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FRIENDS

A preliminary study of future prototype for climate-smart and connected buildings

SMART HOUSING SMÅLAND
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Abstract

The project's overall goal is to create a basis for the future climate-smart and intelligently connected buildings and districts through regional dialogue, research, and education with innovation potential among the business community in Småland. This feasibility study was the first step on the way to a major innovative implementation project. In order to realize a prototype for climate-smart and intelligent connected buildings, a gap analysis was made within the School of Engineering in Jönköping, and interviews were done with several key persons acting in Solar Decathlon for Housing. Eighty-seven companies and others were approached in a written form using the snowball effect (personal contacts). Today, we have 18 companies and two major organizations that are interested and willing to participate in the next step, to establish a research and education-supportive prototype made of upcycled construction wood and metal and also employing a collaborative energy concept. Research applications and a plan for an artistic prototype are planned in the near future as well as a set of education courses to engage student participation. These activities are planned to be closely followed by the industrial and organizational contacts whose contributions are essential for the success of the next step.

Sammanfattning

Projektets övergripande mål är att skapa underlag för framtidens klimatsmarta och intelligent uppkopplade byggnader och stadsdelar genom regional dialog, forskning och utbildning med innovationspotential bland näringslivet i Småland. Denna genomförbarhetsstudie var det första steget på vägen mot ett stort innovativt implementeringsprojekt. För att realisera en prototyp för klimatsmarta och intelligenta uppkopplade byggnader gjordes en gapanalys inom Tekniska Högskolan i Jönköping och intervjuer gjordes med flera nyckelpersoner verksamma inom Solar Decathlon for Housing. Åttiosju företag och kontaktades i skriftlig form och flera andra med hjälp av snöbollseffekten (personliga kontakter). Idag har vi 18 företag och två stora organisationer som är intresserade och villiga att delta i nästa steg, att etablera en forsknings- och utbildningsstödjande prototyp av återvunnet konstruktionsträ och metall och även använda ett kollaborativt energikoncept. Forskningsansökningar och en plan för en konstnärlig prototyp planeras inom en snar framtid samt en uppsättning av utbildningskurser för att engagera studentdeltagande. Dessa aktiviteter planeras att följas noga av de industriella och organisatoriska kontakter vars bidrag är avgörande för att nästa steg ska lyckas.

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Background

Smart solutions in the energy sector and modern technology linked to Artificial Intelligence (AI) are important areas within the necessary transition. The fact is that there are no concrete examples in the Småland region of how the buildings and districts of the future can be designed and developed with materials such as wood and glass. Moreover, how they can be connected intelligently and that zero-energy solutions can already be applied through innovative and new technology. The project's overall goal is to create a basis for the future climate-smart and intelligently connected buildings and districts through regional dialogue, research, and education with innovation potential among the business community in Småland. The feasibility study that is underway is the first step on the way to a major innovative implementation project. The feasibility study aims to investigate and identify forms and competencies within the Småland region to realize a prototype for climate-smart and intelligent connected buildings. Solar Decathlon for Housing. The prototype intends to participate in an upcoming Solar Decathlon for Housing (SDfH) project. SDH is an innovation competition where teams from universities in different European countries participate in presenting new innovative ways to design, build and realize sustainable, smart, energy-efficient solar-powered houses. These teams consist of researchers and students. SDH is held every two years in different cities in Europe with a similar focus and ten competition areas (e.g. architecture, building construction, energy saving, communication and social awareness, neighborhood integration and impact, innovation, circularity and sustainability, comfort conditions, building function, and energy balance). In 2022, SDH was held in Wuppertal, Germany, focusing on renovation. Jönköping Institute of Technology (JTH) has a tradition of self-built solar cars for the World Solar Challenge competition. In this project, the intention is to develop this tradition also to include SDH for the built environment and quality of life. JTH has a lot of knowledge and experience regarding the design for the World Solar Challenge that we can use for SDH. In the preliminary study, an analysis of different aspects of SDH's competition areas is carried out with the region's actors. The feasibility study for the future prototype will include the concept of a learning platform for industrial, societal and political stakeholders as an innovation project. The main difference between this project's conceptual prototype and a living lab (exhibition product) is that the concept includes the physical environment as an active learning hub and distributes knowledge among those interested in the form of an exhibition with built-in interaction.

Methodology

Gap analysis at School of Engineering in Jönköping

A gap analysis was performed following the steps : 1. Identify the area to be analyzed and identify the goals to be accomplished. 2. Establish the ideal future state. 3. Analyze the current state. 4. Compare the current state with the ideal state. 5. Describe the gap and quantify the difference. 6. Summarize the recommendations and create plan to bridge the gaps. Fourteen respondents had answered the question regarding competence in the Solar Decathlon for Housing (SDfH) theme.

Company survey

The company survey approached 87 local companies operating within building construction, logistics, and architecture. Among them, municipality contacts were approached and IoT companies were purposefully gathered. Moreover, two local industrial organizations joined the network. A survey sheet was sent out to the representatives and altogether 16 companies returned with positive feedback for participation in the proposed project. The survey gathered information about the company's name and interest in participation in the FRIENDS project, which competition areas in Solar Decathlon for Housing (SDfH) were appropriate and in what way the company is can have benefit fromn participation.

Workshop

Out of the 16 companies and two organizations, three companies joined for the workshop. The purpose of the workshop was to gather ideas and opinions from companies in what extent they are interested to be engaged in the future collaborations. A separate meeting took place to brainstorm about how an local organization can share our vision about the SDfH to their stakeholders.

Jönköping Energi: Energy smart homes

Jönköping Energi has conducted the in-house project, the energy-smart property. The primary purpose was toestablish smart control and optimization of the house's energy use and resources (electricity and heat).

The project had investigated the design and potential of a comprehensive offering of several services to give single-family homeowners better conditions to make their property more energy smart while supporting the transition to a fossil-free society and stable energy system.

From Jönköping Energi's perspective, the single family house is also seen as a possible asset for the electricity system as the electricity system has an increased need for flexible electricity and power use. The single family home can contribute flexibility if the incentives and solutions are designed correctly. Control and optimization for smart energy use, therefore, aim to generate multiple benefits for the homeowner in the form of lower costs in combination with maintained or increased comfort, society in the form of contributing with system benefits in the energy system, which generates a reduced climate footprint.

Heating accounts for the largest electricity consumption in the home.

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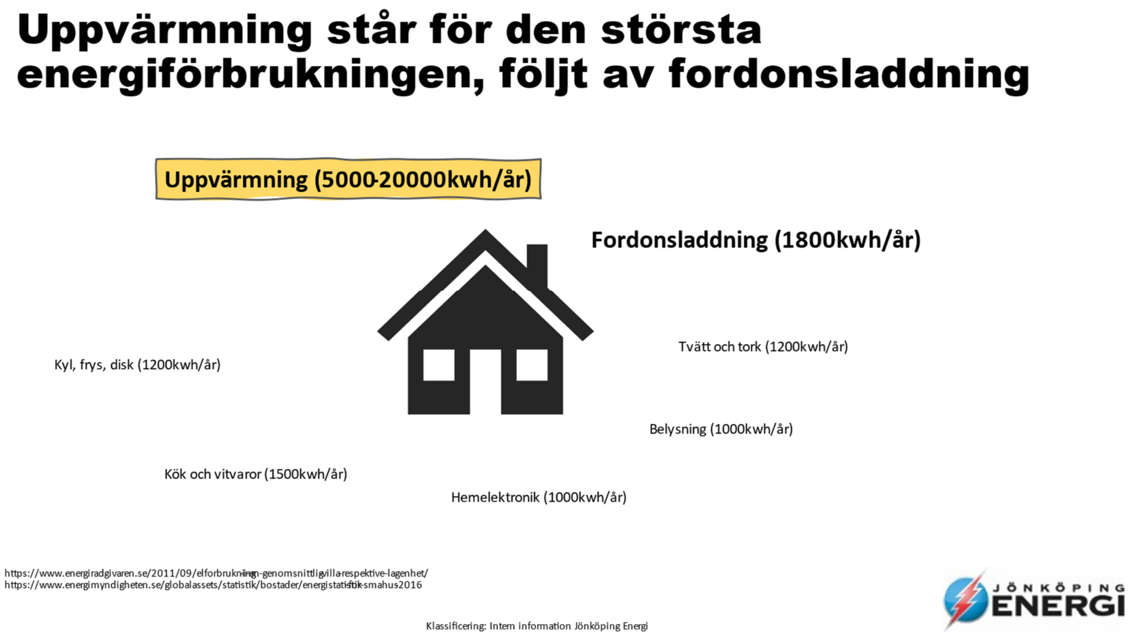

Jönköping Energi see hardware components as important to integrate, control and optimize as a whole, wherein vehicle charging, heat pumps, solar cells, and batteries exist. Vehicle charging and heat pumps account for the largest loads in the home, which in combination with solar cells and batteries become important components in the energy system. The control of the single family homes' energy use, needs to be based on requirements for comfort (such as temperature) while at the same time an economic optimization based on the cost situation and the opportunity to reduce the cost by allowing the home's electricity use to be controlled from the outside to, for example, Svenska Kraftnät's need for flexibility.

Results

Gap analysis at School of Engineering in Jönköping

Identify the area to be analyzed and identify the goals to be accomplished

This section is reviewed from sde19.hu site wherein the competition specific descriptions are also representing a generalized approach to a Solar Decathlon for Housing project. The competition areas are slightly changing according to local building codes and regulations as well as the needs. Generally, this list is representative to describe the areas to be analyzed in the GAP survey.

Architecture: The contest aims to reveal the symbiosis between state-of-the-art architectural design, space use, and technologies, in a highly sustainable manner. Teams have reflected over the future of housing and contributed to the cultural, spatial and socio-economic environment of their respective cities, regions and countries. The challenge is designing, building and operating prototypes corresponding to the local building codes and construction requirements. The prototypes are evaluated based on innovative concepts concerning local contexts, such as expandable and multifunctional space organization, comfortable and decorative lighting design, and coherent and sustainable material use. It is important to integrate natural and electric lights in a comfortable and efficient manner. Materials is assessed based on durability, maintenance, Life-Cycle-Analysis, and incorporation of energy and CO2 cycles. Teams describe bioclimatic (passive design) strategies using daylighting strategies, space planning, and semi-passive conditioning systems. Their exterior solutions must improve the microclimate around the dwelling.

Engineering & Construction: The contest concerns the integration and coherent application of the houses' technical systems. It involves the design, implementation, functionality, and safety of building structures, electrical, plumbing and photovoltaic systems. The assembly phase is vital and challenging, and Teams must prove their ability to adhere to their own planning and goals. Key aspects are the house structure and resulting acoustic performance, the electrical system and its control with detailed energy balance monitoring, plumbing, including water cycles with attention to saving, recycling, and reuse of rainwater, greywater, and accessibility for maintenance and repair. The solar systems must be integrated into the architectural composition and prove to be economically viable. Teams can score higher if their Solar Thermal Systems can provide more than just domestic water heating, e.g. ventilation and air conditioning (HVAC). The Teams' innovation qualities are highlighted within the structure, electrical and plumbing systems, and their integration on the facades. The sustainability measures target energy consumption, solid waste production, water use, and construction time in technical and socio-economic aspects seeking proposals that catalyze a more efficient everyday life cycle.

Energy Performance: The contest provides insight to systems and house design excellence. It aims to present how the finalized buildings and the process that led to their realization contribute to energy efficiency. Teams must underline the climate adaptations they have carried out in the prototypes originally designed for specific local contexts. Teams must be very clear about design elements or systems that have been added to their houses. The teams report simulations that influenced the house design process, HVAC selections and final calculations. The jury places special attention on coupling housing and mobility, observing how energy production can support vehicles that could also perform as storage (20% of the Competition points). The innovation aspects include the active and passive technical contributions that maximize the energy efficiency of the house and the methods that improve its hydrothermal, environmental, lighting and acoustic values, thus promoting liveability and ideal functioning. Both Innovation and Energy Efficiency contests are influenced by innovative concepts of building systems, equipment, functioning, and building-mobility coupling.

Communication & Social Awareness: The Communication & Social Awareness Contest aims to tailor the project narrative to all potential audiences and target groups. Teams communicate how they have promoted the value of their project to the widest possible audience, from the most local to the most global. The Communication Plan defines the goals, key messages, the project's identity and corresponding values, and a sponsorship Manual with engaging offers for partners is also a key component. The communication tools are meant to be unique, memorable, consistent, and accessible to potential audiences. The contest celebrates the Teams' determination to spread the word on energy transition, lifestyle balance and the use of natural resources.

Neighborhood Integration and Impact: The contest showcases the projects' geographical locations and community-driven urban design proposals, in the context of the housing unit's neighbourhood. It includes Key Performance Indicators (KPIs) that the buildings exchange with each other to improve system efficiency. The Decathletes prove the value of the renovations through socio-technical considerations, responsiveness and neighbourhood suitability, with particular attention to intergenerational interaction and community involvement. Some projects study collective housing buildings in dense urban areas, while others promote grouping houses in less dense areas. Teams describe the flexibility of the structures and sizes, possibilities for reuse, and adaptability to future technologies and to the local building industry. The jury will examine the social, environmental, and economic opportunities the projects provide to their neighborhood and urban environment. The innovation of the contest targets how holistic approaches provide ideas on smart building networks and what key information they exchange. The projects emphasize how density and transportation solutions contribute to environmental, social, and economic sustainability while addressing the houses' production and industrialization's economic viability.

Innovation & viability: The contest evaluates the extent to which proposals are socially, technically, and economically inventive and novel while remaining feasible. Teams emphasize innovative elements or systems for the house projects' design, development, construction, and management. The architecture segment of the contest addresses new spatial and functional concepts on all scales, engineering involves the design and construction of the prototypes' structure, systems (plumbing, electrical and photovoltaic), and acoustic performance, and sustainability involves the industrialization of the buildings and their adaptability for multifamily settings. Novel communications initiatives disseminate bold messages for the responsible use of energy, natural resources, and sustainable construction for a broad audience. Affordability and viability address economical, technical, ecological, and social aspects from a universal view. Teams define their plans' economic impact, cost-effective strategies, and decision-making processes, taking into consideration energy-saving and

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retrofitting. New ways of business planning and promoting the selected typologies are crucial to reach potential buyers.

Circularity & Sustainability: The contest reveals how Decathletes understand the sustainable built environment. Design strategies respond to how urban and dwelling-scale density solutions contribute to environmental, economic, and social sustainability. Teams describe the production and flexibility of the structure and any possibilities for reuse or adaptation to future technologies while articulating approaches to efficient maintenance. The viability of industrialization is determined by energy consumption, solid waste, water use, construction time, social and economic aspects. Circularity addresses the system-wide redefinition of products, services, and strategies to reduce consumption and design waste cycles with minimized negative impacts. The Life Cycle Assessment (LCA) evaluates how green the chosen materials are (renewable, recyclable, reusable), and how these relate to embodied energy, CO2 and pollution emission, durability, and the necessity of maintenance. The jury for circularity assesses approaches that build economic, natural, and social capital underpinned by a transition to renewable energy sources.

Comfort Conditions: This contest involves five sub-contests to measure the comfort of dwellings. These include temperature, humidity, natural lighting, interior air quality (CO2) and acoustic performance. The teams must ensure that their appliances and systems operate as they have been designed. There are two days when the houses use only passive cooling or heating. The on-site automatic monitoring systems continuously measure all relevant data. The maximum score is given for keeping the spaces between 23-25°C, optimum interior humidity lies between 40-55%, CO2 level must stay below 800 ppm, and the facade airborne sound insulation value must be equal or higher than 42 dB. The reverberation time that living room installations require to absorb sound must be up to 0.8 seconds. The sound level produced by all HVAC and active equipment must stay below 25 dB(A) for maximum score.

House Functioning: The contest evaluates the operation, performance, and efficiency of electric appliances in their daily operation while reproducing the average energy use of a modern home. Teams aim to maximize the performance of their house while complying with the demanding standards of present-day society. Points can be earned during multiple scoring periods. To rank the Teams, reduced point values per challenge are scaled linearly based on performance. For refrigeration and freezing, a continuous performance score is given. The evaluation criterion is completing the task for clothes washing and drying, dishwashing, oven, hot water draws, cooking and automation. The Dinner party receives points from fellow guests. The refrigerator must be used to store all food and beverages of the dinner contest. The washing machine has to operate automatically and provide an uninterrupted wash and rinse cycle within a specified period where its internal temperature reaches 40°C at some point. The dishwasher's internal temperature must reach 49°C at least once during its cycle, while the oven's temperature must reach 220°C during specified periods. In terms of hot water, 50 liters must be produced maximum three times per day, in 10 minutes per cycle.

Energy Balance: The Energy Balance contest is a competition to promote energy-efficient buildings. Five sub-contests address this: load consumption per surface area, positive electrical balance, temporary generation-consumption correlation, house adjustment to network load state and power peaks. Teams must maintain optimal comfort and energy balance in their homes while considering the network load management and limitations of power peaks. The 'Load Consumption' sub-contest aims to evaluate the electrical energy efficiency of the houses while fulfilling comfort and functioning demands. For a house to have a 'Positive Annual Electrical Energy Balance', the photovoltaic electricity generated throughout the year must be higher than the electric loads' consumption. The balance is calculated on-site and simultaneously calculated towards a yearly consumption estimate. Energy stored in the batteries can only be harvested from the PVs.

Establish the ideal future state

In terms of ideal future state that corresponds to Solar Decathlon's actual competition areas, includes the latest goals of a finished competition in the respective fields. To be in our ideal state, we could reference this list. The knowledge level of starting a competition was assumed as average or medium, and the average human resources needed was set at *medium*. Deviation from this level was due to the author's personal experience and the conducted interviews.

Analyze the current state

The identification of goals and areas are following the SDE19 competition guide. The general requirement is always a location specific list of requirements for the competition. In this stage, the survey had followed a less project specific SDfH structure for evaluation of the current state of the skills and competences.

Competence survey at the School of Engineering, Jönköping

Altogether, 14 participants took part in the survey from the School of Engineering. Their employment position was from PhD student to professor. Eleven were positive about participating in a team to develop this project. The first part of the survey focused on personal interest and skills in project management. This survey gathered information on existing competencies in building project management. Questions were asked regarding organization and logistics skills, project-related research contacts, project-related company contacts, good advisory ability, and experience with similar projects. The respondents' answer is summarized in Table 1. Additionally, a skill was mentioned as "Solar panels and control systems" by one of the participants.

Table. 1. Project management skills among staff members/participants

Project management	***Mean***	***SD***
Would you be interested in participating in our team to build up this project?	3.21	0.80

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Organization and logistics skills	2.93	0.83
Project related research contacts	2.21	0.80
Project related company contacts	2.14	1.03
Good advisory ability	2.93	0.73
Experience with similar projects	2.07	0.92

Note: Ratings are on a 4-point Likert scale: 1- low, 2 - slightly low, 3 - slightly high, 4 - high

Regarding skills and competence in architecture, the following Table 2 summarizes the results. Among the respondents, there were four architects.

Table 2. Architectural skills among staff members/participants

Architecture	***Mean***	***SD***
Site integration	2.07	1.21
Building design	2.29	1.33
Interior & lighting design	2.07	1.27
Solar system integration	2.00	1.11

Note: Ratings are on a 4-point Likert scale: 1- low, 2 - slightly low, 3 - slightly high, 4 - high

The participants' feedback on the Engineering & Construction skills and competences are summarized in Table 3. Only one participant was recorded in the high cluster.

Table 3. Engineering and construction skills among staff members/participants

Engineering & Construction	***Mean***	***SD***
Energy concept	2.07	1.00
Performance analysis	2.21	0.97
Life cycle carbon footprint	1.50	0.94

Note: Ratings are on a 4-point Likert scale: 1- low, 2 - slightly low, 3 - slightly high, 4 - high

Participants generally lacked high experience in energy performance measurement skills, and only one individual reported a high skill level on energy performance, but high competence level was missing on the grid interaction (Table 4).

Table 4. Energy performance skills among staff members/participants

Energy performance	***Mean***	***SD***
Energy consumption	2.07	1.14
Energy balance	2.07	1.07
Self consumption	1.71	0.91

PV system performance	1.71	0.99
Performance	2.07	1.00
Grid interaction	1.43	0.76

Note: Ratings are on a 4-point Likert scale: 1- low, 2 - slightly low, 3 - slightly high, 4 - high

Participants generally lacked high-level experience in affordability and viability skills (Table 5).

Table 5. Affordability & viability skills among staff members/participants

Affordability & viability	***Mean***	***SD***
Affordability	2.00	0.88
Viability	2.14	1.10

Note: Ratings are on a 4-point Likert scale: 1- low, 2 - slightly low, 3 - slightly high, 4 - high

The communication and social awareness ratings are slightly high, meaning a good skill and competence level of self-assessment (Table 6).

Table 6. Communication & social awareness skills among staff members/participants

Communication & Social awareness	***Mean***	***SD***
Communication	2.79	0.89
Education	3.21	0.80
Social awareness	3.00	0.68

Note: Ratings are on a 4-point Likert scale: 1- low, 2 - slightly low, 3 - slightly high, 4 - high

Regarding sustainability and circular economy self-assessments, the participants tended to rate their competence level as slightly low (Table 7).

Table 7. Circularity and sustainability competence levels

Circularity & Sustainability	***Mean***	***SD***
Circularity	2.21	0.89
Sufficiency	1.85	0.80
Flexibility & environmental performance	2.23	1.01

Note: Ratings are on a 4-point Likert scale: 1- low, 2 - slightly low, 3 - slightly high, 4 - high

In the specific areas of human comfort, the participants have some individual competencies, meanwhile, the group's competence evaluations show a slightly low value. More importantly, air, sound, and humidity lacked high competence ratings (Table 8).

Table 8. Comfort conditions

Comfort conditions	*Mean*	*SD*
Temperature	1.93	1.00
Humidity	1.86	0.86
Air quality (CO2}	1.57	0.76
Lighting	2.00	1.04
Sound insulation	1.57	0.85
Air tightness	1.50	0.76
Performance gap	1.54	0.66

Note: Ratings are on a 4-point Likert scale: 1- low, 2 - slightly low, 3 - slightly high, 4 - high

Self-assessment of competencies in house functioning showed the highest need for experts in water management, while user friendliness and appliances were better served.

Table 9. House functioning skills among staff members/participants

House functioning	*Mean*	*SD*
Appliances	1.86	1.03
Water	1.50	0.85
User friendliness	2.57	1.22

Note: Ratings are on a 4-point Likert scale: 1- low, 2 - slightly low, 3 - slightly high, 4 - high

An individual scored high competence on the Mobility (M=1.86; SD=1.03) self-assessment and three others on the Innovation (M=2.64; SD=1.01). A comment was attached to the last field: "*I have seen these types of demonstrators in Europe and think they can be interesting to collaborate around. As my field of research is about integrating production and product development - I can see a lot of small projects that can be jointly done. However, our department is also highly involved in the solar car - so I think we need to find a way to bridge these two ideas to use the resources efficiently. Also, performing something jointly with Träcentrum, one of our SPARK partners, would be interesting. Moreover, if we should perform such a project, I am missing the aspects of developing products as well as the production aspects of them.*"

Interviews

We have interviewed several people in the mapping process to understand how we can build up a project for the Solar Decathlon Europe. The interviews had provided insights about the structure of the competition, level of engagement required, the education relatedness and expected competence development.

Interview 1: Francesco Longo is a student coach for the Dutch team, TU Delft. Their student driven project was built up of graduate students who controlled the activities and set up the specific goals. The project group initially consisted of 15 people, but later formed into 10 smaller project groups. A project management team of six students kept the project together until the finish. The university supported them with premises and some project development capital, and two faculty members were assigned to support and follow the project. The total budget was 1.3 million euro, with 50% allocated to building materials and fixtures, and the other half went on hired consultancy in architecture, construction, and financial calculation. Transportation in the form of eight trucks cost a lot, but once in place, it was the hotel and food that needed to be paid for. A small part of their budget went on rents, licenses for software programs and printed materials. The funds came from sponsors and industrial/educational partners. Francesco strongly recommends JTH to participate in a Solar Decathlon competition as there is no similar opportunity for development projects for students.

Interview 2: Magnus Andersson is the Project manager for the Solar Car project at JTH, which has been going on for several years. It is structured as five independent courses, starting with an introductory course in January and four 15 credits courses. The project courses produce design, and the car itself, and a marketing/sponsorship and leadership course runs in parallel. Two employees at JTH work on the project for 50% and 25%, respectively. Managing the time for the project is a big challenge, and the premises have required a large area and there have been conflicts on resources and use premises.

Interview 3: Lars Eriksson, Professor of Industrial Design at JTH

The industrial design program believes that there are potential collaboration paths for designing specific products in the project. They have a well-functioning form for it in their project courses and have interesting partners with well-established contact networks. They also have furniture design education in Nässjö and local industries such as Huskvarna and IKEA. However, it is difficult to be a full-time partner as they have already built up the progression curve for their students according to other needs.

Interview 4: Jonas Runberg, Professor, Architecture and Civil Engineering, Chalmers. Project leader for Chalmers Solar Decathlon 2021

He has participated in Solar Decathlon in China and London, where he had a budget of 7 million SEK and managed to sell a house for 4.5 million SEK. He also participated in the group that competed in London, where they had a local university to collaborate with. Jonas advises having many resources regarding teacher time and student, and logistics needs to be carefully solved when the competition is further away than Europe. The project needs a great deal of marketing and economic personnel to support throughout the project.

Interview 5: Károly Matolcsy, the coordinator of SDE19 in Hungary

His involvement in the SDE19 was from the main organizer's perspective, providing valuable details on the acquisition of a multimillion-euro project. He encourages participants to participate in the competition but urges them to get the financing straight as soon as possible. He also suggests developing a Scandinavian college competition that better fits the northern climate and suggests that solar panels may not be the only way to deal with a smart home. He would like to see the team in the near future.

Compare the current state with the ideal state

The estimated current and ideal levels are based on the author's personal experience and information gathered from the staff survey and interviews. The competence and skill levels partially correspond to the staff survey rating scale, with the average score on each competence and skill level under two being considered as low, between two and three as medium, and over three as high. These results were validated during an in-house discussion among staff at the Department of Construction Engineering and Lighting Science.

Table 10. Comparison of the estimated current and ideal state for Solar Decathlon for Housing competition

Project part to fulfill	**Current state**		**Ideal state**	
	Resources	Knowledge	Resources	Knowledge
1. Project management	H	H	M	H
2. Architecture	L	H	L	H
3. Engineering & Construction	L	H	M	H
4. Energy performance	L	M	M	M
5. Affordability & viability	M	M	M	M
6. Communication & Social awareness	H	H	H	M
7. Circularity & Sustainability	L	H	M	M
8. Comfort conditions	M	H	M	M
9. House functioning	M	H	M	M
10. Mobility	L	L	L	M
11. Innovation	L	L	L	M

Note: H = High (3≤score), M = Medium (3>score≤2), L = Low (2>score) corresponds to estimated skill and competence level, including staff survey scores and personal estimation.

Describe the gap and indicate the difference

The human resources and knowledge needed in each competition area are summarized in Table 11. The experience from the interviews shows that earlier groups are gradually increased their resources as the construction-related requirements heightened. In terms of knowledge needs, the competition does not require the highest knowledge level initially, but a constant influx of new knowledge is expected to make the participants experts in their field at the end of the competition. The notes section mentions gaps in the knowledge and expert knowledge requirements, validated during an in-house discussion among staff at the Department of Construction Engineering and Lighting Science.

Table 11. Description of gaps in the estimated current and ideal state for Solar Decathlon for Housing competition

Project part to fulfill	**Current state**		**Ideal state**	
	Resources	Knowledge	Resources	Knowledge
1. Project management	H	H	(-)M	H
2. Architecture	L	H	L (External)	H
3. Engineering & Construction	L	H	(+)M (External)	(+)H
4. Energy performance	L	M	(+)M (Internal)	M
5. Affordability & viability	M	M	M	M
6. Communication & Social awareness	H	H	H	(-)M
7. Circularity & Sustainability	L	H	(+)M (Internal)	M
8. Comfort conditions	M	H	M	(-)M
9. House functioning	M	H	M (External)	M
10. Mobility	L	L	L	(-)M
11. Innovation	L	L	L	(-)M

Note: H = High (3≤score), M = Medium (3>score≤2), L = Low (2>score) corresponds to estimated skill and competence level including staff survey scores and personal estimation; (-) means a surplus, (+) means extra needs; External or Internal refers to expertise employed relation to SOE

Summarize the recommendations and create a plan to bridge the gaps

SDfH is a competition to establish a working housing prototype at the announced site. For the European competition, this site is located within the European Union. Option one is to build and then deliver a working prototype at the competition site. Another option is when two working prototypes are being built one after the other, depending on where the competition site is. The solar decathlon organizers can purchase the prototypes on the competition site for a fixed amount. Our experience is that universities are offering optional courses to design and construct prototype buildings. In our case, the outline for such a two-year project could be a two-year long graduate course with 50% or with 100% studies. In this case, the university staff is in an empowering position. Meanwhile, the other option is to offer non-mandatory courses parallel with the ongoing educations (existing bachelor or master), mostly after the regular teaching hours. In this case, the students should be the leading initiative takers, and the staff should be compensated for overtime. Either way, the project is highly dependent on students' attitudes, participation, problem-solving, and cooperation abilities. Involving external experts are standard practice in this competition, and the collaboration can be seen as in-kind resources in the sponsorship.

Two plans are created for bridging the gap and test different approaches to continue the project.

1. Establishing an education driven activity that aims to involve students in the prototype building and evaluation. This alternative requires optional courses fitted to the activities. Company resources are less crutial and leaves space for a stable development.
2. Establish a research driven testbed, that is involving final thesis focused students in the prototyping and evaluation. In this approach, the lead researchers are behind the resource acuisition and invite students for certain task to perform. On one hand, this option is more exposed to externality of funding, thus company resources are cruitial to obtain. On the other hand, the companies flexibility can have a positive effect on the prototyping.

Plan ONE

To create a comprehensive plan for a university course on energy-effective buildings and systems, it is important to consider the latest research and industry trends. The planned courses cover topics such as sustainable design principles, energy-efficient building materials, renewable energy systems, and building automation technologies. Additionally, students should be given hands-on experience through practical exercises and case studies to ensure they have a thorough understanding of the subject matter.

The following course sylabi were made:

- Introduction to Smart Housing Challenge, 7,5 credits / Introduktion till Smart Housing Challenge, 7,5 hp
  Knowledge and understanding:
  - show familiarity with the content, requirements and external factors that are important for Smart Housing Challenge
  - display knowledge of sustainable built environment considering, net zero and energy positive buildings, construction systems, energy consumption, solid waste production, electric and natural lighting, and water use and interoperability of other systems.
  - demonstrate comprehension of project management, group dynamics, public relations, and sponsoring with a focus on Smart Housing Challenge
- Smart Housing Design Challenge, 7,5 credits / Smart Housing Design Challenge, 7,5 hp
  Knowledge and understanding
  - show familiarity with buildings' architectural qualities by the clarity of the concepts and design intentions, as well as the organization of space in relation to the technology sustaining it
  - display knowledge of designing prototypes that correspond to the local building codes and construction requirements
  - demonstrate comprehension of constructing expandable and multifunctional space organization, comfortable and decorative lighting design, and coherent and sustainable material use.
- Smart Housing Performance Assessment, 7,5 credits / Prestandabedömning av smarta bostäder, 7,5 hp
  Knowledge and understanding
  - Students familiarize and critique technological applications that are contributing to the smart building concept
  - Students compare and construct new evaluative methods to measure objective and subjective data
  - Students simulate future scenarios with the development of a Digital Twin
- Smart Housing Construction I., 7,5 credits / Smart boendekonstruktion I., 7,5 hp
  Knowledge and understanding
  - show familiarity integrated architectural design and construction
  - show familiarity construction safety
  - demonstrate electrical and sensor installation for smart systems including energy performance and balance, lighting, temperature and acoustic performance
  - demonstrate plumbing and water treatment systems
  - demonstrate integrated photovoltaic system installation
  - demonstrate maintenance and operabilit

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Plan TWO

The company survey approached 87 local companies operating in building construction, logistics, and architecture. 16 companies returned with positive feedback for participation in the proposed project. The survey gathered information about the company's name and interest in participating in the FRIENDS project, which competition areas were appropriate, and how the company can benefit from participation. Figure 1 shows the result of the company survey with regards to interest area. Several interest areas could be marked simultanously, therefore altogether, 51 interest areas were chosen, on average three per company.

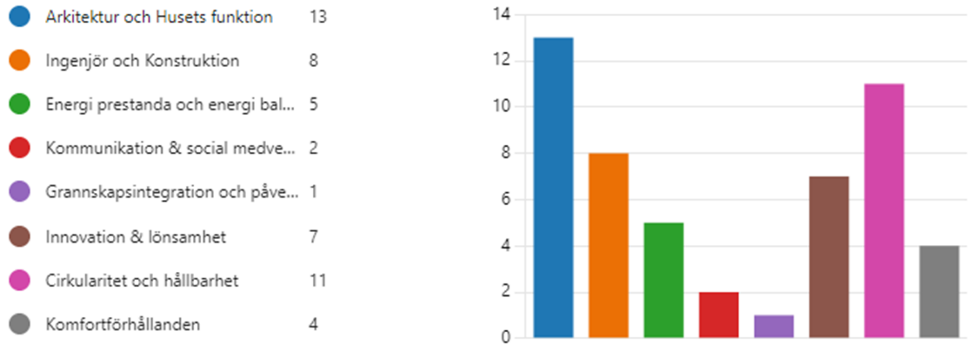

Figure 1. The selected interest areas that the companies are currently engaged with (N=16).

Another purpose of the company survey was to investigate how would the companies in question benefit from an SDfH prototype and the reason behind the interest in collaboration. Most companies would like to renew themselves (M=3.13; SD=0,62), and only two looked less likely into this option. The companies joined this initiative (69%) because they h*ave an idea for climate-smart and connected buildings* (M=3.06; SD=1.00), while only three companies were not sure about it. Afterward, all of the companies were *curious* (M=3.88; SD=0.34) and *would like to know more in terms of knowledge* (M=3.56; SD=0.51) about climate-smart and connected buildings. The *increase in economic feasibility* (M=3.00; SD=0.89) was the least motivating factor for participating in the project. The *starting and or continuing collaboration with the School of Engineering* also scored high on the four-point scale (M=3.44; SD=0.63), and the *platform* concept *for exchanging ideas* became fourth in the overall ranking (M=3.38; SD=0.72). Figure 2 shows the summary of the questionnaire.

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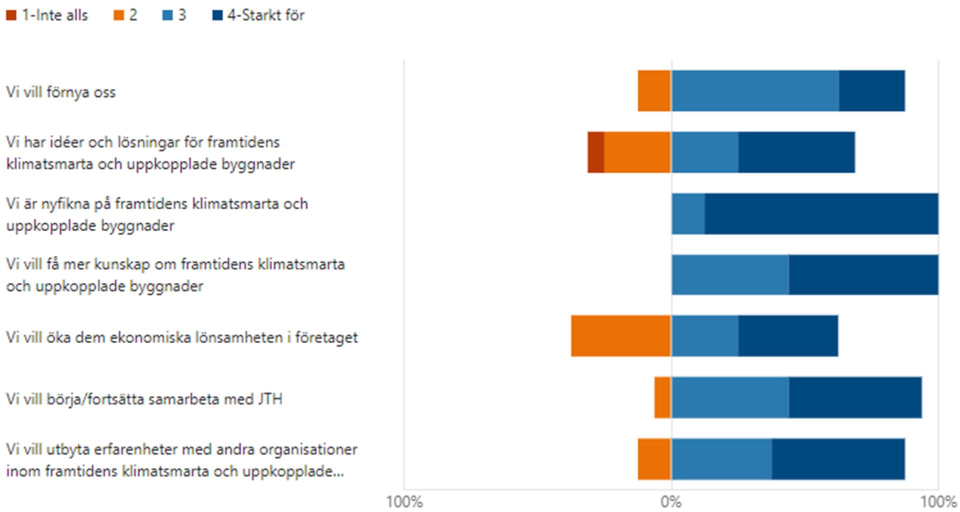

Figure 2. Summary of reasons why companies were interested to join the platform for climate-smart and connected buildings. (Note: 1-Not at all interested; 4-Strongly interested)

The following companies had indicated willingness for participation in the SDfH type of project:

OrganoWood AB	produces sustainable timber and wood protection products
Cembrit Sverige AB	Cembrit is a distributor and manufacturer of fiber cement products in Europe
ROCKWOOL	Inorganic material made into matted fiber used especially for insulation or soundproofing
PEAB Sverige AB	Peab is the Nordic Community Builder with 15,000 employees and net sales of SEK 63 billion
Byggkonstruktioner AB	A smaller consulting company that specializes in building construction
Sweco Architects	Sweco is Europe's leading engineering and architecture consultancy
Fredblad Arkitekter	is the personal and family architectural office
PE Teknik & Arkitektur	PE is one of Sweden's leading architectural and technical consultants with a focus on buildings and their immediate environment
Rits Arkitekter	is an architectural office with good and long experience in designing and developing living environments

Sanna Bygg AB	is a comprehensive supplier of houses and homes that offers both architectural and construction services.
SYSTRA AB	is a consulting and engineering company, a world leader in transport infrastructure
SM Smart Teknik AB	helps companies with smart technology solutions
Eld & Vatten	supplies products for passive fire protection all over Sweden, mainly to the construction and painting industry, and have both small and large customers

Continuation

Two research project themes were developed during the project period, one dealing with the energy collaborative of a responsive system and the other investigating a circular wooden material.

1. Recently, the rapid increase in electricity prices has affected the attitude and occupant behavior toward electricity and energy demands in residential environments. A misunderstood and oversimplified occupant behavior cannot predict and tailor new smart services in the electrical energy supply model. Independently of the recent crises, the electric energy sector has evolved from an integrated hierarchical structure to a more deregulated model, but still not entirely up to date with the ongoing transformation to a more open, shared, and collaborative structure. An energy collective's goal is a locally produced, more environmentally, economically, and politically sustainable way of using and generating energy. In practical terms, this energy collective can be utilized through a Virtual Power Plant (VPP) that meets market expectations of a decentralized, decarbonized, and digitized electric grid and responds to fast market changes as the exceptional growth of Distributed Energy Resources (DER). The repertoire of a VPP includes hierarchical control methods that enable the VPP to utilize the various capabilities of the DERs by data sharing between higher- and lower-level controls, thereby increasing the flexibility of the VPP in providing electric services in a power system. This study aims to map and simulate an occupant-driven energy collective using locally produced energy in a VPP system.

2. The collaboration of architecture, design, and co-creation with customers has become increasingly popular in recent years. This approach involves involving customers in the product development process, allowing them to provide feedback and suggestions. This results in products that better meet the target market's needs and wants, increasing customer loyalty and satisfaction. The circular wood product is an important part of a future demonstration project produced in collaboration and meeting the Solar Decathlon for Housing design requirements. This international competition challenges collegiate teams to design and build energy-efficient homes powered by renewable energy. By involving customers in

the production process and meeting design requirements, stakeholders can ensure that the resulting homes are sustainable and meet the needs and preferences of end users. This strategy can lead to a more sustainable future by increasing satisfaction and encouraging the adoption of sustainable housing practices. The architectural design seamlessly integrates the new wood-based material into the building's overall aesthetic and function, promoting sustainable practices and demonstrating the versatility of circular wood as a building material. The collaborative production process fosters a sense of community and encourages local businesses to work together towards a common goal.

SMART HOUSING SMÅLAND

– INNOVATIONSARENA FÖR LIVSMILJÖER I GLAS OCH TRÄ

Genomförandeorganisationerna RISE, Linnéuniversitet, Jönköping University och Träcentrum i Nässjö i Smålandsregionen. I samverkan ingår förutom finansiärerna representanter från näringslivet genom OBOS, Tengbom, CBBT- Centrum för byggande och boende med trä, TMF – Trä och möbelföretagen, Sveriges Träbyggnadskansli, Glasbranschföreningen, Glasforskningsföreningen Glafo och dessutom de tre länens Länsstyrelser. Utöver detta sker samverkan med andra universitet, innovationsplattformar och samverkanskluster både nationellt och internationellt.

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