (< 100 €/m²). This shall motivate other actors in the sector to multiply the concepts. The costs were documented in the demonstration building report. Schools of the future can be realised already today.
- Reducing reservations against innovative energy saving retrofit concepts in public building administrations by provision of reliable information, energy saving potentials and costs. The deliverables and the number of downloads are measurable and verifiable.
- Development of national and European benchmarking systems including estimation of potentials for innovative, cost-efficient energy retrofit strategies

1.3. DESCRIPTION OF THE MAIN S&T RESULTS/FOREGROUNDS

The project partners performed the following **work**:

- Development of the energy efficient retrofit concepts with the help of the Advisory Group consisting of the industry and the research partners in the project.
- Detailed planning and realisation of the energy efficient renovations in the four demonstration school buildings

- Documentation of the building design in the design phase report
- Documentation of the construction work in the building diaries
- Evaluation of the planned energy savings and indoor environment improvements by monitoring and questionnaires
- Documentation of the whole process of planning, realisation and evaluation of the demonstration buildings in the final demonstration building report.
- Production of a database of experiences with school retrofit taking into account both energy efficiency and indoor comfort
- Screening of various energy efficient renovation technologies concerning the energy savings, the impact on the indoor comfort, the investment costs and the payback times for different school types and different countries
- Writing, reviewing and publishing the retrofit design guidelines
- Developing the structure, the content and programming of the extended information tool
- Developing the training material and realising the test trainings for care takers, teachers and pupils
- Dissemination of the project, its aim and the already available results on the project website, the project community on EU's portal for energy efficiency in buildings "BUILD UP", at conferences and in technical journals
- Project management and communication with the EU

The **main results** are:

- The key result is the improved energy efficiency defined in the retrofit concepts of the 4 demonstration buildings and the realisation of the renovation on the construction site. The retrofit concepts are presented in detail in the design report available on the website http://www.school-of-the-future.eu/images/files/d61Final140613.pdf. The concepts, the realisation and the monitoring results are documented in the Final Demonstration Building Report available on the website http://www.school-of-the-future.eu/index.php/project-results.

Figure 1: Photos of the 4 demonstration buildings that underwent energy efficient retrofitting within the School of the Future project.

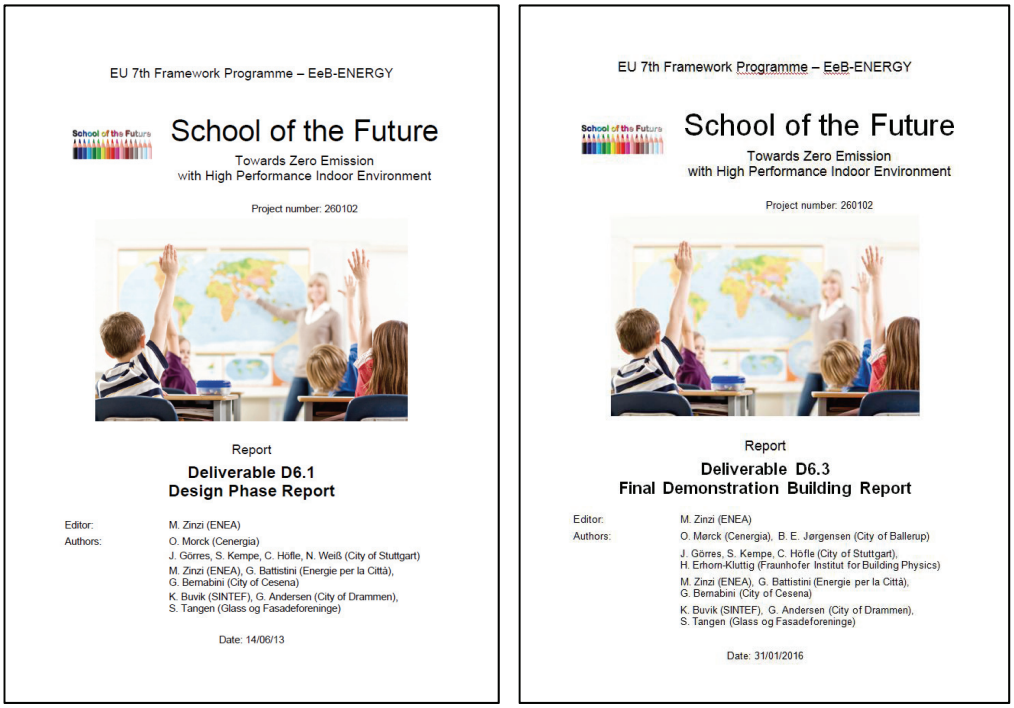
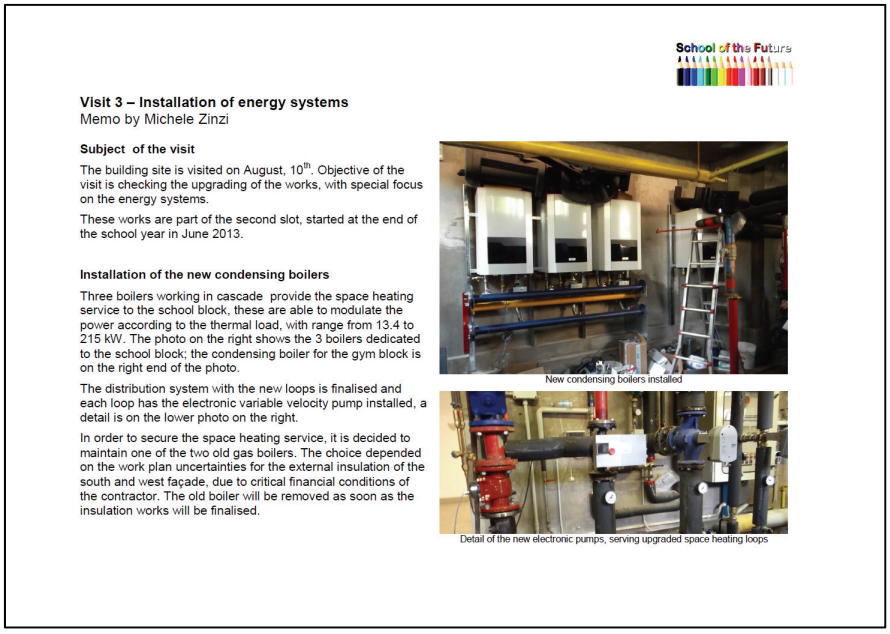


Figure 2: Title pages of the design phase report and the final demonstration building report of the four school buildings.

- The follow-up of the construction work at the 4 school buildings documented in the building diaries that are available on the project website (http://www.school-of-the-future.eu/index.php/project-results/demonstration-buildings)



School of the Future

Visit 3 – Installation of energy systems
Memo by Michele Zinzi

Subject of the visit

The building site is visited on August, 10th. Objective of the visit is checking the upgrading of the works, with special focus on the energy systems.

These works are part of the second slot, started at the end of the school year in June 2013.

Installation of the new condensing boilers

Three boilers working in cascade provide the space heating service to the school block, these are able to modulate the power according to the thermal load, with range from 13.4 to 215 kW. The photo on the right shows the 3 boilers dedicated to the school block; the condensing boiler for the gym block is on the right end of the photo.

The distribution system with the new loops is finalised and each loop has the electronic variable velocity pump installed, a detail is on the lower photo on the right.

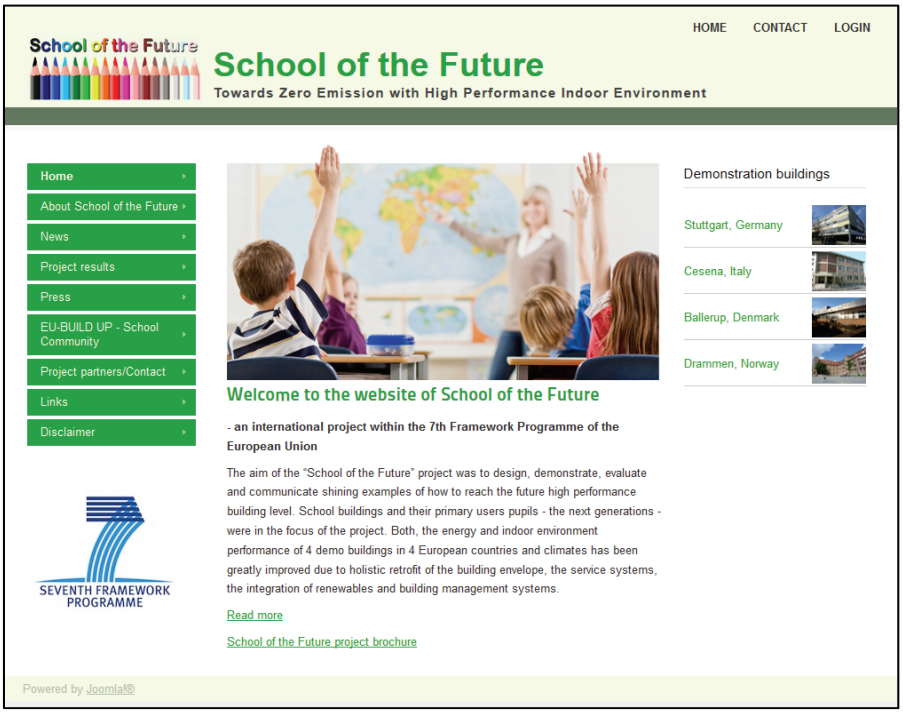
In order to secure the space heating service, it is decided to maintain one of the two old gas boilers. The choice depended on the work plan uncertainties for the external insulation of the south and west façade, due to critical financial conditions of the contractor. The old boiler will be removed as soon as the insulation works will be finalised.

New condensing boilers installed

Detail of the new electronic pumps, serving upgraded space heating loops

Figure 3: Example page of the building diary for the Tito Maccio Plauto school in Cesena, Italy.

- The continuously updated School of the Future website (www.school-of-the-future.eu)



HOME CONTACT LOGIN

School of the Future

Towards Zero Emission with High Performance Indoor Environment

Home
About School of the Future
News
Project results
Press
EU-BUILD UP - School Community
Project partners/Contact
Links
Disclaimer

SEVENTH FRAMEWORK PROGRAMME

Demonstration buildings

Stuttgart, Germany
Cesena, Italy
Ballerup, Denmark
Drammen, Norway

Welcome to the website of School of the Future

- an international project within the 7th Framework Programme of the European Union

The aim of the "School of the Future" project was to design, demonstrate, evaluate and communicate shining examples of how to reach the future high performance building level. School buildings and their primary users pupils - the next generations - were in the focus of the project. Both, the energy and indoor environment performance of 4 demo buildings in 4 European countries and climates has been greatly improved due to holistic retrofit of the building envelope, the service systems, the integration of renewables and building management systems.

Read more

School of the Future project brochure

Powered by Joomla!®

Figure 4: Screenshot of the start page of the project website.

- The School of the Future community on BUILD UP, the EU's portal for energy efficient buildings at http://www.buildup.eu/en/topics/school-future-veryschool, http://www.buildup.eu/node/9234, that is also embedded in the project website.

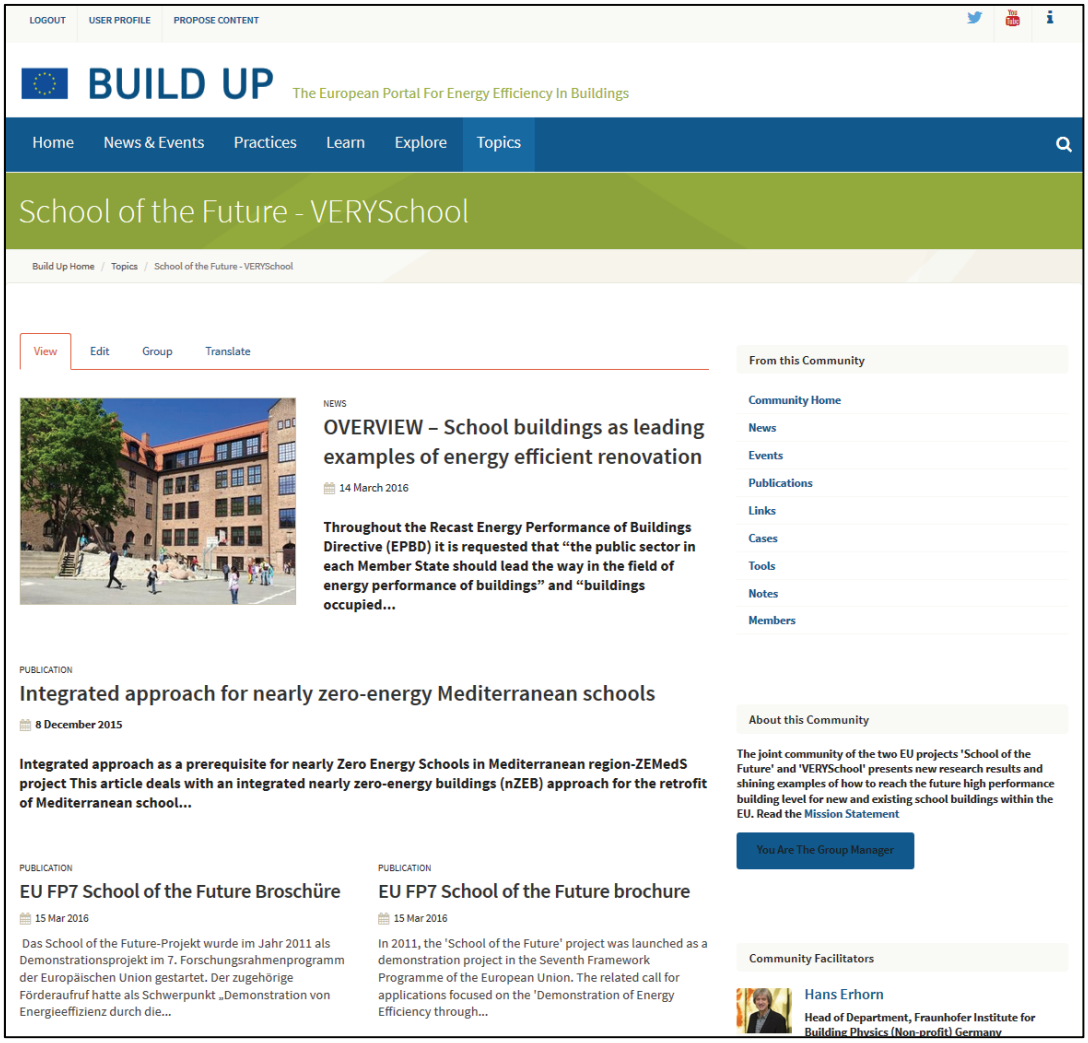


Figure 5: Screenshot of the BUILD UP community School of the Future.

- A report on selected publications and projects about energy efficiency and indoor environment quality available at http://www.school-of-the-future.eu/images/files/sotf_d1.1_report_wp1_report_selected_publications.pdf
- A database of publications and projects about energy efficiency and indoor environment quality available on the project website at http://www.school-of-the-future.eu/index.php/database-about-energy-efficiency-and-indoor-environment-quality

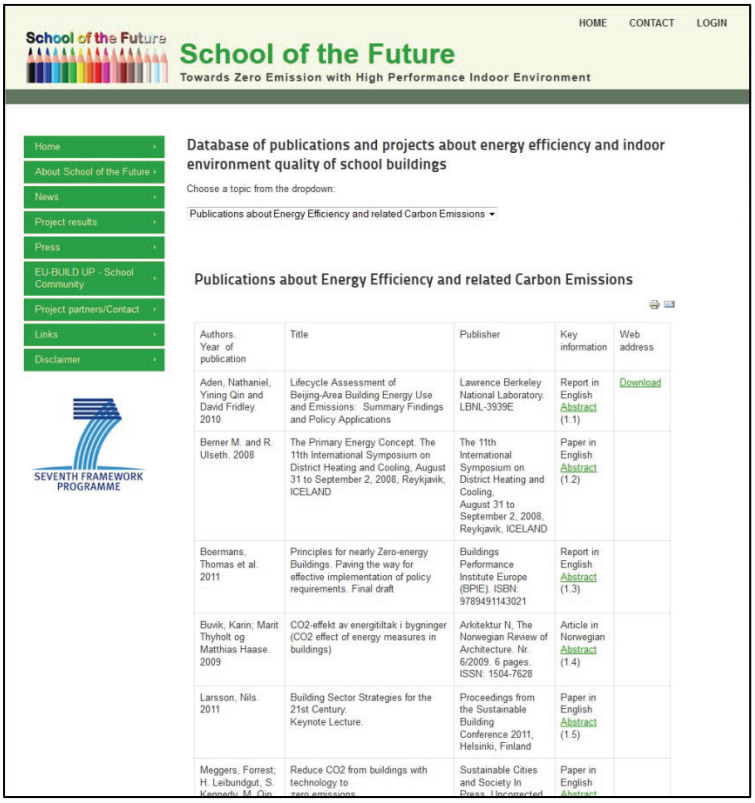


Figure 6: Screenshot of the database of documented experiences of energy efficiency and indoor environment quality available on the project website.

- A report on the assessment of the indoor environment including an occupant questionnaire for complaint discovery and measurement instructions available at http://www.school-of-the-future.eu/images/files/sotf_ad_report_assessment%20of%20indoor%20enviroenvir_.pdf
- Four national reports documenting the results of the screening of energy efficient renovation technologies for school buildings in terms of energy savings, impact on the indoor comfort, investment costs and payback times available at http://www.school-of-the-future.eu/index.php/project-results/technology-screening

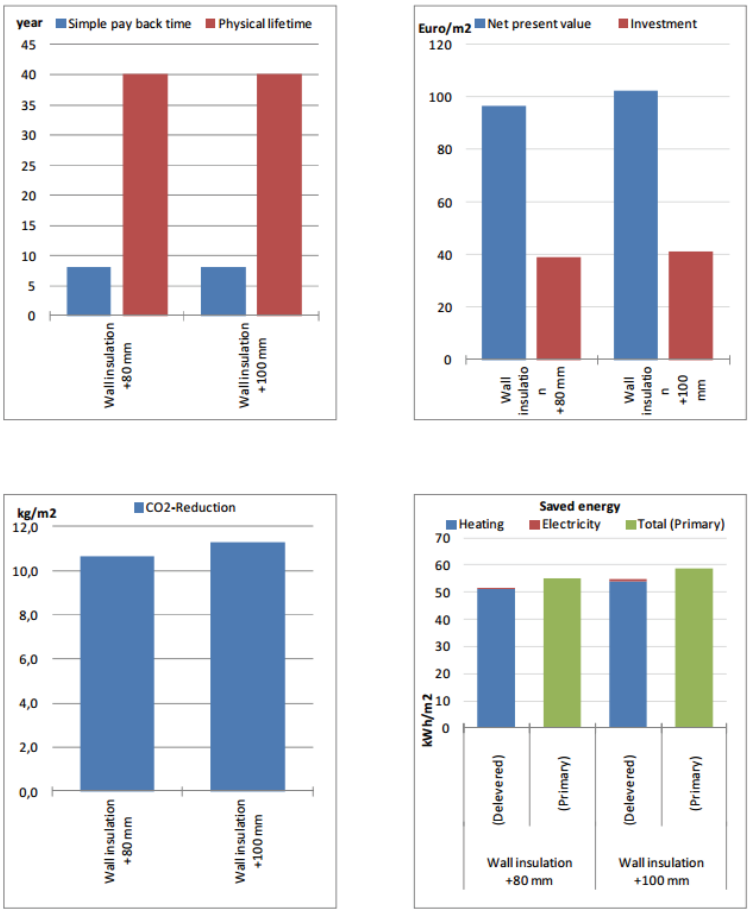


Figure 7: Example of plots resulting from the screening calculations of the impact of additional roof insulation on a side corridor school building in Turin.

- 4 retrofit guidelines for schools buildings on building construction elements, building service systems, improved indoor environment quality and solution sets for zero emission/zero energy schools

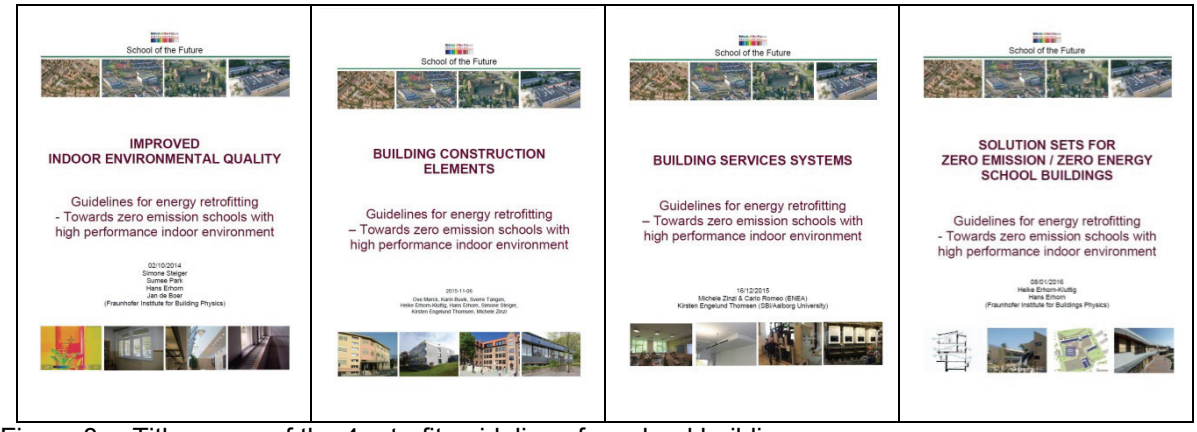


Figure 8: Title pages of the 4 retrofit guidelines for school buildings.

- An extended information tool presenting more than 40 school retrofit case studies, retrofit technologies and offering interactive benchmarking tools for energy uses and indoor comfort

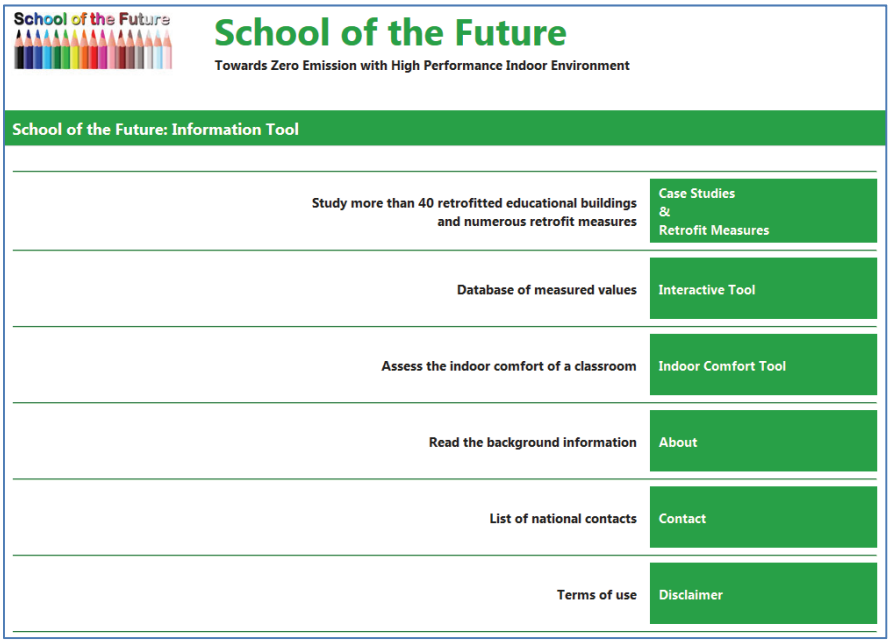


Figure 9: Menu of the School of the Future information tool.

- Training material for care takers, teachers and pupils in 4 languages tested at the demonstration schools

Figure 10: Training session held by Kirsten Engelund Thomsen at the Hedegaard School in Ballerup. The MS Power Point training material is available in 5 languages.

- A simple to use energy assessment tool for school buildings – ASCOT Light . It can be used by pupils in lectures and working groups. It consists of MS Excel spreadsheets including guiding text.

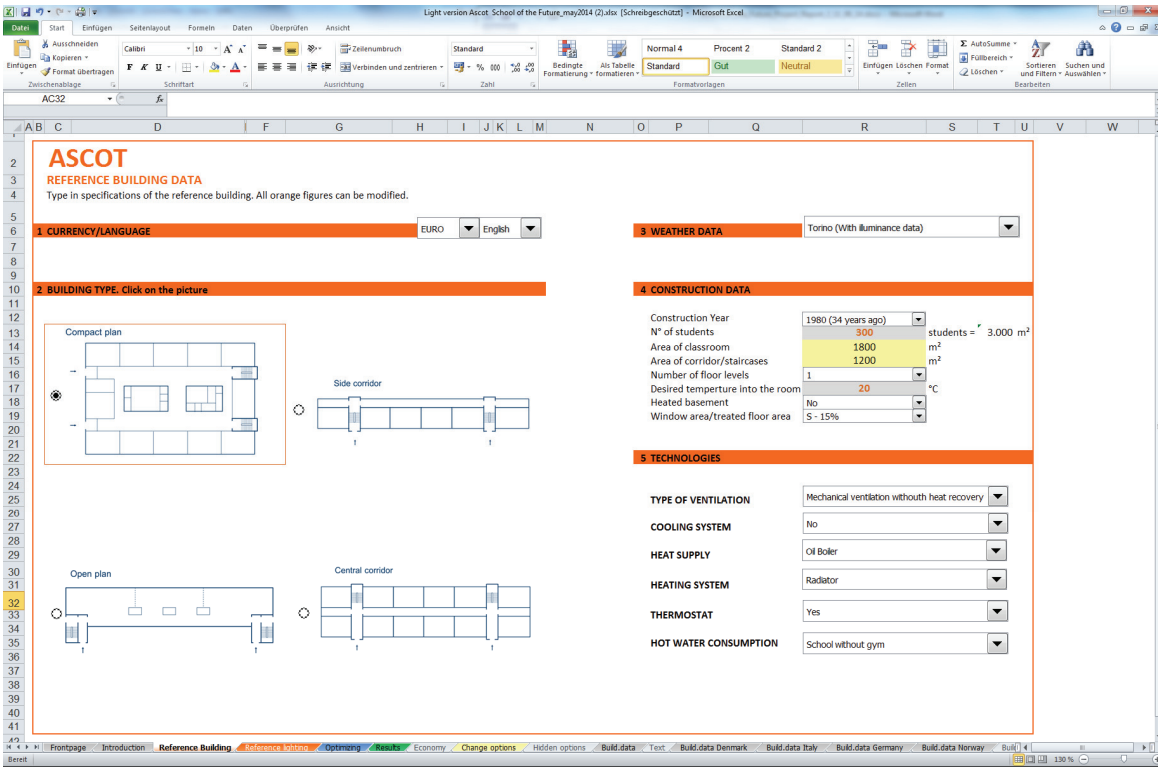


Figure 11: Screenshot of the ASCOT Light tool, here the part reference building data.

- A specific session with 5 presentations and papers on the “School of the Future” project at the IEA SHC conference in Freiburg in September 2013 and a specific session with 6 presentations and papers on the “School of the Future” project at the IBPC conference in Torino in June 2015.
- Multiple project presentations at other conferences
- Various articles about the demonstration buildings and other project results in technical journals
- Various dissemination activities in the industry channels and the dissemination channels of the demonstration partners
- A project brochure available in English and German language

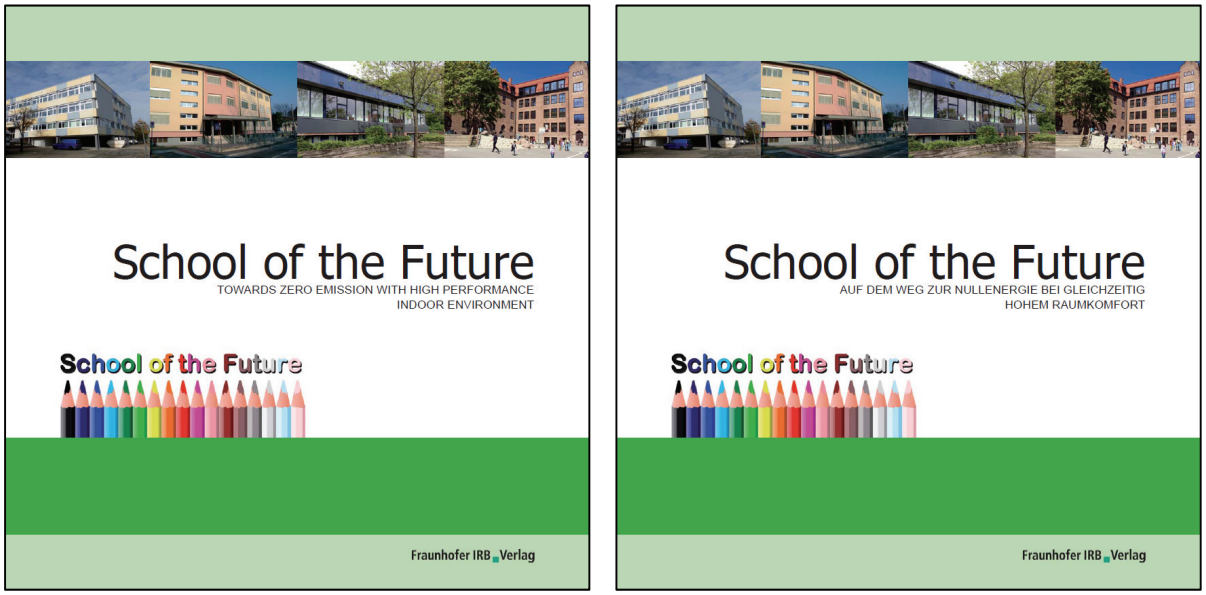


Figure 12: Title pages of the English and German version of the School of the Future brochure.

- Multiple news articles available on the website and submitted to the BUILD UP portal
- An overview article on energy efficient school project written for the BUILD UP portal available at www.buildup.eu/en/news/overview-school-buildings-leading-examples-energy-efficient-renovation-0 and www.buildup.eu/node/48070

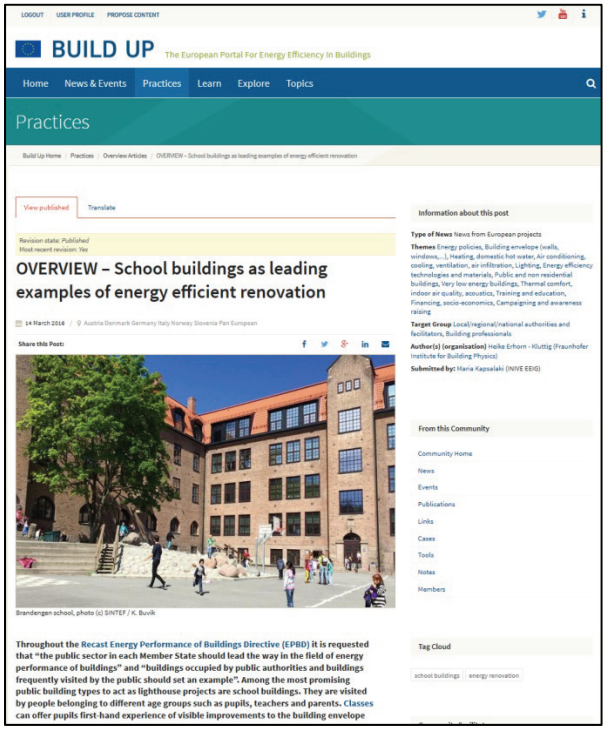


Figure 13: Overview article on energy efficient school projects written by the School of the Future consortium for the EU BUILD UP portal.

- Awards won by the renovation concepts of the school buildings

Figure 14: Photo from the award ceremony of the "Enova Green Gold Conference". Second person from right: Geir Andersen, Drammen Eiendom.

- Contributions to the EeB PPP Project Reviews 2011, 2012 and 2013 available at
  http://www.ectp.org/cws/params/ectp/download_files/36D1813v1_EeB_Project_Review_1.pdf
  and
  http://www.ectp.org/cws/params/ectp/download_files/36D2270v1_EeB_Project_Review_2.pdf
  and
  http://www.ectp.org/cws/params/ectp/download_files/36D2982v1_EeB_Project_Review_3.pdf

All results are available on the project website (www.school-of-the-future.eu)

1.4. POTENTIAL IMPACT

The demonstration projects proved the viability of a number of innovative energy saving and renewable energy supply technologies that are at or are close to a cost-efficiency stage and thereby pave the way for a faster introduction of these technologies into the market and mainstream use. Broadening the market for advanced components and increasing the attractiveness of advanced products for SMEs will lead to lower prices for customers and additional employments in this sector. The whole retrofit process includes 33 of the total 126 handicraft occupational groups (such as bricklayers, chimney constructors, carpenters, roofers, road workers, tilers, thermal, chill and sound insulators, composition floor layers, plasterer, house painters, plumbers, glaziers etc.). This shows the big influence of this and other retrofit projects on the SME sector in Europe.

The project is firmly based on national and international research. The research partners all introduce experiences from long time involvement in national research activities and the project will utilise and further develop products out of IEA ECBCS Annex 36 and Annex 40 and for example the EU 6FP BRITA in PuBs project. The involvement of research partners from 4 European countries and climatic regions of Europe assures the relevance of the project results to these regions. Furthermore it provides the project with access to the most up-to-date knowledge and tools from

these 9 countries. This is further extended by up-to-date knowledge of available industry solutions provided by the involved industry partners. This means that the project constitutes a unique possibility to exploit the combined fund of knowledge and develop this further to the benefit of all the participating countries and to Europe in general.

The partners of the School of the Future project firmly believe that dissemination is the key to the success of demonstration projects – measured as number of replication projects. This is the main reason for choosing public buildings or more specifically school buildings as demonstration projects. Public buildings are often central in the minds of the public in general and the demonstration projects and their successors are very likely to initiate a chain-effect that will result in an exponentially growing number of replication projects within few years.

Calculated on the basis of the number of schools within the city of Stuttgart (232 schools for 602,304 city inhabitants) there are about 196,000 schools in the European Union. A very high ratio of them is in need for renovation. Therefore the possible multiplication factor is huge. Furthermore it is expected that the pupils, that have experienced the renovation work and the positive results on both energy use and indoor comfort and have been trained for a positive user behaviour to support the energy savings and the good indoor environment, will be ambassadors for the benefits of energy efficient renovation also at the homes of their family.

1.5. PROJECT PUBLIC WEBSITE

The project website with all project results is available at www.school-of-the-future.eu.

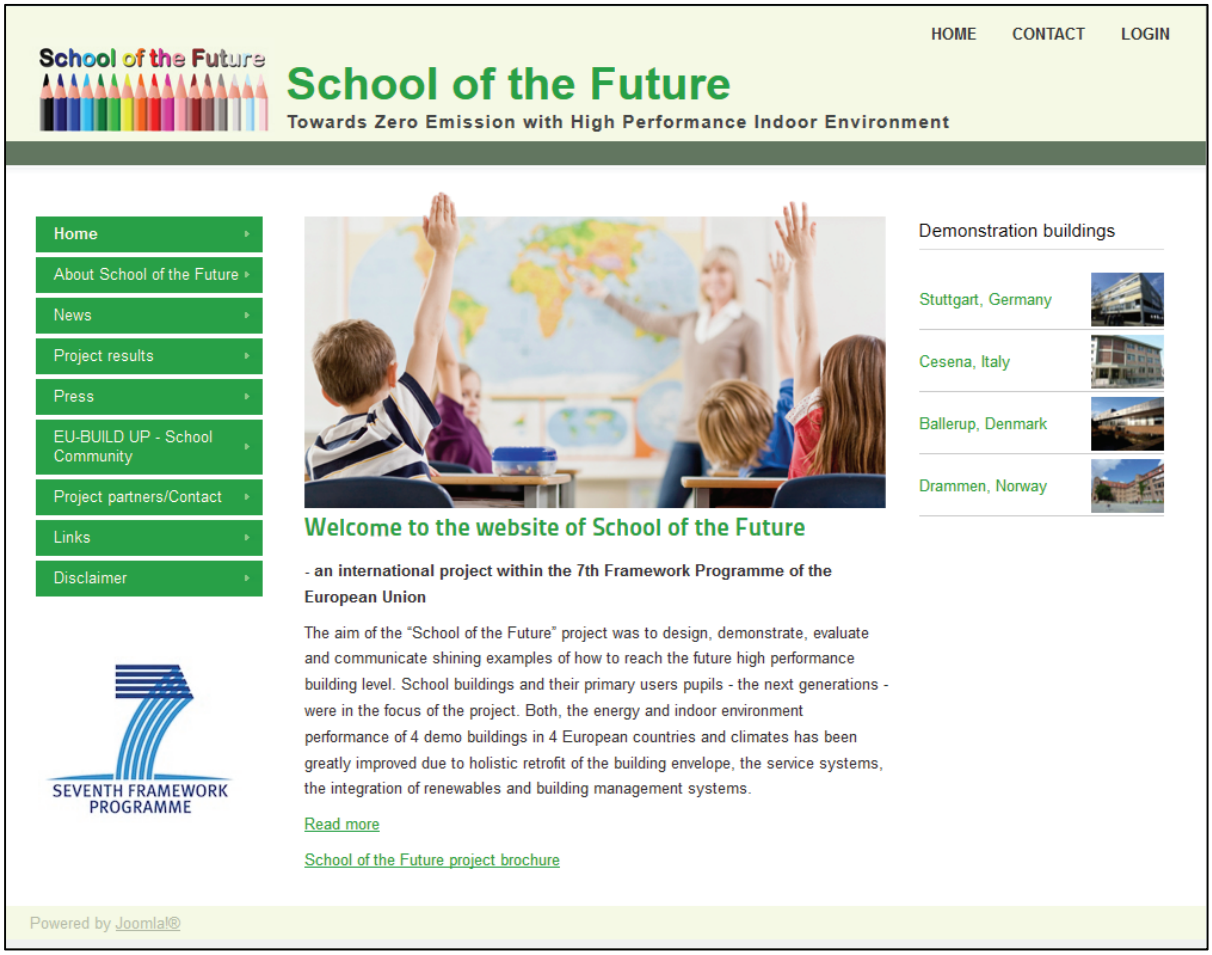


Figure 15: Screenshot of the start page of the project website.

The contact to the coordinator Hans Erhorn at Fraunhofer Institute for Building Physics can be made via sekretariat-wt@ibp.fhg.de.

The project has also managed a community on BUILD UP, the EU website for energy efficient buildings: www.buildup.eu/en/topics/school-future-veryschool

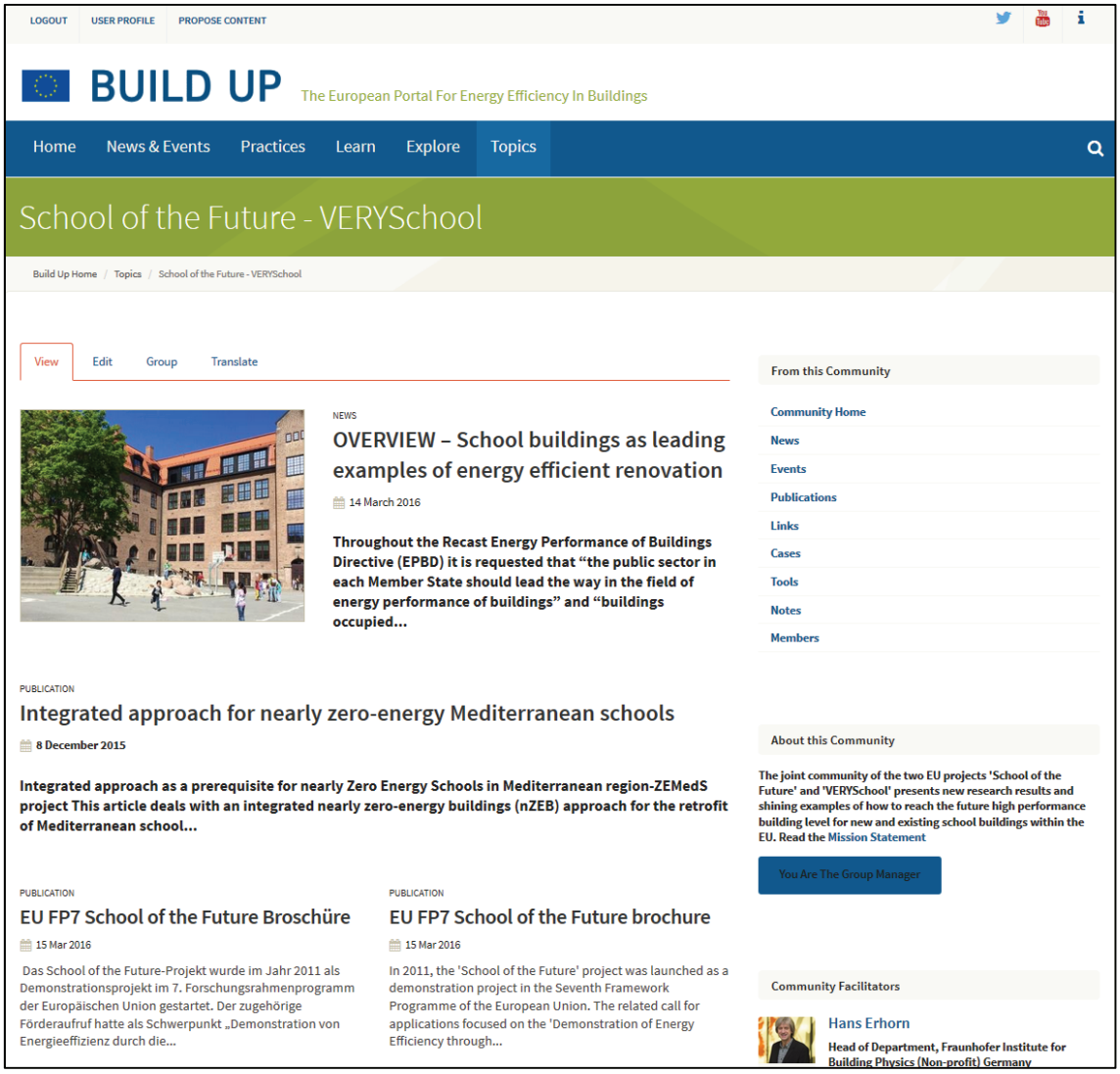


Figure 16: Screenshot of the BUILD UP community School of the Future.

1.6. LIST OF BENEFICIARIES

Partner		Logo	Origin	Type	Contact
01	Fraunhofer Institute for Building Physics	Fraunhofer IBP	Germany	Research, Coordinator	www.ibp.frauhofer.de
02	ENEA	ENEA	Italy	Research	www.enea.it
03	Cenergia Energy Consultants	CENERGIA	Denmark	Consultant	www.cenergia.dk
04	SBi - Danish Building Research Institute, Aalborg University	STATENS BYGGEFORSKNINGSINSTITUT AALBORG UNIVERSITET KØBENHAVN	Denmark	Research	www.aau.dk
05	Stiftelsen SINTEF	SINTEF	Norway	Research	www.sintef.no
06	Landeshauptstadt Stuttgart – City of Stuttgart	LANDES-HAUPTSTADT STUTTGART	Germany	Public Body	www.stuttgart.de
07	Comune di Cesena – City of Cesena		Italy	Public Body	www.comune.cesena.fc.it
08	Municipality of Ballerup	BALLERUP	Denmark	Public Body	www.ballerup.dk
09	City of Stavanger (withdrawn before the start of the project)	-	Norway	Public Body	www.stavanger.kommune.no
10	ALDES spa	aldes	Italy	Industry	www.aldes.it
11	Saint-Gobain Isover a/s	ISOVER	Denmark	Industry	www.isover.dk
12	Glass og Fasade-foreningen - Glass, Glazing and Facade Federation	Glass og Fasadeforeningen	Norway	Industry	www.glassportal.no
13	Schneider Electric Buildings Denmark A/S	Schneider Electric	Denmark	Industry	www.tac.com/dk
14	Drammen Eiendom	DRAMMEN KOMMUNE	Norway	Public Body	www.drammen.kommune.no