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## The design process for achievement of an office living laboratory with a ZEB standard

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# The design process for achievement of an office living laboratory with a ZEB standard

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**Abstract.** ZEB Laboratory is a full-scale office building with a ZEB-COM ambition, searching a high degree of flexibility and where components and technical systems can be modified for research purposes. Project delivery of a living laboratory with a ZEB standard is not an easy task. The implementation of the ZEB method in a partnering contract as a project delivery model has been developed. This paper describes and elaborate the development of the project delivery and design process for ZEB Laboratory seen by the client. The ZEB Laboratory design and procurement process has given valuable insight and experience into the use of partnering and collaborative elements for planning and production of ZEB buildings.

## 1. Introduction

The ZEB Laboratory is an office living laboratory 4 stories high and approximately 2000 m<sup>2</sup> located in Trondheim, Norway. The design of the building is ongoing and construction started May the 7<sup>th</sup> 2019. ZEB Laboratory is a full-scale office building with a ZEB-COM ambition [1], searching a high degree of flexibility and where components and technical systems can be modified for research purposes. The building will form a living laboratory where the client (NTNU and SINTEF) is using it as an (ordinary) office building and for educational purposes, where the users also become an experimental parameter giving variations in loads with their use of the premises.

The funding for an office living laboratory has been achieved by an application to the Research Council of Norway. NTNU/SINTEF was awarded 63 million NOK from the Research Council, 8 million NOK from Enova, and together with in-kind contribution from NTNU and SINTEF, a total budget of 127 million NOK for the research office building with a ZEB-COM ambition is made available.

## 2. Vision and ambitions

The vision of the Norwegian Zero Emission Building Laboratory (ZEB Laboratory) is to be an arena where new and innovative components and solutions are developed, investigated, tested and demonstrated in mutual interaction with people.



The ZEB Laboratory shall be:

- a basis for knowledge development at an international level,
- a basis for international competitive industrial development,
- an example for new and retrofitted zero emission buildings,
- a research arena for developing zero emission buildings,
- an arena for risk reduction when implementing zero emission building technologies,
- a national resource for all research organisations in the research area,
- a tool for NTNU and SINTEF for institutionalizing the post ZEB Centre [3].

The focus is on making the initial building a relevant research case, both with regard to energy performance, climate mitigation and adaptation and mutual interaction with users-building interaction in a Nordic climate. In order to make the building a relevant research case, NTNU/SINTEF has defined and asked for a building to fulfil certain ambitions for the ZEB Laboratory [6]. These are, in prioritized order:

1. The building should be a model project and achieve ZEB-COM level (simulated in a 60 years perspective) [1]
2. Separate control and measurement systems, one for ordinary operation and one for research
3. Flexibility in design of energy and climatization systems
4. Flexibility in design of working spaces
5. Progressive selection of materials and enabling rebuilding parts of the facades
6. Adaptation of the building to climate change [5]

### 3. Theoretical framework

#### 3.1. *Project delivery - Contract models*

Selecting a project's delivery method is an imperative client decision. The delivery method defines the roles and responsibilities of all project participants, how to finance the project, and it sets the framework for the delivery. In regards of different delivery methods to adopt, the owner has a wide array to choose from [19]. However, the choice is often limited by factors such as procurement laws, tradition, competence, etc. Furthermore, the project delivery method for buildings have to take into account the boundaries, framework and complexity of the particular project. For traditional building projects where the main issues are time, cost and quality *Design-Bid-Build* and *Design-Build* are the most used project delivery methods. However, as The ZEB Laboratory is a complex project with ambitions to deliver in areas beyond time, cost and quality, a new type of project delivery method is needed. A central aspect of construction projects is the allocation of risk between the actors, and one of the most prominent elements for managing risk is the use of construction contracts. In traditional project delivery methods, the contract is often extensive and carefully written, clearly defining the relationships of all parties. Furthermore, the contract determines at which phase the contractor gets (part) responsibility and has a direct impact on risk distribution and innovation in a design and construction process [4]. Due to the complexity of the project, a tradition contract for managing risk was seen as adversely towards achieving the client's ambitions. Taking this into account when crafting the right project delivery method for the ZEB Laboratory, three distinct methods were considered relevant for the project. The three methods were Design-Bid-Build, Design-Build, and lastly a collaborative form of project delivery method.

##### 3.1.1. *Design-Bid-Build contract and Design-Build.*

The Design-Bid-Build is often referred to as the most prevalent project delivery method. The method is centered around the owner engaging an architectural or engineering firm to produce a set of plans, specifications, and specific project requirements. These are again used as bid documents that are being

distributed to contractors. Then the contractors submit a bid to complete the work as outlined in the bid documents [9].

The Design-Build is a project delivery method in which the owner provides requirements for the project and awards a contract to the contractor who will both design and build the project [10]. Consequently, there is only one contract for the client to manage, removing some risk at the expense of influence. Both the Design-Bid-Build and Design-Build are typically used and suited if the project is clearly defined and the technology involved are well known. Under traditional contractual conditions, there are strict differences in terms of what the parties should do. The contract consequently contains detailed provisions on the placement of responsibility for something going wrong, for example. In case of delays, errors made during the execution of the work and defects discovered after delivery. Because the financial responsibility is placed solely on the "guilty one", a contradiction between the parties can easily be developed and disagreements arise with regard to who has caused the problems. The parties are naturally more concerned about document their "own excellence" and the "other's inability" than by trying to solve the problems in the best possible way.

### *3.1.2. Partnering/Collaborative contract*

The Partnering approach may take many forms due to the lack of one consistent framework. The Partnering concept is often attributed to Oil and Gas development projects in the North Sea. The approach was later adopted by the construction industry, as Alliances in Australia and Finland, IPD in North America, and Partnering in the UK. According to the literature, there is a division between those who see partnering as an informal development and those who regard it as something that can be actively engineered. Towards the formal spectre, partnering may be archived by the use of specific contracts, and the use of incentive systems based upon risk/reward [11]

The American Institute of Architects defines Integrated Project Delivery (IPD) as a project delivery method that seeks to integrate people, systems, business structures and practices into a process that maximise the effort to optimise project results, increase value, reduce waste, and maximise efficiency through all phases [12]. The contract used in the IPD is referred to as so-called multi-party contract where the owner, architect, contractor and other key execute a single contract. Another specific approach is the Australian Alliancing method. An alliance is defined as a non-equity alliance between a client and service provider using a contract. A project alliance is formed under interorganizational cooperative arrangements for delivering a specific project or outcome and has a defined end [17].

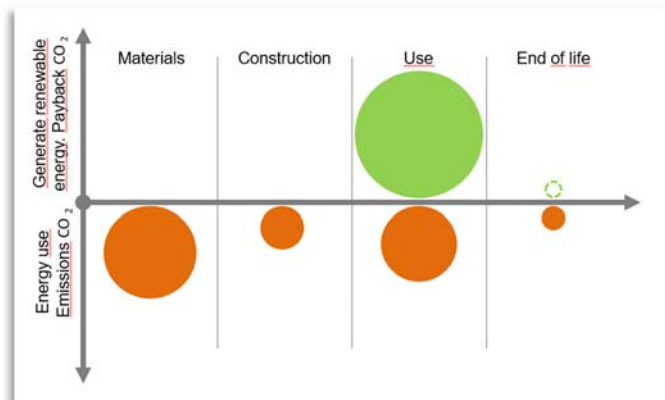
As stated previous, selecting the project delivery method is determined by the client. Furthermore, each delivery method has its advantages and disadvantages depending on the characteristics of the projects under consideration. Some of the common features of the different collaborative project delivery methods is that they go further in seeking integration than the more traditional Design-Bid-Build and Design-Build methods. Fischer summaries key elements for archiving such integration through the following elements [18]:

- Early involvement of key participants.
- Profit disassociated from units of cost.
- Costs without profit paid to completion.
- Profit adjusted based on agreed outcomes.
- Joint setting of targets.
- Joint project management.
- Reduced liability among team members.

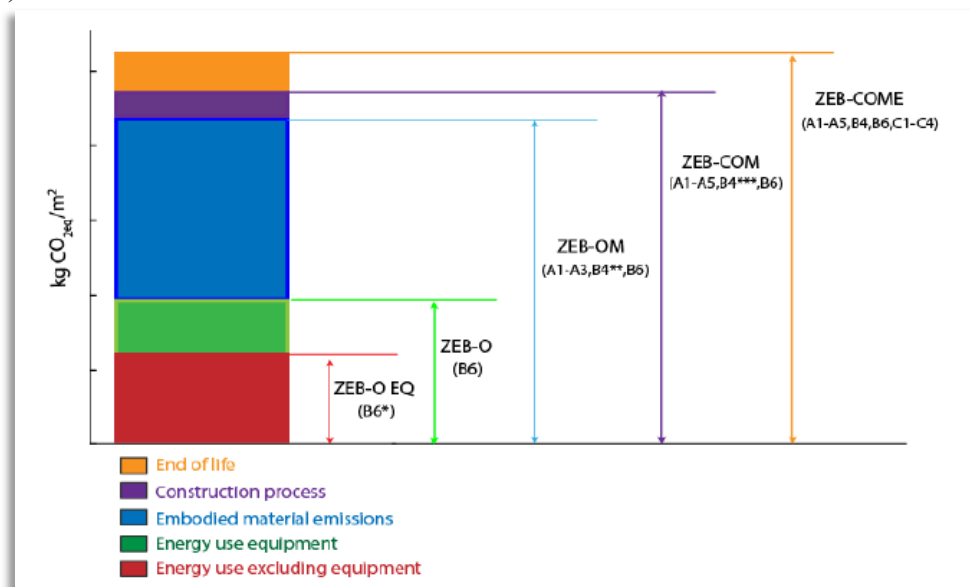
### *3.2. ZEB design method*

The EU Commission asks for (Directive 2010/31/EU) the transformation of the building stock and the shift to more sustainable energy supply and nearly zero energy buildings. It also promotes that Member States can choose to further rise the ambitions in terms of mitigation actions and provide numerical indicators, for example for the entire building's overall energy use or greenhouse gas emissions. In the

Norwegian ZEB Centre [3] zero emission building (ZEB) concepts and technologies have been developed and five ambition levels have been defined [1], see Figure 1.



a)



b)

**Figure 1.** a) An illustration of the whole life greenhouse gas emissions are constituted by manufacturing of construction materials and building services, the construction process, building operation, and finally demolition, including reuse or recycling of materials b) The numbers in brackets refers to the included life cycle stages according to NS-EN 15978 Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method. The "O" refers to emissions associated with Operational energy use. The "M" refers to embodied emissions associated with building construction Materials. The "EQ" refers to operation emissions from technical Equipment. The "C" refers to emission associated with Construction and installation, while the "E" refers to embodied emissions associated with end of life phase of the building. [1]

The ZEB design method is described in Hestnes et al. 2017 [3]. The method is recently developed and introduced in the building sector. In the former ZEB Centre [3] nine pilot building projects were performed, and an integrated energy design process (IED) was used to achieve the ZEB goal in the best possible way. In the simplest of terms the IED has these main characteristics:

1. It calls for a different approach from the very early stages of design

2. It requires a high level of general skills (energy knowledge in a broad sense) and communication within the team
3. It leads to a high level of integration and synergy of systems
4. It involves modern simulation tools where suitable

## 4. Results and discussion

### 4.1. Designing the project delivery

Project delivery of a living laboratory with a ZEB standard is not an easy task. NTNU/SINTEF went through a project delivery of ZEB Living Lab (a residential living laboratory) from 2012-2015 [2]. Some valuable lessons were learned, and experiences were made related to project delivery, i.e. project development, procurement and contracts.

The ZEB Laboratory is being built with "tomorrow's" technology. Principles and overall needs were defined in the project description for the *Norwegian Research Council*, but design and solutions for how we could best fulfil the high ambitions of the building was not determined in the application. In the initial planning phase, we draw on the research environments at NTNU and SINTEF to clarify the thoughts and needs for the use of the building/laboratory in order to obtain maximum benefit for measurement on components, as well as the development of new solutions. The users of the building also had to enter the planning early so that their need for a modern office building is satisfied. In addition, the educational aspect for students and doctoral candidates was mapped. The initial planning phases resulted in the project group at NTNU/SINTEF expressed the ambitions for the building in a note – *Level of ambitions* [6], which has followed the project and acted as a guiding document. The overall ambitions are expressed in chapter 1. Introduction.

With the high ambitions in terms of complexity and innovation the risk picture was evident. For the ZEB laboratory it would have been extremely demanding to define exactly what the delivery should be early in the project. We saw it as beneficial and an important part of the success of the project to collaborate closely with and draw on a skilled group of architects and engineers in both design and construction to achieve an excellent team within all relevant fields. Project complexity, the need for innovation, and the risk picture made the client choose a collaborative project delivery method. As opposite to traditional methods, this approach let the client focus on integration through early involvement of key participants, profit disassociated from units of cost, joint project management, and reduced liability among team members.

The first stage of the delivery of the project was initiated by a search for the right people, a team, eager to innovate and participate in a multidisciplinary group developing the laboratory. The assembled team needed to understand that changes in the project was expected and as well as understanding the client's need for innovative solutions. This also included taking care of end-user needs and influence in the upcoming planning and implementation stage. Therefore, a team of people with high level of general skills, i.e. energy knowledge in a broad sense, and evident communication skills were necessary. Not all people/personalities fit within this kind of project. Today's engineers and consultants are specialists performing very narrow and sequential tasks, which again creates fragmentation, and lowers productivity in the design process [13]. An integrated team is often proposed as a possible solution for tearing down the interfaces between the specialists. Consequently, the integrated team might aid the project in achieving its ambitious goals through allowing the skilled group to work in unison, towards some common project objective. Furthermore, the complex risk picture and interfaces in the project, made it necessary for early involvement of the contractor. This led the contractor to understand the risk picture early, leading to better planning regarding the implementation stage. A common understanding of the risks involved is also highly relevant to the cost of the project and the complex interfaces are better handled by actors with common goals.

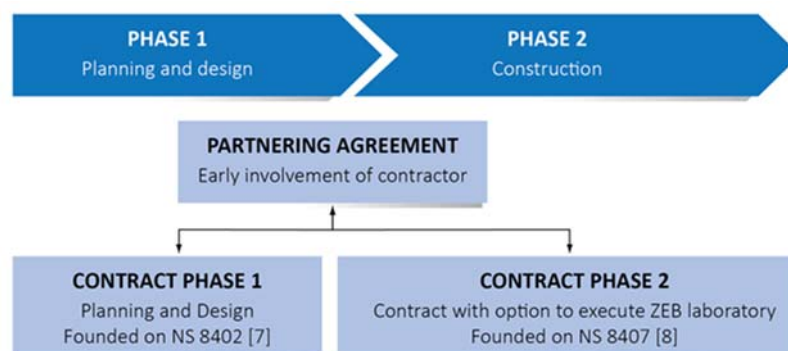
As for the overall project delivery method, NTNU/SINTEF as client spent time to find and develop a method that could fit the current project together with an expert in project delivery method. A partnering contract structure was developed (see Figure 2) and asked for in the bid. The project delivery was divided into two phases, Phase 1; Planning and Design and Phase 2; Contract with an option to execute ZEB Laboratory (if target cost was accepted). A pre-project was developed through an integrated team approach in Phase 1 and a target cost was established. The client (NTNU/SINTEF) took the risk and they were also in charge of the decision making. The target cost principle is centered around the idea that the contractor's involvement in the pricing process improves the chances of developing an accurate estimate, as well as a useful mean for gaining commitment to project objectives [14]. In Phase 2, the contractor (Veidekke) has the responsibility for the design and the construction, the client contributes. The contractor has its expenses compensated but carries risk when exceeding the target cost. The client has decision making competence through change mechanisms.

A bid was developed focusing on the content of the contract for planning and design (Phase 1) and construction (Phase 2), competition rules, the project and overall requirements. The description with the overall ambitions for the project [6] were made as part of the bid. In the evaluation of the offers from the different contractors, the award criteria and the weighting of the different parts of the offer was:

1. tender amount 0,30
2. implementation plan 0,30
3. the project organization's expertise and experience 0.40

The selected contractor was Veidekke Entreprenør with their team; LINK Arkitektur, Aas Jakobsen, Siemens, Multiconsult, Oras/Bravida Trondheim and Vintervoll.

Figure 3 shows the partnering organization of the project. The steering group for the partnering consists of the regional leader of the contractor (Veidekke) and the property manager at NTNU. The partnering management team consists of the project leader for NTNU/SINTEF and his assistant and two responsible leaders from Veidekke. They meet weekly to sort out issues related to the partnering. The project team consists of a group of people from the contractor, its team and people from the client's core group. This team is led by a project leader from the contractor.



**Figure 2.** Contract structure. NS 8402 [7] and NS 8407 [8] refers to Norwegian contract standards

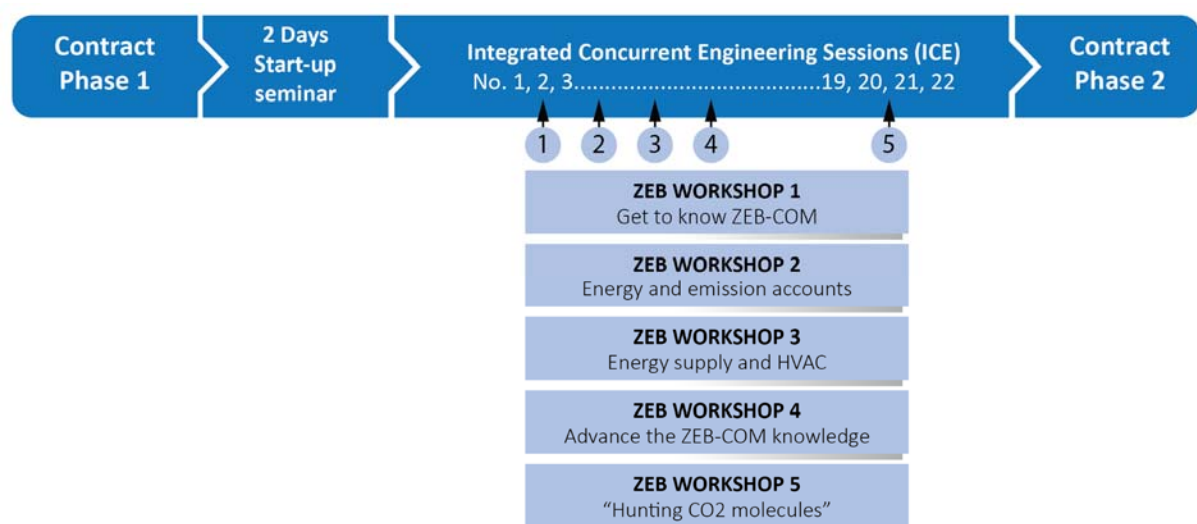


**Figure 3.** Partnering organization for the ZEB Laboratory project

#### 4.2. Integration of the ZEB-method

The ZEB design method [3] is recently developed and introduced in the building sector, very few actors, i.e designers, contractors and manufacturers have learnt, experienced and are familiar with the method yet. This was also the situation for the selected ZEB Laboratory project team. The client facilitated the partnering in their BigRoom close to the building site, seeking to utilize the benefits of having a co-located project team. The BigRoom is the physical manifestation of the co-location principle, often designed as a room furnished with desks located in a horseshoe around SMART boards [15]. The contractor organized the development of the project with a two days start up seminar followed by co-location of the project team in *Integrated Concurrent Engineering (ICE)* sessions weekly, see Figure 4. While not being a radically different working method, the ICE methodology is a client-driven approach that focuses on getting the most out of the design team by relying on teamwork [16]. The main working period in Phase 1 started in the beginning of May 2017 (ICE session no. 1), ending late November 2017 (ICE session no. 19). Due to unforeseen circumstances the client had to move the building to a new site, next to the original site. Consequently all project documents needed to be revised. That meant a stop in the development of the design of the ZEB laboratory and it lasted one year between ICE session 19 and 20.

The achievement of a ZEB building calls for a different approach from the very early stages of design. We decided to organize a group of ZEB workshops integrated in the partnering. All together five workshops focusing ZEB definition, energy and emission accounts, relevant ZEB technologies for buildings and indoor environment were arranged with an extended group of people from the contractor, the consultants, the suppliers and the client as work on the design of the building prolonged in Phase 1. See also Figure 4. An important part of a ZEB process is to care for and take responsibility for the overall ZEB achievement more than only your own deliveries. A collaborative positive engagement is needed and developed collaborative skills among the people in the group are necessary. If this is not the case, changes in personnel should be done, this was also the case in this project.



**Figure 4.** Sketch of implementation of measures to perform the ZEB methodology in the partnering process in the ZEB Laboratory

The project is now in Phase 2 doing the detailed design and the construction. The ICE-sessions are replaced by design meetings weekly for the project team, where relevant consultants are present in addition to the key personnel from the contractor. People from the client is also present in the design meeting, making sure the solutions from Phase 1 are implemented in the detailed design and as "consultants" in decision making. Dedicated personnel by the contractor have the responsibility for the



LCA account. Solutions and suppliers are selected based on documentation of embodied emissions in addition to cost/price. The delay of one year due to unforeseen circumstances made the contractor and some from the team of consultants change their personnel, this has been a drawback for the project and the design process.

#### 4.3. Mutual evaluation and the use of performance measurements

Focus on improvements is essential for success working in partnering contracts with a common goal. A system for evaluation, both the process and mutual evaluation between the parties, is recommended. In order to be able to improve the process as well as keeping the productivity high in the team, the work flow was continuously measured using PPC (percent-plan-complete) [19]. PPC is calculated by dividing the number of assignments completed by the total number of assignments made for each ICE session. Such measurement helped the design manager track the process and the progression, as well as keeping the team members accountable.

#### 4.4. Limits and potential of ZEB design processes

ZEB projects have a specific ambition aiming at a zero emission building level and a high technical quality, not only economy and progress. Achieving ZEB-level requires process iterations in architectural and technology design which you might not have in a traditional building project. The iterations are necessary to mature and optimize the building and solutions. A consequence might be a rise in initial costs and need for more time initially.

A common goal and trust between partners are a key to success for complex projects like ZEBs. The building industry do not have a reputation for a high degree of trust and confidence between partners. There is a great potential for the building industry to develop with complex projects like ZEBs. It is the authors experience that a collaborative contract is very suitable for ZEB buildings, but also other buildings with specific targets. Compared to Design-Bid-Build contract and Design-Build we experience that the planning and design (Phase 1) of a collaborative contract takes half the time, and for Construction (Phase 2) the spent time is the same. This project has shown that there is a potential and to move forward a particular focus should be in development of project delivery. Keys to success are, bring all the actors together early to be reunited and create professional, but also social competent teams with little replacement of people through the project.

## 5. Conclusion

This paper reports on the design process for achievement of an office living laboratory with a ZEB standard. The implementation of the ZEB method in a partnering contract as a project delivery model has been developed. This paper describes and elaborate the development of the project delivery and design process for ZEB Laboratory through the perspective of the client. The ZEB Laboratory design and procurement process has given valuable insight and experience into the use of partnering and collaborative elements for planning and production of ZEB buildings.

## 6. Acknowledgement

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