ZE+hytte | Norwegian Wood team

Technical Proposal

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sd europe
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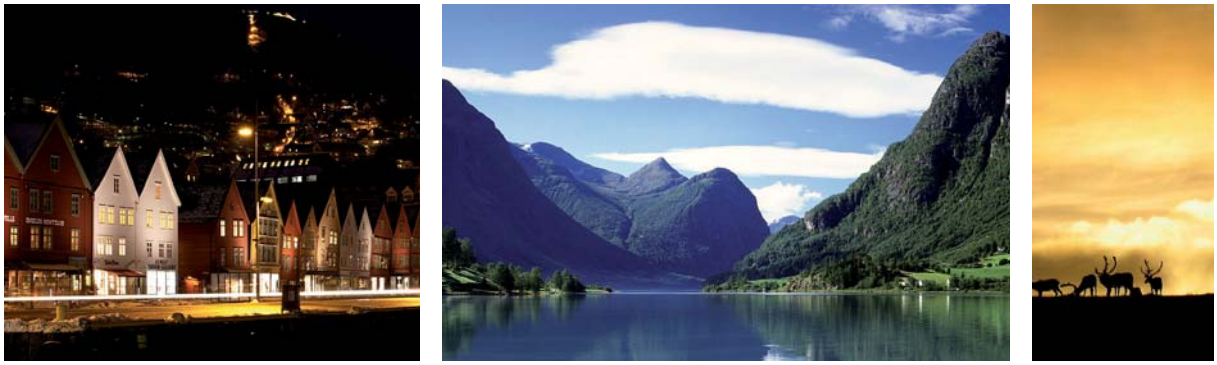

Fig. 1 - *Norway: landscapes*

Fig. 2 - *An old wooden norwegian hytte.*

Fig. 3 - *The ZE+hytte.*

0. INTRODUCTION. Hytta: a salient trait in Norwegian culture.

Norway is a country of outstanding natural beauty, whose fjords and mountains attract millions of tourists every year. Norwegians revere nature and cultivate an active relationship with it. Cabins - or *hytte* (s.) /*hytta* (pl.) in Norwegian - represent for many of them the necessary tool for conducting a life close to pristine nature, outside modernity. Attachment with nature is therefore transmitted into these small houses, where the entire family can "experience an extensive contact with the surroundings" (Thomas Berker). The hytte is far more than a physical structure: it is almost an icon, a salient trait in Norwegian culture.

With unequalled economic growth based on a relatively evenly distributed income from oil and gas, hytta have become more numerous. Nearly half of Norwegians have today regular access to a cabin often located within driving distance from population centres. Also their quality and size increased significantly in the last twenty years. Hytta measure averagely today 65 square meters and can be effectively considered proper second houses frequently used in summer and winter time for leisure purposes: outdoor activities include skiing, hiking, watching wildlife, picking mushrooms and berries, relaxing and sunbathing. "During the last two decades Norwegian cabin tourism has moved from "hard" forms of ecotourism (few, prolonged stays, strong identification with the site) to softer ones (shorter, more frequent stays, commercialization of the site)[…]. This has led to a steady rise of energy consumption and related CO2 emissions in this sector, shifting the desire to live close to nature from a core tenet of Norwegian culture to an unsustainable threat to nature" (T. Berker and H. J. Gansmo). Furthermore, cabins with improved standards demand the extension of grid infrastructures, putting a strain on local ecosystems. Second houses represent therefore today the most dynamic architectural typology in energy statistics in Norway.

Municipalities and developers have just recently discovered the green potential of more coordinated and denser forms of developments, resembling the image of villages but still trying to accommodate the existing desire to find untouched nature at the cabin. A significant majority feels anyway that the municipality needs to be restrictive and critical when they consider expansion or concentration of second houses areas, both for environmental and social reasons. These people would prefer minimal changes over the next years in infrastructure, extent, accessibility, amount of use, people in the area, etc. The clear preference for no, or small changes, can also be an expression of the desire to keep life at the second home as a predictable and stabilizing factor in an otherwise dynamic existence. Holidays at the hytte are still seen as a return to a pre-modern state of peace in a close relation to nature where any symbol of stress should be removed or minimized. The introduction of new technologies however only apparently contrasts this philosophy. There is a wide margin of action in stressing the use of advanced technologies in coherence with this philosohpy. The ZE+hytte - a small technologically advanced cabin offering a modern concept of living - is indipendent from the grid thanks to the use of natural resources, strengthening the desired feelings of distance from modern society and symbiosis with nature. The surplus of energy produced by the PV integrated systems will permit the use of a cable car and solve mobility issues – due to more frequent visits - and other problematics related to second houses.

0.1 NTNU, the ZEB centre and the development of the ZE+hytte.

Research is a driving force behind the advancement of Norwegian society and is vital to promote scientific development towards sustainability. Renewable energies and energy efficiency represent two of the seven national priorities individuated by the Norwegian research council that established a scheme for eight national centres for environment friendly energy research. NTNU hosts today one of them: ZEB - Zero Emissions Buildings - built on 30 years of interdisciplinary cooperation at NTNU and relying on a budget of 38 millions Euros until 2016. The Solar Decathlon competition was included as a key innovation project when the ZEB centre was founded in 2009. Highly motivated master students and faculty leaders have today initiated an integrated design process aiming at developing a prototype of an energy positive hytte able to solve energy issues of second houses, today representing the most active typology in energy statistics. The development of the ZE+hytte, fundamental step towards a zero emission environment, has been totally integrated with the MSc calendar on sustainable architecture. Three peer reviews, involving external professionals and researches, have been organized during the 8 weeks of development of the concept. Students gained awareness of ongoing researches and a first understanding of future challenges.

SDE represents a unique opportunity for the ZEB centre; the ZE+hytte will become a shared platform for strengthening internal relations and implementing the external ones. Once back from Madrid the ZE+hytte will become a Living Lab for action research on technology and lifestyles in co-operation with private industries and public institutions. Research proposals will be forwarded in the meantime to the Research Council and other institutions in the next months in order to implement co-operation with industries and support the development of the project. In the Klimax frokost, a dissemination event monthly organized by NTNU involving external professionals, the SD module will be focus of debates increasing awareness about sustainability. On the other hand ZEB represents an opportunity for Solar Decathlon. ZEB, together with SINTEF, is the biggest scandinavian research centre on embodied emissions and energy efficiency. “Grønne Trøndelag”, in co-operation with South-Trøndelag County Authority, is promoting Sør-Trøndelag as the greenest region in Europe and will significantly contribute in supporting and promoting the event. With the municipality of Trondheim, we are already discussing the possibility of locating the module inside the Brøset site, a new housing development with a marked environment friendly identity. In the Technoport exhibition, that will be held in Trondheim in 2012, the module will become an exhibition pavilion of advanced technologies developed at NTNU and ZEB.

1. TECHNICAL INNOVATION AND DESIGN

In 2007 Abram noted that Norwegians often assume a strong moralistic authority when talking about what hytta are and what they should or should not be. This narrative describes hytta as simple, family owned wooden cabins characterized by a “charming rusticity” and without connection to public utilities. Detachment from the grid, as distance from modernity, and symbiosis with nature are two musts of the hytte philosophy. In the ZE+hytte symbiosys with nature is implemented through the maximum of use of natural resources. Detachment from the grid is made possible by the extra energy produced by BIPV. A challenge exists to enhance, on the basis of the last years development, the boundaries and the levels of performance and integration of solar cells technologies in the design of a hytta able to reduce the distance between research and market. The ZE+hytte, developed in the first 2 months of the MSc in Sustainable Architecture at the Department of Architectural Design, History and Technology of NTNU,

Fig. 4 - *ZE+hytte can be attached to existing buildings and compensate their energy efficiency lacks.*

coherently with the SD rules and regulations, aims to be:

- Flexible - able to satisfy different functional requirements varying its spatial configuration.
- Easily assembled and disassembled - Modularity of the construction system should solve transport issues.
- Energy positive - able to reduce its thermal demand through the use of passive strategies optimizing the environmental behaviour of the prototype. Maximizing PV energy production and minimizing the energy demand of the internal apparatus through the use of energy efficient equipment.

In agreement with the philosophy of the ZEB centre the ZE+hytte will represent:

- A step towards a zero emission built environment - controlled embodied emissions.
- Market ready - A detached hytte in symbiosis with nature reflects the desire of most of Norwegians.
- Elastic - Possibility of altering the external perimeter through aggregations or modifications of the module in order to obtain bigger blocks or settlements. The ZE+hytte can be also attacheed to "detached wooden houses"(Fig. 4), representing the most energy thirsty architectural typology in Norway (fig.10) and compensate energy efficiency lacks of the existing building stock.

The prototype has been developed with great enthusiasm and a positive competitiveness among the different groups of students, including both architects and engineers. Each concept presented a markedly different character and solved the issues arisen in the call for proposal in a different way. Groups recurred to different tools and methodologies according to their abilities and background. Choosing one out of the four proposals was a hard task. Priority was given not only to the excellence of the design but also to the potential of the prototype for future development within the next eighteen months. Once chosen, the selected concept has been implemented by a smaller group of students in one week of intensive work where ideas coming from other concepts were, when possible and convenient, integrated. The resulting prototype was finally discussed again with all the students, which could recognise the project as representative of the whole course. We believe that this feeling of attachment will be positive for the future development of the prototype involving all the students again.

1.1. The ZE+hytte concept: environmental sensitivity and flexibility.

On the base of researches previously conducted at NTNU and ZEB a high grade of uncertainty related to climate change and the development of new components and materials is today questioning traditional assumptions around bioclimatic design in cold climatic contexts and giving space to new architectural scenarios in such contexts. Passive strategies once peculiar of warmer climatic zones are now extending their geographic boundaries of applicability to our context. This is leading architectural design of energy efficient building into a new complexity. In-between spaces, a fundamental tool for environmental control and efficiency of the architectural form, are now becoming more and more important. In the ZE+hytte environmental sensitivity of form is maximized through an extremely simple but efficient flexible plan, sorrounded by a living buffer space. The designed modules can assume markedly different spatial configurations. The buffer spaces included between the outer layer and the living space will be able to assume different environmental behaviours according to different external environment conditions. This variety of possible circumstances will permit also to test in the next eighteen months a wide range of systems. On the base of a complex system of sensors, disposed both inside and outside of the house, the buffer space will expand or draw back itself and create a living breathing interior space in symbiosis with the external environment. The contribution of the buffer space can be occasionally cancelled through a system of valves included in the outer

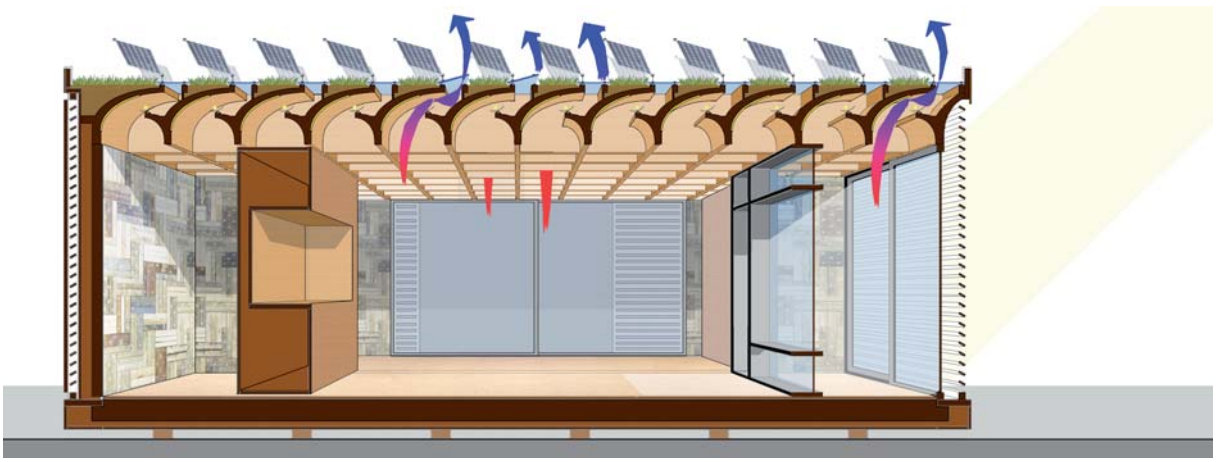

Fig. 5 - *Section of the ZE+hytte: permeability of the roof, buffer spaces and solar protection.*

layer. The roof, conceived as a grid of valves and integrating both low and high tech materials, will act as a permeable skin and will adapt its environmental behaviour to the movements of the plan. The ZE+hytte is able to take advantage of different external resources maximizing natural ventilation possibilities through the compact volume and following the sun through advanced technology. The ZE+hytte will benefit from the sun in all possible ways: daylighting, passive systems, microclimate generation, maintenance, and food production. Passive strategies efficiency will be implemented when required with integrated active systems.

1.2. Architectural components and materials: engineering and innovation

The ZE+hytte will be mostly constituted of Norwegian wood, traditionally representing the most important locally available building material. The construction system of the architectural components constituting the ZE+hytte is characterized by a strong duality: the geometry of the roof module will be rather complex and will be controlled through advanced digital modeling. On the other hand all the vertical partitions will be rather simple and characterized by a rather "low-tech" nature. The use of the massive wood "Klimablokka" (Fig. 7 and 17) made of cross-laid boards fastened by wooden dowels - developed in the department of Product design by Anne Sigrid - will be evaluated. This material is based on the reuse of reclaimed wood coming from demolished projects, which would otherwise be shredded and burned. Wood is collected and reclaimed directly from companies' storage yards. The Klimablokka production is kept at a low or medium level of complexity in order to keep it as a labour- and cost-efficient building system. Blocks are suitable for self-building thanks to low weight, simplicity and safety of assembly. Walls will be constituted of one layer of blocks sufficient for the structural requirements of the ZE+hytte. An extra layer of insulation will be added for improving thermal performance. External cladding will be durable, low maintenance, relatively low cost and resistant to snow, ice and rain. External deck around the house will be designed in order to maximize potential use of natural resources: rainwater will be collected through a drain system, stored in a cistern disposed in the void beneath the house and then used for organic growth. The void beneath the ZE+hytte will also provide space for the batteries deck and the water supply system.

The outer layer of the roof will not only be devout to energy production but will also be responsible of filtering and diffusing the solar radiation both for thermal and luminous comfort. With the movable insulation skin closed the performance of the roof will be fundamental for the environmental behaviour of the SD module. The PV leafs and the ventilations valves disposed on the roof will be characterized by high flexibility of angle in order to maximize energy production and sensitivity of form to different external conditions. The inner layer of the roof will be on the other hand highly insulated, minimizing summer heat gain and preventing heat island effects thanks to the use of a thin layer of vacuum insulation panels. Integration of advanced phase changing materials in the inner layer of the roof will be investigated in order to stabilize temperature fluctuations inside the living space. Windows will be constituted by a triple glass respecting national regulations in force TEK10. Energate, German company with office today also in Norway, has just recently developed a new window with extremely low U-value=0,3 and has already offered its support to NTNU for the development of the ZE+hytte.

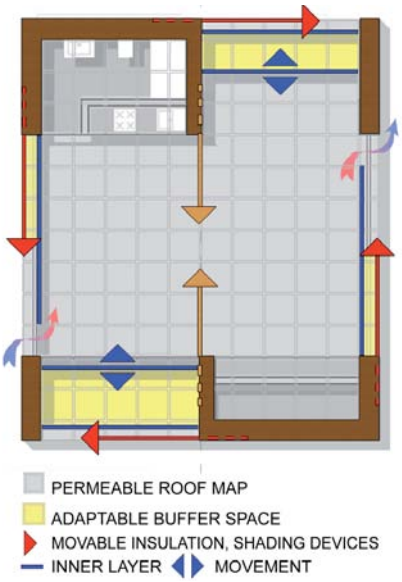

Fig. 6 - *Environm. adaptability of the plan*

Fig. 7 - *Interior of the ZE+hytta with the Klimablokka on the left wall.*

1.3 Integrated energy systems

We estimate the energy usage for a two people home to be, on average, 10-12 KWh/day. According to PVGIS - photovoltaic geographical information system developed by the EU community - PV panels are expected to produce 2.06 KWh per year of electrical energy (value per squared meter calculated for Trondheim - in Madrid 3.60 KWh/y*m2). Electrical efficiency of adopted photovoltaics is of 125 Wp/m2 and 1.2 GJ/m2yr. We need therefore a minimum of 6 m2 panels and sufficient battery storage to meet the electricity demand of the house. It is expected that the 64 m2 solar array of PV panels (together with the EPDM membrane eventually integrated in the solar shading device) will make the ZE+hytte a energy positive producer over the course of the year. A variety of solar technologies will be assessed during the design process for performance and cost effectiveness, and implemented in the project realization. ZE+hytte will take advantage of ongoing research in the field of photovoltaics at the institute for energy technology actually testing and developing solar cells based on chystalline silicon. The IFE is provided of different laboratories equipped with a dedicated line for producing silicon-based solar cells and characterization equipment for measuring all kind of structural, electrical and optical properties.

Different efficient HVAC systems, easy to install, commission and monitor, providing a wide range of functions will be tested. Prefabricated floor concrete slabs thermally activated through a reverse hydronic system - for both heating and cooling requirements - will be tested. The in-floor system functioning will be intimately related to a integrated heat-recovery system using exhasted air and grey water. Efficiency of the heat exchanger located in mechanicalservice box will reduce the demand for electricity and maximize advantages deriving from the use of external resources. Efficient lighting systems will be also adopted in order to minimize energy loads; its functioning will be connected to the system of sensors guaranteeing sufficient lighting for different purposes. Roof and walls will act as permeable skins able to react to impulses sent by sensors distributed both inside and outside the hytte, maximizing lumious and thermal comfort even in adverse climatic conditions.

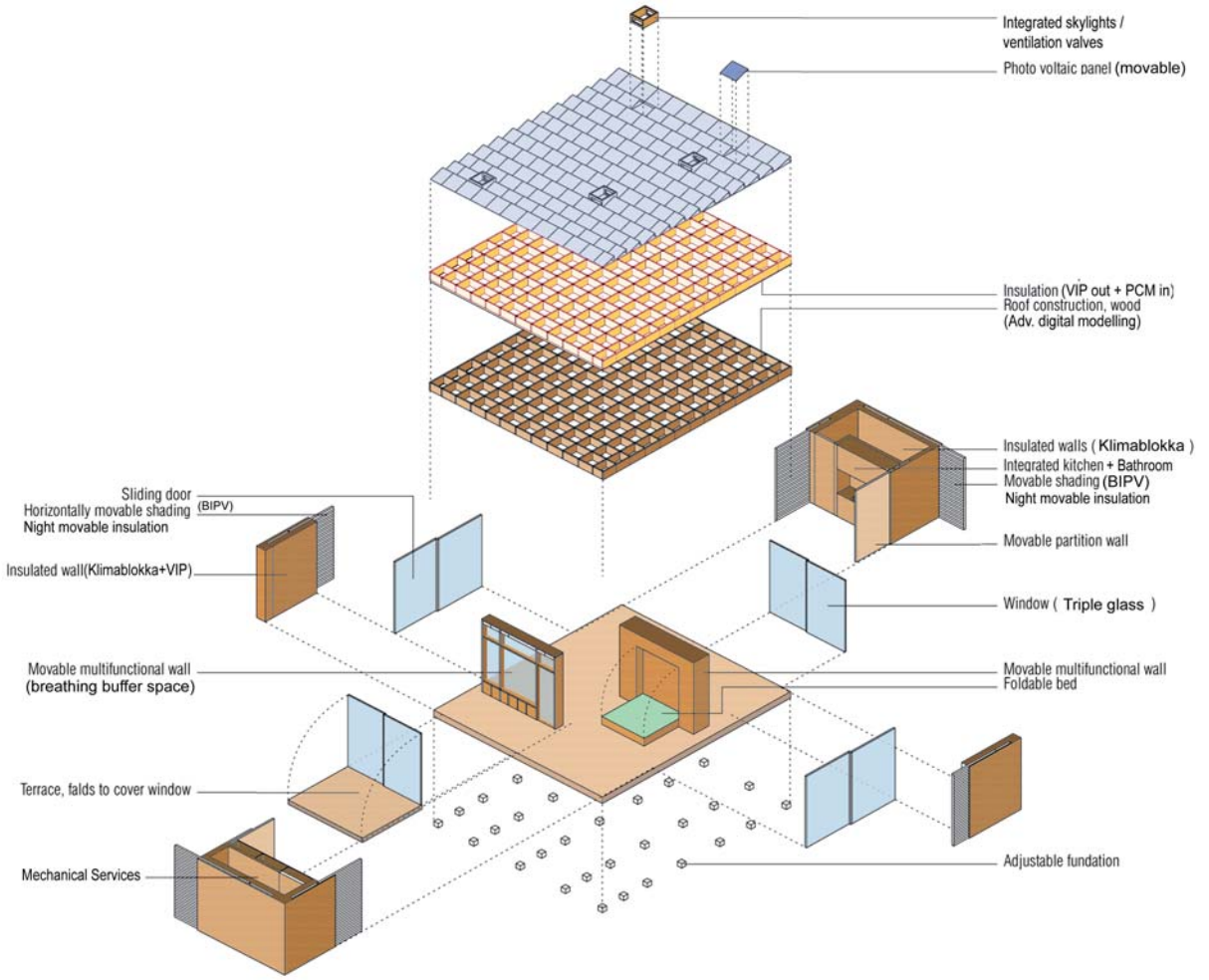

Fig. 8 - *Architectural components constituting the ZE+hytte.*

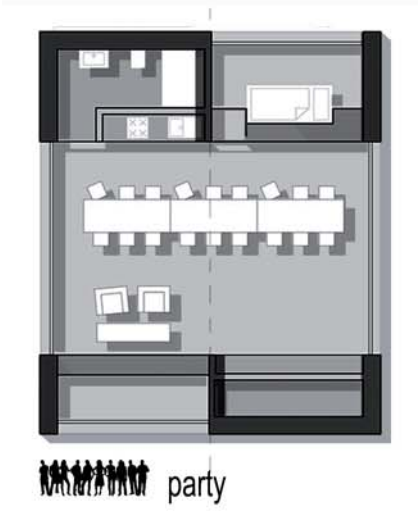

Fig. 9 - *Internal flexibility*

1.4 Industrialization, manufacturing and prototyping.

Detailing of all the architectural component constituting the ZE+hytte has been based on a modular system of dimensions that will facilitate the operations of assembly, disassembly and transport. Emphasis will be placed in the next months on the minimization of weight through the use of advanced materials able to ensure anyway best thermal performance like PCM or VIP. Students will be responsible of digital modelling of all the architectural components on the base of the results of experiments and analyses conducted by expert researchers and professionals. Pasi Aalto is today assistane professor at the digital fabrication Lab at NTNU and will cooperate in modelling the wooden structure that will require a more complex production process due to its geometry.

1.5 Internal flexibility and elasticity

A hytte is not something personal, it is an object you share with your dears and friends, each of whom can have a different way of experiencing and living inside it. Flexibility is therefore a fundamental requirement: the plan of the ZE+hytte will be able to accommodate very different situations. Inside the extremely compact footprint, able to minimize the outer surface of the skin, (almost a square of 8,4 meters of side with a footprint area<75m2) the plan of the SD module is conceived as a living organism able to assume different configurations in extremely short time. As mentioned above flexibility of the plan is conceived to enhance environmental sensitivity of the prototype. The intermediate space included between the two external layers will be able to assume different physical configurations and environmental behaviours according to the exterior conditions. The living space can expand its boundaries to the outer layer able to breath either reduce itself into an extremely compact and highly insulated volume (conditioned space will anyway measure more than the required 42 square meters).

Hierarchization of architectural components was fundamental in the development of the concept in order to enhance flexibility. The two horizontal slabs, floor and roof, represent the only timeless primary elements within the project; they are characterized by a high degree of abstraction creating an isotropic functional space in between. Everything included between them can be moved and easily arrenged in a different position. The location of the two service boxes in two opposite corner of the plan was strategic to solve technical issues like integration of the outer movable skin (for shading and insulation), but also enhance indeterminacy of the orientation and environmental adaptabity of the prototype.

1.6 Users involvement and awareness

The inner layer of the ZE+hytte, facing the living space, is conceived as an extended interface between the user and the exterior, between Nowegians and nature. It is through this layer that users acquire awareness of the potential of the integrated building systems in using external resources. A system of sensors displaced inside and outside the module will provide diagnostics of thermal demand, performance and desired correction and monitor all the architectural components. Integrated systems filtering the access of solar radiation and air, like shading devices and roof valves, will respond both to automatic and user-driven controls. Private Norwegian companies provide already today remote control of the heating system of hytta through the mobile phone. Such service will be

implemented into a more complex control systems able to ensure simultaneous control of all the integrated passive and active systems. Some of these companies might be interested in supporting NTNU in the development of such system. The department of Product Design has already developed a user friendly interface aiding decision making about energy use choices by providing visualization of energy use in context; this interface will be used as base for further development under the guidance of the same department in collaboration with ZEB work package 4.

1.7 Market viability of the prototype

Second houses represent more than 10% of the Norwegian building stock and the most dynamic sector in energy consumption statistics. These numbers already give an idea of the potential of developing a market ready ZE+hytte. It is infact becoming more and more common to convert old cabin once detached from the grid into second houses. Once attached to the grid such buildings become energy thirsty structures: big use of photovoltaic is already registered in such projects. Indipendence from the grid as detachment from modern society and simbiosys with nature reflect the desire of most Norwegians. The design of the ZE+hytte will spontaneously generate a lot of interest around it. Recent researches proofed also that the second house issues recurs with similar characteristics not only in other scandinavian countries but also in spevific geographic zones of mid Europe countries. Further research will evaluate in the next months the commercial viability of the ZE+hytte in such geographic contexts.

The ZE+hytte can also be used for expanding existing detached houses. Such buildings represent, due to their high number, the most energy consuming typology in Norway (fig.10). Extensions of detached houses below 50 square meters don't require any official permission. Both the two modules constituting the ZE+hytte measure 37 square meters and can be adopted for such use. With their positive energy production they will compensate energy efficiency lacks of the existing building stock. People would be interested in buying one or more modules for improving the environmental performance of their house and save money in a not long term.

1.8 Scientific technical analysis of the proposed design

Different preliminary evaluations have been run in order to estimate the environmental behaviour of the structure and the sensitivity of the model under different external conditions. Specific characteristics of architectural components have been in the first analyses fixed in accordance with the Norwegian regulations in force TEK10 assumed as a starting point (see appendices at page 20). Possibility of adopting new technologies and materials today under development in the different departments and research centres involved in the development of the ZE+hytte will be investigated. Initial energy modelling (using Simien - a simulation software developed in Norway and commonly used in research - and TRNSYS) of the conceptual model has indicated an optimal environmental behaviour of the house, with extremely low energy demand both for heating and cooling. Different climate analysis have been developed by the students during the conceptual design for defining the proper passive strategies and for detailing the models. Digital modelling will be in the future supported by the information flow coming from simulation tools of different nature handled by SINTEF expert energy modellers able to provide an accurate prediction of environmental performance. Architectural design is therefore converted into a multidisciplinary meaningful process towards a zero emission built environment. Students will co-operate with engineering students in the Integrated Energy design course at the climate engineering department, under the guidance of professors Matthias Haase and Hans Martin Mathiesen.

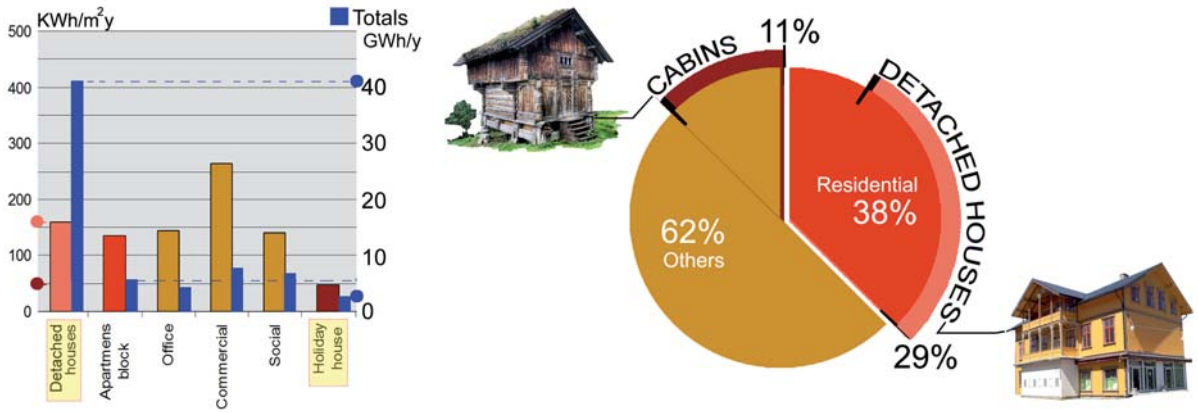

Fig. 10 - *Energy consumption. Cabins and detached houses represent 40% of the total Norwegian building stock.*

1.9 Norwegian codes compliance and environmental standards towards ZEB.

The ZE+hytte will be designed in order to meet Norwegian standards for usability, safety and performance. Architects, engineers and professionals of construction, involved in the prototyping process, will be responsible for the safety planning during assembly and disassembly phases (Assist. Prof. Per Monsen is main architect at GASA in Oslo). Universal design and the respect of national standards and requirements will be essential for market viability and asking the financial support of public and private companies. Compensating CO2 emissions producing more energy then demanded is one of the main focus for the ZEB centre. The ZE+hytte is not intedend to reach "zero emission" standard but will work as a living LAB for individuating key issues and problematic of the second houses sector. The team will evaluate embodied energy of materials and measure the impact of design decisions in financial and pollution terms. LCC and LCA will become necessary design tools influencing the design process. CO2 emissions coming from building operation and material use will be calculated on an annual and lifetime basis (60 years) using a simple, accurate method currently being developed by PhD Aoife Houlihan Wiberg in her post doctoral research. These emissions will also be compared with those calculated using a Norwegian green house gas accounting tool, Klimagassreneskap.no, created by Civitas and Stattsbygg and developed with ZEB.

2. FUND RAISING AND TEAM SUPPORT

The expected budget for the construction of the ZE+hytte is of almost 700000 € (table 1), excluding consultancy, travelling etc. and 1.1 million including the rest. The team is therefore committed to raise approximately 1 million euros beyond the 100000 Euros received from the SDE organization. The fundraising strategy for the support of the ZE+hytte development is built on the base of existing efficient structures of connections aiming at stimulating the interest of both private sources and public institutions at different political levels. The design process until June 2011 – coinciding with the second phase of the SD time schedule - will be supported by small scale funding coming from the SB centre - located inside NTNU - and the Research Council. NTNU will in the meantime provide space for the design and computers for digital modeling. Research centres involved will provide numerous facilities and labs. For financial support and fundraising NTNU can rely on the technical support of the following associations:

- The Norwegian Research Council - NFR - is Norway's official advisory body for the development and implementation of national research strategy and also works actively to encourage international research cooperation. The Research Council identifies research needs and recommends national priorities facilitating the translation of national research policy objectives into action. Renergy is a research programme recently established; it individuates energy efficiency and use of reneweable energy as prior interest for further research.
- Green Trøndelag is partner for Nyskaping and the Sør-Trøndelag Fylkeskommune and is a key-organ for getting fund from Innovasjon Midt-Norge. This last organization works to increase the competitiveness of Norwegian industry in the mid region, and stimulating innovation within this field, enhancing collaboration within and between industry groups, and between industry and research institutions.
- The Husbanken (Norwegian State Housing Bank - NSHB) is the main agency implementing Norwegian housing policy supporting private lenders in financing new homes and contrasting homelessness. The NSHB works closely with local authorities and the private sector to improve the quality of housing on a market mainly dominated by direct and indirect (co-operative) home ownership (77%). Particular weight is given to the promotion of universal

DIRECT MATERIALS		
ROOF PROTOTYPING - CUSTOM MACHINE COMPONENTS		24000
MASSIVE WOOD for structural walls / KLIMABLOCK		6000
OPENINGS		38000
METALS		18000
THERMAL AND MOISTURE PROTECTION		36000
FINISHES		6000
ELECTRICAL POWER GENERATION AND BATTERY DECK		60000
FLOOR PREFAB CONCRETE SLABS, INSULATION AND FINISHES		24000
SOLAR PV		75000
PURCHASED EQUIPMENTS (washing machine, kitchen, etc...)		24000
HVAC system		20000
PLUMBING		12400
ELECTRICAL		12000
SOLAR SHADING DEVICES, integrated PV		40000
FURNISHINGS		12000
DECK AND LANSCAPE MATERIAL		10000
FOUNDATION		4000
VAT 16%		84280.0
TOTAL DIRECT MATERIALS		505680.0
MATERIAL OVERHEAD		
	% ESTIMATED RATE *TOTAL DIRECT COSTS	
FABRICATION	10 %	50568
CONSTRUCTION	15 %	75852
VAT 16%		20227.2
TOTAL MATERIAL OVERHEAD		146647.2

Fig. 11 - *Extract from the price list*

Fig. 12 - *Interior view*

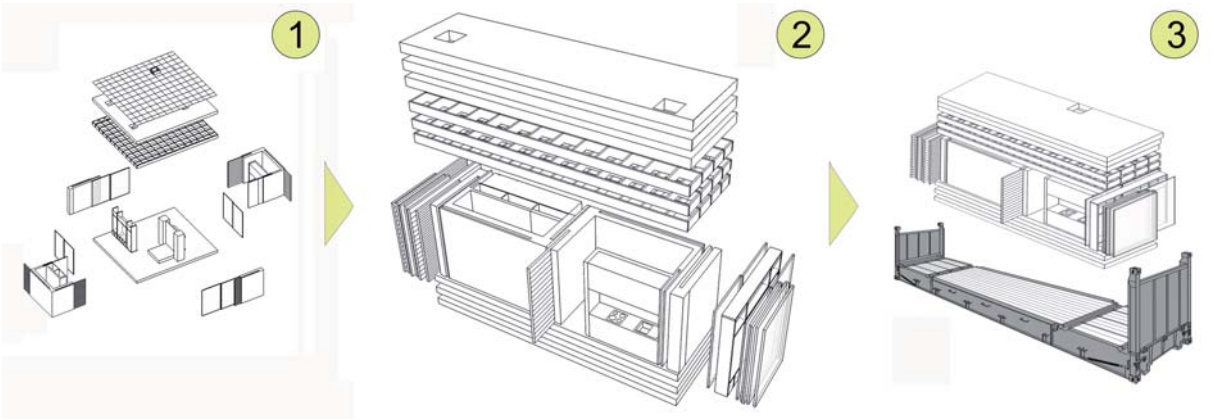

Fig. 13 - *Disassemble of the modules and transport*

design, aesthetics and environmentally friendly solutions in the building sectors and in design. After five years of co-operation with our MSc courses on energy- and environment-friendly architectural design (including international student competition with Chalmers in Sweden) the HusBanken is interested in supporting new projects and is going to open in June for funding for competency development. The SD that will be most likely located in the Brøset - where Hubanken already cooperate - will be inserted in a call for funding that will be forwarded to NSHB.

The project management board responsible for the development of the project is currently trying to concretize the support of organizations that showed already a strong interest in the project. The request for funding will be augmented through new research projects and grant applications aiming at attracting the interest of private industries and research centres. Maersk-Line showed also interest in supporting the ZE+hytte contributing to the transport of the modules. This company was - together with others - a founding member of a recently launched "shifting towards sustainability" program, aiming at bringing "together shippers, customers, financial consultants and NGOs with the aim of shifting shipping towards greater sustainability and profitability".

2.1. The ZEB centre: organization and available facilities

The research centre on Zero Emission Buildings (ZEB) is one of the eight national Centres for Environment friendly Energy Research (FME), and has been built on 30 years of research expertise and collaborations conducted in the NTNU University of Trondheim. FME include, among the others, the Centre for Environmental Design of Renewable Energy (hosted by SINTEF) and The Norwegian Research Centre for Solar Cell Technology (IFE). ZEB aims at developing competitive products and solutions for existing and new buildings of different nature that will lead to market penetration of buildings with zero greenhouse gas emissions from the production of materials to the demolition. Such buildings will be able to compensate for CO2 emissions by producing more energy than required for their operation. ZEB include experts within material science, building technology, energy technology, architecture, and social science. The strong involvement of industries and private consultants and architects facilitates the finding of cost-effective competitive solutions. ZEB encompass the whole value chain of market players within the Norwegian construction and focus its work in five internal areas that interact and influence each other:

- WP1 - Advanced material technologies (directed by Prof. PhD Arild Gustavsen, Dept. of Architectural Design, History and Technology, NTNU) focus on the development of new concepts and innovative materials and solutions, and the improvement of the current state-of-the-art technologies.
- WP2 - Climate adapted, low energy envelope technologies (directed by PhD Berit Time, SINTEF Buildings and Infrastructure) develops climate adapted and cost effective solutions for new and existing building envelopes aiming at optimizing the thermal performance through the integration of active elements in the envelope.
- WP3 - Energy Supply Systems and Services (directed by Prof., PhD Vojislav Novakovic, Dept. of Energy and Process Engineering, NTNU) develops new solutions for energy supply systems and building services systems with reasonable energy and indoor environment performance appropriate for zero emission buildings.
- WP4 - Use, operation, and implementation (directed by Prof. PhD Thomas Berker, Dept. of Interdisciplinary Studies of Culture, NTNU) provides knowledge and tools, which assure usability and acceptance, maintainability and efficiency, and implementation of ZE buildings.
- WP5 - Concepts and strategies for ZEB (directed by PhD Tor Helge Dokka, SINTEF Buildings and Infrastructure) develops concrete concepts for zero emission buildings which can be translated into realized pilot buildings within the time frame of the Centre.

2.2 The ZEB centre: partners and potential involvement.

The building industry is facing today radical new challenges with respect to more energy efficient and robust products and solutions. Many companies are expecting the ZEB centre to be an important partner and a catalyst in the development of new concepts and solutions towards a zero emission environment. Connections with the industry will be fundamental for the development of the ZE+hytte both for financial and technical support. We expect several corporations to give a significant contribution for the success of the project. The Ze+hytte will create synergy effects for all the different industries by developing optimal solutions together. Through the Centre the products can be tested and the results documented and used to show the market that building environmentally friendly is possible and profitable. This will help the company to bring knowledge to its manufacturers and to guide them to optimize their products. Among ZEB partners we can find producers, contractors, professionals, governmental institutions and federations able to attract funding from the architectural and engineering side:

BUILDING PRODUCTS / SUPPLIER:

- Weber: easy to apply products in the facades, construction mortars, flooring systems and tile fixing materials.
- DuPont: innovative products for building and construction.
- Glava: New superior insulation materials and thermal protection building systems.
- Protan: technology and solutions for sustainable roofing systems.
- Hydro Aluminium: active solar energy generation, passive energy efficient and building envelope solutions.
- Brødrene Dahl HVAC equipment supplier.

BUILDING CONTRACTORS AND DEVELOPERS:

- Skanska: sustainable construction company developing new quality concepts, components and materials.
- ByBo: housing contractor.
- YIT: technical installations contractor continuously developing energy-related technologies and solutions.

PROFESSIONALS AND CONSULTANTS:

- Multiconsult: development of analysis tools evaluating environmental impact of new products or services, leading to new standards, guidance, and analysis models.
- Snøhetta: The Centre currently expanding the office's competence in designing buildings with very low impact on the environment, with special focus on climate. Generation of sustainable solutions is implemented thorugh many projects all over the world.

GOVERNMENTAL INSTITUTIONS:

- Statsbygg (Directorate for Public Construction and Property). Innovation and higher efficiency in the Norwegian property, building, and construction industry.
- Forsvarsbygg (Norwegian Defense Estates Agency): NDEA as a public-owned building client is under considerable political pressure to act as a role model for private building clients. By applying the latest technology public construction activities are targeted to be demonstration objects for the whole construction industry.
- Husbanken (The Norwegian Housing Bank): The Centre has the potential to play a decisive role concerning reduced energy use and emissions from the building stock, both by research and other related activities. Husbanken especially sees a huge potential in using pilot projects as centre points and arenas for regional dissemination of ambitions, knowledge and for regional market development. This will be an essential foundation for innovation and value creation and implementation of results and experiences done by the ZEB Centre and its partners.
- BE (National Office of Building Technology and Administration): Development of building requirements regarding energy efficiency and energy supply, on the base of research results. Research on actions will be of fundamental importance for further development of building regulations and building practise.

FEDERATIONS:

- NORSK TEKNOLOGI (Norwegian Technology; Confederation of companies within the technical and technological sector): Norsk Teknologi is a federation of 1550 companies with a total of 32,800 employees and annual revenue of 3.8 billion Euros. It is relying on .. A significant potential for innovation and value creation is possible related to investments in energy efficiency measures.
- BNL (Federation of construction industries, incl. Construction products association): Rethinking construction and stimulating renovation is of utmost importance for a healthy development of the industry. The potential for social profit from increased innovation within the industry is considerable: the society itself will benefit from the innovative efforts to be addressed by the Centre.

2.3 The location inside Brøset and the involvement of the municipality of Trondheim

The 35 hectars housing programme in Brøset provides for about 1200 units of different type and density and aims at shaping a piece of city of the future characterized by carbon neutrality, low energy demand, and efficient land use. High environmental standards and carbon-neutrality are qualities that will create attractive dwellings. The topography of Brøset, a slightly tilting site with good solar access, enables housing qualities such good possibilities for daylight and ventilation, comfortable and sunny balconies and outdoor spaces. The required density will most likely not allow for single housing, but rather for solutions like apartment blocks, terrace and row housing, 20% of which will be for market-controlled rent or affordable low joint debt. Trondheim aims for a varied resident composition within the neighbourhoods for age, gender, ethnicity and family composition. Quality and diversification of users and types will be ensured by different means of regulations and design guides. Collective facilities and services will enhance residents' sense of ownership to the neighbourhood and strengthen local quality.

Municipal ownership increases the potential for active guidance of the development and the construction of pilot projects that can be used for strengthening an alternative identity like the ZE+hytte. Upon the return from the solar decathlon context week in Madrid the ZE+hytte will be installed in the Brøset housing municipal development where will be accessible by the public and will also become a living Lab for action research on technology and lifestyles. If financial support will permit, a third but simpler SD module will be built during the first construction phase and left in the Brøset even during the context week in Madrid. On the way nack from spain the other two modules will be attached to the permanent one in the meantime used for public events (fig.14).

2.4 Publication, communication and post-competition exposure

The development of an energy positive hytte is inevitably going to attract a lot of interest from the public. The norwegian research centre on PV - IFE - gives evidence of the increased interest of the government towards this technology. Many persons are anyway still skeptical about applicability of these technologies in such a climatic context. Researches conducted at IFE and preliminary calculations - also performed in PVGIS - proofed anyway a wide margin of applicability and integration of solar technologies in norwegian hytta. Our intention is to maximize the potential of the project for increasing public awareness around these solar energy applications and how these can be used to enhance symbiosis with nature, reason of being of hytta. Different kind of public initiatives will be periodically organized in the next eighteen months; in already existing ones, like the KLIMAX frokost, the ZE+hytte will be focus of discussions increasing awareness around sustainability issues.

The WIKI-portal - during the design process accessible only to the members of the team - will provide the structure for the construction of a website where the public will be able to follow all the different stages of conception and construction of the ZE+hytte. Texts, images and videos will be available for download and will show not simply the result but also the process. Navigating the website will become a pedagogic experience. The ZE+hytte will also be built on a network of excellent media relations. The team will have daily press partners at national, regional and local levels. NTNU students have their own TV channel but national coverage will also be ensured through the support of NRK (Norwegian television). TV programs like Schrödingers Katt and Newton are already following the development of the Brøset project. The department of architectural design history and technology is already evaluating the possibility of publishing the first stage of the concept development in a report that will be used for making resonance of the event in both local and national networks.

Fig. 14 - *Aggregability of the module.*

Fig. 15 - A view of Trondheim from the *Brøset area.*

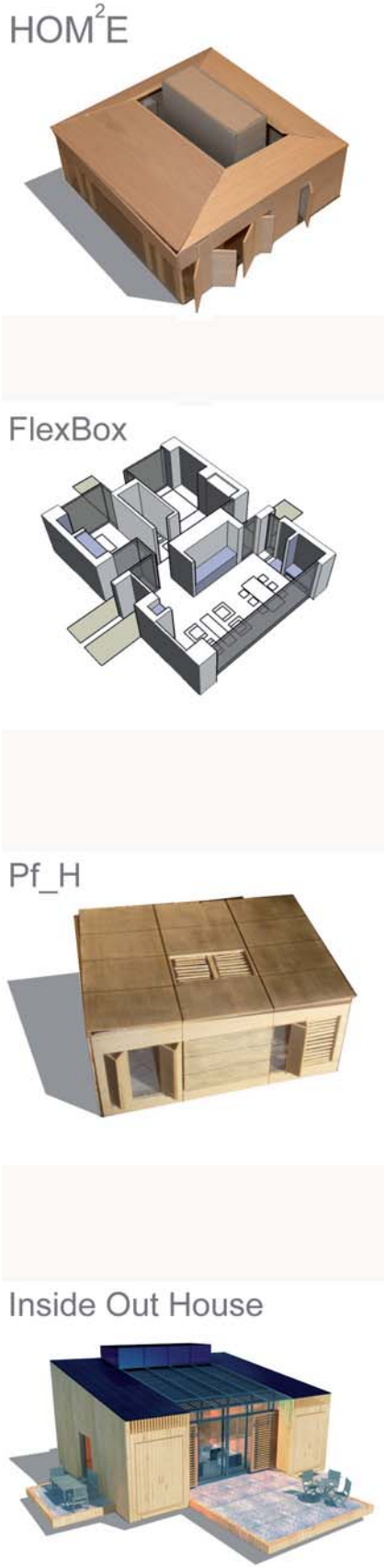

Fig. 16 - *Concepts proposed by the students at the MSc*

2.4.1 KLIMAX breakfast seminar.

The Industry Forum includes among the other activities a monthly breakfast seminar,called Klimax and financed by NTNU, in which researchers, policy makers and practitioners are invited to share and comment their professional experiences. The breakfast seminars provide a low-threshold meeting place for actors from different sectors to discuss challenges that often supersede traditional professional boundaries. Each session includes two presentations by invited experts, followed by discussions with the audience. The topics and lecturers are chosen in co-operation with Trondheim policy makers and other stakeholders, related to the progress made in the Brøset project. The seminars are usually attended by 50 to 80 participants (occasionally more) coming from academia, public organizations and the building industry. The SD module will be in three occasion - one for each stage of development - become focus of debates aiming at increasing awareness around sustainability and coping with different issues.

2.4.2 Technoport

Technoport was founded in 2005 to promote Design, technology and research by the city manager of Trondheim and quickly generated enthusiasm among local businesses and industry, education and research institutions and regional governmental bodies. In its early years, Technoport was both an exhibition to show the citizens of Trondheim examples of the cutting edge technology produced in their city and a presentation of awards to celebrate the individuals or organizations that have generated this new technology and knowledge. In 2012, Technoport will arrange an international conference. The focus will be on “Transition towards a Green Economy” and how to implement innovative green technology into society. Technoport is potentially a financial source for the ZE+hytte that will become an exhibitions pavilions for advanced technologies developed at the ZEB centre and NTNU together with the support of SINTEF.

3. CURRICULUM INTEGRATION AND SPECIAL CONSIDERATIONS

The ZE+hytte represents for ZEB a rare opportunity for enhancing the interrelations between research institutions, departments, faculty and the students. Students already worked intensively in the development of the architectural concept together with faculty leaders and external consultants, gaining a fundamental understanding of problematics and challenges of energy efficient designs. The development of the ZE+hytte will be in the next eighteen months implemented through different activities. Each participating institution will provide a complimentary expertise and give a significant contribution to the development of the concept.

3.1 The MSc in Sustainable Architecture: towards a zero emission built environment.

The MSc programme in Sustainable Architecture at NTNU is an interdisciplinary, international master programme aiming at educating students and professionals in the use and development of competitive methods and solutions for lowering GHG emissions in the construction sector in a life-cycle perspective. The curriculum consists of 3 consecutive semesters including both theory and project courses, and a fourth semester during which the participants write their MSc thesis. High demands are made within the courses towards integrated design strategies. The de-

velopment of the ZE+hytte has been integrated in each semester of the MSc programme. In the first semester students developed concept design & detailing related to Climate and Built Form; the second semester will be used for energy analysis and materials, in co-operation with Faculty of Engineering Sciences and Technology and the programme for Industrial Ecology; the third semester will handle facility management and user interaction issues, in co-operation with Department for cross-cultural studies; in the fourth semester students will have the possibility of developing a master thesis intimately related to the SD project. The students will be continuously trained in interdisciplinary co-operation with engineering departments and research centres on the base of already established collaborative relations between the different departments. MSc students in sustainable architecture will also co-operate with the Civil Engineering student group called “Bygg:verksted”, working on wood construction, for detailing the SD module next spring (leader: Prof. Rolf André Bohne).

3.2 EXPERTS IN TEAM village. A light, strong and bright future with materials.

Experts in team is a village at the Department of Materials Science and Engineering suitable for students of different disciplines. The production of primary aluminium is a 100 year long tradition in Norway, historically due to an abundance of cheap hydroelectric power, a prerequisite we no longer have. However, technologically Norway is in the forefront in most areas of aluminium production and is today used for Solar cells production today representing the fastest growing energy platform, with a more than 40 % annual growth. Today, lack of pure silicon limits the production of solar cells. An expected and environmentally desired development in solar cell use thus requires a large increase in new production capacity for silicon and access to NEW electrical energy. The process for silicon production is robust and can adapt to variations in power supply over a day, a week or a year. REC, Elkem Solar, FeSil and NorSun make Norway leading in materials for solar cells. More than 50 % of the world’s PC’s and solar cells use silicon from Bremanger. Off-shore based wind energy, also analysed at the experts in team village, may be a future power supplier for silicon production. The development work to realize this is considerable, but is more a question of combining existing technologies in new ways than developing new, unproven technology.

4. ORGANIZATION AND PROJECT PLANNING

The Department of Building Technology is part of the Faculty of Architecture, Planning, and Fine Arts at the Norwegian University of Science and Technology (NTNU). The Department of Refrigeration and Air Conditioning is part of the Faculty of Mechanical Engineering. These departments, with their affiliated research groups at SINTEF (The Foundation for Scientific and Technical Research at the Norwegian Institute of Technology), have been doing research on energy conservation and the use of solar energy in buildings for 30 years. They now have a leading role in this field. Their experience covers both the use of passive solar technologies, daylighting technologies, active solar technologies, and photovoltaics, and they have educated a number of PhDs in these areas. In several of these they have had a leading role. They have also been, and still are, participating in a number of European Union projects. In addition, they do contract research for the Norwegian Research Council and for industry, also developing solar building elements for the mass market. The group has published several handbooks, reports, and papers on the use of solar energy in buildings and has participated in several national and international dissemination activities on the subject. Professor Hestnes, one of the group’s leaders, is considered an international expert on solar architecture and building integration and is frequently invited to give lectures and talks on the subject at international conferences. She is also used as a jury member in architectural competitions where this is an issue. Thirty years

Fig. 17 - *Ongoing research at ZEB and NTNU: Klimablokka, cable car and nano structures*

of experience in interdisciplinary co-operation in research at NTNU and SINTEF culminated in the ZEB Research Centre and Brøset planning & research project. This interdisciplinary co-operation is reflected in the education of architects and engineers at the MSc in sustainable architecture organized by Assoc. Prof. Annemie Wyckmans whose students will be continuously involved in the development of the project. Adjunct Prof. Per Monsen is main architect at GASA and will provide consultancy for the architectural design of all the components constituting the Sd modules. The department of architectural design, history and technology will provide expertise in developing specific components of the building envelope. SINTEF will ensure expertise in energy modelling while engineering and social studies departments will be involved for maximizing researches involvement during the development of the ZE+hytte. TwoPhD and one postdoc will partially focus their research on the SD module as a key case study, with the help of MSc students and student assistants.

4.1 Design team: Sub-teams and responsibilities

In order to facilitate the design process an intensive mentoring and collaborative model, involving different faculty members, was established. Different task specific layers of organization have been created. Students will be for the second phase of the development divided in sub-teams leaded by NTNU professors and having one representative that will report their work in physical meetings appropriately scheduled. The Key organizational body for the development of the project will be a project management board, already formed before the summer, including professors, research assistants and ZEB members.This main body will supervise the project progress, technical decisions and financial status. Meetings will be periodically scheduled to coincide with the specific demands of each project phase and fluctuate with workflow and critical path scheduling. The project management board will make formal decisions concerning the project. Sub-teams have been formed in order to include both architects and engineers in different disciplines and guarantee an interdisciplinary approach in handling the different issues and challenges that the development of the ZE+hytte suppose. The structure of the team and the division in sub-teams partially reflects, for maximizing efficiency, the organization of the ZEB centre:

- Project management board: construction and logistics
- Fundraising, business and marketing team
- Communication and logistic team: web-site and dissemination.
- WP1: building integration, solar technologies
- WP2: responsive envelope
- WP3: HVAC
- WP4: adaptive living interface team
- WP5: ZE+hytte concept and potential
- Digital modeling and fabrication team

4.2 External consultants and advisors

Different professional peer review sessions are already scheduled throughout the whole time schedule for the development of the hytte drawing upon professional external consultants. An advisory board consisting of leading academics, professionals will be called upon to provide strategic council to the team on a regular basis coordinated with the schedule of deliverables required under the project contract and design process milestones structured by the team. The project schedule will be coordinated with the key solar decathlon phases and key-deadlines for the project development. The modular structure and constructive system of the module based on prefabrication will permit different sub-teams to work in parallel - sharing informations and results in a web-based platform - on specific components and facilitate the integration of the systems.

4.3 WIKI system _ ORAKEL

One of the targets of the architectural design is to maximize the involvement of industries and research centres and permit the simultaneous development of different researches even if located in different part of the country. In order to ensure efficiency is fundamental to provide a common physical framework where all the individuals involved will be able to share informations and access data coming from other sub-teams regarding all the architectural components constituting the ZE+hytte. NTNU IT support group Orakel has just recently developed a wiki system for internal use. This system will constitute the platform on which will be built the web-portal for sharing information during the design process. The WIKI system will act as a distance-reducing technology able to facilitate internal communication and interaction. anyway supported beyond physical meetings. The efficiency of the web-based platform

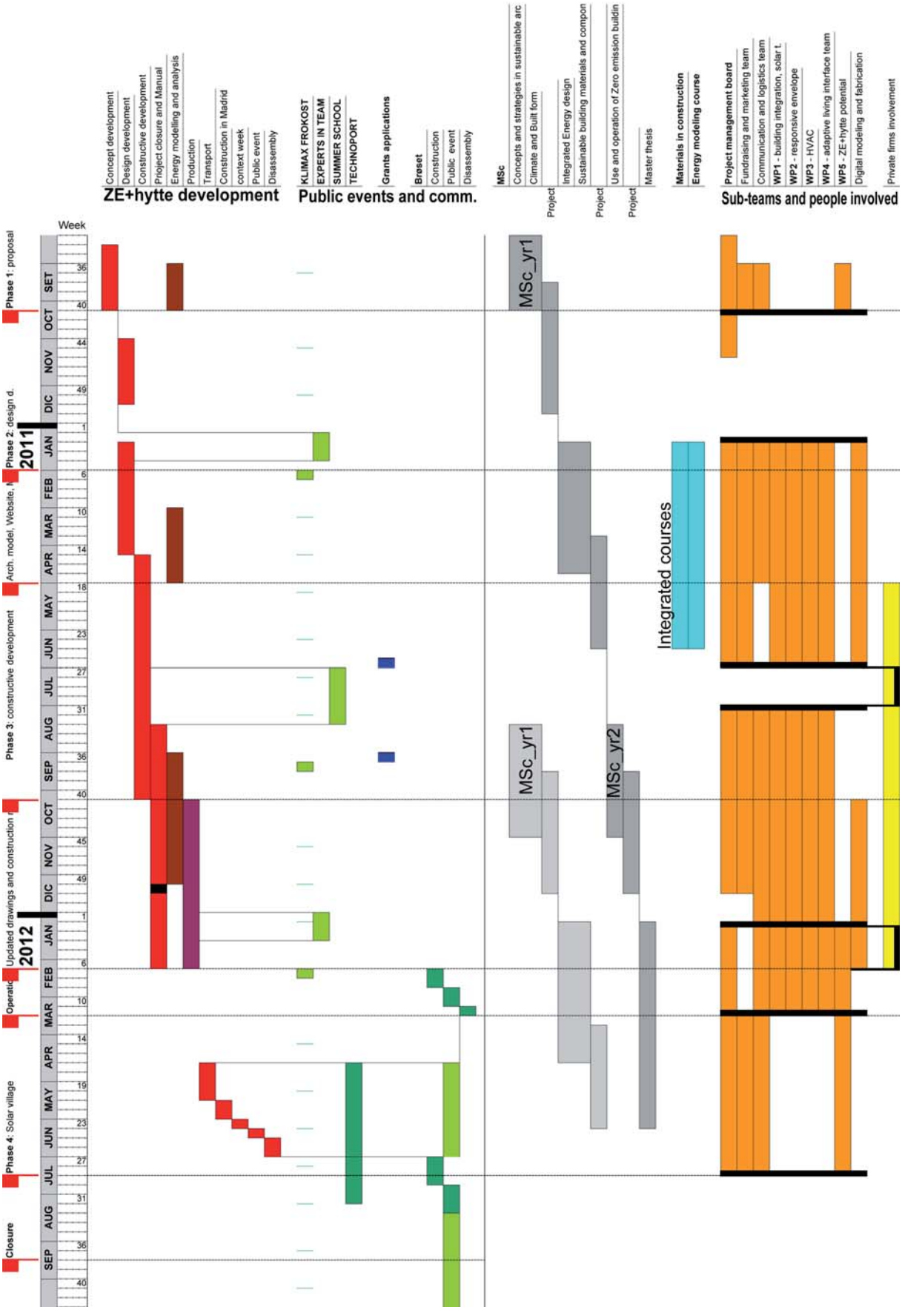

Fig. 18 - *Time schedule for the development of the ZE+hytte*

will be essential in order to guarantee collaboration and communication within a multidisciplinary team comprising individuals with different expertises. The integrated design process will help in testing design assumptions through the use of energy simulations throughout the process, provide aid in decision making and performance evaluation, give voice to subject specialists within the design team, and facilitate clear articulation of performance targets and strategies from which work will proceed, improving results from conception to the delivery of the project.

5. CONCLUSIONS

SDE represents a unique opportunity for the ZEB centre; the ZE+hytte will become a shared platform for strengthening internal relations and implementing the external ones. Once back from Madrid the ZE+hytte will become a Living Lab for action research on technology and lifestyles in co-operation with private industries and public institutions. Hundreds of students and researchers will benefit from the SD module in the next eighteen months during which the ZE+hytte will be developed. NTNU will create a product that will affect the present detached houses scenarios and effectively enter in the market since the very first stages of its life. The ZE+hytte – a small but technologically advanced mountain cabin – will be independent from the grid thanks to the use of natural resources, strengthening the desired feelings of distance from modern society and symbiosis with nature.

On the other hand ZEB represents an opportunity for Solar Decathlon, giving an outstanding contribution to the competition in 2012. The ZEB centre represent an efficient structure able to develop and deliver an innovative solar house. The Solar Decathlon competition was inserted as a key innovation project when the ZEB centre was founded in 2009. An integrated design approach has already been initiated in which public resonance has been integrated from the very first steps of the design process. “Grønne Trøndelag” is promoting Sør-Trøndelag as the greenest region in Europe and will significantly contribute in supporting and promoting the SD event. In the Technoport exhibition - Trondheim 2012 - the module will become an exhibition pavilion of advanced technologies developed at NTNU and ZEB giving even more resonance to the SD event. Maximum media coverage and social diffusion will be ensured through an already existing network of media relations. The team will have press partners at national, regional and local levels. A web site will be developed by ORAKEL, responsible group of IT systems at NTNU, on the base of the web-based platform used for sharing information during the design process. Information of different nature regarding the module and its design process will be available for download: navigation will become a pedagogical experience.

6. APPENDICES

6.1.1 Faculty team members

Prof. Anne Grete Hestnes is an architect with degrees from M.I.T. and UC Berkeley. She has been full professor at the Norwegian University of Science and Technology since 1985. Her main scientific interest is in the areas of energy conservation and the use of solar energy in buildings, and in 2005 she was awarded an honorary doctorate by Chalmers University for her work within the field of sustainable development. She is now Director of the National Centre for Environment-friendly Energy Research – Zero Emission Buildings.

Assoc. Prof. Annemie Wyckmans is an architectural engineer and Associate Professor at NTNU, Faculty of Architecture and Fine Art. She holds a PhD in Building Technology, and a post-doctoral degree in creating learning environments for sustainable architecture. Wyckmans is engaged in a variety of interdisciplinary research projects related to the low-impact built environment, on a Norwegian and European level. Among them is the Brøset research project in close co-operation with Trondheim Urban Planning Office. Wyckmans is the initiator and leader of an international, interdisciplinary MSc in Sustainable Architecture, and also leads an interdisciplinary course “Experts in Team” and the monthly series of breakfast seminars (KLIMAX).

Assoc. Prof. Matthias Haase is associate professor at NTNU at the Department of Architectural Design, History and Technology. He is also part-time research scientist at SINTEF Building and Infrastructure, where he works on developing energy efficient building design solutions. He received his PhD from the Department of Architecture of Hong Kong University in the field of advanced facade technology for warm climates. As solar engineer from his background with seven years industry experience in BIPV facade design, Haase is very much interested in a climate responsive approach to building design that takes climate change challenges into account.

Adjunct Prof. Per Kr. Monsen has been a co-owner at GASA Architects AS since the beginning in 1980. As co-owner at GASA, he has headed work on development plans, housing projects, education facilities and environmental projects. He is constantly involved with the firm's work on architecture competitions. As head of several of the firm's environmental projects, he has built up special competence with regards to environmental issues in planning and architecture. He is employed as Professor II at NTNU in Trondheim.

Adjunct Prof. Inger Andresen has more than 15 years of experience in research and development within building technology and utilization of renewable energy. Her main scientific interest is in the area of energy conservation and the use of solar energy. She was educated at the University of Colorado (M.Sc) and the NTNU (PhD). Since 1991 she has been a researcher at SINTEF Architecture and Building Technology, Trondheim, and from 2008 a professor in energy and environment at NTNU. She has been active in several international research projects both within the IEA's Solar Heating and Cooling Programme and within the EU.

Prof. Steffen Wellinger is Associate professor at NTNU since 2004 and has been recently awarded by SINTEF for his outstanding teaching. Wellinger is Master of Architecture from the University of Stuttgart and has been in the last years involved in the design of many complex programs bublic buildings. His main research interests concern design methods, teaching and sustainability.

Prof. Rolf André Bohne is Associate Professor at NTNU at the Faculty of Engineering Science and Technology. He is currently the leader of the research group on "building and material technology". He holds a master of Science in Microbiology from the University of Bergen (Norway) and a PhD in Industrial Ecology from the Norwegian University of Science and Technology (NTNU). Bohne is engaged in a variety of interdisciplinary research projects related to the low-impact built environment, on a Norwegian and European level. He is responsible for the teaching of the introductory course in "Building Materials" and "Refurbishment, Renovation and Management".

6.1.2 ZEB team members: workpackages leaders

Prof. Arild Gustavsen (WP1 leader). Arild Gustavsen is professor in Building Physics at Department of Architectural Design, History and Technology at the Norwegian University of Science and Technology (NTNU). His research interests are heat, air and moisture transfer in building envelope systems, and energy use in buildings. He is currently involved in the research projects "Robust Envelope Construction Details for Buildings of the 21st Century" (ROBUST) and The Research Centre on Zero Emission Buildings - ZEB, where he is investigating the usability of advanced materials technologies in energy efficient buildings. In addition he is researching the potentials for highly insulating window frames with The Windows and Daylighting Group at Lawrence Berkeley National Laboratory

PhD Berit Time (WP2 leader) is a civil engineer and has a doctoral degree in building physics from NTNU. She is the manager of the building physics research group at SINTEF Building and Infrastructure. Her main scientific interest is in the areas of climate adaption of buildings, moisture, heat and air transport in building envelopes. She is in charge of the research project Climate Adapted Buildings (CAB) and she is a part of the management team of the ZEB. Time is and has been a member of national and international commitées.

Prof. PhD Vojislav Novakovic (WP3 leader)

Prof. PhD Thomas Berker (WP4 leader) is an associate professor at the Centre for Technology and Society at NTNU, Norway. His present research activities comprise the whole range of political, societal and cultural aspects connected to socio-technological innovation. He is particularly interested in the diffusion and implementation of new products and services and how these innovations become embedded in everyday life.

PhD Tor Helge Dokka (WP5 leader)

6.1.3 Faculty team members: research assistants, PhD students and postdoc.

PhD Anne Sigrid Nordby is an Architect and works as a Postdoc Research Fellow at the department of Product Design, Industrial Ecology Programme at NTNU. She worked for approximately 10 years in various Architects offices before starting her PhD with the title "Salvageablity of building materials. Reasons, criteria and consequences regarding architectural design that facilitate reuse and recycling". Her current research includes developing a reusable building system based on reclaimed wood called Klimablokka.

Anne Solbraa is Research Assistant at the Norwegian University of Science and Technology (NTNU), Department of Architectural Design, History and Technology. Her main occupations are coordination of the MSc in Sustainable Architecture and dissemination of research to students and professionals in the city through organizing breakfast seminar series on sustainability in architecture and planning.

PhD Aoife Houlihan Wiberg is a Post Doctoral Research Fellow at ZEB at the NTNU. She is a Chartered member of RIBA since 2001 and has worked in practice in The Bahamas, Malaysia, UK and Ireland. Her PhD research at The University of Cambridge researched the effectiveness of selected certification schemes in reducing global CO2 emissions in the hotel sector and proposed a simple, accurate method of CO2 emissions calculation for operational energy. Her current research is developing this method further.

Julien S. Bourrelle is Research Fellow at ZEB centre and PhD Candidate at the Norwegian University of Science and Technology (NTNU). His current research focuses on energy calculation methodologies for Zero Emission Buildings and the study of associated flows and boundaries. He has been a regular participant to the International Energy Agency (IEA) Task 40 Towards Net Zero Energy Solar Buildings since 2009.

PhD Luca Finocchiaro is a building engineer today Postdoc Research Fellow at the department of Architectural design, history and technology of NTNU. Luca got Master in Urban Building from the Glasgow School of Art and practiced architecture in Italy and Spain. His current research focuses on architectural design of low-energy office buildings. His scientific interest are bioclimatics, aesthetics and morphology of sustainable architecture.

Nicola Lolli is currently employed as PHD candidate at the Norwegian University of Science and Technology (NTNU) within the department of Architectural Design, History and Technology since 2009. His research work is carried on within the Zero Emission Buildings Research Centre. His research topic focuses on energy retrofitting of existing residential stock in Norway.

Assist. Prof. Pasi Aalto is an architect working with digital modeling and fabrication using parametric generative algorithms and CNC technology. His masters thesis explored the possibilities of a prefabricated building system for disaster response and aid organizations, as well as housing strategies after disruptive events. His areas of interest include digital analysis, Building Information Modeling and programming based generation of geometry

6.1.4 Student members

MSc CANDIDATES

Alise Plavina (MSc) Riga Technical University, Latvia.
Arjun Basnet (BA) Tribhuvan University, Nepal.
Chenchen Guo (BEng) VIA Univerisity, Denmark.
Elisabetta Caharija (BA), University of Trieste, Italy.
Isabelle Davoult (BEng energy) Mines de Douai, France.
Ivan Kalc (MA) University of Novi Sad, Serbia.
Kristof Lijnen (Beng) University of Xios, Belgium.
Lin Du (BEng) Shanxi Agricultural University, China.
Michael Gruner (BArts), Univeristy of applied sciences of Dessau, Germany.
Mila Shrestha (BA), Purbanchal University, Nepal.
Nigar Zeynalova (BA) architecture and arts, State academy of Arts, Azerbaijan.
Noora Alinaghizadeh (BA), Shariaty university, Tehran, Iran.
Vegard Heide (MSc), Norwegian University of Life Sciences, Ås, Norway.

Fig. 19 - The *ZE+hytte in a typical Norwegian landscape*

NTNU Energy course students
Bjarte Lykke (BA) NTNU, Norway.
Elisabeth Lilleby (BA) NTNU, Norway.
Maria Coral Albelda-Estellés Ness (MA), Universidad Politécnica de Valencia, Spain.
Nico Dürr (MArts) Hochschule Luzern, Switzerland
Ole Kristian Kråkmo (BA) NTNU, Norway.
Pablo Alarcó González BA, Polytechnic University of Madrid, Spain.
Thea Hegstad Foss (BA) NTNU, Norway.

6.2 Preliminary analyses based on TEK10 regulations in force

		TEK10 (residential)
a	Total glass-, window- and door area (BRA)	< 20% of heated area
	U-value walls:	0,18 W/m2K
	U-value roof:	0,13 W/m2K
	U-value floor to ground and to open space:	0,15 W/m2K
	U-value glass/windows/doors:	1,2 W/m2K as average incl. frame
	Specific cold bridge value should	< 0,03 W/m2K
b	Air tightness:	2,5 acph at 50 Pa pressure difference
	heat recovery system efficiency	70 %
c	Spesific fan power in ventilations system, SFP-faktor	2,5 kW/m3s (whole day)
	Night and weekend set-back of internal temperature	19 ° C for building with variable occupancy

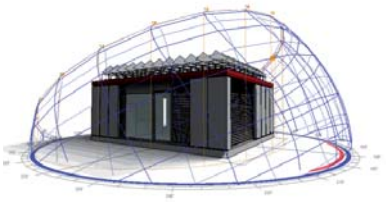

Fig. 21 - *ZE+hytte model used for part of the simulations*

Fig. 20 - *TEK10, norwegian regulations in force.*

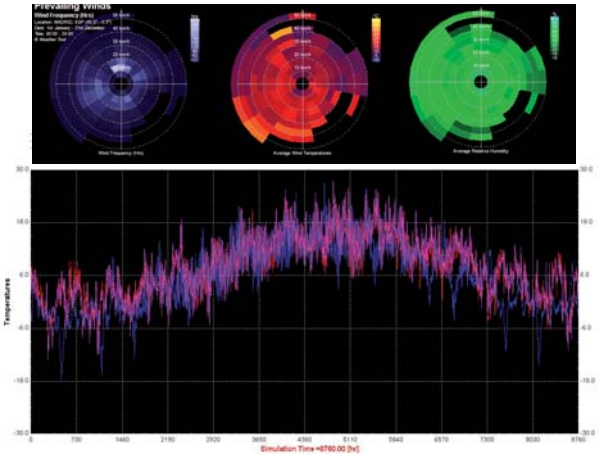

Fig. 22 - *Weather data: TRNSYS + WEATHER TOOL*

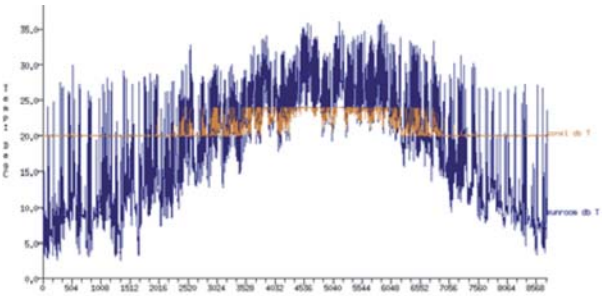

Fig. 23 - *Model performance*

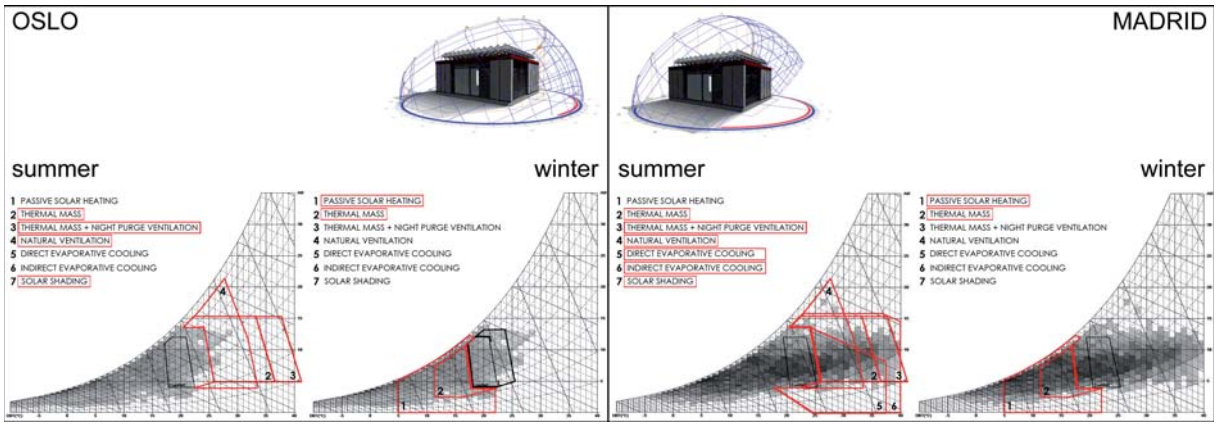

Fig. 24 - *Climate/comfort zone comparison in Oslo and Madrid used for defining the proper passive strategies.*

ZE+hytte | Norwegian Wood team

Price proposal form

Tore Haugen,
Dean of the Faculty of Architecture and Fine Art _____

NTNU
Det skapende universitet

Terje Jacobsen,
Vice President, Research _____

SINTEF

Anne Grete Hestnes, Centre Director _____

ZEB
The Research Centre on Zero Emission Buildings

ZE+hytte

PRICE / COST PROPOSAL FORM

NTNU_Norwegian University of Science and Technology
Department of Architectural design, history and technology
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Values in EURO

SUMMERY BUDGET. DESCRIPTION OF COST ELEMENTS (page 1)

1. - DIRECT MATERIALS

		ESTIMATED BUDGET	
ROOF PROTOTYPING - CUSTOM MACHINE COMPONENTS	24000		
MASSIVE WOOD for structural walls / KLIMABLOCK	6000		
OPENINGS	38000		
METALS	18000		
THERMAL AND MOISTURE PROTECTION	36000		
FINISHES	6000		
ELECTRICAL POWER GENERATION AND BATTERY DECK	60000		
FLOOR PREFAB CONCRETE SLABS, INSULATION AND FINISHES	24000		
SOLAR PV	75000		
PURCHASED EQUIPMENTS (washing machine, kitchen, etc...)	24000		
HVAC system	20000		
PLUMBING	12400		
ELECTRICAL	12000		
SOLAR SHADING DEVICES, integrated PV	40000		
FURNISHINGS	12000		
DECK AND LANSCAPE MATERIAL	10000		
FOUNDATION	4000		
VAT 16%	84280,0		
TOTAL DIRECT MATERIALS		505680,0	40

2. - MATERIAL OVERHEAD

	% ESTIMATED RATE *TOTAL DIRECT COSTS			
FABRICATION	10 %	50568		
CONSTRUCTION	15 %	75852		
VAT 16%		20227,2		
TOTAL MATERIAL OVERHEAD			146647,2	12

3. - DIRECT LABOR

	#	HOURS /WEEK	WEEKS	HOURLY RATE	ESTIMATED COSTS		
PROFESSORS AND RESEARCHES	5	10	48	35	84000		
RESEARCH ASSISTANT	3	15	48	25	54000		
GRANTED STUDENTS	2	20	48	15	28800		
LABOURERS	2	15	24	22	15840		
ADMINISTRATIVES	1	6	36	25	5400		
TOTAL DIRECT LABORS						188040	15

4.- LABOR OVERHEAD & FRINGE BENEFITS

	#	HOURS /WEEK	WEEKS	HOURLY RATE			
ZEB centre leaders (Prof. Excluded)	3	8	24	35	6720		
GRANTED STUDENTS	2	20	36	15	10800		
LABOURERS	8	20	24	22	10560		
ADMINISTRATIVES	1	12	36	25	10800		
TOTAL LABOR OVERHEAD & FRINGE BENEFITS						38880	3

5.- LOWER - TIER SUBCONTRACTORS

PROJECT MANAGERS	HOURS /WEEK	WEEKS	HOURLY RATE			
PROTOTYPING PHASE	12	4	35	1680		
1ST CONSTRUCTION PHASE	12	4	70	3360		
2ND CONSTRUCTION PHASE	12	4	100	4800		
VAT 16%				1574,4		
TOTAL LOWER - TIER SUBCONTRACTORS					11414,4	1

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SUMMERY BUDGET. DESCRIPTION OF COST ELEMENTS (page 2)

7.- OTHER DIRECT COSTS

DIGITAL PHOTOGRAPHY for fundraising and promotional booklets			1200	
ARCHITECTURAL MODEL - material			300	
COMMUNICATION			33000	
video display component		14000		
video production		8000		
display hardware		7000		
website mantainance / podcasting		4000		
PUBBICATION AND PRODUCTION			24000	
fundraising booklet, publication and printing		6000		
promotional booklet		6000		
SPACE RENTAL IN BRØSET			donated	
FUNDRAISING PROMOTIONAL EVENT			4000	
POST COMPETITION MONITORING			12000	
		TOTAL OTHER DIRECT COSTS		74500	6

8.- TRAVELS AND COSTS FOR FINAL PHASE IN MADRID

	TEAM MEMBERS	UNIT COSTS	ESTIMATED COSTS		
TRAVEL COST FOR THE TEAM	24	240	5760		
TEAM ACCOMODATION	24	840	20160		
FOOD	24	400	9600		
UNIFORMS DESIGN AND PURCHASE	48	60	6400		
SHIPPING			240		
documents		40*4			
model		80			
TOOLS AND MISCELLANEOUS EXPENSES			4800		
SITE SUPERVISION AND SECURITY			8000		
		VAT 16%	8793,6		
			TOTAL TRAVELS AND COSTS FOR FINAL PHASE IN MADRID	63753,6	5

9.- ASSEMBLY, TRANSPORT, DISASSEMBLY PROCESSES

DISASSEMBLY IN ORIGIN			6000	
TRANSPORT			33400	
customer broker		7400		
cranes		14000		
ASSEMBLY IN MADRID			12000	
DISASSEMBLY IN MADRID			6000	
TRANSPORT			7400	
		VAT 16%	10368	
			TOTAL ASSEMBLY, TRANSPORT, DISASSEMBLY PROCESSES	75168	6

10.- INSURANCES POLICIES

LIABILITY INSURANCE			4800	
TRANSPORT INSURANCE			3600	
ACCIDENT INSURANCE			12000	
MEDICAL INSURANCE			10600	
		TAXES	6200	
			TOTAL INSURANCE POLICIES	37200	3

TOTAL PRICE / COST ESTIMATED 1172603

ZE+hytte | Norwegian Wood team

The Norwegian University of Science and Technology - NTNU – together with the research centre on Zero emission buildings – ZEB - and the support of SINTEF, foundation for scientific and technical research, commit to produce all the required deliverables necessary for participating to the Solar Decathlon competition in case of successful offer to this solicitation. All the deliverables, mentioned in the following statement of work, will be transmitted according with the time schedule edited by the SD organization board. Drawings and project manuals will be produced in a proper scale and with an adequate detailing of all the architectural components. Structural drawings, calculations, plans for site operations, safety and fire life-safety, will be regularly signed by a licensed architect or engineer, when required. Energy analysis and simulation input reports will provide all the information necessary for reproducing the model and evaluate its environmental behaviour in simulation software for scientific use. NTNU will provide technical support for the development of the project while the research partners involved will use their laboratories and facilities for testing and verifying components and materials digitally modelled by the students.
The ZEB centre was built on 30 years of research collaborations and expertise at NTNU. The Solar Decathlon competition was inserted as a key innovation project when the ZEB centre was founded in 2009. The development of the SD module has been totally integrated with the schedule of the Master of Science in sustainable architecture at the Department of Architectural Design, History and Technology of NTNU. Highly motivated students and faculty leaders have already initiated an integrated design process aiming at prototyping an energy positive module that can be used in different circumstances and solve different energy issues. The ZE+hytte – a small but technologically advanced mountain cabin – is independent from the grid thanks to the use of natural resources, strengthening the desired feelings of distance from modern society and symbiosis with nature. The surplus of energy produced will permit the use of a cable car and solve mobility issues related to the second house sector, today the most dynamic in energy statistics in Norway. The ZE+hytte can be also attached to detached wooden houses, representing the most energy thirsty architectural typology in Norway, and compensate energy efficiency lacks of the existing building stock.
The SD module will be used in order to generate and disseminate knowledge around sustainability and energy issues both for students and general public, promoting the use of renewable energies. Maximum media coverage and social diffusion will be ensured through an already existing network of media relations. The team will have press partners at national, regional and local levels. A web site will be developed by ORACLE, responsible group of IT systems at NTNU, on the base of the web-based platform used for sharing information during the design process. Information of different nature – images, video and documents - regarding the module and its design process will be available for download: navigation will become a pedagogical experience. Once back from Madrid the SD module will become a living Lab for action research on technology and life style in co-operation with industries and institutions, both private and public. With the municipality of Trondheim we are already discussing the possibility of locating the SD module inside the Brøset site, a new housing development with a marked environmentally friendly identity. In Technoport - Trondheim 2012 - the ZE+hytte will become an exhibition pavilion of advanced technologies developed in Norway. In the Klimax frokost, a dissemination event monthly organized by NTNU, the SD module will be the focus of debates with all the external professionals involved.

Trondheim, 18th October 2010

Tore Haugen,
Dean of the Faculty of Architecture and Fine Art _____

NTNU
Det skapende universitet

Terje Jacobsen,
Vice President, Research _____

SINTEF

Anne Grete Hestnes,
ZEB Centre Director _____

ZEB
The Research Centre on Zero Emission Buildings

ZE+hytte

sd europe SOLAR DECATHLON ESPAÑA 2010

ATTACHMENT A

REGISTRATION FORM FOR ENTRY - SOLAR DECATHLON EUROPE 2010
(Please Type)

SCHOOL NAME	Norwegian University of Science and Technology
SCHOOL INITIALS (3)	NTNU, Faculty of Architecture and Fine Art
SCHOOL ADDRESS	Alfred Getz vei 3
CITY, STATE, ZIPCODE	7491, Trondheim
COUNTRY	Norway
PHONE NUMBER	+47 73550275
E-MAIL ADDRESS	fak-adm@ab.ntnu.no
KEY FACULTY CONTACT	Annemie Wyckmans
WORK ADDRESS	NTNU, Alfred Getz vei 3
CITY, STATE, ZIPCODE	7491, Trondheim, Norway
PHONE NUMBER	+47 73593666
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E-MAIL ADDRESS	annemie.wyckmans@ntnu.no
KEY STUDENT CONTACT	Anne Solbraa
PHONE NUMBER	-
CELL PHONE	+47 93006888
E-MAIL ADDRESS	anne.solbraa@ntnu.no

LIST OTHER PARTICIPATING SCHOOLS IF APPLICABLE:
partners: ZEB centre and SINTEF research foundation

TEAM NAME: NORWEGIAN WOOD

Tore Haugen,
Dean of the Faculty of Architecture and Fine Art

NTNU
Det skapende universitet

ATTACHMENT B

(Please print)

STATEMENT OF WORK - SOLAR DECATHLON EUROPE 2012

Date: November 3rd, 2010

Background

The Solar Decathlon is an international collegiate competition in which Student teams compete to design, build, and operate highly energy-efficient, grid connected, net-metered, completely solar-powered houses that incorporate building-integrated photovoltaics (BIPV). Solar Decathlon houses are nominally 75,00m^2 (800-square-foot) modular structures. No basements are allowed, and the house must not disturb the ground on which it sits. The energy source for the house will be limited to only the renewable energy incident upon the specified space that the house will occupy during the competition.

The Solar Decathlon Europe 2012 will take place in Madrid, Spain. Previous events were held in fall 2002, 2005, and 2007, and 2009. The 2010 Solar Decathlon Rules and Regulations document, which is the basis for the 2010 competition, will be revised prior to the 2012 event based on lessons learned and technology advancement from the other recent Solar Decathlon events.

Whereas the competition will be held in spring 2012, each team is required to produce a number of project deliverables associated with project fund-raising, building design and modeling, and materials specification, acquisition, and construction processes.

Objectives

To generate knowledge on the industrialization and sustainability of the homes, bringing about suitable scientific benefits, as well as, the dissemination of the knowledge.

To make both students and general public aware of the environmental and sustainability issues, especially in the responsible use of energy and natural resources, promoting the use of the renewable energies.

To maximize the publicity of the event by taking advantage of the competition´s characteristics and potential to achieve the maximum media coverage and social diffusion.

Scope of work

In addition to the competition, the project encompasses the solar home's design development, construction, and commissioning phases necessary to participate in the competition.

Project Deliverables

During the period of performance, teams are required to submit the following deliverables:

• **Business and Fund-Raising Plan**: Early in the development of their Solar Decathlon Europe projects, teams are required to submit plans that describe their overall project, including a projected budget and fund-raising plan. The plan should include a description of each team's interactions with other departments involved in fund raising (e.g., the school's development office), identify key sponsors, and describe the means by which these sponsors may be reached.

• **Drawings and Project Manuals**: On three separate occasions (design development, construction and as built), teams shall submit drawings and project manuals documenting the house and its components. The competition organizers use the drawings and project manuals to determine constructability, system operational parameters and requirements, potential for industrialization, Rules and Regulations compliance, and code and design standards compliance.

• **Energy Analysis Reports and Simulation Input Report**: The Energy Analysis Reports (schematic and comprehensive) shall summarize the results of computer simulations created by teams to inform the design process and project the energy performance of their houses after the designs are complete. The Simulation Input Reports provide information that a building scientist would need to develop a detailed computer model of the house and its systems.

• **Web Site URL**: Teams develop Web sites as a means of communicating their experiences in the project with the general public. Submission of Web sites that meet usability, design, coding, and content standards is required on at least two occasions. Initially, Web site URLs are submitted, and competition organizers provide feedback regarding compliance with competition requirements. Approximately six weeks later, the Web sites must meet minimum requirements. Organizers continue to work with teams until the final deadline for Web sites at the beginning of the 2012 event. Each team will be required to link their Web site to the Solar Decathlon Europe Web site.

• **Market Viability Report and Detailed Cost Estimates**: The Market Viability Report shall summarize the results of the analyses done by teams to determine the potential for market viability of their houses. The Detailed Cost Estimates specify all development and construction costs in a standard format.

• **Preliminary audiovisual and scale architectural model for Workshop**: At the Pre-Event Workshop in 2011, there will be exhibited a scale architectural model and a preliminary audiovisual of every participant project. Deliverable should be a month prior to the Workshop.

• **Updated Project Information for Workshop**: At the Pre-Event Workshop in 2011, each team will have the opportunity to participate in 20-minute sessions with various Solar Decathlon Organizers. Prior to the Workshop, the Organizers will request updated project information that is intended to make the Workshop sessions more productive. (Date for the Workshop will be announced to the selected Teams in November 2010).

• **Stamped or signed Structural Drawings and Calculations**: Organization requires that the team's structural drawings and calculations are stamped or signed by a licensed architect or engineer. Without possession of these stamped or signed deliverables, the Organization will not permit the house to be assembled in Madrid.

• **Project Summaries**: The Project Summaries each consist of a narrative and team information. The narrative is the story of the project to date, in narrative form. Projects are works-in-progress; after the first project narrative submission, teams should update previous information. The team information section shall describe how each team is organized and approximately how many students, faculty, and others (e.g. sponsors, volunteers, and family members) are involved in the project.

• **Project Financial Summaries**: These summaries are due on two occasions. The first deliverable summarizes the "income" and costs of the project at the time of the 2012 event. The second deliverable, due post event, shall include the same information as the first deliverable, but it should be more accurate. The second deliverable also includes a report about the actual implementation and results of the Business and Fund-Raising Plan.

• **Dinner Party Menu**: Teams shall submit a proposed menu in preparation for the cooking contest activity. The menu will be evaluated by the organizers prior to the competition.

• **Site Operations Plan**: This Plan shall include descriptions of the team's Assembly and Disassembly plan, transportation plan to and from the Event, and the necessary equipment and personnel that will be on site.

• **Comprehensive Safety Plan**: This Plan shall identify the hazards of the activities and state the related controls to mitigate risk to the lowest reasonable level.

• **Fire Life-Safety Plan**: This Plan shall indicate the location of fire extinguishers, how egress will be made from the unit, and who will be responsible for life-safety during the Event.

Electronic Reporting Requirements for Report Deliverables will be included in the 2012 Rules and Regulations.

Event Participation

Teams shall participate in the Solar Decathlon Europe competition and all other elements of the Solar Decathlon Europe event. The expected range of dates is within May-June 2010, and exact dates will be determined closer to the event. Preliminary calendar is:

- Spring, 2012: House assembly and inspections (approx. 10 days)
- Spring 2012: Finish work and commissioning (one day)
- Spring 2012: Opening ceremonies (one day)
- Spring 2012: The competition and public tours (approx. 10 days)
- Spring 2012: Closing ceremonies (one day)
- Spring 2012: House disassembly (approx. 4 days)

Review meetings

A calendar and means for review meetings during the period of performance will be included in the 2012 Rules and Regulations. Extraordinary meetings may be arranged with individual teams at various times throughout the period of performance.

ATTACHMENT B - statement of work signatures

Tore Haugen,
Dean of the Faculty of Architecture and Fine Art _____

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Det skapende universitet

Terje Jacobsen,
Vice President, Research _____

SINTEF

Anne Grete Hestnes,
ZEB Centre Director _____

ZEB
The Research Centre on Zero Emission Buildings