

# DEVELOPMENT AND REALISATION OF THE CONCEPT HOUSE 'DELFT' PROTOTYPE

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**AN EXAMPLE OF A COLLABORATIVE CONCEPT DEVELOPMENT  
FOR ENERGY POSITIVE APARTMENTS**

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# DEVELOPMENT AND REALISATION OF THE CONCEPT HOUSE 'DELFT' PROTOTYPE

**AN EXAMPLE OF A COLLABORATIVE CONCEPT DEVELOPMENT  
FOR ENERGY POSITIVE APARTMENTS**

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## **DEVELOPMENT AND REALISATION OF THE CONCEPT HOUSE 'DELFT' PROTOTYPE – AN EXAMPLE OF A COLLABORATIVE CONCEPT DEVELOPMENT FOR ENERGY POSITIVE APARTMENTS**

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# PREFACE



Jón Kristinsson

The building industry in general and the housing industry in Western Europe in particular are facing a turning-point. At first glance, this turning-point does not seem too remarkable; definitely not from a safe vantage point of 500 kilometres away. The announcement that, as of 1 January 2013, gas boilers may no longer be sold in Denmark is of great importance for the building industry and installations technology. It heralds a new era of thinking about the different forms of energy, and thus exergy as well. The background behind this radical decision is to avoid burning a resource as valuable as natural gas at 1200° Celsius to achieve temperatures of 20° Celsius in our homes. In Denmark, process heat for low caloric heating is seen as an unwise and unnecessary exploitation. The functional lifespan of a gas boiler is approximately 12 years, thus it will take ten years before the gas flame goes out in Danish houses, and the transition to district heating and sustainable energy will be carried out on a large scale.

In the Netherlands, the only sustainable source of energy is the sun; a large nuclear fusion reactor at a safe distance of 149 million kilometres away. Fossil energy is the raw material for upcoming generations. From a technical point of view, we have been able to build minimum energy dwellings for thirty years. Now we are witness to a completed self-sufficient dwelling, the Concept House Delft Prototype at Heijlplaats in Rotterdam. Here, on the other side of the Nieuwe Waterweg on Woudhoek Noord 184 minimum energy dwellings were built in 1980-1982. During the designing phase, the architect of these flats, Jón Kristinsson, discovered that the then common two pilot flames in the kitchen geyser – practically a second heating device – consumed half of the gas that the new energy efficient apartments required. Thus, electronic ignition was devised. Since then, gas appliances with pilot flame are no longer available in the Netherlands. We live in the land of the Gasunie [gas union]; thus things will not continue at that speed. But changes are coming. We can drastically reduce the heating demand of new and existing dwellings by handling ventilation intelligently, based on CO<sub>2</sub> inside air quality measurements. And most importantly, by switching to very low temperature heating. Solar energy and waste heat in

the industry and cooling water in electric power plants is low temperature water, albeit with seasonal heat storage in the ground.

The electric heat pumps that, in the Netherlands, will replace the gas boilers have a useful yield (COP) of 3 to 4. At very low temperatures the yield can increase to 8 to 10, i.e. twice as much. The new coal plant on the Maasvlakte has a yield of 40 to 45%, the remaining 55 to 60% of the thermal energy either goes into the air or to the North Sea as valuable cooling-water; but it does not contribute to district heating.

A sustainable society is very comprehensive, and energy is an important subject that requires solutions. My definition of sustainability is short and simple: 'Anything that future generations would like to inherit and use and are able to maintain is sustainable'.

The long history of the recently completed concept house Delft prototype, in 'Het Nieuwe Dorp' of the workers district Heijplaat next to the former RDM dry-dock terrain in Rotterdam, which at present undergoes a transformation into a sustainable knowledge and innovation campus, is invisible. At the time of completion, this energy positive experiment is a snapshot of the 'state of the art' in 2012 of sustainable, stacked industrial wood skeleton construction in the Netherlands; based on existing and relatively affordable technology. The innovation lies in the way that these technologies are industrialised, developed, integrated and realised in a process of close cooperation and adjustment between various industry partners and academic researchers. The initiative of the underlying academic research originated in 2005 from Harry Oude Vrielink, a retired contractor in Vriezenveen. What is to be commended is how high the bar has been set for this difficult task that designers, producers and researchers have taken upon them to find integral solutions for all the problems of self-sustained industrial building. In spite of financial adversities and administrative meanderings, and with some delay, a habitable prototype has been realised. General Dwight D. Eisenhower supported the view "The process of working together on a solution is more important than the solution". Since 2005, two of the main academic scientific staff members of the long process concept house have also been appointed professors. Thus, the acquired knowledge is certainly heard and spread at the two technical universities.

Time will tell in how far super-components such as the sanitary unit, preassembled ducting channels with connected installations and home automation devices will be considered and applied in the future renovation of residential dwellings in the Netherlands. "Predictions are difficult, particularly as far as the future is concerned", Dutch cabaret artist Wim Kan once said. My prediction is that from an architectural point of view the concept house Prototype will remain unchanged for a while, but the installations and execution of the energy concept will be caught up with. Luckily the concept is developed as a 'plug and play' system which anticipates such a development. It seems plausible that in a few years time, for renovation projects, very low temperature air heating will appear in addition to underfloor heating. Unfortunately, this is one of only a few highlights without governmental political visions about renovation that allow Dutch voters to keep warm in the future, even without natural gas.

It is also to be expected that intelligent decentralised balanced ventilation in residential dwellings is easier to install than today's central ventilation with air ducts. The concept house Prototype, the ambitious pilot project of the Concept House Urban Villa, and the simultaneously conducted zero series developments [with several ongoing initiatives] should be able to accommodate such transformations of subsystems without abandoning the core of the concept. It is also precisely this flexibility for change, together with addressing the urgent task, the [new] necessity along the path of integral design as well as building and maintaining the buildings over the entire time of use, and even the unavoidable end of life that forms the power of this concept. It forms the basis for the correct effect of sustainability in the sense of perseverance.

In short: All praise for the initiative, the persistence and the final result of the concept house Delft prototype, which will prove its service.

Jón Kristinsson

*Emeritus Professor Environmental Design TU Delft, architect and inventor. [Kristinsson, 1991, 2001, 2006, 2012]*

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# INTRODUCTION

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During the first 4-year period beginning in 2004, the research project Concept House by Mick Eekhout's Chair of Product Development at TU Delft is set up with a broad orientation; the second 4-year period from 2008 to 2012 focuses on designing, developing, engineering, producing and building a single prototype of a concept house apartment, the 'Concept House Delft Prototype' on the estate of Concept House Village in Heijplaat (former shipyard village), Rotterdam. From the start of the prototype process it takes one and a half years before the focus is established on industrialisation and sustainability, depending on the project leader. Mick Eekhout focuses on industrialisation, Wim Poelman on material innovations and Arjan van Timmeren on sustainability. Although it is unusual that an academic chair is responsible for this type of product innovation, the practical experiences of the chair holder ensures the continuation of the process, despite all problems. This scientific report treats the prehistory and the development and realisation process of the prototype up to the building technical completion after which the prototype is provided with furniture and a garden, and is opened in October 2012. The technical content of the process is heavily influenced by social behaviour.

The prototype is a single apartment of a not yet realised Concept House Urban Villa which consists of 16 apartments on 4 floors. The urban villa and the prototype show the characteristics of high level industrial production with an extremely low ecological foot print, energy positive use, and both are suitable for multi-storey housing. This research, development, production & built project result in a unique novelty on the Dutch building market: a sustainable energy-positive apartment system for medium-rise energy-positive housing.

The development was initiated by the chair at specific request from the building industry and is performed in close collaboration with a consortium of partners from the SME building supply industry. The project is entirely externally financed for 8 years [crowd{1}<1} funding]. Innovation progresses further in these partner industries. Apart from initiative and natural project leadership, the novelty introduced by the chair is the design, co-ordination and integration of the many components into one coherent entity of the prototype as an artefact.

The building technical composition shows an assembly of floor, roof, wall and façade components and a central sanitary unit which concentrates all services of the apartment. The extreme level of prefabrication of the 'plug & play' concept leads to the integration of all cables and service elements in the building components. The sanitary unit is furnished with all installations, and is hoisted in completely finished, which enables an extremely short building time. The cables and other installations are designed to be reallocated and adapted for the benefit of future generations of users.

The project is realised by Jaap van Kemenade, Rutger Wirtz, Arjan van Timmeren and Mick Eekhout on the chair side and the SME partners: VDM, Unica, Faay, Icopal, Itho Daalderop, Niko, Raab Karcher, Renson, Solarlux and Woonplaats. Further materials sponsoring is realised by some 30 SME building supply companies. Subsidies from 'Pieken in de delta' and Concept House Village Facility.

[[www.concepthouse.bk.tudelft.nl](http://www.concepthouse.bk.tudelft.nl); contact: [a.c.j.m.eekhout@tudelft.nl](mailto:a.c.j.m.eekhout@tudelft.nl) / [m.eekhout@octatube.nl](mailto:m.eekhout@octatube.nl)].

The prototype will be used from the time of opening to November 2015 for further building technical development under supervision of Mick Eekhout and Arjan van Timmeren. For that purpose, the partners and sponsors have been invited to install new components and to replace existing components with innovated ones. The prototype will also be used to measure and evaluate the true sustainability of the apartment by temporarily housing different inhabitants or guests. These guests and their reactions will be monitored and evaluated. The prototype also welcomes visits and presentations organised by partners and sponsors, if planned well. A three year long research program is laid out by the Faculty of Industrial Design Engineering, focussing on the behaviour of the guests, user friendliness of the equipment, and mainly energy consumption. This research sees the prototype itself as a laboratory environment: in this case the SUSLab under Prof. David Keyson.

Third period of the concept house research will be the development and realisation of the concept house urban villa, for which a developer and a location are being searched for. The chair will hand over its leading and pulling role and concentrate only on an advising, researching and developing role.

# 01 GLOBAL PROCESS OVERVIEW

---

The Chair of Product Development is established in 1992 with the appointment of Prof. Dr. Mick Eekhout. On one hand it focuses on the methodology of design, development and research; and on the other on lightweight materials and new technologies for building materials, elements and components. Heavier materials (concrete, brick), load-bearing structures and existing building constructions are handled by other chairs. The aim is improving the state of technology via high-tech components and design creativity. In 1995, the chair inaugurates the Prototype Laboratory, where students learn to create shop drawings, to work with tools, to weld and to make build prototypes under docent Peter van Swieten. The chair concerns itself with building products: Standard products, building product systems and special components. In his own design & build company, the professor excels in the development and realisation of new building components that, as project systems of high-tech facades and roofs, are built around the entire globe. [[www.octatube.nl](http://www.octatube.nl)].

## 1.01 REALISED RESEARCH PHASING

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The research task, culminating in the realisation and opening of the prototype in Rotterdam consists of four clearly defined phases which are each characterised by the research leaders. The path almost resembled Moses' biblical search through the desert to the Promised Land. The short employment periods and the coming and going of researchers play a major role in the short-windedness of this research – financed entirely with external SME money – as do the limited availability of academic positions in the Netherlands and the quality of the associate professors [it is a compliment in itself for the chair that two associate professors are appointed successively professor at different universities]:

- 1 Concept House Preparation: September 2004 – May 2005 Mick Eekhout begins research into industrial housing; from May 2005 to September 2008 Wim Poelman leads the preparatory industrial research;
- 2 Prototype Start: September 2008 – September 2009 Wim Poelman starts the prototype project, employs Jaap van Kemenade as researcher, on 1 December 2008 leaves for the Universiteit van Twente; Mick Eekhout takes over until September 2009.
- 3 Prototype Definitive: September 2009 – June 2011 Arjan van Timmeren changes the objective toward industrialisation, sustainability and multi-floor constructions, and makes preparations for realisation together with Jaap van Kemenade. The contract for execution is signed on 30 June 2011.
- 4 Prototype Realisation: July 2011 – October 2012 Jaap van Kemenade, accompanied by Arjan van Timmeren and Mick Eekhout, executes engineering, production, and assembly in Heijplaat, and the finishing; architecturally completed by 1 May 2012, Rutger Wirtz makes the prototype habitable until the opening in October 2012.

## 1.02 CONCEPT HOUSE PROCESS FROM 2004 TO 2010

The start of the concept house project was a telephone request by a retired contractor, Harry Oude Vrielink. After he was relieved from a lifetime of daily worries in the traditional building industry, he asked the university to develop industrial apartments. From the beginning, complete external financing stood firm by a consortium of SME [Small and Medium Enterprises] in the Dutch building industry. But since none of the companies was large enough or had the necessary overview, the initiative and leadership was fully laid into the hands of the chair. The chair holder was seasoned and tried in innovative projects, and did not object to such practical realisations. At the time, the chair was busy with creating a 1:5 prototype model of the Maison d'Artiste. Thus, it was agreed to first complete that research project before venturing into the new challenge.

### MAISON D'ARTISTE

Maison d' Artiste is a design for a residential dwelling with atelier from the beginning of the 'De Stijl' period by Theo van Doesburg and Cor van Eesteren in 1923. It is only known as a cardboard model on a scale of 1:50, made for an exhibition in Paris. Nevertheless, due to its sculptural appeal the design attracted great interest in the architectural world. It was published in many architecture history books. Unfortunately, the design was never further developed than that first cardboard model. And the model was lost. In the 1990s Victor Veldhuizen van Zanten, architect and nephew of Cor van Eesteren [1897-1988] asked the EFL foundation, heritage administrator, to approve a possible true-to-size realisation of the design. In 1998, the EFL foundation asked Mick Eekhout to generate a building technical feasibility study. This is the beginning of Prof. Eekhout's interest in Maison d'Artiste.



FIG. 01 Maison d'Artiste behind the former architecture building at TU Delft. A prototype model on a 1:5 scale made in 2003 by third year students

In 2000, Maison d'Artiste is introduced in a two-year study module 'Production & Realisation'; here, the design is one concept amongst 25 alternatives for which the students have to develop their own materialisation. It proves to be a difficult task because Maison d'Artiste consists of an intricate system of stacked spaces and dangerously cantilevering constructions. None of the student groups manages to provide a satisfactory answer, mainly due to the many cantilevers. They are stacked on top of each other, and are suspended from a much too narrow vertical core. The weight of the exterior walls must be transferred to the core via the cantilevering floors. The core, however, is much too weak as a structure and can therefore not carry the full load. With any of the known materials, this is too great of a challenge. Thus, the design is yet far from realisable. The conclusion is that the only possibility to actually build the design is to use a carbon fibre reinforced epoxy sandwich construction, because such structures are stiff and light-weight. But this is an expensive solution. In 2002, the third group of second year students, amongst whom student Joris Braat, undertake the project to create a reconstruction of the original model using the 8 original black and white pictures that are in the possession of the Centraal Museum in Utrecht, and can be borrowed there. With help of a computer, the pictures are continuously compared to each other from different perspectives. Thus, with a very laborious process the original three-dimensional model is reconstructed from the two-dimensional pictures. A process reversed as compared to creating a three-dimensional model and then taking two-dimensional pictures of it. There is great consternation when

it becomes obvious that the reconstructed measurements deviate up to 15% from those of the cardboard construction model published by Victor Veldhuizen van Zanten in 1983; 3,000 of which were sold, by the way. According to a limited number of ribs that were not visible on any of the photos, the accuracy of the reconstruction can be deemed almost perfect: 98%. In addition, the students, under supervision of Monique Suttorp make a colour reconstruction with a colour spectrometer, which demonstrates that the colours as well are very different from those presumed from the cardboard model of 1983. However, the accuracy of the colour reconstruction is estimated lower, at approximately 70%.

Both geometry and colour reconstructions are reason enough for this successful group of second year students to continue their work in the third year module 'The Prototype'. During this module they create a 1:5 model according to the actual measurements so that the object can be admired in its pure original dimensions. Since the colour analysis might be improved upon in the future with up-to-date devices, the scale model is executed in white; no other colours yet. The students build the prototype model in autumn 2003 in the laboratory work place of Octatube, working enthusiastically until late at night.

In January 2004, the model is set up and presented near the auditorium during the 'Dies Natalis' of TU Delft. Then it is relocated to the rear entry of the architecture building. The model miraculously survives the Great Fire of Architecture [13<sup>th</sup> of May 2008]; if with some damage from falling glass and debris. Until September 2013, the prototype stands next to the new building of the architecture faculty at the corner of Julianalaan and Schoemakerstraat. It shows three-dimensional stacking of spaces, structural cantilevers in all four directions, and the mystic atmosphere of a never developed design that draws 'academia' to the Maison d'Artiste. We discover that the entrance is far too small and that the stairs are not correct. Compared to a functional residential building, the bedroom with its 5 m high ceiling is rather large. It is obvious: This is an exterior design which, after its presentation in Paris, requires further development of the interior in order to be functionally useable and buildable.

Upon completion of the education course – which factually led to research – a public debate is held on 5 April 2005 in the presence of Prof. Dr. Manfred Bock, Van Eesteren connoisseur par excellence, about the value of the reconstruction. He was asked whether this reconstruction of the geometry was valuable. His opinion is partly stimulating, partly merciless: "The geometric reconstruction is of great value and can well be called a reconstruction. However, if you work on a different scale and with different materials, the prototype model is no longer a reconstruction but an interpretation." Many interpretations are possible but there is only one original cardboard model, and that was lost shortly after 1923. This necessarily also transforms Victor Veldhuizen van Zanten's plan to actually build the Maison d' Artiste on a 1:1 scale from a reconstruction to an interpretation. The same way an orchestrator interprets or arranges an original musical piece created by a composer. In the meantime, a 'Foundation Maison d'Artiste Prototype' is established, the restoration is executed, and the prototype model is given as a loan to the Eesteren Museum in Amsterdam, together with the book 'The Making of a Long Lost Prototype: Maison d'Artiste' [Eekhout et al, 2014].



## REQUEST FROM THE BUILDING INDUSTRY TO DEVELOP INDUSTRIAL APARTMENTS

In 2004, Harry Oude Vrielink, a retired Dutch building contractor asked Mick Eekhout to develop an industrial dwelling; this request was taken as a question from the Dutch building industry to his chair. When developing a prefabricated housing unit, typical goals are to increase aesthetic quality, perfecting building methods, improving process safety, and achieving a better price/performance ratio as well as freedom of choice for the user. The concept house research & development is a [imitable] exception from the rule that the building industry is extremely traditional. In line with the professor's personal experience, the development of the concept house was understood as creating a 'super-system of systems and subsystems' that must not necessarily be based on completely new components but rather on improvements to existing components; naturally all state-of-the-art, the coordination and integration of all those systems into an effective and efficient super-system. Often, building a prototype during the planning and development phase provides more opportunity to identify possible problems than publication, designs and, in our time, even digital designs in the tradition of designing research can offer. At the architecture faculty research is usually conducted on a theoretic level; seldom as physical research. The concept house prototype research has no predecessors.



FIG. 02 Scale model space in the south glass hall of the Faculty of Architecture TU Delft [arch. Mick Eekhout]

Creating physical prototypes is part of the chair's curriculum since 1995; building up from 50 Master students in the first year, up to 100 students in 2013 learn to build their prototypes at the Prototype Laboratory. Many only come to 'see the light' when actually building such prototypes. [[www.buckylab.blogspot.nl](http://www.buckylab.blogspot.nl)]. The inspiration to have the students create prototypes stems from the professor's practical working period at Renzo Piano in Genoa in

1970. He is globally renowned for his architecture but certainly also for the prototypes of special components that he builds in his own building workshop. And his components are also shown in worldwide exhibits [see figure 3]. [www.rpbw.it]. Arjan van Timmeren's interest in materialisation was also stimulated when he worked for the Renzo Piano Building Workshop in Genoa in 1990. Mick Eekhout is a regular guest at RPBW due to a large project in Spain that his design & build company is working on. Even after more than 40 years the inspiration has not dwindled. His own firm is continuously working on making experimental technical prototypes in the Octatube Laboratory, which are directly applied to innovative projects. The prototype laboratory, set up for students, is a miniature copy hereof.



FIG. 03 The prototype laboratory in the Renzo Piano Building Workshop (January 2013)

The production hall of Octatube, Prof. Eekhout's homebase, contains a large area with prototypes of typical experimental projects. Here, critical or characteristic parts of structural systems are realised, optimised, and often presented to the client architect. In other cases, assemblies of elements and components if the client so desires. In extreme cases, if dealing with foreign projects, often with an Anglo-Saxon background, entire mock-ups are built that can be tested. Not only in terms of how they are composed constructively or aesthetically but also how they behave under stress loads. A few times, large facade areas are built in a specially built façade box in or near the Octatube Laboratory. These were then tested for over and under-pressure with additional rain spray to test and control leakages. When visiting the company in 2005, former dean of architecture,

Professor Hans Beunderman says about the prototypes in the Octatube laboratory: “Many architects in this country see this prototype laboratory as a super model space where dreams can come true”.



FIG. 04 Prototype with glass fins and cold twisted double glazed panels for the glass roof of the Victoria & Albert Museum London, in the Octatube laboratory

The challenge to build a prefabricated dwelling is not new: as early as in the 16<sup>th</sup> century Leonardo da Vinci plans a series of new cities in France, encouraged by his patron, king François I. In the centre of each of these cities he positions a factory to produce the basic elements for the new buildings [Schleifer et al., 2011]. Leonardo thinks as a builder does. In the 19<sup>th</sup> century, the English casting industry transports the metal components of houses [often done with iron casting] to new lodgings in North America and Australia. And during the 20<sup>th</sup> century prefabrication in the USA is partly boosted and accelerated in the aftermath of the Second World War and the necessity to [quickly] rebuild entire cities. First in the form of rational and traditional buildings, later in more industrial designs. Due to a shortage in construction workers, contractors are forced to consider more prefabrication of components. The last decade sees a focus on Industrial, Dismountable and Flexible [IDF] building.

#### THE SWITCH FROM MAISON D'ARTISTE TO CONCEPT HOUSE

Upon completion of the research of the Maison d'Artiste, the research into the concept house can begin. This project obtains its name in analogy to 'Concept Cars'; cars with

entirely new design ideas. Concept cars are indeed developed to show the market future possibilities. The concept house challenges the building industry to show society the future of sustainable and industrialised apartments. Concept house is the first step toward a realistic new systematic of future apartments.

In 2004, Harry Oude Vrielink quickly assembles a group of interested companies who form a solid sponsoring consortium. Which means that research financing is done entirely outside of TU Delft, even though the project is guided by the staff of the chair. The sponsor consortium consists of 4 to 8 companies who deposit 10.000 Euro per year. With these funds two young graduated engineers can be employed to do the actual research and coordination work. Since financing is guaranteed over short periods of time of one or two years – according to the agreement with the partners – this proves to be no basis for PhD research which typically takes four to five years and requires complete financing to be accounted for ahead of time. It is a much more short-winded setup. And the participating SME companies have no interest in long term promotion work. Individually they are too small to oversee, let alone to finance research. It is up to the chair to take on leadership and continue the research and development.

#### PROMETHEUS AGREEMENT

The consortium agreement is elaborated as a standard and approved by the higher regions of the TU bureaucracy to bind industrial partners from the SME to research at the TU Delft. The principle is that each industry party donates a fix amount per year to the chair in exchange for research conducted on the basis of gross salary cost plus expenses for the researchers. The costs for the time of the professor and/or associate professor are carried by the chair itself. The contribution is guaranteed every two years by signing a Prometheus agreement in order to allow the chair to attract researchers who are then relieved of other obligations. The subject and the progress of the research content are discussed several times a year during a workshop. Once a year, the progress is presented during a symposium. According to this formula, the concept house consortium and the chair collaborate from September 2004 until May 2012. Usually, a minimum of six partners and two full time researchers is sufficient.

#### DEBATES AND SYMPOSIA ABOUT CONCEPT HOUSE AND INDUSTRIALISED HOUSING

It is not easy to find suitable student candidates in the so-called applied science of product development. It appears to be a patchwork of shorter and longer research projects. During quarterly meetings, progress is discussed, guests are invited to give lectures, and new sponsors are introduced. And interested scientists and other interested parties are welcome to enter debates to further push the boundaries. Once a year a symposium is held with typically eight to twelve speakers. At the Concept House Symposium 2005, for example, the following people gave lectures: Prof. Dr. Joop Halman [U Twente], Alex Sievers [Inbo], Han Michel [former director Lieven de Key], Sannie Verwey [researcher], Prof. Dr. Alan Brookes [TU Delft], Erwin Hofman [PhD UTwente], Ype Cuperus [former researcher Obom TU Delft], Dr. Bernard Leupen [Chair Housing Development], Richard Horden [TU

München), Andreas Vogler (PhD student/designer Architecture & Vision), Ties Rijcken (industrial designer / researcher), Prof. Age van Randen (emeritus TU Delft), Henk Westra (Associate professor Real Estate & Housing TU Delft) and Mick Eekhout. These are years of broad discussions about industrialised housing.

#### THE RESEARCHERS OF THE PREPARATION PHASE

From September 2004, architectural engineer Sannie Verweij is the first researcher to generate an overview of the then known predecessors of prototypes of the concept house. Her studies result in the publication 'Towards Customized Industrialized Concept Houses', published by the chair in 2007. [Verweij, 2007]. Since leaving the university in 2006, Sannie Verweij works at the Dutch Foundation Building Research / Stichting Bouw Research (SBR) in Rotterdam.

Architectural engineer and architect Marloes Friedhoff conducts a one-year research into creating apartments in old factories, with adaptation to the old halls of the RDM (former submarine wharf) in Heijplaat, Rotterdam. Daylight, ventilation and fire protection play a major role, as do the isolated locations of the old factory halls, which decrease the attraction for potential inhabitants. Living in former factories is acceptable if they are located in exciting neighbourhoods with many and variable social contacts. Currently, Marloes Friedhoff works as an architect at Paul de Ruiter Architects, Amsterdam.

Ties Rijcken, a brilliant graduated industrial designer is conducting a two-year research in living on the water as an extension of his graduate project. The result of his work is expressed in presentations and short articles; public relations oriented rather than scientific, and more solo than group focused. His work ends after, at the time of the research evaluations by the Department of Building Technology during the spring of 2007, the invited peers Jos Lichtenberg and Richard Horden found too little progress in between the milestones. Thereupon he leaves the concept house group. Since then he works at the Faculty of Civil Engineering where he partakes in the 'Water' research of the Delft Research Initiative (DRI) 'Infrastructures'. [www.ecoboot.nl and www.floatingcommunities.com]. Living on the water in combination with timber as the construction material offers interesting possibilities for building in the Netherlands; although with a maximum of 3 storeys in the form of ground-bound water apartments. On the water, multi-storey housing is not the obvious choice; or at least a challenge for a future research group.

Erik Vreedenburg is a practising architectural engineer and architect in Scheveningen, who has vast technical experience in adding apartments on top of existing or new buildings. Mick Eekhout challenges him to write a scientific text to accompany his book 'Luchtgebonden bouwen' (Air-borne building) [Melet, Vreedenburg, 2005] in order to combine the two into a PhD-worthy project. This has not yet been done.

Stef Janssen is an architectural engineer with vast experience in the processes that are inherent to housing corporations and the current housing industry. He conducts marketing studies about the field of application of the concept house.

Ype Cuperus joins the group due to his experiences with 'Open Bouwen'/OBOM (Open building), established by emeritus Professor Age van Randen, of whom he is the last successor. His insight into the technological developments of apartments is considered important for the concept house.

As an external PhD student, architect Martin Smit is busy with a PhD thesis about cyclic design processes. He works as an architect at Inbo, one of the financial partners of the concept house. He occupies himself with step-by-step improvements of products such as they sometimes occur in the building industry in the form of long series of identical tasks, exploiting the experience he gained at ABN-Amro offices. Concept house could include similar tasks. He finally graduates in February 2008 with his PhD thesis titled 'Naar een Cyclisch Iteratief Ontwerpproces en Ontwerpomgeving' /Towards a Cyclic Iterative Design Process and Design Environment [Smit, 2008]. Herein he works out his experience and insights of series of identical jobs with progressive flexibility and perfection in answer to the question. This will certainly be of value for a future application phase of the concept house. He is the successful PhD student affiliated with the concept house research. In 2012 he establishes himself as an architect in Israel.

Dr. Liek Voorbij is an industrial design engineer, who was recruited by the chair in 2005 as an assistant professor. She has broad knowledge of ergonomics and, as a researcher focuses on the topic 'Domotica' (home automation) which is closely related to the concept house. She accompanies and supports the approximately 20 PhD students of Mick Eekhout and Wim Poelman on a daily basis. In July 2009, her three-year contract is not prolonged due to cost savings decided on a higher up level. Thus, most of the PhD students end up at 'www.Marketplace.nl', much to the dissatisfaction of rector of the TU Delft, Prof. Dr. Jacob Fokkema. Unfortunately, the latter is not able to undo the cost reduction realised by the interim dean under consideration of maintaining quality. Liek Voorbij leaves for the Hogeschool / polytechnical university Rotterdam.

Andreas Vogler is a German architect educated at TU Munich with great interest in soloistic architectural objects such as apartments, up to the extreme of spaceflight-like objects. He partakes part-time in the research group, wants to start a PhD thesis, but gradually his work at his design office Architecture & Vision [www.architectureandvision.com] takes up too much time. He writes a book about the historic development of innovative apartments 'The House as a Product' which is also published by IOS Press in 2015 [Vogler, 2015].

Since 2011, Ed Melet [Melet, 1999 en Melet / Vreedenburg, 2005] is connected to the chair as an external PhD student to write his thesis 'Duurzame architectuur' (Sustainable architecture) following research in the field of feedback of the performance of sustainable architecture and buildings.

Additionally, as of 2013 external PhD student Frits Schultheiss, working at Hogeschool/ polytechnical University Arnhem (HAN), is busy with applying the knowledge of the concept house to a renovation variant.

## PEER REVIEWS ABOUT THE CONCEPT HOUSE RESEARCH IN 2007

In the spring of 2007, the Department of Building Technology, which the research project concept house is part of, holds five research colloquia with peer reviews. Every researcher is asked to give a 10 minute presentation, and a committee of peers from other universities then discusses their questions and doubts. Peers are invited on 8<sup>th</sup> of February 2007 from one of the five research programs of the department of building technology, namely 'Industrial Building', of which concept house accounted for a third. The discussions are earnest and expansive. The peers are Prof. Dr. Jos Lichtenberg (TU Eindhoven), Prof. Richard Horden (TU Munich), Prof. Dr. Joop Halman (U Twente), Prof. Dr. Gerhard Hausladen (TU Munich) and Prof. Dr. Thomas Herzog (dean of the Faculty of Architecture TU Munich). Between 2003 and 2008, Mick Eekhout functions as research nester of the department; in this function he organises the five colloquia between January and March 2007, while Wim Poelman is the formal leader of the concept house research group during this time.

The result of the reviews is similar to those of a lot of research projects; 10-20% are considered brilliant, 60-80% require additional work and amendments, and 10-20% are advised negatively. Reading the report of these colloquia five years later gives a sense of openness, directness and honesty, in as far as this can be derived from the subjective points of view of the peers. It is a unique time with enormous acceleration of internal and external insight, and with the notion of quality and opportunities and norms of scientific research. Additional scientific reviews are conducted following these internally organised peer reviews: The mid-term review of 2008 and the review of 2010, but none of these are as in-depth as the BT-review from 2007. Besides, in the academic world a lot of energy flows into the preparation of peer reviews. So much time is spent on reviews that there is little time left for the actual research, so it seems.

## THE GREAT FIRE OF ARCHITECTURE

A clear marking point in the development of the concept house is the so-called 'Great Fire' of Architecture on 13<sup>th</sup> of May 2008, during which the beautiful building designed by architect Jacob Bakema went up in flames. The building was lost completely due to a silly series of small errors and regulations. But also due to the fact that the building was full of flammable materials and no sprinkler system was installed yet. As a result of the Great Fire, many books, slides and materials are lost; staff and students are first accommodated in tents and then relocated to other faculties' buildings. It was a year of 'Diaspora'.

In September 2008, associate professor Wim Poelman decides that it is time to make a real prototype which he calls 'Bare House'. This marks the breaking point between the first initialising phase of the concept house research and the second, the prototype phase. Three match meetings are organised in Zeist in the centre of the Netherlands to convince the invited parties to participate in the initiative. The idea is to build an industrialised prototype of a residential dwelling. Wim Poelman's strength is to design innovative materials; therefore the goal is to create a prototype that focuses on material innovation.

Wim Poelman's sudden departure from Delft a few months later, to take on the professorship Product Realisation at University Twente per 1<sup>st</sup> of December 2008 meant another blow to the concept house. Mick Eekhout takes over the leadership of the concept house research. One month later, the faculty is subject to severe budget cuts so that none of the temporary positions are prolonged after running out. This also means that there is no successor for Wim Poelman.

#### SUDDEN STAFF CUTS PER JANUARY 2009

Due to the drastic budget cuts of 1<sup>st</sup> of January 2009 by interim dean Jan Rots no temporary employments can be prolonged. Unfortunately, the concept house research group is one of the victims of this formulated way of thinking because the SME can only negotiate short-term contracts. And the faculty cannot deal with such short-term planning. As per that date the size of the chair is suddenly reduced from 6,4 fte to 2,5 fte; and after the involuntary departure of Dr. Liek Voorbij in July 2009 even down to 1,5 fte. It proves difficult to keep the focus on the goal of the concept house. And all this while, at the same time the external income from the partners will cease immediately as well. A 'lose-lose' situation. Determination is very important during these days. The academic world serves a function as well, even in comparison to the everyday and short-winded practise of the building industry. However, in spite of budget cuts and deans, the research and development process of the concept house at the chair continues.

Jaap van Kemenade, who is employed as project researcher, has a temporary contract that has once been prolonged already but is now terminated due to the fear of the consequences of the Flexwet [Dutch law stating that an employee may only be granted two consecutive temporary contracts: A third is automatically considered permanent employment]. He is factually prohibited to enter the faculty, a unique situation in the history of the faculty. For the following seven months, Jaap van Kemenade is employed by one of Mick Eekhout's companies, who later declares the cost with the faculty. The costs are reimbursed.

It takes until September 2009 to employ associate professor Dr. Arjan van Timmeren as Poelman's successor; chiefly because his work was cost independent due to the many research projects he secured himself. So the dean approves this move. His arrival proves to give the chair a great impulse for sustainability. Due to the emphasis on sustainability, the starting points of the concept house research change considerably; meaning that they are more directed on the scientifically and societal important focus of energy, water and resource optimisation as well as at health and the human aspect of use of the more common housing types.



## RESEARCH DIRECTED AT THE FAR FUTURE OF THE BUILT ENVIRONMENT AND THE BUILDING INDUSTRY

After 2 decades of exploding prices, the bank crisis and the mortgage crisis cause the bubble to burst in 2008, which leads the way to a new, balanced economy. However, we are not there yet. There will be a new balance of objectives and means. In addition to the building industry itself, the university also needs to foresee the future of building. Extremely put: How will Dutch society look in 2040, what will be the requirements on the built environment, which buildings and infrastructure will be needed and which type of building will the building industry need to create or amend? A long-term vision instead of the short-term vision of survival. Mick Eekhout has written a research proposal for 'The Built Environment of the Netherlands 2040'. This is reasoned as follows: What will society be like in 2040 considering all influencing aspects, for example on a social/geographical, ecological, economical and political level? Which adaptations and additions or reductions in the built environment are necessary between now and 2040? What are the tasks for new buildings, renovation, refunctioning and demolition for the built environment? As a consequence hereof, what is the task for the building industry between now and 2040, and to what degree does the quality level shift? How big will the building industry be? What must the education for the youngest generation of architectural engineers include to prepare them for the future? [www.Speerpuntbouw.nl]

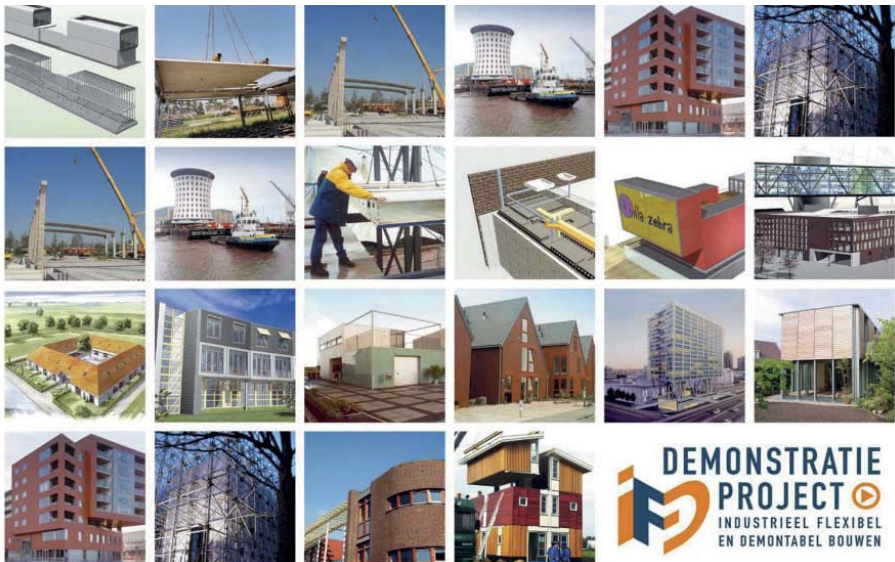


FIG. 05 Status quo in 2008 of industrial, flexible and dismantlable building projects in the Netherlands [source: SEV, 2008]

The initial phase of the concept house research is funded by eight industrial partners for a period of four years. This period includes working on preparatory studies. Since the chair is not an architecture firm, no competitive situation arose; thus, the issue is elaborated on a more academic, broader and basic level, and set up for long-term study. The focus of this first period lies in 'Industrialisation versus customisation'. Each staff member brings with them their own domain in interests and networks. From a market analysis, starters in the housing market seem the most logic target group because, until 2008, they seem to constitute a forgotten market segment [Verweij, 2007].



FIG. 06 Innovation in every part

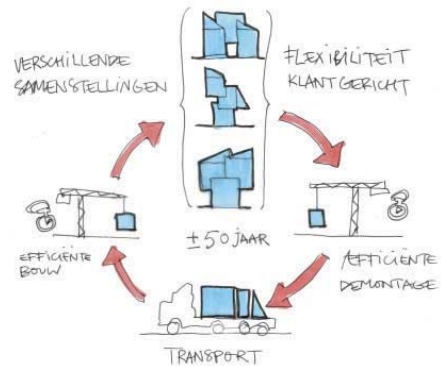


FIG. 07 Thinking through and considering the entire life cycle

Gradually, the concept house project seems to offer an easily accessible platform for architects, designers and producers to meet and to work on experimental product development. With regards to product development and innovation, the ways of thinking of exploratory architects and designers on the one hand and revenue-focused producers on the other are fundamentally different; which results in a fundamentally different manner of addressing product development. The added value of the collaboration in the concept house project is mutually recognised by all participants. In practice however, such collaboration between architects, designers and producers remains limited to personal networks. In the building industry, architects and producers do not have very close business relationships. Traditionally, the general contractor sits somewhere in between the designers and the component producers, and often is the unfortunate victim of distribution and power tactics. In addition, the construction sector always has several issues: many different parties who have never before worked together need to collaborate; building teams are often put together ad hoc, based on the criterion of lowest price rather than quality and reliability. In many cases, they successively undo someone else's contribution [in order to realise/integrate their own part of the process]. Additionally, there is a strong focus on the project instead of the product or the process [Damen rapport, 1997].

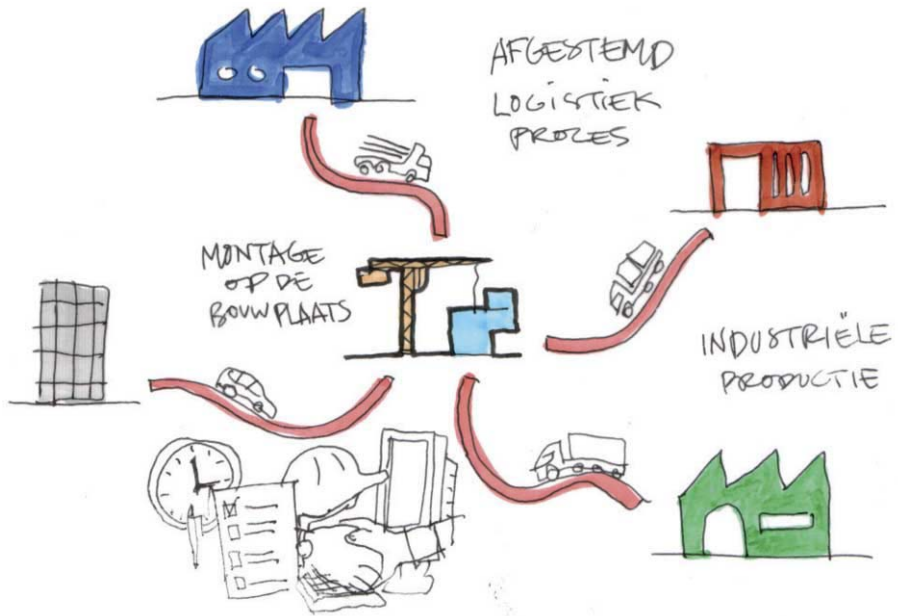


FIG. 08 Schematic illustration of the building process 'new style'

To achieve more productive collaboration, the fundamentally different thought models of architects and industrial designers need to be synchronised. This idea is supported by the 'New Product Development' experience stemming from the Faculty of (IDE) Industrial Design Engineering. Namely due to the input of industrial design engineers Wim Poelman and Jaap van Kemenade, this idea – new to the building industry – is brought to the table. This synchronisation process includes a large transfer of implicit knowledge and tacit knowledge. Due to its scientific nature in the architecture faculty as well as the IDE Faculty, concept house was able to see this process through, to make it explicit and to accompany it. The chair is at the intersection of the two faculties at TU Delft.

The presumed advantages of the proposed and realised building methods of concept house include improved building lifetimes, shorter construction times, improved performance with regards to the environment and sustainability (in all its broadness), consumer orientation and improved working conditions in the building industry. In addition, the new building offers many opportunities for the existing city, and for the renovation of existing apartments. Disadvantages include more extensive preparations and involvement of all stakeholders at an early planning phase due to the different approach. Flexible execution, new products and new manners of agreeing and decision making are required. Acceptance is hindered by unfamiliarity and reservations. Finally, there is the economic regime which, even for experimental projects, requires provable economy which in turn strongly limits free experimentation. The easy accessibility of the building industry with its many competitors plays an impedimentary role here. And the response from the organisation

of the building supply industry [www.nvtb.nl] to calls from the academic circle to jointly work on new developments as Mick Eekhout has done since 2007 has not yet led to large-scale collaborations. The new master plan for 3TU.Building Research in the Netherlands 'Bridging the Gap', published in January 2009 [Eekhout, 2009] has not yet been initiated effectively by the management of the 3TU.Bouw faculties. In Bridging the Gap, the 80 Dutch building professors are invited to take on the many future societal challenges, and the door of the ivory tower of 3TU has been completely opened toward society and the building industry.

From the very beginning, several learning points from earlier IFD (subsidy) projects were taken into consideration resulting from the experiences of the management of the research group:

- Better process synchronisation;
- Employing a strong coordinator;
- Thorough logistics preparation;
- Well thought through selection of choices;
- Better cost estimates;
- Focus on measuring discipline;
- Inform users.

At the beginning of 2008, Wim Poelman decided to transition to a materialised prototype, which he named the 'Bare House'. This is the beginning of the prototype research. The shift derived from his interest in laying a greater accent on the material level and industrialisation. After all, Poelman is a material designer. Hereby, from the start industrial and flexible building was seen as a means (not as a goal). Due to Wim Poelman's many contacts with the SME and his experience with its members in various stimulating design sessions a number of match meetings are organised in the centre of the country; sometimes with as many as 30 parties present. There is obvious enthusiasm and interest in the adventure. Innovation is in the air.

When in September 2008 the Lehman Brothers Bank in the United States goes bankrupt, this is still considered a unique and temporary incident. Gradually over the years, the research grants from the participating SME companies prove to be the first victims of the savings efforts. When considering that the crisis continues, which by now economists have declared a recession as per definition, it is no wonder that more and more candidates drop out. Fortunately, enough hardliners remain who believe in the research project.

During this initial phase, industrial designer Jaap van Kemenade is employed to execute the project. Match meetings are organised which produced a number of commercial SME parties who are sufficiently interested and, with their annual cash deposit each make the research possible. This means that two 'external' researchers can be hired; the project researchers. Besides Jaap van Kemenade they are the young structural engineer Joris Veerman and later architecture engineer Rutger Wirtz. Professor Thijs Asselbergs (Architectural Engineering) as experienced housing architect involves himself with the architectural and urban planning design of the prototype in the form of a

combination of several apartments [www.ataindex.nl]. Later, amongst others this leads to the sketched design of the first concept house urban villa. The concept house Delft prototype is derived from the urban villa as a single apartment.

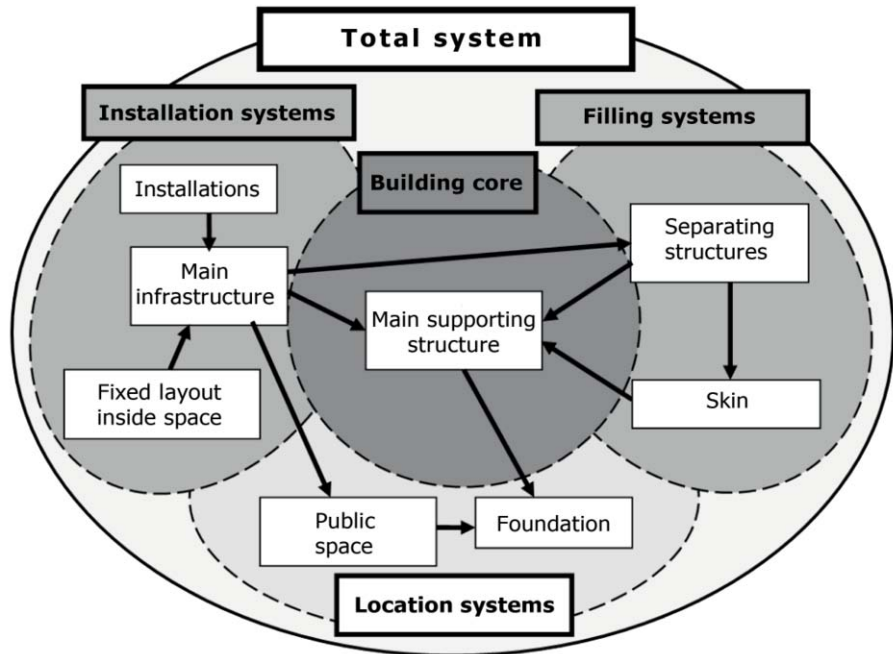


FIG. 09 Schematic representation of the overall task of Bare House and the inherent relationships

#### DEFINITIVE STARTING POINTS FOR THE CONCEPT HOUSE

In September 2009, Arjan van Timmeren, an experienced and financially independent scientist is accepted as fulltime associate professor in the chair. He specialises in sustainability. From this time on, he leads the concept house project. And the project's focus now broadens from 'Industrialisation versus Customisation' to include a strong interest in 'Sustainability'; particularly as it relates to long-lasting and affordable energy supply.

One of the university goals is to spread knowledge. Keeping in mind the government posed target to realise 100% energy neutrality for all new housing in 2020, many steps forward must be taken on many different levels. Nationwide, several initiatives are started. In this context the development process of concept house is seen as a humble contribution as well. The faculty tries to lead along the Dutch building industry by conducting research in the field of sustainability. Jon Kristinsson [1937, professor 1992-2001] is the pioneer architect/inventor, Wiek Röling [1936-2011, professor 1998-2002] is an environment-

conscious architect, Kees Duivesteijn [1943, professor 2005-2010] the environment-conscious researcher. In today's corps of full professors Andy van den Dobbelsteen, Anke van Hal and Arjan van Timmeren focus on sustainability.

Under Arjan van Timmeren's influence and activities, the focus is laid on multi-storey apartments (and therefore the possibility to realise higher densities). And, in addition, more sustainable, energy neutral to possibly energy positive in (architectural) use while maintaining the lowest possible CO<sub>2</sub> footprint and industrial fabrication for the benefit of affordability and timeliness. Thus, this becomes the new and definitive focus of the concept house prototype project. The 4 axioms for the concept house prototype are reformulated as follows:

- Suitable for multi-storey apartments;
- High degree of industrialisation with an extremely low CO<sub>2</sub> footprint;
- Plug & play, sufficiently customer oriented / customisable;
- Energy positive in use by the habitants.

Herewith, only in spring of 2010, the four starting points for the research and development of the concept house project are finalised.

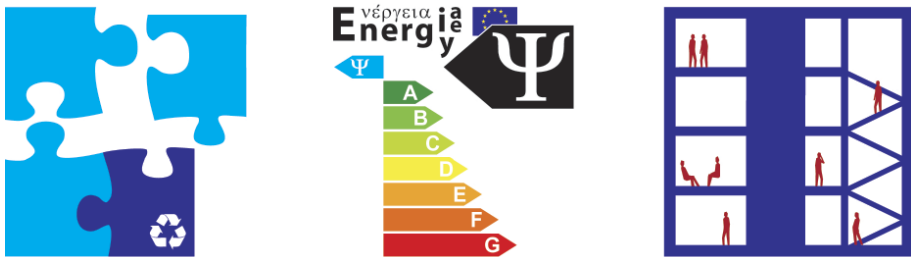


FIG. 10 The most important starting points for the concept house Delft prototype: plug&play, energy positive, apartments

#### THE CHALLENGE OF SUSTAINABLE MULTI-STOREY APARTMENTS

It is the concept of multi-storey apartments in particular that makes this project an especially interesting experiment in the Netherlands. Not only because most of today's sustainable housing projects – non-experimental, that is – are earth-bound dwellings. But also due to the fundamental question of affordability, an increasing urgency, and the demand for upgrading and (energetic) renovation of apartment buildings. This stems, for the main part, from the high and medium rise buildings from the Fifties and Sixties neighbourhoods which still score badly today. In addition, the Netherlands is an urbanised, densely populated delta, where medium to high rise buildings play an important role. All of the existing buildings have to be energy-neutral in 2050. With their results and the focus on technically relatively easy to realise new constructions, experiments such as

this prototype research also indirectly aim at stimulating concepts to upgrade existing buildings and realise future renovation projects. Because the urgency for and the scope of energetic upgrading of the existing housing stock, particularly as it relates to medium and high rise constructions, are significant and quantitatively much larger than for new buildings. Renovation of existing multi-storey buildings will be large-scale, and an unavoidable societal task. The goal is that the knowledge and insights of concept house will be transferred and incorporated in this endeavour. We know that even during the heydays up until 2009 new buildings account for a maximum of 1% of the building stock. Now that the energy upgrading must be completed in a short time period [far less than 99 years to go] the main need for energy gains certainly lies in renovation and energetic upgrading of the existing building stock. But new innovation first and renovation later is the concept house adage.

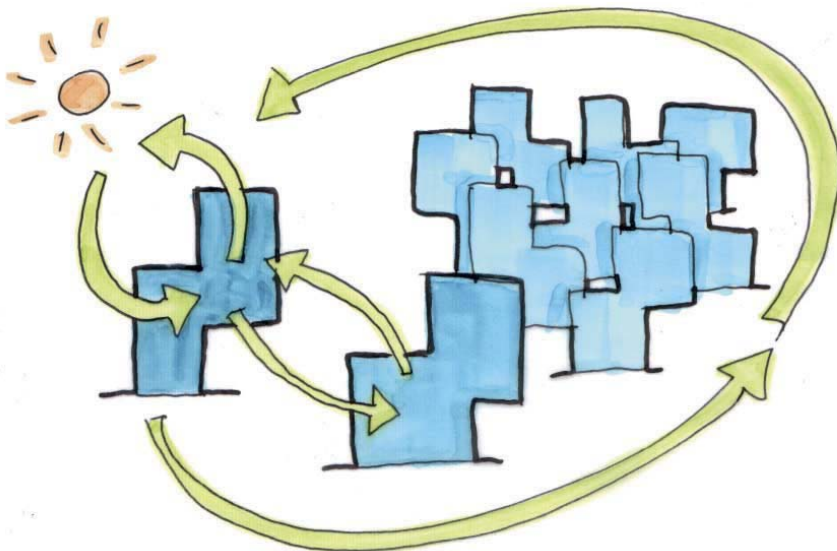


FIG. 11 Emphasis on small-scale cycles under consideration of possible synergies through linking

#### FOCUS ON SUSTAINABILITY

The Netherlands face a number of significant challenges: Getting used to the deterioration of the economic bubble, sorting out government finances, strengthening the Dutch economy and making the Netherlands future-proof. Out of necessity, the current emphasis lies on overcoming the Euro crisis and the recession. Future-proofing Dutch cities, i.e. protecting them against the expected rising sea level and climate changes [adaptation], reducing greenhouse gas emissions [mitigation] and the dependency on fossil fuels [energy transition], is a major task that has a significant impact on the set-up, arrangement and building technical execution of the Netherlands. In this context it is

important to withdraw energy transition from an atmosphere of voluntary self-regulation. Energy consumption rises dramatically worldwide; the Netherlands are no exception. Fossil resources are running out. No significant steps are taken in the field of energy savings and generating sustainable energy. In comparison to other countries, the Netherlands today run far behind with regards to research, innovation and technology related to sustainable energy. And consequently in the ratio of renewable energy of the nation's overall energy portfolio. It seems that no one really tackles the issue of sustainability and multi-storey apartments in a conscious and well-planned approach.

However, there is an awareness in the Netherlands that a lot more consideration and space must be given to water storage and green environments. Generating, exchanging and storing energy in urban areas requires even more consideration and space, just as a more careful management of the resources we use to create our built environment. Above all, the way we build and how we deal with end-of-life scenarios and re-use should be the focus for a transition to a more enduring manner of living together.

The necessity to integrate sustainability into many areas of engineering and on a great number of levels has become unavoidable. Research and development of the concept house research group is established in the chair. It was further broadened by Arjan van Timmeren. The scope was widened to the fields of materials and urban engineering respectively.

#### PREFERENCE FOR TIMBER WITH ITS SMALL ECOLOGICAL FOOTPRINT

During the course of the process it became apparent that currently the maximum achievable energy positive arrangement that can be accomplished with appropriate [available] methods and systems is a four storey construction. The reason here for is the available [limited] roof area and the desire to create a minimal ecological footprint. In this case related to the energy generating PV cell roof which needs to neutralise a maximum number of underlying energy consuming storeys. In this prototype project it was decided to realise a prototype of a single apartment in the form of a starters home with three rooms. Timber used as the base material for the construction has a very small ecological footprint since, with careful planning, wood can be continuously replanted once cut down. There is no better ecological material for load-bearing building structures, but it has material-related limitations.

In addition, the following choices are made: larger [wider] than usual room dimensions and a larger span; a technical challenge to develop in timber and to experience and work out the characteristics of a completely wooden floor. And to demonstrate that, even for multi-storey housing such large spans do not necessarily require concrete. And that timber constructions with their far smaller CO<sub>2</sub> footprint than that of concrete or similar materialisation need not be any problem. On the other hand, we are aware that 98% of residential buildings are made of reinforced concrete. This prototype, based on timber load-bearing structure, interior walls, floors and ceilings, offers a transfer point between the use of concrete and timber; whereby the acquired knowledge and insights about timber



constructions can be transferred to reinforced concrete structures. Naturally, concrete suppliers usually have a different point of view when hearing about this experiment. For the chair, one of the following steps does indeed include an execution in concrete; if with a less favourable ecological footprint. But this leap will have to wait until the pilot project urban villa.



FIG. 12 Studies in four-level gallery typologies with the developed building system, and outdoor space per apartment

On a ministerial level, sustainability goals are determined by Minister Jacqueline Cramer as minimum requirements for 2020 [‘Energy neutral for all new buildings: Residential housing and utility buildings’]. The chosen apartment prototype meets all requirements and certifications currently practised by housing corporations. The goal of the realisation of the prototype is to build a stand-alone prototype, and thereby coordinating and integrating the individual parts of the building system itself during the engineering phase as well as testing and possibly optimising it during the production i.e. the assembly process. And moreover by realising a test apartment that can be measured and evaluated. From this perspective, the concept house Delft prototype becomes a (minimum) three-year research laboratory for research by the IDE faculty, besides subsequent building technical research; a true ‘Living Lab’.

#### AN EXCITING PROCESS FOR EVERYONE INVOLVED

The results of the actual process surrounding the realisation of the concept house prototype show that with quite a bit of visionary thinking, energy, intelligence, stubbornness and persistence but also a good portion of naiveté [not yet knowing how much headwind will be encountered] this process comes to an end result.

In the beginning it seems difficult to find enough industry partners with their contribution for the project. During the entire process from 2004 onward some participants dropped out but, luckily, others joined. Since 2009 there are about 10 SME industrial partners who slowly but surely developed from a more or less random or ad hoc group into a real development team. They are proud of the process and the results developing over time. And this, even though every new potential partner needs to be voted on. During the

realisation process, the faculty seems to be the biggest hurdle due to its timid appointment policy, its fear to play the bank until the end of the project, and by not reimbursing the professor for his privately pre-financed investment. With very negative consequences in terms of perseverance and good relations. The design of the concept house urban villa and its possible floor plans is done and optimised in firm cooperation with the chair of Thijs Asselbergs, based on his name, reputation, and experience in housing development. Mick Eekhout does not have an impressive background or experience in this particular field but as an innovation professor he has stimulated that every party enlisting as a project partner takes at least one step forward with regards to their products and innovation of components. In this project, not everyone has yet succeeded in doing so.

The companies contribute their respective products and/or components in an innovative manner. These are then discussed in close deliberations, are attuned to one another, coordinated, further developed and integrated. On a second level, the chair has further integrated and coordinated these particular optimisation paths toward the concept house prototype as a technical artefact, a prototype of an independent apartment that also shows qualities as a stand-alone prototype. However, it is obvious that the single prototype always bears reference to the concept house urban villa.

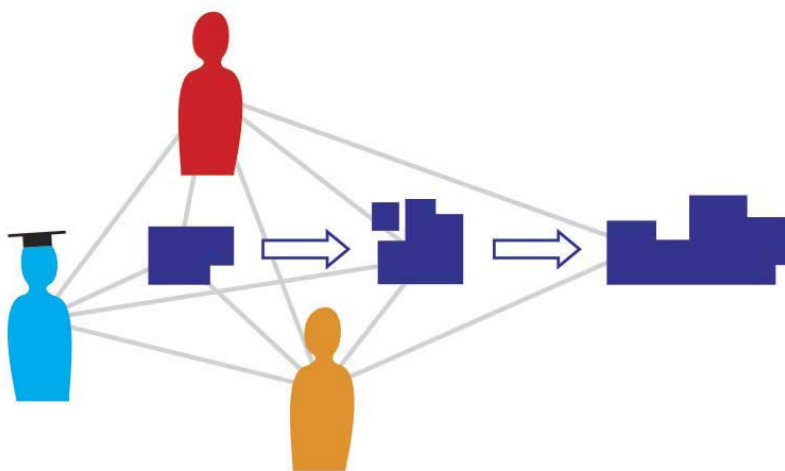


FIG. 13 Participation of the academic world, contractors and suppliers in the building industry, and thereby the future customers/clients as well

#### REGULAR PRESENTATION TO THE BUILDING WORLD AT BUILDING TRADE FAIRS

In the meantime, during each year of development of the concept house prototype the process of the project is presented at the bi-annual 'International Building Exhibition' / 'Bouwbeurs' in Utrecht, and the 'BouwRAI' in Amsterdam. Building trade shows provide

the opportunity to increase publicity and to solicit new partners to help realise the actual execution of a complete test apartment [it is currently very doubtful that this can be accomplished]. The building system, which at this moment is not yet completely detailed, is presented at the 'Bouweurs 2011' by means of two mock-ups of complex construction nodes. They show the most important building details on a 1:1 scale, executed with the real materials. The physical construction nodes draw a lot of interest and cause constructive discussions.



FIG. 14 Intermediate mock-ups of the essential construction nodes at true scale. [Bouweurs February 2011]

#### SIGNING THE REALISATION CONTRACT FOR THE PROTOTYPE

The first half of 2011 is designated to the design of the prototype, detailing and drive for optimisation of individual components (product development at the individual partners), coordinating and integrating these components into an appropriate artefact of the prototype apartment. And for deliberation with partners and co-makers and sponsors about financial consequences. The partners are so determined to realise the prototype after three years of deliberations that no one drops out anymore and no new partners need to be recruited. On the other hand they are put under pressure to make do with a budget that, in spite of all the promises for partner financing and subsidies, is rather tight, by seeking out discounts for parts that need to be purchased.

On 30 June 2011, a milestone is reached when the contract between 'Concept House Prototype Consortium' and 'Concept House Village Facility' is signed, whereby the prototype consortium (chair/TU Delft plus SME partners) commits to build the prototype, and the village facility (Hogeschool Rotterdam, TU Delft and housing corporation 'Woonbron' on behalf of the city of Rotterdam as landowner) allows building on its land and partially accommodates and finances this with additional sponsoring. The architecture dean, Karin Laglas, signs as the responsible person for the budget of TU Delft. The main persons responsible for the execution of the process can now sign as well. The realisation process can begin.



FIG. 15 Signing the building contract between the Concept House Consortium and the Concept House Village Facility by respective project leaders Mick Eekhout and Bert Hooijer in June 2011

#### ENGINEERING THE PROTOTYPE

Between the beginning of July and the beginning of December 2011 the already developed and partially innovated components are chosen, coordinated, attuned and integrated, and, where ever necessary, further developed. The necessary work drawings of the entire apartment and of the components are made during this period. Naturally, this is done from integral drawing in a central BIM model (and with help of Autodesk Revit). Thereafter, during the autumn months 2011, the elements and components are produced and assembled into super-components at various factories; for example the sanitary unit including the ducting for the entire apartment. In addition to the innovation and product development efforts to drive the partners to further innovate their products it is the chair's task to combine the improved products into a prototype that is a complete work of art, a technical artefact, and to coordinate and integrate. Thus, after choosing the components and the desired innovative upgrading, an integral part of the work is the coordination and integration into the entirety of the prototype, knowing that on a larger scale it will be part of a concept house urban villa.

From the beginning, the development is separated into the two clusters 'Building Technology' and 'Installation Technology' even though these two clusters need to be integrated and coordinated. Due to the focus on individual components, the phase of

developing and building the prototype is still very much oriented on product development. The following post-prototype period [2012-2015] of the urban villa as a pilot project shall include more architectural engineering, with a link to the built environment [larger scale, cross linking with potential of the surroundings] in all of its aspects. The location of the prototype in the middle of a little neighbourhood in Heijlstraat where existing apartments will eventually need to be replaced, is seen as a commitment by Woonbron as a motor for renewing insight. But the entire process to realise the Delft prototype is very internal and, above all, focused on own realisation.



FIG. 16 Aerial photography bird's eye perspective of 4 prototypes on Corydastraat in Heijlstraat, Rotterdam. The Delft prototype is the first built prototype in the concept house village. The skewed position of the prototype on the location was chosen for best visibility. Due to the demolition of existing houses this was unnecessary

### ON-SITE ASSEMBLY

Construction on the site begins on 6<sup>th</sup> of December 2011. A storm, force 9 on the Beaufort scale, causes delay in installing the floor components and the sanitary unit, the wall and roof components. But thereafter, the components are assembled and joined so quickly that after a few days the prototype is wind and water tight, and energy can already be produced [measurable and usable] due to the direct plug & play links from the PV cells which are integrated into the roof elements.

But following these eight days of assembly there are still parts that require fairly traditional finishing (such as the major part of exterior and interior finishing and painting). Therefore it takes until February for the apartment to be officially ready. Besides, on-site work poses a hurdle on the path toward complete prefabrication. Plastering the ceiling in order to achieve the look of a smooth concrete ceiling is something you do not expect in a prefabricated apartment. But one of the sponsors is a painters and decorators school who strives for exactly that perfection of craftsmanship. Detailed additional finishing – for outsiders part of the building [such as the stability supports of the underlying steel construction and the outside staircase, but in fact not part of the prototype apartment] is the reason that the building can only be considered as actually delivered in mid June. According to the chair the

project remains within budget; according to the faculty, who in the meantime had raised the hourly rate for researchers to the level of 'integral TU Delft costs', the project made a great loss, which was the solely due to bookkeeping and university/faculty politics related reasons. The partners and sponsors hurtled themselves into an adventure, partly from naiveté, that cost them all more energy and thus money than anticipated. Therefore the readiness to continue to support the project after delivery of the prototype has dwindled. In the middle of June 2012, laying the now also sponsored sustainable floor covering rounds of the building phase. Completing the floor covering also means that the prototype finally turns into a habitable apartment.



FIG. 17 Photo of outside view of the architectural completion (June 2012)

#### HEADACHE DOSSIER FOR TU DELFT

In the meantime, a controversy has manifested itself between the faculty and the chair; based on different points of view resulting from the long duration of the externally financed project since 2005. Even though the dean had signed the realisation contract, her financial advisors continue on their path and demand to calculate with an 'integral cost price' which is three times higher than the actual gross salary for the researchers which in turn is the basis for the original budget calculation. Naturally the SME partners are surprised. The faculty wants to get rid of the project and the dean considers it a 'headache dossier'. A matter which is comprehensible in an accounting sense but in terms of scientific work

hard to understand, and very demotivating for the participating researchers who now feel as if they have to fight on all fronts. The faculty would prefer to write off the project and forget about it. However, a write-off would cause the chair and thereby the faculty and the university as a research institute to suffer from a reputation of being unreliable; definitely from the viewpoint of the partners, sponsors and grantees. The mistrust will last through the end of the project.

The chair holder proposes to split the 'bare property' and the 'usufruct' [see appendix 5] which results in an agreeable understanding between it and the IDE faculty. In the meantime Professor Daan van Eijk from that faculty has brought in a European grant project, titled 'SUSlab'. This results in a collaboration whereby the chair and architecture faculty shall be responsible for the building phase and subsequent architectural developments, and the IDE faculty for the laboratory research phase upon delivery and commissioning; particularly as it relates to the man/machine relationship: Research in home automation and other housing designs. The IDE faculty takes on financing the Living Lab period until November 2015, while each of the participating researchers must find external sources to finance their planned research projects. In the summer of 2012, Professor Dr. David Keyson takes over the implementation of the laboratory phase from his colleague Daan van Eijk [www.suslab.com](http://www.suslab.com). After much discussion, the maintenance agreement between the two faculties is finally signed in June 2013, whereby the merit of the project due to the contribution of the SME partners has completely disappeared. Furthermore, the property claims of the participating partners and sponsors are completely neglected. No waivers are signed. Certainly food for future discussions.



FIG. 18 Inside view of the architectural completion

Jaap van Kemenade leaves the project on May 1<sup>st</sup> 2012. Rutger Wirtz is prolonged for 6 more weeks – to prepare the prototype for its finishing floor, furniture and garden. Mick Eekhout and Arjan van Timmeren take the scientific report into their own hands. Later, the dean refuses to pay back the pre-financed cost to the professor. Rutger Wirtz obtains a

part-time employment until the end of 2012 by Hogeschool Rotterdam and later the IDE faculty; for maintenance, research assistance and planning. This ensures that by means of several sponsorships the outside area as well as furnishing the house including the kitchen, lighting etc. is completed. Furnishing, placing the kitchen and installing lighting also serves to make the prototype ready for opening as part of preparations for the following research period, the use of the prototype as a laboratory. Exterior areas are also paved and planted.



FIG. 19 Official opening by emeritus Professor Environmental Design Jón Kristinsson and the dean of the IDE faculty Prof. Ena Voûte

#### FROM OPENING TO LABORATORY

Final preparations lead to the official opening on 5<sup>th</sup> of October 2012. In the presence of all participating partners, sponsors, grant providers and other interested parties, the opening is led by sustainability pioneer Prof. Jón Kristinsson, together with the dean of the IDE faculty, Prof. Ena Voûte. She also introduces the next phase: User research over a period of three years until 30<sup>th</sup> of November 2015.

The contractual end of the collaboration with the industry partners and sponsors for the realisation of the prototype already occurs before that time on 1<sup>st</sup> of May 2012. The opening marks the transition from building phase to Living Laboratory phase. At the same time it marks the point at which the building patronage of the architecture faculty is transferred over to the laboratory patronage of the IDE faculty. The respective contracts [land agreement and faculty patronage] are discussed at length, written up and signed in June 2013. Here upon follows a period of laboratory work relating to various research, such as (especially) energy, the prototype as a building, the interface between human and machine, and the psychological behaviour of the habitants with regards to the prototype as a residential dwelling, as well as the actual (measured) performance, of course. For this phase of the research, a warranty is applied for with the Board of TU Delft, so that smaller research projects can take place under this umbrella; each with its own financing, in the known short-winded SME mode. Contractually, the end of the laboratory research agreed upon with the concept house village facility is anticipated for November 2015.



## END-OF-LIFE OF THE DELFT PROTOTYPE

In December 2012, the end-of-life issue is discussed: What is to happen with the prototype upon completion of the three-year laboratory phase, during which Woonbron tolerated that the experimental Delft prototype in the concept house village is used as a laboratory? No trivial question for the village. Because the adventures and experiences with this concept house Delft prototype will have a great influence on the decisions about subsequent prototypes. The temporality of the Delft prototype certainly does not facilitate obtaining a building permit from the city. The approval process for a single apartment is approximately as long as for an apartment block with 60 units. And cost distribution amongst the participants influences the process; no one wants to take responsibility and decisions are more often deferred than taken. The question of the consequences of permanence versus temporality arises. Certainly if future prototypes are made from non-dismountable materials.

The prototype is intended to be maintained and used as a permanent residency. This might involve that the new plan of the urban design information must be adapted to the prototype as an obstacle, as a permanently present apartment, with new residential dwellings to be grouped around it. At the start of the concept house village a strip is dedicated for prototypes. The continuing removal of houses in the neighbourhood results in a cleared area that allows for a new master plan for future housing. Figure 18 shows that the prototype is designed into an existing residential neighbourhood.

The Delft prototype could also be relocated to a location at the edge of the concept house village on the borders of the housing terrain so that it could be used as a permanent dwelling without inhibiting the design of the new residential neighbourhood; the south-western side of figure 18 on the triangular terrain. Furthermore, this could make possible a permanent location and non-commercial sale.

At that moment it becomes obvious that the prototype is not part of the redesign of the built surroundings of 'Het nieuwe dorp'/'the New Village' of Heijplaat, which turns the prototype into a foreign object in its bare environs; quite possibly an obstacle for any restructuring plan. Unfortunately, an urban design discussion has not yet taken place.

The prototype could also be sold to the public so that it could be moved to a different location. In this case the potential owner would need to acquire a building site plus a construction permit ahead of time; otherwise the real estate would change into moveable property and would lose all or most of its value. Many visitors experience the prototype as a comfortable dwelling even though it is scarcely furnished and does not even have a TV or internet connection yet. Which can be remedied easily with an all-in-one package, by the way. But the comfortable atmosphere of the interior space, the warmth of the wooden surroundings, the noise level, the insulation; they are all charming aspects. But according to real estate agents, putting it on the public market without a new building permit will not make much sense and will not draw potential buyers.



FIG. 20 Layout concept house village Dec 2012: The concept house 'Delft' prototype in a neighbourhood that, in the meantime, has been completely removed. This changes the surrounding environment in a bare wasteland the Prototype looks odd. Best solution would be to reposition the Prototype south in the map on the triangular plat used for other Prototype experiments (July 2015), so in the upper groundplots 3 new blocks of houses can be built.

Since TU Delft has little experience in the area of moveable property, the SME partners are asked whether they see a future for the prototype. The answers are negative. One solution could be to 'haul up the anchor', move it to the water on a platform, from there onto a pontoon, and then transport it inland via the water. For example, to place it on the terrain of TU Delft for further student research. See Figure 20. For such a trip, the width of the locks, clear openings between bridge landings and sufficient height clearance are relevant. The transport can go as far as the Kandelaarbrug in Zwethheul at 4 km distance from TU Delft, which is not wide enough for the pontoon carrying the 7,80m wide prototype. Then, the prototype must be hauled out off the water, transported to the other side of the bridge, and put back into the water, from where it can be shipped to the harbour of Delft on Rotterdamseweg. A location directly on open water is better than one further inland.



FIG. 21 Concept house as a prototype, possibly placed on the forecourt of the IDE faculty after November 2015 to provide students with the opportunity to execute experiments

Until now, no decision has been made about a possible reuse of the prototype after November 2015. In the meantime, concept house village has announced that they would very much appreciate a 5-year extension after November 2015; not least due to the slow realisation of the other concept house projects. It is obvious that the chair, i.e. the faculty should handle the project with great respect considering the total investment from many parties. No spontaneous capital goods liquidation or liquidation due to ignorance. Most partners and sponsors are prepared to sign a waiver for their financial contribution to the prototype and to grant possible profit to the chair if such potential revenues are used for new research along the lines of the original sponsoring and donation goals. This is also what has been communicated to the sponsors and partners over the past years. What remains is the moral responsibility of the chair to act as a good patriarch of the prototype. After all, the 'bare ownership' places the ownership at the architecture faculty while, as per the agreement, the 'usufruct' falls to the IDE faculty from October 2012 until November 2015. For three years, this faculty has allocated a yearly budget to establish the laboratory phase. By means of its Bucky Lab, with almost 100 Master students annually, the chair wants to work on additions and replacements of individual components of the prototype. These experiments include new facades for the green container as a storage space, an elliptical glass substructure of 7 m in diameter to exhibit the plans for the concept house Villa in Rotterdam in a structured and designed manner. Thus, the decision to maintain or demolish is an important one, and indeed a requirement if new energy and effort shall be invested.

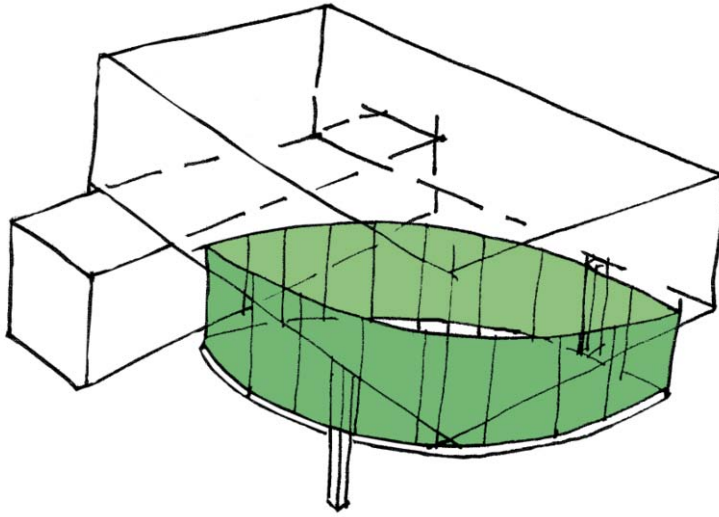


FIG. 22 Bucky Lab student proposal for a glass substructure, sponsored with curved and, in the meantime devaluated, double glazed components from the Fletcher hotel in Amsterdam, opened in January 2013

#### SIGNIFICANCE OF THE PROTOTYPE PROCESS FOR THE DUTCH BUILDING SME

The prototype is meant to increase technical understanding for the future. With 150.000 people working in the building supply industry, 30 billion Euro of national revenue, and a very uncertain future for the next five years of the building industry in general, the building supply industry is well advised to explore future trends and opportunities. Exploration usually happens on a small scale; otherwise it becomes too obvious or disturbs the normal state of affairs which after all focuses on revenue and company survival.

Besides, it is evident that the concept house consortium, consisting of SME industry partners, can be accused of trying to work together on forward oriented integration in the direction of contractorship. The consortium held several discussions about this topic. Initially, Dura Vermeer as a main contractor is initially a member of the consortium; but they leave in 2010 because concept house puts too much focus on developments on the component level. Thus, the focal point lies on the level of subcontractors and suppliers, and not on the building contractors. Whereas a great challenge actually lies on the level of integration and coordination; precisely the terrain where contractors know to manifest themselves. Which leads to the consequence that the chair [as a sort of unpaid general contractor] needs to integrate and coordinate the consortium in a collaboration of co-makers. And that plans need to be made, from out of the basis of the consortium, to tackle further developments as builders. Timber housing manufacturer VDM, one of the partners, very reluctantly agreed to act as general contractor for the following period of the urban villa. They might end up as a competitor of their clients, the main contractors. Upward integration is not new. HBG, the Netherlands' largest general contractor, meanwhile

integrated in the BAM, also had its origins in 1905 as a concrete subcontractor. Thus, upward integration is not culpable. But VDM prefers to act as specialised subcontractor for large skeleton constructions working for a general contractor, or as a general contractor only for smaller projects such as owner-occupied houses.

Yet, the concept house prototype research is one of these rare research areas where the practical result is a material product, a prototype apartment as part of a larger concept house urban villa complex. A prototype that is tangible; can be seen and walked into, and in which you can imagine a multitude of these prototypes. Shortly, we will be able to render a digital representation of such an urban villa through which you can walk and experience with 3D glasses. But there is nothing better than to actually materialise something when the opportunity arises. To live in, and provide feedback, and to read just the principles for the future. No matter how much digitalisation increases around us; sometimes true materialisation is very valuable.



# 02 CONCEPT HOUSE

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## FROM INITIATIVE

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## TO URBAN VILLA

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The initial mission of Concept House from 2005 is formulated as follows: "The goal of the research group concept house is to design, develop and research new industrial housing concepts. The aim is to offer a positive contribution; firstly to the wishes and demands of the user/habitant, secondly to the quality of the built environment, and thirdly to the interests and concerns of the Dutch industry. Since new concepts shall be mostly based on applying new materials and methods, collaboration with other industry sectors than the traditional building industry is high up on the agenda. Together, one or more versions of the concept house shall be realised as prototypes of consumer-oriented, pre-fabricated apartments." Naturally, this means that the general objective of the project includes offering a scientific contribution to building technical innovation, and to work as a consortium of collaborating companies and organisations who, individually and mutually, promote innovation.



FIG. 23 First configuration and typology studies

In September 2008, Wim Poelman as the supervisor of the research group decides that it is time to make a real prototype which he calls 'Bare House'. Three match meetings are organised in Zeist in the centre of the Netherlands to convince the invited parties to participate in the initiative. The idea is to build an industrialised prototype of a residential dwelling. Wim Poelman's strength is to design materials; therefore the idea is to develop a prototype that focuses on innovation on a material level.

After the four previous years during which the concept house research group conducted studies about various aspects of industrially made, consumer-oriented apartments, the foremost focus now lies on industrial product development related to residential buildings. In this field, industrialisation offers many opportunities for product optimisation: Higher quality, better process control, and lower costs. Slowly but surely, the building industry discovers the benefits of industrialisation as well. From out this perspective it is decided to focus on multi-storey apartment buildings as a scientific challenge. And, to begin with, with particular focus on developing new multi-storey apartment concepts for the ill served group of starters in the housing market.

Just like initiator Mick Eekhout, Wim Poelman as an industrial designer is convinced of the added value of industrialisation in the building industry. Industrialisation means that apartments become more affordable while maintaining the same quality level, or can be of higher quality at the original price. Building time decreases, and suppliers can collaborate better; which in turn means that costs due to errors, traditionally high in the building industry, can be lowered. And all of the subsystems and components must be selected according to quality, attuned to each other, coordinated and integrated. Whenever individual systems can be replaced by an integrated 'super-system of systems and subsystems' the result is more space for innovation and sustainability.



FIG. 24 Industrialisation in the building industry: Building becomes assembling components that are prefabricated elsewhere

Poelman sees a different approach between architects and industrial designers: The first group is more oriented toward form, construction and exterior appearance; the second toward usage and interior. According to Poelman a combination of the two can lead to a valuable synergy; resulting in designs that are very interesting from an architectural point of view as well as for the user [and therefore the market]. He envisions a building system



made up of existing subsystems of light-weight, modern materials by different suppliers. With the bare house system, entire apartments (or smaller offices) can be realised including the exterior space; in the form of new buildings as well as on vacant lots, for example, for temporary or permanent application; always architecturally appealing.

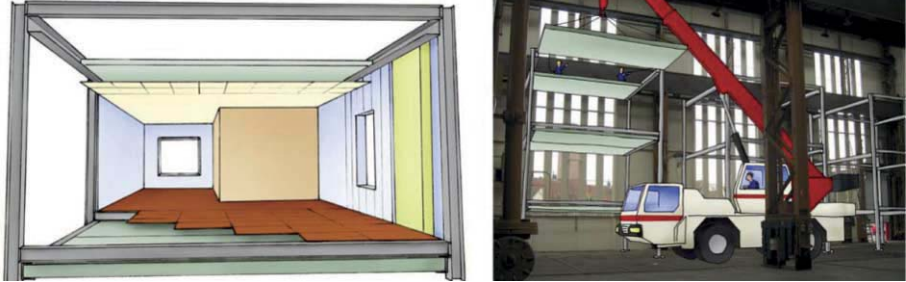


FIG. 25 First concept sketches of the 'bare house', the predecessor of the Concept House 'Delft' Prototype, (still) based on a modular steel load-bearing structure

Based on her earlier research into industrial building concepts, architectural engineer and external researcher Marlou Vriethoff concludes in 2006 that the acceptance of industrialised buildings in the market is still rather limited, and that industrialised building at that moment has a limited chance of success. A good starting point would be to begin with temporary buildings and apartments for the student and starters market because these user groups are less picky and also more progressive. And, they seem to be a forgotten target group. If industrialised building is accepted in this market segment, new possibilities for others will arise.

SEV (Stuurgroep Experimentele Volkshuisvesting/steering committee experimental public housing) is interested in new concepts for temporary buildings. But housing corporation Woonbron and the neighbourhood Delfshaven in Rotterdam also share this interest. The bare house system can be adapted to phased neighbourhood renovation projects, for temporary repurposing of unused terrain, and temporary accommodation for seasonal workers or foreigners. Appropriate locations in former industrial areas can be found in many cities. From a functional and aesthetical view point, existing solutions for this sector are meagre: The perfect challenge for industrial designers in the building industry. Via this intermediate step, the research comes into discussion with the RDM initiative in Rotterdam / Heijlplaat. The old halls of the RDM (Rotterdam Drydock Company), where large ships were once built and for the last decades even submarines, are now transformed into the RDM campus, accommodating vocational and professional schools together with the TU Delft and innovative companies. The RDM campus is a regional cradle of innovation. And following conversations between Wim Poelman and Bert Hooijer, our initiative leads from the concept house prototype to the larger-scale Concept House Village. Since there are several other prototypes still to come, we call it the 'Delft Prototype'.

## THE FIRST DESIGN ITERATIONS, SYSTEM AND MATERIAL CHOICES

In 2008, at the beginning of the development process of the new industrialised building system with added architectural value, there is a broad scale of goals and wishes and flexibility in the selection of possible partners. Initially, the type of building system to be chosen and its further development remain relatively open: 'unit systems' as well as 'element systems' have their own advantages and disadvantages. At that time, Poelman presumes a module grid of 6 x 6 meters and chooses a typical Italian mountain village as the design reference for the apartment complexes: A pleasant if densely populated environment including streets and green areas.



FIG. 26 One of the references of the reference study

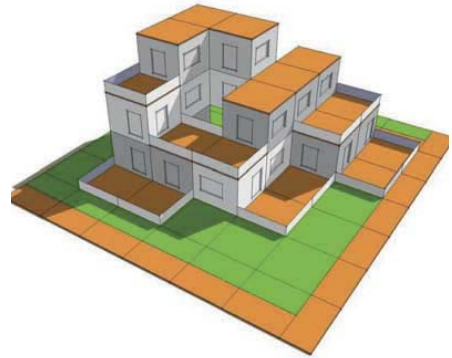


FIG. 27 initial studies into the interconnection of the individual apartments within the building system approach

The Great Fire of Architecture on 13<sup>th</sup> of May 2008, Wim Poelman leaving the university in December 2008 and the concurrent miniaturisation of the chair from 6,4 fte to 1,5 fte cause the vigour and enthusiasm at the chair to dwindle a little. Mick Eekhout takes over supervision of the project. Based on his assessment, the design sketches are developed further into a unitised building system consisting of elongated apartment units of 60 m<sup>2</sup> that can be connected with each other. He puts a stronger focus on the desire to utilise this building system to develop ground-breaking technical innovations and to be able to realise spectacular architecture. His point of reference for this is the project 'Maison d'Artiste' from 1923, of which he and his students made an accurate reconstruction on a 1:5 scale. Remarkable are the spectacular cantilevers that still seem to defy realisation.

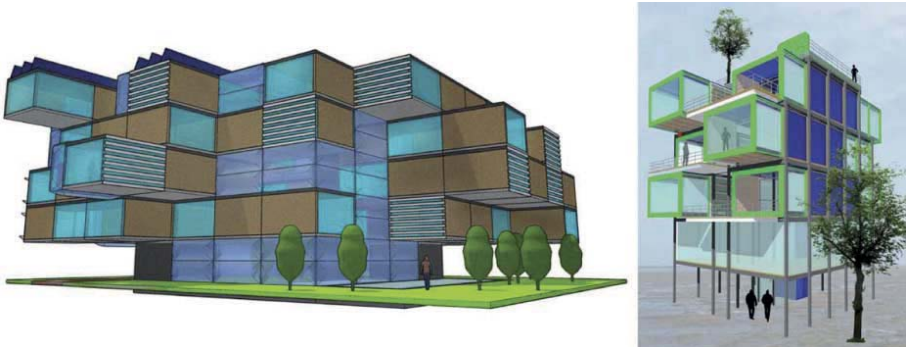


FIG. 28 Several design studies of building configurations in consultation with Thijs Asselbergs. They still show the influence of the Maison d'Artiste

During the practical elaboration of this research phase, researchers Jaap van Kemenade and Joris Veerman conclude that the very high demands on building technical performance in combination with a lifelong flexibility and reuse possibilities lead to building elements of high complexity using expensive high quality materials. Since the intention was series production instead of mass production this would result in more expensive rather than more affordable building. Furthermore, budgets as well as quality demands for temporary buildings in the market are low, which means that the concept misses the point of the high ambitions of the concept house development project. Based on these facts, it is decided to leave temporary building for what it is, and to concentrate on high quality, permanent buildings for the starters market. Separable joints and dismantling options can still be adapted since they offer possibilities for a certain flexibility in use and for recycling and reuse of materials.



FIG. 29 Wim Poelman, Mick Eekhout, Jaap van Kemenade and Arjan van Timmeren

After the four previous years during which the concept house research group conducted studies about various aspects of industrially made, consumer-oriented apartments, the focus first shifts toward product development related to sustainable [serial] housing. However, with a greater emphasis on flexibility and possibilities for variations: 'customising'.



FIG. 30 Flexibility and variation as an important [added] sub-target

In this field, industrialisation offers many opportunities for product optimisation: Higher quality, better process control, and lower costs. Slowly but surely, the building industry discovers the benefits of industrialisation as well.

Subsequently, Arjan van Timmeren is recruited as associate professor for the chair in September 2009. His expertise in sustainability will also strengthen the concept house research, which means that the research again takes on a different direction. The standard library of building elements now also includes sustainable and ecological intervention on the building level. Sustainability dominates as the primary concern. Arjan van Timmeren reasons from a larger to a smaller scale of the technology.

He introduces vast knowledge of sustainable building and flexibility to the team; thus enabling the energy goals to be further sharpened toward zero energy apartments or even energy producing [energy positive] apartments. There is even talk of ‘zero value energy bills’. But there is also an increasing emphasis on variation; to avoid the so-called ‘container look’ of multi-storey apartment houses.

Due to the urgency for wide-spread sustainable residential housing and particularly with a focus on energy neutrality of the apartments in use, the focus is now definitely set on multi-storey apartment buildings. And this because energy positive or energy neutral building in the Netherlands as well as in other countries, is mainly realised with single-family apartments [almost always free-standing, two-family houses and sometimes row houses: ground-bound houses]. Not only because the available budget per habitant is generally larger, but also because there is more space available, inside the apartment as well as per roof or ground area. And last but not least, because in most cases the investor is also the user, since he is the owner. And because the habitant/owner is the only user of the systems, handling errors are the owner’s own problem. In themselves, free-standing houses are often innovative and inspiring; but in view of the urgency of a necessary energy transition in the existing building environment they seem to offer too little reach with regards to the necessary transition of the share of energy in the more sustainable built living environment.

Consequently, under the influence of Arjan van Timmeren the decision is made to shift the focus toward multi-storey apartment buildings in combination with improving sustainability, energy neutral to possibly energy positive features for [architectural] use. To be further realised in an industrial building process focused on economy, quality and an extremely low ecological CO<sub>2</sub> footprint.

Thus, in 2010 the defined focus of the concept house research project can be summarised with the following three starting points: goal, production, use:

- Multi-storey consumer-oriented housing, possibly with higher densities and focused on the individual inhabitant by means of choice options and alternatives;
- High degree of industrialisation, 'Plug & play'; apartments made of industrially produced elements and components (IFD), with attention to assembly techniques. The place of assembly has become less important (offsite / onsite / partially offsite / partially onsite) than the overall efficiency and sustainability of the assembly process itself;
- Very low CO<sub>2</sub> footprint in production and building; here CO<sub>2</sub> is used as the general term for all greenhouse gases (thus SO<sub>2</sub> and methane, as well);
- Strongly future-oriented in terms of energy balancing: Energy positive or at least energy neutral in use; thus, according to the common norms in the Netherlands an EPC of 0.0 or less [negative value]. The lower this value, the better the energetic result.

It is determined in the very beginning that the concept house project should not only be developed on paper but should also lead to real material results. Such an attitude is rather unusual in the academic environment of the architecture faculty, since desk research is more common than material research. But ever since 1992, the continuously updated curriculum of the chair of product development includes that new materialistic components need to be developed in the tension field between materials science and architecture, between the fundamental and the application-oriented. Since 1995 the chair, as one of very few in the world, runs a prototype laboratory with workplace where students learn to realise their designs with processing methods and materials. Even though this laboratory has had several different names over the years, the intention remains the same: Bring to life the dreams of your heart with materials, your hands and your brain. The successive names are: The Laboratory for Product Development or the 'PO Lab', the Building Technology lab or the 'BT Lab', the 'Prototype Lab', and currently the 'Bucky Lab'. Since 1995 there are approximately 900 students, chiefly from the Master tracks Building Technology and Architecture, who come "to see the light" (quote by former student Robert Capel) during the prototype study. After having learned to create a prototype with their own hands, techniques and architecture suddenly become much clearer: The possible and the impossible, the desirable and the undesirable. With the experience of making a prototype under their belt, working toward a complex prototype in the form of an apartment is indeed a larger scale than usual for components, although very logical and based on the experiences and insights from the chair. The prototype apartment is seen as a technical artefact; as a product it is the subject of the chair.



FIG. 31 Bucky Lab results from 60 students in 2012/2013: Three sunshade systems and a cardboard cupola

In order to be able to bring the complex task of the concept house to a good end, a cyclic process is chosen as part of which one intermediate product shall be completed per year. Since developing everything from scratch simply costs too much time and money, the concept house is developed as a system, developed on the basis of existing products that fit well into the overall system. But this also includes innovative adaptation to make the concept house suitable. The intermediate results are discussed on a regular basis by the consortium, and are presented at a national building exhibition (alternating in Utrecht and Amsterdam). Then, the composition of the consortium of SME partners can change. Subsequently, the concept is developed one step further to make the jump into the next year. This incremental approach suits the expectations and possibilities of the participating SME partners. At TU Delft it is more common that larger companies support entire PhD projects over 4 to 5 years, contacted by the industry. With SME's in the building supply industry this is not typical, not desirable, and as per current experience absolutely impossible. Thus it is also impossible to plan longer term research but rather requires working with overview targets within one or two years. And this has considerable consequences, not least for the supporting organisation of the faculty; which will not have escaped the observant reader. Nevertheless, this is the only path that SME's can maintain and that delivers good results for them.

In this manner the consortium of SME partners forces itself to come to concrete results and to show the courage to realise the improbable. Initially, the goal was to build one 1:1 prototype per year ('the Octatube method') but it quickly becomes apparent that this is

impossible due to the available effort and budget. Consecutive results were 1:50 and 1:20 models of the urban villa and of the prototype [2009], 1:1 mock-ups of important detail construction nodes of the prototype [2010], and finally the completely functioning and habitable 1:1 prototype [2011/2012].

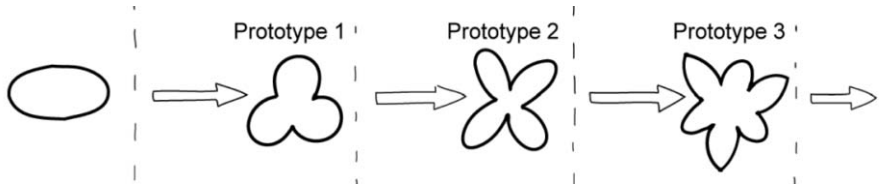


FIG. 32 A constructive series of prototypes and mock-ups is important for the product development process



FIG. 33 Coherence of current and new SME partners via various activities: Presentation models [l] and mock-ups [c] at trade-shows and exhibitions and [midway] drinks [r] to keep up the spirit

An important goal is to realise one or more versions of the concept house (also to steer the participating industry partners) composed of material systems and subsystems whereby each system or subsystem encompasses at least one innovative aspect, and which, in the form of apartments, can be applied to multi-storey apartment complexes. This is the chair's ambition. And energy and patience are exerted to this effect.

It is the concept of multi-storey building in particular that makes this project an especially interesting experiment in the Netherlands. Not only because most of today's sustainability experiments in the field of residential housing are ground-bound. But also due to the fundamental questions of affordability, increasing urgency, and the demand for upgrading and [energetic] renovation. This stems, for the main part, from the high and medium rise buildings from the Fifties and Sixties neighbourhoods which still score badly today. Furthermore: The Netherlands are a densely populated delta, where [medium to] high rise buildings from the post-war era play an important role. With their results and the focus on technically relatively easy to realise new constructions, experiments such as this prototype also aim at stimulating upgrading efforts for existing buildings. Because the urgency for and the scope of energetic upgrading of the existing housing stock, particularly as it relates to medium and high rise constructions, are significant considering the governmental requirements and expectations per 2020.

## DESIRED END PRODUCT

The targeted end result of the 'design & build' period of the prototype is a completed innovative prototype. In the form of a high quality, industrially fabricated apartment based on the hierarchy of elements and components in systems and subsystems which are innovative, coordinated and integrated to the highest possible degree. The innovative character is created by combining new solutions for energy balance, materials, components, joining techniques and installation systems. The prototype is to be the beginning of future developments oriented toward different material/component variations, and of the first zero-series or 'pilot projects' of arranged apartment buildings, called the concept house urban villas. These apartments shall ultimately be placed on the market at a 'market conform-plus' price by a consortium derived from the development consortium concept house. During the first research phase the focus lies on the lagging market of temporary housing for starters who are factually excluded from the housing market. The renovation of apartment complexes, entire neighbourhoods or phased building projects requires good temporary and permanent sustainable apartments. This could also include temporary accommodations for students, foreign workers and low-income groups. Temporality does not have to equal apartments of inferior quality. The guideline should be that the arrangement of spaces must be able to accommodate several habitant cycles. At least these are the thoughts within the team. Ultimately, the realisation of this prototype should help with the further development, research and building of prototypes and zero-series of industrially fabricated, consumer-oriented apartments. With market-oriented spin-offs on a subsystem level as the result for the participating consortium members, and up to possible application in a so-called zero-series.



FIG. 34 First studies (from end 2010) into possible configurations and variations for application in the concept house urban villa, of which the Delft prototype is merely one apartment

The core of the prototype design is the larger part; the urban villa with 16 apartments that together shall be energy neutral in use. The urban villa has not yet been fully elaborated architecturally, but the following floor plan gives an indication. It is obvious that this floor plan is only the beginning of a future development. The designers have created common floor plans that are up to date and are architecturally correct.



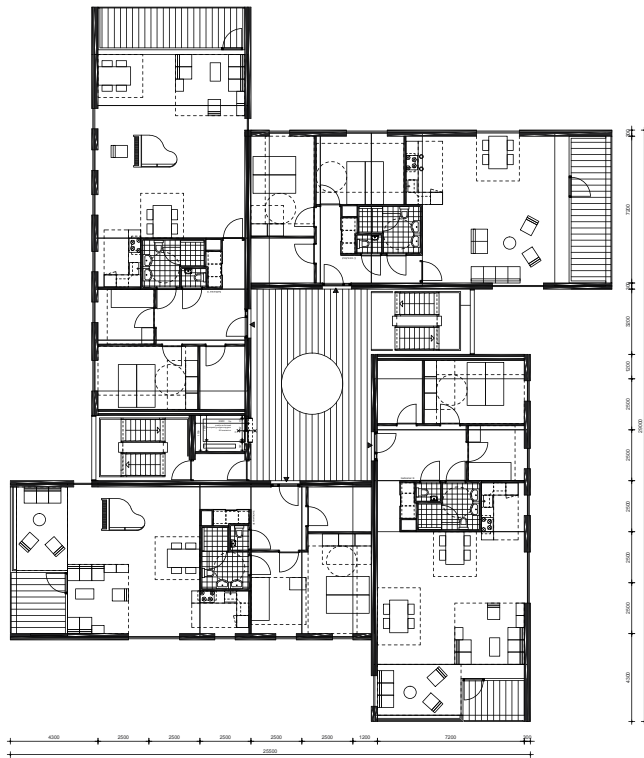


FIG. 35 Arbitrary floor plan of 4 apartments of a typical storey in the urban villa (redesigned June 2015)

A new opportunity, a new location and a project developer who takes the lead in this ambitious project, a true 'product champion' must be found for the subsequent urban villa project. After 2008, not an easy task in times of recession. However, the profession and the 2020 requirements demand it. The generous Dutch subsidy options by the Ministry of Economic Affairs [TKI Energy savings in the built environment] do not seem to offer any possibilities to materialise the broadly advertised support from the Ministry of EA to SME. Thus, SME must accomplish it by themselves. If need be, the chair will take over the leadership again to challenge and accompany SME Building [supply]. The search is for a product champion, a client who is so taken with the possibilities of the concept house system that he/she wants to have the idea further developed and realised into an energy neutral urban villa apartment complex. Preferably somewhere in Rotterdam, such as for the housing corporation Woonbron in Heijplaat, or in Delft, as proposed to the housing corporation Duwo on Kanaalweg. But new building initiatives are currently thinly sown. And yet, there are hopeful initiatives as well that try to explore the future, such as the Barbahuis by Portaal. Yet, the adage in terms of the prototype must be to develop the urban villa "in half the time and for half the money" [Wormack et al, 1991]. A task and a challenge for future research.



FIG. 36 Urban Villa with 16 apartments located on one of the possible locations that the consortium of the concept house is looking at, on Kanaalweg in Delft

02.02

## OPPORTUNITIES AND POTENTIAL PROBLEMS AT THE BEGINNING OF THE PROCESS

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Back to the status of spring 2011. During this phase, the opportunities and threads to the projects were explicitly discussed with the SME partners. Everyone seems to keep the reassuring thought in the back of their mind: “Even if this comes to nothing, I will have still broadened my network, gained more knowledge, and got a glimpse of the academic world.” However, in the meantime all activities are directed at overcoming the countless problems of the project. With an experiment such as the prototype in question with the many hurdles on the way there is a great chance of failure or bleeding to death. Often not even due to conscious obstruction but caused by ignorance or naiveté. Mick Eekhout’s company has been creating successful experimental developments for the past 30 years, often project-related with direct application all over the world. One after another, small steps forward are taken with every project, researching a new experimental part with each one; resulting in great progress over the years. Designing and developing ‘step by step’ as architect Renzo Piano calls it. But always with an enabler, a ‘product champion’, someone who believes in the project and is ready to bring it to completion no matter what comes in the way. This results not only from an attitude of determination to continue and realise innovation, but also from a methodical approach. In literature, the methodology of designing, developing

and researching is well established, and is always used as the backbone. Mick Eekhout has written several books on the subject [Eekhout, 1997, 2008, 2014]. This project combines the methodology of the Faculty of Architecture [Eekhout 1997, 2008 and De Jong 2003, 2012] with that of the faculty of industrial design engineering [Rozenburg & Eekels, 1991]. Highly theoretical methodologist Professor Dr. ir. Taeke de Jong's [De Jong, 2012] most famous quotation is: "Designers search for a desirable future, for a possible future, but always for an improbable future as well. If the future they are pursuing is likely, it is already being built." Thus, designers are unruly people who consciously strive for an improbable future that does not yet exist, that shall never come to life without them, hoping and expecting that the imaginary future contributes something new to society.

The concept house project is situated at the overlapping domains of the faculties of architecture and industrial design engineering. Not least due to the fact that the chair sits on the crossover point of two scientific fields. Which in turn makes it plausible that the two project staff members Jaap van Kemenade and Rutger Wirtz come from those two faculties. In spite of the affinity of the disciplines there are great differences in the typical approach and execution of design tasks between the two professions. In the project, these disciplines are thus clearly differentiated during the process in order to challenge each other, to complement one another, and thus help lead the consortium toward an innovative integral approach.

## 02.03

# ORGANISATION CHART PRODUCT DEVELOPMENT

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The methodology of Mick Eekhout describes a design method with 5 phases, of which the first [Design Concept], the third [Prototype Development] and the fifth phase [Product Manufacturing] are applicable to the prototype project in question. See figure 37. A detailed description can be found in the book 'Methodology for Product Development in Architecture'. [Eekhout, 2008] Eekhout's domain is that of unusual building products, building systems and special components. Joining, coordinating and integrating to a higher level of the building or apartment as an artefact demands a slightly different approach. After all, many different components must be attuned to one another. All of the components fulfil a list of requirements and wishes. Individually. But combining several functional components that must fulfil a mutual ambition, serve a functional goal, the game of coordinating and integrating is also what makes the process rewarding. And which, of course, is never free of errors. The domain is valuable enough to strive for improvement. It becomes the playing field of the concept house. It is also the domain of technical execution of the designs created in architecture firms. In fact, the focus lies on coordinating and integrating the individual partial solutions to a generally applicable total solution. In Mick Eekhout's organisation chart integration and coordination is brought back to a more simple station of 'the combination', between 10a and 10b. It deserves a detailed description. [Eekhout, 1997, 2008]

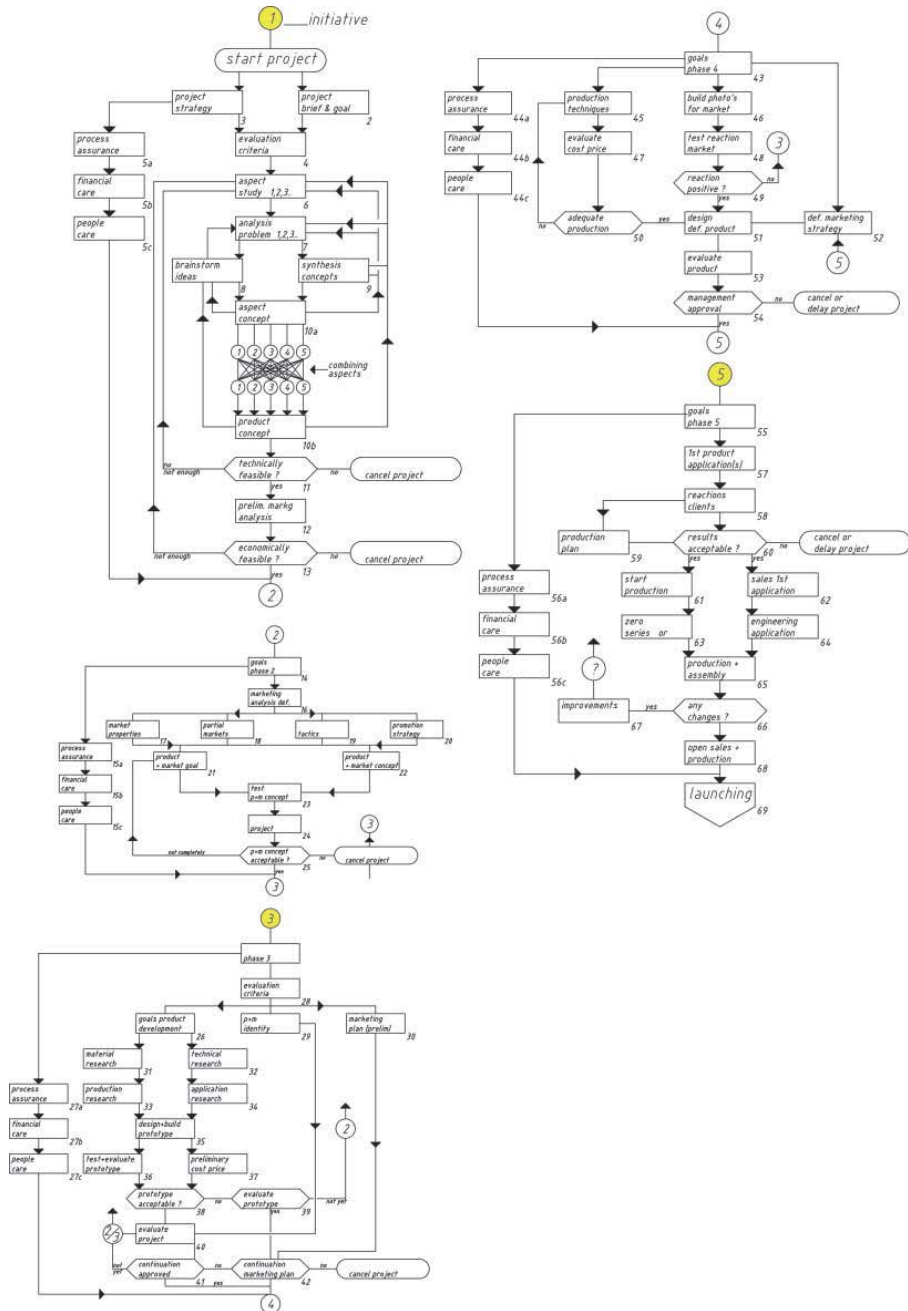


FIG. 37 Methodology by Eekhout whereby the first, third and fifth phase apply to the concept house

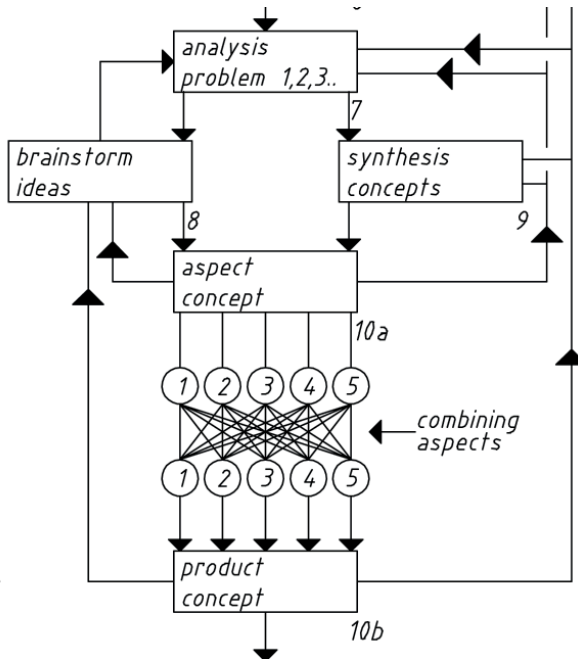


FIG. 38 Combining individual partial solutions within one building project or different components that together make one prototype apartment requires selection, coordination and integration

When designing and developing building products or components it is relatively simple to separate a number of important aspects and influential subsequent aspects. This is why the organisation chart methodology renders a rather clear view of the crossover points of partial solutions of the sub-aspects. The schema includes five randomly chosen aspects, each of which can be crossed over with one or more other aspects.

For buildings that are considered a technical composition of a large number of components and elements that can be developed according to a methodology, combining a number of aspect solutions is a little more complicated. For components it can be said that the functional aspects have the upper hand; they are also clearly visible. If we deal with combining, coordinating and integrating different components in a building, each with its own function, then a more complex process takes place. Which is precisely what we have been dealing with in this project: Selecting, coordinating and integrating components with different functions into a functioning apartment entity as a technical artefact. For scientists this is not fundamentally new. However, in a technical sense it is the work that architects do over and over for each new building. But the architect should be able to choose from turn-key components available on the market, typically certified or produced according to norm. It becomes more complicated when a fire-cracker is placed amongst all components of a building, an experimental component or an experimental building part. For 30 years, Octatube has done nothing but develop mostly experimental building

parts for buildings of architects, who in turn have their hands full controlling the building process and, particularly, selecting, coordinating and integrating components to create a building entity as a technical artefact. Considering this it seems unwise to try to develop more than one or very few experimental fire-crackers in one building. In terms of the status quo of building technology it would be very beneficial if every new building would comprise at least one innovation on component level: the 'One Component Rule'. Most likely, this would instantly transform the building industry from backmarker to recognisably innovative. In this book we cannot do more than to plead and hope that this thought hits home.

But continuously experimenting with components and attuning new components to one another is precisely the core of this part of the chair's work, realised in the development of the prototype. Selection, coordination and integration, plus synchronisation of the components, improving the 'loops' in the organisation chart with feedback. This all seems to make the process chaotic but in fact these are cycles that keep being run through. Without these cycles it would be a rigid process without innovation. And as a general rule, architects like to show something new with every building they work on. Now, it often happens that architects act as composers and make their own compositions from known musical parts, while technical development has more to do with inventing, exploring and developing. Thus, besides the composition deriving from the design sketch, in which the architect thinks in spaces and functions plus of the flair of his own designs, the unique, the characteristic, a certain intonation; there must follow a selection for each part of the design, to identify the appropriate materials and construction methods and the natural appearance: The selection process. If the architect does not like certain existing components, new components must be contrived. Here, the intelligence of the engineer is combined with the creativity of the applied artist.

Many members of the supporting consortium of the prototype project come from the producing building industry. Often, their backgrounds and competences differ greatly. Stimulated by the staff members of the chair, these partners try to innovate their own subsystems, which supports the surprising yet realistic character of the concept house system. The collaboration of the partners amongst each other and the chair and the involved hogeschool Rotterdam creates a synergy with a strong momentum for innovation. The difference between Eekhout's methodology of product development, which can be seen as a linear process in spite of the admittedly many technical influences, and the development process of an architectural/technical artefact is that the latter is much more coloured by concentric reasoning. Product development is more linear and the process of architectural/building technological or 'archi-technical' integration and coordination is more concentric. Herein the entire development can be followed from idea to sketch to definite design to ultimately the engineering. Again and again in a new cycle. In the hierarchy, a concentric sequence is more logical than a linear one which, in spite of cyclic feedback, is part of Eekhout's organisation chart as can be seen in figure 37. Certainly, this approach deserves elaboration in a unique methodology which, however, also takes time to develop. It will be part of future academic tasks for the chairs in the section Architectural Technology under professors Thijs Asselbergs, Ulrich Knaack and Mick Eekhout. Possibly to be developed after Mick Eekhout's retirement from the university.

## PROCESS DEVELOPMENT AND PRODUCT DEVELOPMENT

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The choice to make a materialistic prototype as proof of innovation at the end of the prototype development is mainly due to Mick Eekhout's experience in designing and realising technological innovations in his design & build company. It seems that such a feat was never undertaken, and impossible to accomplish without sufficient financing from external sources. Eekhout's book on methodology [Eekhout, 2008] clearly describes that there must be a parallel route in a development process that provides calmness to the process organisation. This comprises three steps: [5a] 'Process assurance', followed by [5b] 'Financial care' and [5c] 'People care', respectively. In the concept house process almost as much attention must be awarded to this parallel route of process means as to the contents of the product development. It requires a lot of energy; and this energy draws directly from the energy needed for contextual aspects. Now and then it seems that the average time the supervising associate professor spends on the prototype process [0.2 fte] is entirely taken up by controlling the process.

It can be concluded that in this prototype process such parallel management steps have not been as well secured. Firstly, because no one of the participants of the prototype process is an experienced expert. Secondly, because every one or two years the project supervisors need to re-discuss finances with the partners and sponsors. This meant short-windedness in financing, short-windedness in employment; making the faculty nervous. And it means disruption in the composition of the consortium partners; the rules and characteristics of the partners have to be explained over and over in order to achieve a certain degree of uniformity in expectation and behaviour. But the project supervisors of the chair exercise even greater influence. Mick Eekhout aims for industrialisation and architecture. Wim Poelman is interested in materials innovation. Arjan van Timmeren focuses on sustainability. As described earlier, the process resembles the biblical search of the Jews through the Sinai for the Promised Land. But the three successive project supervisors each also follow a different path. Fortunately it ultimately does result in a unique and never before realised goal and a remarkable prototype. Since the process described in this book does not have a goal or ambition that is easy to determine ahead of time, it can be concluded that the means have to be gathered together continuously, and that the cast of personnel fluctuates. Thus, if this process were to be conducted by a single company with the same investments, it would be quicker and more efficient. At least this is the professor's thought when pondering how much tighter/more streamlined the process could have been if run by his own company. It would have run more linear, with a clearer goal, and faster and more efficient process control. The consortium requirement of the process has thus caused greater financial and social complexity. Coming to and following up on agreements is very problematic. It reminds us of the assumed dangers of the Cold War. "What will we do if the Russians cross the border?" How effective and efficient will our defence be? Are we able at all to overcome our paralysis? Or does the mobilisation process look just as changeable as the prototype process? Thus a process conducted by a single

company, which ultimately is the basis of the organisation charts in Eekhout's books, is still relatively clear with its 69 steps. But if the goal runs errant and financing stagnates, the social process also becomes much more complex.

The external partners who, together, provide the financing for the project, find it very enjoyable to work toward a prototype because it gives them a chance to show what they are capable of, as well as what the consortium as a whole can do. Furthermore, they are curious as to how the materialisation process shall proceed. If the research development does not end up as a report stored away in a drawer, but leads to a prototype that can be seen and experienced and stimulates further reflection and discussion. And if the prototype will ultimately function as a stimulus much broader than what the participants currently expect. In 2009, there is a clear desire for the chair to take the lead in developing the material prototype. None of the partners wants to assume leadership. Harry Oude Vrielink's original appeal to develop an industrial apartment is directed toward the chair of product development. Thus, even after six years of development the chair still leads the project. The chair holder does not consider this a problem since he is used to this type of project in his own design & build company, which specialises in innovative light-weight facade constructions. But there is a second problem: That of the faculty. The attitude should be accommodating but, in many instances, seems to be the exact opposite. The dean and her advisers have problems with the budget for the process and want to eliminate all uncertainties ahead of time. They change the rules as agreed to between the chair and the partners during the game. Ultimately, this causes so many problems that an irreconcilable estrangement between chair and dean arises. A financial trifle since ultimately all income is scored and the project ends with a small profit, which disappears within the faculty. The conclusion is that only independently entrepreneurial professors are able to accomplish such processes, and that such processes must not be conducted by a faculty which is run calmly and orderly and which does not consider contextual innovation as one of its goals.

The independency of the 10 partners and 30 sponsors who have not signed a financial contract but an agreement of 'benevolence' leads to polite agreements rather than harsh and to the point discussions. Which naturally hinders the process as compared to a typical building project.

#### SWOT ANALYSIS OF THE DEVELOPMENT METHODOLOGY

The previously described problems can also be illustrated in a typical SWOT analysis. Of course with positive and negative aspects. There are sure opportunities and potential problems. They can be summarised as follows derived from the known SWOT analysis [Strength, Weakness, Opportunities, Threats]:

##### STRENGTH:

The knowledge and skills that lead to an innovative, complete and balanced design are available. The expertise present and the fact that innovative developments are based on existing systems make it possible to develop and realise an innovative prototype over a



one-year or several year cycle. The possibility to realise test set-ups and prototypes on the terrain of the concept house village in Heijlplaat will deliver practical experience with the Delft prototype as a 'system of systems', as an educational route, and as a project serving to monitor the energetic aspect of residential housing. In addition, the concept house village location in Rotterdam offers a chance to realise a zero-series according to the 'market conform-plus' principles in the long run because of the City of Rotterdam's and the housing corporation Woonbron's mutual interest in the project.

#### WEAKNESS:

The large number of SME players, a complex coordination and integration task, the financially and time-wise fragmented budget, the involvement and numerous individual moments of decision can cause the project to become very complex and let obscurity take over the reign. The intensive collaboration creates a dependency on each other's results with the risk of waiting and awaiting and making incorrect adjustments. A single dawdler can throw back the entire team. Discontinuity of one or more participants can cause damage to the project as a whole. Lack of financial transparency due to the introverted and risk avoiding administration of the TU Delft can cause incongruence with the desired process. The participating young engineers indeed do not have the traditional ballast of knowledge and insight but they can land in known pitfalls due to their lack of experience.



FIG. 39 From adjustment by intrusion and cutting and gluing to an integral attunement with dry joints [image A.van Timmeren]

Piling functions such as researcher and developer, research coordinator, integrator, practical jack-of-all-trades and scientist one on top of the other can result in improvised behaviour because of financial underestimation. It will be supported but with visible consequences, as is the case in this report. Caused by naiveté and inexperience in this type of process handling. And, in turn, this can be traced back to the ambition to realise the goal of the prototype, no matter what happens. Not wanting to know what kind of hurdles are thrown at you. Never stop. Taking a deep breath and give feed-back only at the very end.

We hope that this report is read in this sense: as a sort of ‘Perry Winkle and the Rinkeydinks’ story; without moralistic fingers wagging, by the way. These sorts of adventures happen all the time in experiments anywhere. Most likely, Brunellesci has had similar experiences when building the cupola of the cathedral Maria della Fiori in Florence, 600 years ago. Very adventurous, bad for your heart, but good for the world. Be prepared.

#### OPPORTUNITIES:

Today’s building practices are set up quite traditionally; even though gradual changes are taking place due to the industrialisation of elements and components. But in its entirety it can still be coined as conventional, even traditional. There are opportunities for an innovative, non-traditional total materialisation of apartment buildings. Innovation is very important to the current Dutch government. And from the viewpoint of costs and sustainability the demand for light-weight building methods for the temporary as well as the permanent market grows as well. There is a strong need for innovation in the field of process control: To improve control over the planning process and to avoid or at least drastically reduce the ever increasing share of building failures. Building norms are becoming more stringent, and labour cost account for a large share of the building costs; thus creating a demand for product and process innovation as well. Energy saving and CO<sub>2</sub> neutral building as well as realising the highest possible degree of ‘cradle to cradle’ for buildings and components are considered inevitable and important aspects for the future. And finally, adjusting apartments to the desires of the first inhabitants while furnishing them with a degree of adaptability [flexibility] for future generations provides a competitive edge. Developments are under way in all of these areas. There are opportunities to realise a physical research platform for various innovation, energy and controlling related aspects; but also with respect to new materials and fastening methods. This in connection with establishing the necessary certifications for new technologies, for which few other facilities are available. Norms and certificates are at the other end of the experiment, which actually prospers the best in a world poor in norms.

There are opportunities to apply so-called ‘low-tech’ and ‘soft-touch’ home automation in the framework of linking to the SUSlab, the European project, acquired by the faculty of industrial design engineering which studies inhabitant behaviour and technological developments based hereupon; research that after delivery of the concept house will be executed in this prototype.

#### THREATS:

Introducing building innovations can be difficult because new solutions are still unknown, and therefore unpopular with clients. Or because they stimulate changes in the approach and cash flow of building ventures, which can make contractors feel threatened. The high price for innovations can create a blockade when trying to introduce building innovations to the residential market because the ‘plus’ in market conform-plus is very small; too small to accommodate target-oriented work with an understanding for the client. The solo nature of an innovative experiment inherently involves the lack of looking at subsequent

serial production and possible cost reductions based on larger-scale constructions, with the result that the experimental price is seen as the final and too expensive price for an infeasible pilot project.

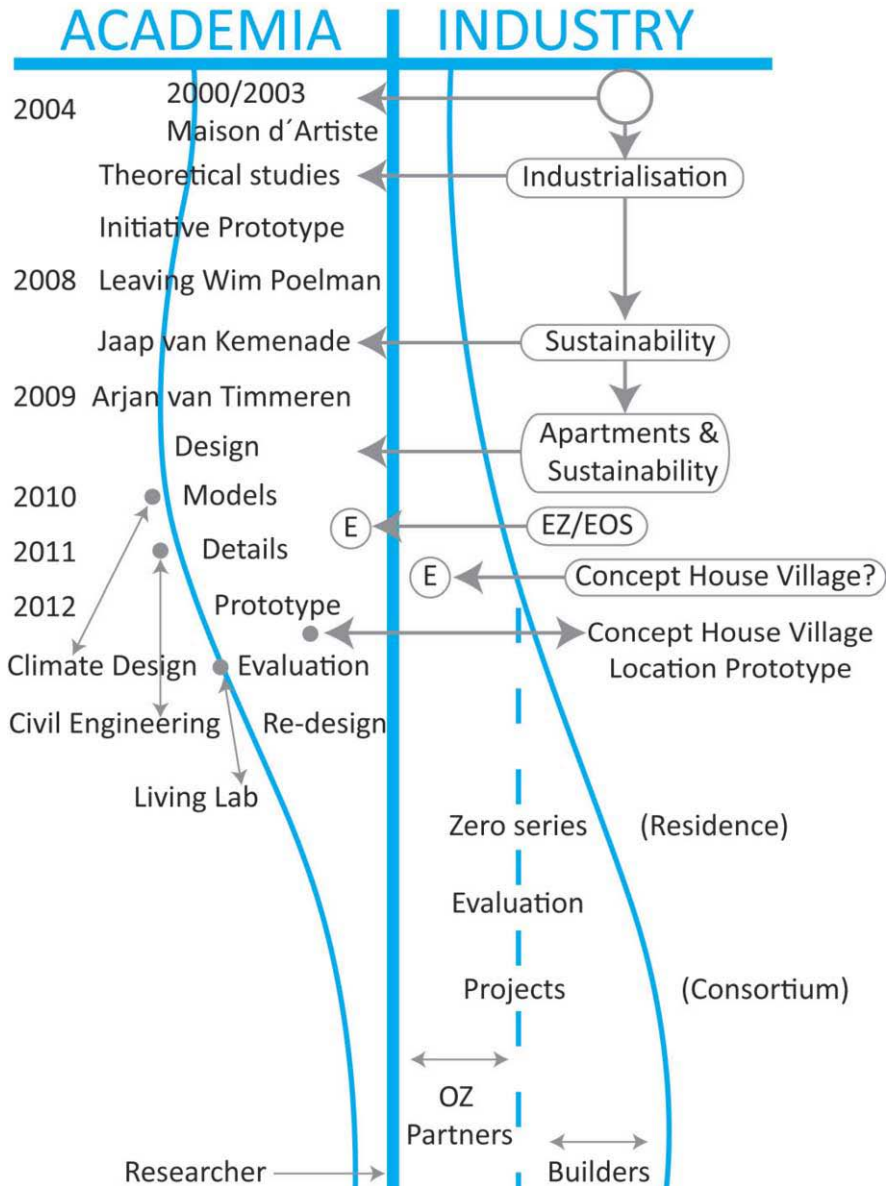


FIG. 40 The relationship between initiatives and activities on the university and the SME side. The prototype is pulled along by the TU Delft as 'academia', while the pilot project must be pulled along by the builders, being the 'industry'

# PILOT PROJECT AS THE NEXT STEP TOWARD A CONCEPT HOUSE URBAN VILLA

The observant reader will have noticed that the development of the concept house prototype is an initiative entirely organised by the chair. The costs for the research are gathered from contributions from SME partner companies, sponsors and a few subsidies. The following phase, that of the urban villa, is of greater economic importance for society but also of much greater economic value, and should therefore be led by commerce. Meaning by the building industry, SME Building and possibly by the concept house consortium. The balance changes and the centre of gravity shifts from 'academia' to 'industry', as can be seen in figure 40. It remains the ambition of the professor to be able to realise an urban villa within a number of years, to show that the developed principles of the concept house prototype are correct and that, by means of measurements and evaluation, a firm step is made in the technological development toward sustainable apartment building architecture. This is the motivation to keep going, in spite of the miniaturisation of the chair and Eekhout's upcoming academic retirement. Furthermore it is obvious that SME Building must find a practical, steady balance in the tension field between project-oriented but revenue-targeted activities and long-term research.

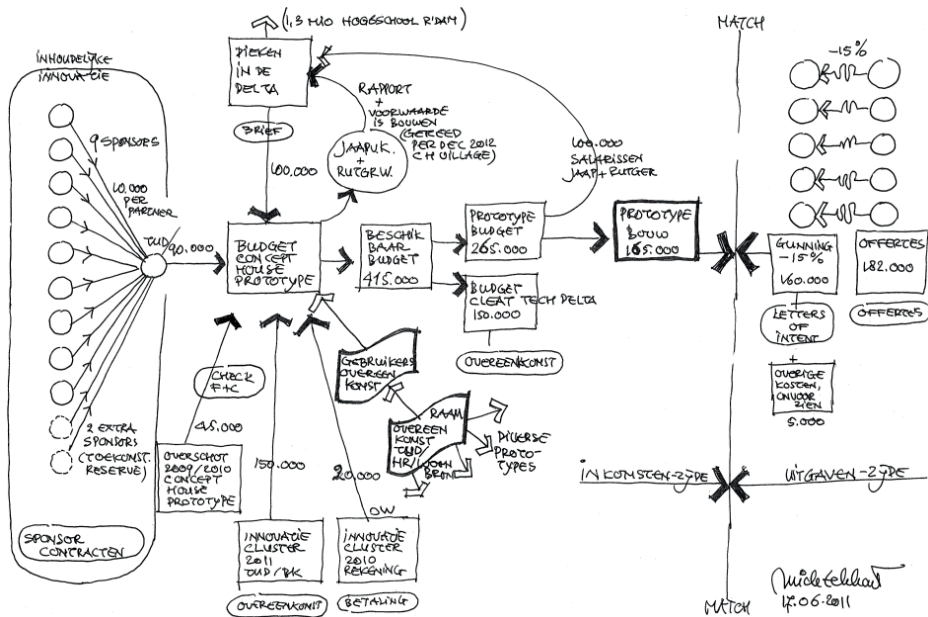


FIG. 41 Overview of income and expenses of the project in June 2011: Total revenue 415,000 Euro excl. tax (of which the innova-tion cluster of 150,000 Euro are not realised.) Excl. sponsor contributions

The chair is conscious of the fact that the SME do not have the power to support research in the near future. Yet, the chair maintains its mission to stimulate in this domain. The chair sees it as its mission to lead the way for the building industry in the method of thinking of the future, to make mutual plans, and to discuss and implement these in order to overcome the current recession. The financial framework of the project is worth a brief explanation. The yearly contributions from the SME partners, 10.000 Euro excl. tax per partner, form the financial backbone of the project. Besides this, project staff members ascertain subsidies from the Rotterdam share of the subsidy program 'Pieken in de delta' and the 'Innovatiecluster', which however disappears at a later stage. And there is a surplus of 40,000 Euro from previous years available at the chair for this project. Thus, the chair contributes 40,000 Euro gained from earlier partner contributions. When all contributions are added up it seems that they just balance out the budgeted expenses if handled frugally. The partners are partly subsidy grantees and partly subcontractors and producers. The builders and producers are heartily welcomed to take on parts of the execution work provided that they offer large discounts on their cost-price. Furthermore, in addition to up-front investments, many of them accept a project loss due to process inefficiency or the experimental nature of the project. Another understandable reason for the hesitant process planning, by the way. The complexity of the coordination makes it almost impossible to bring the process to a timely and efficient end, ready for the realisation phase starting in the beginning of December 2012. The supervising party of the project understands the dilemma all too well, and has drawn its conclusions in terms of filling in the gaps of the process. Everything has to do with the development of research in combination with a consortium of SME building companies. And it is an unavoidable characteristic of these types of consortia, particularly during times of recession in the building industry. The chair opens itself up toward the building industry, and such issues are part of the process. The times of scientists locking themselves up in ivory towers are over. Universities are also respected for realising 'valorisation', for distributing their knowledge, skills and insights to the building industry; and this type of experimental project is part of it, too. In spite of the fact that this experiment is anticipated with fear and shivering from all sides. If we abandon it now, everything will stop. Someone needs to continue; and in this case it is the chair and the chair holder. From a conscious displayed naiveté. Then naiveté turns into strength rather than weakness. And into inspiration to continue on.



# 03 SUSTAINABILITY

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## ASPECTS

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### 03.01 GENERAL FRAMEWORK SUSTAINABILITY

When Arjan van Timmeren takes over project leadership in 2009 sustainability becomes one of the important starting points. On one hand this is a direct consequence of the necessity and unavoidability to handle non-renewable resources of material and energy more carefully, and the actuality of the issue [energy politics, emission, resource shortage, etc.]. This is certainly true for the building industry. The building sector accounts for approximately 6% of the economy [GNP], but at the same time for 25% of transportation, 35% of generating waste, and no less than 43% of the national [Dutch] energy consumption, of which approximately 10% are used for the production of building materials and 33% for the use of buildings. In the Netherlands, 90% of the energy is generated with fossil fuels, which lets the numbers for CO<sub>2</sub> emission almost level out with those for energy. In short: the building industry is a large pollutant. On the other hand it seems that the problems related to the environment actually offer great opportunities: In terms of quality of life, health, comfort, and increasingly in terms of earning back the added investment that they require.

On the building level, just after commission Brundtland introduces the term 'sustainable development', a tentative relationship develops in the policy between [at first] energy saving, building material and the building process itself, and [later] water saving on one hand and improving the environment on the other [Van Timmeren, 1999/2006]. In addition to material cycles, waste and emission reduction, [energy] savings and quality improvement of products and processes are currently a crucial element of the national environment policy.

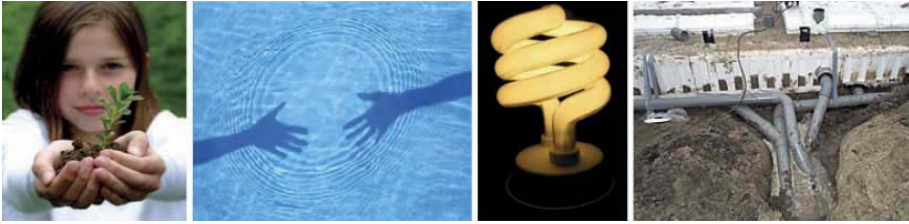


FIG. 42 A representation of the different 'flows' and the way in which feasibility is anticipated via linking to a centralised infrastructure and facilities [r] (Image A.van Timmeren)

The European Commission has its goal set to reduce greenhouse gas emissions by 80 to 95% by 2050 as compared to 1990. In the climate letter 2050 (I&M 2011a), the First Cabinet Rutte gives an interpretation by laying out how the Netherlands can switch to a climate neutral economy. For the built environment this will require a reduction of greenhouse gas emissions in the range of 80 percent (PBL & ECN 2011), which means a gigantic challenge from which we cannot exclude ourselves.

In the European Community the energy consumption of buildings accounts for 40% of the overall energy consumption. The previously mentioned 43% in the Netherlands do not deviate greatly from this value. To reduce the energy dependency and, following the Kyoto protocol, emissions of greenhouse gases thus requires fundamental regulations that restrict energy consumption and promote the use of renewable energy resources. But climate goals also require long-term deadlines.

The European Commission's ambition regarding 2050 has not yet been translated into binding targets. However, European law has established binding targets for 2020 for all EU member states; thus for the Netherlands as well. In order to achieve such CO<sub>2</sub> reduction, the energy demand must be reduced and the energy available must be cleaner. Despite the lack of a binding international agreement (post-Kyoto, whereby it should be said that the goals of Kyoto have been ratified again in December 2012 in Qatar, and have been set as the international starting point in case there is no general consensus for a new agreement), the European Council postulated the following targets for 2020 (also known as the 20-20-20 targets):

- A target of greenhouse gas reduction for the EU of 20% in 2020 as compared to 1990 (in expectation of an international climate agreement);
- A share of 20% renewable energy of the energy consumption of the EU in 2020;
- Realisation of energy savings of 20% as compared to a business-as-usual situation in 2020;
- A first step in the right direction is taken in 2002 with the approval of the European guideline regarding the energy performance of buildings, the so-called 'Energy Performance of Buildings Directive' (EPBD). Amongst other things, this guideline dictates that an energy performance certificate must be generated for each building, and formulates minimum requirements for the energy performance of new



buildings. This guideline is revised in 2010. The following aspects are important for new residential buildings:

- Each member state will have to calculate the optimum cost level of the minimum requirements regarding energy performance; and with regards to the complete lifecycle of the building;
- For each new building, the feasibility of alternative energy generating systems must be researched, regardless of size;
- From 2021 onward, all new buildings must be 'almost zero-energy buildings'.

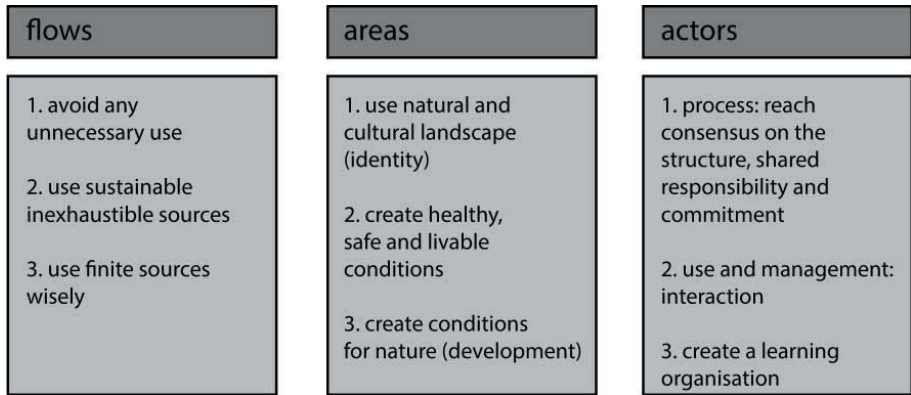


FIG. 43 Translation of the Triple P (People, Planet, Profit / Prosperity) to a three-step strategy for essential flows, areas and actors [VanTimmeren, 2006]

Within this context, the Netherlands are obligated by the EU to produce 14 percent of their national energy demand from renewable energy resources by 2020. In the current state of development this seems a target difficult to achieve that will require a lot of effort to realise. Presently, the general attitude is not yet ready for this endeavour.

The context, the debate about the future of energy in the Netherlands can be roughly divided into two directions. First of all, the general consensus assumes that we can continue using fossil fuels for a long time yet, and that generating sustainable energy does not add to anything. According to this group there is 'sufficient natural gas available for decades to come, considerable amounts of coal, and if all this is not enough, we still have nuclear power'. This is opposed by the opinion that fossil fuels are finite, and that their use is harmful; that, based on ambitious energy saving regulations and technological innovation, it is possible to achieve completely sustainable energy supply in 2050, whereby 95% comes from renewable resources. It has to be noted that the Netherlands currently rank in the lowest regions of the EU member states with regards to realising renewable resources for their energy supply. Almost 92% of the energy used in the Netherlands stems from crude oil, natural gas and coal. Transportation, for example, is based entirely on crude oil. Heating and electricity in the built environment are generated mainly from natural gas and coal. We have a long way to go. The Energy Report, the result of a collaboration

between the World Wildlife Fund (WWF) and energy consultancy Ecofys, shows the consequences of the other picture. They describe an ambitious scenario which anticipates a completely sustainable renewable energy supply, and that, in addition, withstands climate changes. In very general terms, this scenario comes down to ambitious energy saving measures and electrification. The energy saving measures must lead to a 15% lower energy demand by 2050, despite the fact that population, industry and transportation will continue to grow. Wind, sun, geothermal energy and waterpower are the most important sources for electricity. Sun, geothermal energy and heat pumps facilitate the largest share of the heating supply.

Whichever way you look at it, if such energy transition is taken seriously this has an effect on planning and design of town and country: the built environment. Applying new technologies is essential to advance the energy transition, but it is not a goal in itself. We have the knowledge, we have the information, we are aware of the urgency; yet we are not able yet to link the correct goals to the appropriate tasks. In order to make projects feasible we drop our ambition too quickly and are too ready to fall back on known solutions even if they are inadequate in the long run. How often do we see that innovative projects with heating networks and local energy generation could not be continued because too much was already invested in traditional infrastructure? When will the switch be turned?

We have a lot to invest in integration, innovation and inspiration over the coming years. The central issue here is to achieve fundamental change in terms of how we deal with energy with societal processes and integral design. In 2011 and 2012, the First Cabinet Rutte sent three policy papers to the Parliament / Second Chamber. These are the Administrative Agreement 2011-2015 ('Bestuursakkoord' 2011-2015), the Energy report 2011 ('Energierapport' ) and the Structural Vision Infrastructure and Space ('Structuurvisie Infrastructuur en Ruimte'). True to the motto 'decentralise whatever possible, centralise the rest', the administrative agreement between the state, provinces, municipalities and water boards must contribute to a compact and alert authority and a clear distribution of tasks between the four administrative levels. The Administrative Agreement 2011-2015 determines that the individual authorities mutually apply themselves to the goal of a coherent policy and distributing the tasks throughout the different administrative levels as they relate to living, water, mobility, activity, climate, energy, environment and cultural heritage. The state focuses on national issues such as defence and foreign affairs, but also employs itself to the economical structure of town and country, to health, safety and unique regional and cultural historic values as well as to the (inter)national main networks. The core tasks of spatial development and physical environment are subject to the provinces. They act as area director by establishing integral development visions, switching or shifting interests, and protecting and advancing complementarity between cities and between individual regions within the provinces. The municipalities, finally, provide for a safe and habitable living and work environment, and are responsible for social, economic and spatial development of town and country and for balancing the requirements for the environment, nature, water, economy and living [Dubbelling, 2012].

At first glance, the Energy Report 2011 is a paragon of how things should be. It assumes an energy management that is more sustainable and less dependent on increasingly diminishing fossil fuels. The state wants to profit from the power of the Dutch energy sector; offering growth, jobs and income. The heart of the energy policy consists of three parts: The transition toward cleaner energy supply, the economically perspective energy sector and the necessity of reliable energy supply. The energy report describes the ambition to reach an economy low in CO<sub>2</sub> in 2050. The goal: 'To make connections and choices' seems simple, but it is not. The energy report clearly states that the built environment and the transportation in the Netherlands account for a substantial share of the overall energy consumption, and are a significant source of CO<sub>2</sub> emissions. Both sectors offer large savings potential. Yet, the energy report does not reach much farther than to state general ideas for developing intelligent transportation systems, for stimulating electric cars, and improving the energy labels of existing and new buildings [Dubbeling, 2012]. Thus, it seems to fall short in terms of formulating an adequate and effective policy for necessary changes in the built environment. Striving for an economy and society low in CO<sub>2</sub> emissions in 2050 demands a revolution in the field of high-quality public transportation and a completely different way of materialising and composing buildings [and the connected infrastructure].



FIG. 44 Installation of PV cells to generate electricity

The question is whether the government will want to coldly pursue this task if society turns its back on the problem. In reality, no one takes charge. There are sporadic initiatives. Concept house is such an initiative. In this sense, the market forces that the government aims for do not work. The housing corporations are gagged by their losses from investments in the cruise ship SS Rotterdam (owned by housing corporation Woonbron) and by being forced to participate in the recent two billion Euro loss of the housing corporation Vestia, for which all Dutch housing corporations have to compensate. Due to politics, the housing market will be locked down for the coming years. In Denmark, the general attitude of the government is very different, see the preface by Jón Kristinsson.

03.02

## SPECIAL APPROACH TO SUSTAINABILITY AT THE CONCEPT HOUSE

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In addition to offering an affordable implementation of increasing sustainability and comfort, the concept house project aims at achieving a more flexible building stock with the immediate consequence of a longer lifetime. Placing the user at the centre of the effort serves the same goal. Employing 'lean' constructions can ultimately result in material reductions of at least 50%. With flexibility and an intelligent use of materials in combination with material reduction and dry joints alone, and based on full general acceptance, over time we will reach a reduction of building waste of 75% (from 22 million tons to approximately 5,5 million tons) and an energy reduction related to the production of building materials of 75% (from 10 to 2,5% of the national consumption). Energy saving approaches in (industrial) building concepts, based on the active house principle, such as the concept house, make energy generating apartments feasible in new buildings. In addition, the energy consumption of the existing apartment stock can be significantly lowered in short term. Based on the theoretical assumption that all technology to be developed will also be applied across the market, energy neutral coexistence (of new and existing buildings) in the area of living and working (with the exception of production processes in the heavy industry) is feasible in such a manner. In this context of strategies to achieve continued sustainability there are different terms and definitions that are often used interchangeably. Energy neutral building, CO<sub>2</sub> neutral building, zero-energy building, passive building, low-energy building, zero-invoice building et cetera. Hereby, the concept house prototype and, in the future, the urban villa as well must be seen as a zero-energy building, with further sub-goals in the direction of energy neutrality. In order to grasp what this involves, this fact needs to be put in context.

An initial classification can be made based on the duration that a building is looked at. An energy neutral building can be defined as a building that does not consume energy in the course of its lifetime. Here, the building is considered from design to after the end of life (now this often includes demolition, but in the near future this will change to dismantling),

repositioning, re-assembly and, only if absolutely necessary, possibly recycling. [Recycling means capital destruction of more than 90%]. Amongst others, possible factors to consider are the production energy for the materials, transportation during design and execution, energy consumption during lifetime, energy consumed by demolition/dismantling and transportation [again], necessary processing energy for recycling, et cetera. This can be elaborated further by compensating for the fuel [generated] for the transportation of habitants/users during the usage phase, for example. In practice, this leads to complete evaluations of the entire lifecycle of the building. It extends to primary energy (if the scale of the analysis itself is increased and the building is not merely considered as a unit but energy yield aspects on larger scales as well) or CO<sub>2</sub> emissions and a so-called life cycle analysis [LCA]. These types of analyses are not only very comprehensive but also susceptible to weighting factors that the subcontractor assigns to the various aspects [Geysel et al., 2011].



FIG. 45 Study of elements of preservation in the concept house 'Delft' prototype, and the method of integration (sun shading and heat collectors in facades) and maximisation (surface area PV on flat roof).

If the focus is laid on the usage phase of the building, an energy neutral building can transition to a so-called zero-energy building. Principally, this is a building that over a specific period of time, on an annual basis for example, does not consume any energy, net or averaged, in terms of occupation or use. The energy consumed is thus compensated. With regards to which elements are concerned, thus what exactly is compensated, there are various effects. Space heating and cooling, sanitary warm water, [fixed] lighting and household devices could also be considered. On top of all this it is important to determine the level on which this energy is compensated: Energy demand, final or primary energy. In any case, the energy must be compensated with renewable energy; preferably by locally generated sources. Thus, a zero-energy building does not necessarily have to be connected

to the power network. Self-sufficient (or energy-autarkic or zero-bill-energy) buildings guarantee to fulfil their own demands. In these cases, such concepts must provide for large overcapacity in terms of energy generation (since peaks become the determining factor) and / or a buffer in the form of onsite storage.

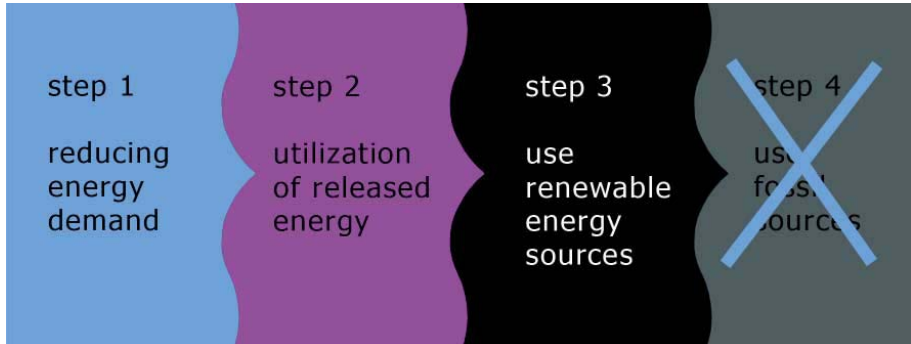


FIG. 46 The subsequent steps to be taken when striving for energy neutrality

Cascading the energy flows and (in case of a broader focus than energy alone) closing water and dust cycles is paramount. Here, the basis is formed by the interaction between integrated ecosystems and ecosystems that consist of functioning technical systems. The so-called 'New TRIAS stepped strategy for sustainable building' is preferably used for this purpose:

- Reducing the demand;
- Reuse residual flows;
- Produce sustainable energy [Complement the remaining demand in a sustainable manner, and remember that waste can be a resource].

Thus, with a zero-energy building the first goal is to achieve this in the most sparing manner possible. Of course, technical, social as well as financial parameters play a role. These are some of the reasons that zero-energy buildings are elaborated in different ways: there is an infinite number of possible definitions to indicate the economy of a building. The most commonly used 'standards' are: Low-energy buildings, min-energy buildings, passive buildings. The requirements of the mentioned concepts still differ somewhat from country to country or even region to region. But, for example in the case of passive houses, the requirements resemble each other [maximum 15 kWh/m<sup>2</sup> floor space annually for heating and cooling, and air tightness of n<sub>50</sub>=0,6h<sup>-1</sup>].

As mentioned earlier, the concept house prototype is worked out following the zero-energy building principle. Considering the building-bound energy consumption. In the Netherlands, this results in an EPC of 0.0, or rather a negative EPC [in comparison: The requirement of 2012 is an EPC +0.6 for apartments]. Here, EPC stands for Dutch

Energy Performance Coefficient: a standardised value to determine building-bound energy consumption relatively easily. An EPC of 0,0 indicates an accounting equilibrium between demand and supply of sustainable generated energy for one calendar year. This is the target set for 2020.

The energy concept is mainly based on passive buildings, even if this (as it relates to the ventilation concept and filling in techniques) is elaborated toward so-called active building principles: To fulfil the requirements the building, and in this project particularly the apartment, must be actively designed toward a maximisation and optimisation of the naturally present renewable energy resources. Furthermore, the active techniques and systems must be synergetically integrated into a whole, with the goal of activating the entire apartment. This results in an active apartment that in its entirety becomes an energy delivering system.

In addition to intelligent energy solutions, characteristic features of the concept house are a low CO<sub>2</sub> footprint, a large degree of flexibility, and a faster and higher quality building process. Some other essential considerations that, from the above mentioned perspective of IFD and sustainability, come into play are:

- The building envelope (the shell of the building) is the climate separation, which, besides its role as separator or the first step within the “Trias Energetica” (Concept to save energy developed by TU Delft), also plays a role in energy storage and reuse (step 2), and energy generation (step 3), but also with additional (health related) aspects such as air filtration.
- The different lifetimes of building parts can provide a guideline for design decisions. A (rhetoric) question that also plays a role is: Do we have to cast installations of which the working principles are still entirely under development, in concrete that will last for a hundred years?

Starting point: Building parts of different lifetimes should not be joined tightly.

- The different decision-making levels (control) of the built environment can provide guidelines for design decisions. Energy generation (nuclear power plants in France, wind parks in the North Sea, coal centres in Poland or the Eemshaven seaport) are political economic decisions. A bathroom heater is a user decision. Between Europe and the apartment there are many other decision-making levels: national, regional, city, neighbourhood, street, block, building.

Starting point: It makes sense to attune the building parts from different decision-making levels to each other, but to decouple them as well.

- Decouple energy generation and building, or do it on a local level.
- Different manners of energy generation are discussed. Are we ready or will the concept house be popular even if powered by nuclear energy? What is the minimum configuration for apartments with independent sewer cleaning?

- The appropriate balance between energy generation and the scope of the project must be determined per individual project.

Starting point: The so-called 'subsidiarity principle'; based on cycling through the new trias energetica across all levels [what is the smallest possible self-sufficient mass customised apartment].

- Decouple the executing parties [so-called: 'open building']. The process of building apartments involves several different parties. All of them are represented in concept house. Different parties have their own needs. These rules and agendas have to be optimised and coordinated. For example: The plumber must not damage the plasterer's work and vice versa.

Starting point: It is wise to decouple the building parts / subgroups along the lines of the building technical disciplines. This is key to a lean building process.

In view of the fact that the prototype is actually meant to prove a singular apartment in an urban villa complex of 16 apartments, the possibilities that arise when realising such buildings must be taken into consideration. In this context it is also important to see the prototype as part of further development toward larger scale projects. In addition, a recent study by the Netherlands Environmental Assessment Agency (2012) has shown that a combination of building and area related measures is the most efficient manner to restrict the CO<sub>2</sub> emissions of the built environment. This results in greater CO<sub>2</sub> reduction than applying only building measures, such as insulation or more efficient heating facilities, or only area measures, such as using residual heat, geothermal energy or thermal storage. Applying all profitable building and area measures prevents 15 to 30% of the CO<sub>2</sub> emissions derived from the built environment by 2050. The size of the percentage depends on two factors: The energy price and the cost invested in energy savings measures. It is questionable whether large and infrastructural investments to advance energy transition actually matter. Energy is on a level too low to efficiently control it. Therefore, comparable households, next to each other in almost identical apartments can consume very different amounts of energy. This underlines the need to realise the principles of zero-energy buildings. As well as the need to focus on the individual apartment, keeping in mind larger projects and considering intelligent connections and exchanges, and possibly better fulfilling the energy demand by cascading toward [usage] quality and appropriate scale. The latter is, in view of reusing residual flows on an individual scale, actually less desirable because of the relative low quality. At the same time, definite advantages can be achieved by realising systems or applying techniques on the level of clusters, neighbourhoods or even cities or a collaboration of cities. The solution includes applying the trias sequence whereby the matrix approach is oriented toward sustainable systems or resources.



TRIAS steps	Step 1 Reduce demand	Step 2 Recycling	Step 3 Use sustainable sources	Step 4
Scale				
<b>Concept House (Building)</b>				
Area / Cluster (Nieuwe Dorp Heijplaat)				
District (Heijplaat + RDM campus)				
City harbor				
Cluster of (sub) districts				
Metropolitan Rotterdam				

FIG. 47 TRIAS method



# 04 THE TECHNICAL DEVELOPMENT PROCESS 2009-2012

The system such as Wim Poelman envisions consists of a number of separate subsystems. He provides a thorough background in methodology [Eekels en Poelman, 1998 en Poelman 2005]. For each of these systems, a participating party with the right innovative ambition and readiness to collaborate must be found that, additionally, has the time and the money to invest in the project. This involves visiting many companies to discuss the concept, which at this time is still very open to the visions and desires of the visited SME companies. These discussions help the concept to grow, and give Poelman the space for latest developments in the market. Several sustainability characteristics related to energy generation are already considered.

In order to be able to develop the building system completely, the underlying consortium should mirror the building practice, which typically involves many different parties working on one project. The process of gathering a multidisciplinary consortium of sufficiently complementing SME partners for the concept house is a true puzzle. Coincidence plays a role; it is difficult to achieve a homogenous circle of consortium members that complements the overall building team, to find one designated co-maker in the consortium for every innovative component. The number of building team members is too low to complement all components. Consequently, specific [not yet found] component producers are allocated to an already participating co-maker (clustering of subcontractors); later a call is made for an external party as sponsor. It is obvious that the consortium is not composed as ideally as one would have wished. It is indeed difficult to look a gift horse in the mouth. But the project will likely be followed through with the consortium of partners and sub-partners.

Which will not become easier if sustainability is the reigning aspect and influences the composition of the supporting consortium of SME partners. In general, the reasons for companies to participate in the project concept house are a mutual consensus that certain things in the building industry need to change and the fact that future-oriented companies try to identify new ways of building. In addition, the project offers the companies the opportunity to learn about new technologies and trends from the Faculty of Architecture and TU Delft. And there is interest in spin-offs of the project within the individual companies. And ultimately, the good name of the chair, the faculty and TU Delft gives the decision makers the confidence that the project is in good hands. The relationship of trust is a motivation for behaving with integrity toward the partners and sponsors. But there are also several reasons for companies to hesitate to participate: Necessary investments in time and money; revealing company secrets and methods in the open and innovative atmosphere of the project; the inability of company specific materials to fulfil sustainability targets; and the not yet proven trust in the success of the consortium as a whole. Naturally, the collaboration can only work well once all basic parts are covered by a partner. In September 2008, Wim Poelman therefore organises a kick-off meeting with many of the partners interested at that moment. Following this meeting and several accompanying company visits, the project can officially start in April 2009.

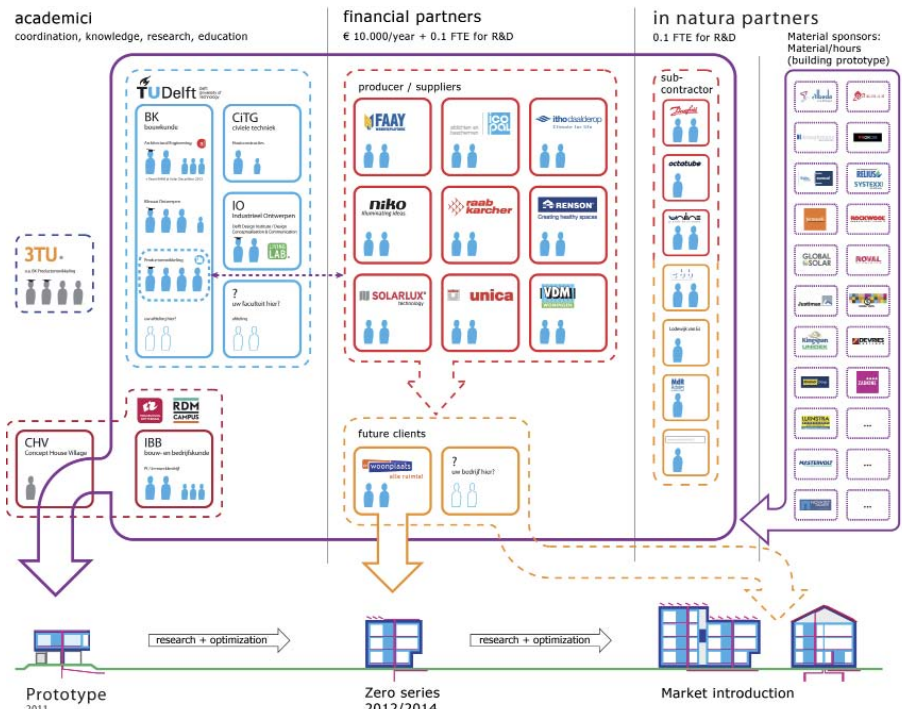


FIG. 48 Collaboration scheme universities and industry, with a timeline seen from the realisation of the prototype: Development post-concept house prototype toward market introduction

The consortium contract is set up in such a way that over a period of two years the companies commit themselves to the program for a one-year period, followed by the opportunity to stay on for another term or to leave the project. At those moments, new partners can join the consortium provided that the existing partners agree. They have the power of veto. Thus, participation follows a voting procedure. This setup reduces the risk that participating companies compete with each other within the consortium. And it secures the obligation to stay connected with the wishes of business life. At the same time, the comings and goings of partners makes it particularly difficult for the researchers to manage the process, to establish a coherent line throughout the development and creation of the prototype, because it is very company-focused. Over the three years that the development project officially lasts, more than half of the partners change and the number of companies involved has doubled.

A number of clusters is formed within the consortium to maintain a workable process. And smaller teams within those clusters work on partial solutions, precisely attuned to each other: installations, building components, sanitary units, applications and BIM [Building Information Model, a digital model of the building composed of all elements and components, including installations and ducting]. Here, sustainability is always the overarching goal. Principally, the researchers are present at every meeting and are in close contact with the individual parties discussing possible realisation and integration of their own innovations. Thanks to monthly plenary meetings, the partners can stay informed about all developments, can adjust and further fine-tune them. These meetings also offer the possibility to network.



FIG. 49 Partners following one of the monthly plenary meetings

During the formation of the consortium it become obvious that some of the companies can deliver valuable input but that this input does not equal that of the main partners or that the results are not very valuable for the companies themselves. Not all companies have the same drive for innovation. The SME knows many different shades in terms of size, specialisation, quality and eagerness to innovate. Thus, leaders and followers develop within the consortium. There are the pioneers, a main group forming the peloton, and the dawdlers. A need for primary and secondary partners arises. Thus, the position of subcontractor or in kind delivering sponsor is established so that the system can be developed in more detail without the secondary partners having to contribute financially. The first sketches of the apartment complexes are mainly an exercise in sharpening the boundary conditions of the project, and directed at researching the consequences of the complicated set of requirements. In addition, it is important to have graphic material available to present to potentially interested parties since it makes it easier to provoke feedback. Only with the official start of the development project in April 2009 it becomes known which partners are participating, and concrete work on elaborating the 'system of systems' can commence. As of this moment, an architecturally educated researcher is employed to work beside industrial designer Jaap van Kemenade in the day-to-day project team of TU Delft. The appointment of architect / civil engineer Joris Veerman helps to further develop the technical aspects for the housing system. The actual materialisation of the building system is in part determined by the involved partners. Installation partner Unica is very flexible, and since there is no partner yet for the building shell, the researchers are rather free in filling in an important part of the concept development. Hereby, concept innovation, industrialisation, integration and inspiration are taken to heart.

#### 04.01

## THE CONSORTIUM CONSISTS OF TWO PYRAMIDS: BUILDING TECHNOLOGY AND INSTALLATION TECHNOLOGY

Already, two clusters of co-makers seem to slowly materialise; one architectural cluster and an installation cluster. The co-makers of the two clusters speak a different language. The educational background certainly differs: Architecture versus mechanical engineering. It is difficult for the co-makers on either side to understand the other language and to learn how to deal with it. It is obvious that in case one aims at extensive prefabrication there is no way to avoid integrating mechanical engineering installations within architectural components. For example, the wooden floor construction comprises a floating screed which contains a system of PVC pipes for under floor heating, which in turn, finished and ready for the surface layer, is delivered to the site. Therefore, the more extensive industrialisation and prefabrication are, the closer the two clusters need to be integrated. The prototype process quickly shows that it is important to be able to speak each other's

language, to know the other's expectations and problems, in order to be able to integrate and develop the integral product of architectural components [floor, roof and walls segments] with therein contained prefabricated installation elements and components. This is the consequence of the term 'plug & play'. Later in the development of the process we will no longer speak of two clusters but of two pyramids: The architectural pyramid and the installations pyramid, which together fit on the base of the larger pyramid of the main contractor. However, speaking of a pyramid instead of clusters implies a hierarchical structure. It is not necessary for the product development, but indeed for the more regular production of a pilot project, the first series of apartments in an urban villa.

#### DEVELOPMENT PROJECT BASED ON SUSTAINABILITY TARGETS

Apart from the general and specific starting points with regard to a realisation of the prototype described more closely earlier in this text, the primary goal of the apartment design is to guarantee a comfortable indoor climate during the usage phase. It does not only determine user satisfaction but also has an important effect on their health. In an uncomfortable indoor climate, users might also take measures that possibly have a negative impact on the expected energy consumption. The most important factors of comfort are general thermal comfort, indoor air quality, visual comfort and acoustic comfort. The design process for the prototype is a little more complex than that for a traditional apartment. Very early in the design process, i.e. while determining the program and thus before the first preliminary sketches, the energetic performance level of the apartment is specified. This means that a number of energy measures must be introduced quite early. Amongst others, this concerns the geometry of the building, the impact of glazing, daylight optimisation and solar energy, shading of required technical rooms and the minimum amount of surface area necessary for energy generation. Information about the use of the apartment is also estimated during this early phase; internal heat gain, wishes concerning sanitary warm water, possible comfort requirements. You cannot create a requirements program without having a clue about the direction you are aiming for. After all, the design process comprises different cycles and feedbacks. In a traditional building process, such a program phase is usually limited, and restricted to research according to the wishes of the client and financial feasibility. For passive and active houses – concept house does indeed fit into both concepts – such feasibility studies are shifted forward toward the program phase. Hereby, the first preliminary design is the result of this program phase.

On the building level, there are various aspects that have an effect on the energy consumption of the apartment, which have to be dealt with consecutively. These building related parameters are:

- 1 Building typology;
- 2 Volume compactness of the building;
- 3 Compartmentation and planning set-up;
- 4 Daylight apertures in the apartment;
- 5 Sun shading devices;
- 6 Material use.

## TPOLOGY

On a larger scale than that of the individual apartment, typology plays a major role [ref. 1]. By decreasing the envelope around the protected volume [surface area subject to heat loss] of the building, heat loss by transmission through the envelope can be proportionally reduced. In the case of the prototype, of which only one apartment is being realised without adjacent units, the ratio is naturally less advantageous than what it would be in the arrangement within an apartment complex that it is designed for. Thus, extra measures such as additional insulation are required to compensate for the relatively larger surface area [subject to heat loss] and the lack of buffer space and vertical compartmentation. These measures are thus included.

The typology [urban villa, gallery or veranda arrangement across multiple storeys, etc.] and the ratio between the footprint of some apartments and the height of the apartment complex play an important role in this context of trying to identify the extreme balance of energy neutrality.

## VOLUME COMPACTNESS

This is often indicated by volume compactness [ref. 2]. For a surface that is subject to heat loss [At], the starting point must be that it is kept to a minimum. It is determined by all enveloping parts of the shell, except for walls that adjoin heated spaces. Therefore it is not applicable to the prototype in question but certainly to the intended and tested application within an apartment complex. Volume compactness [C] is determined by the [gross] volume of the apartment and the total surface of loss. An energy saving apartment is characterised by the highest possible volume compactness. The goal is to realise a compactness of 1.4m or more [whereby  $C=V/At$ ].

In the case of the prototype, C equals 1, but for the planned application in an urban villa C equals 1.46 [as a reference: for a spherical apartment building as the theoretic ideal C would be approximately 1.84]. Important in this context is that larger, and especially less compact buildings [as Mick Eekhout prefers them] result in a greater energy demand. They do not have sufficient roof surface area to install photovoltaic panels to compensate the residual energy demand. If no alternatives can be found [other energy sources, integration in the facade, larger roof surface area than apartment floor area, offsite production, etc.], this must be evaluated early in the design process with focus on feasibility. It underlines the necessity of an integral design process and the building team. This is also discussed during the realisation of the prototype [therefore the building cannot be realised with a much higher C].

## PLANNING SETUP

One important aspect with zero-energy buildings is compartmentation and planning setup [ref. 3]. It is important to differentiate between the various temperature zones [in the building and in the individual apartments] in order to reduce the energy demand. Then, separate comfort requirements can be determined for each of these zones. Principally, the



design of the prototype provides for lower temperatures in circulation spaces (hallways, lavatories) and rooms with low comfort requirements (more movement than resting), and for higher temperatures in spaces of higher comfort (living areas, bathrooms).

The interest of an intelligent plan setup relates to [1] daylight, [2] the production (and reduced transportation) of warm tap water and [3] building services (ventilation and other ducting, space for various facilities).

With regards to visual comfort in (living) spaces, daylight openings are provided for with a surface area of at least 1/5 of the footprint of the space. Orientation also plays a role: Rooms with a greater heat demand are oriented toward the south as much as possible.

With regards to the function of producing warm tap water, an intelligent plan setup mainly involves reducing losses by keeping distribution pipes as short as possible. This means that the location of the bathroom and other tap points in the apartment as well as their relationship to the technical room is considered and determined in a very early phase of the design process.

Concerning the building services, balanced ventilation with heat recovery must be realised if the apartment should fulfil passive house standards. This requires well optimised, or in current jargon, 'intelligent' positioning. In order to integrate balanced ventilation in the apartment, it is important to arrange the rooms according to the ventilation requirements during the design phase (air supply, flow and exhaust). For the prototype however, the deliberate choice was made not to install balanced ventilation but a system with on-demand supply and mechanical exhaust with heat recovery. The reasons for this choice are described in detail later; but it originates in the wish to let the user open and close the windows etc. at their leisure.

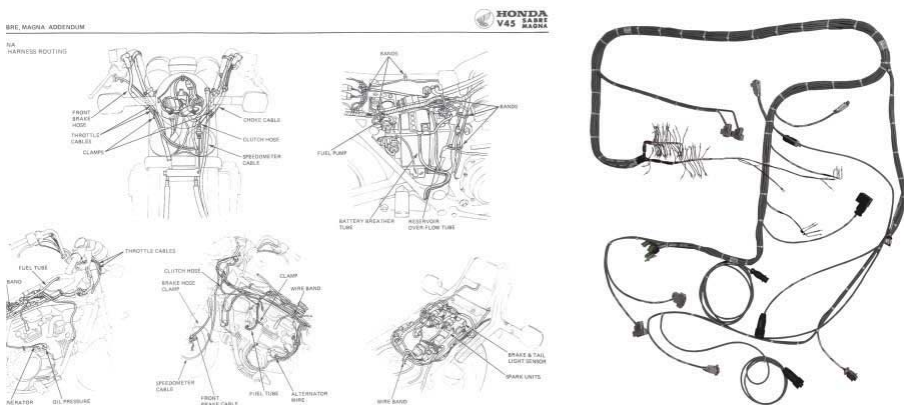


FIG. 50 References for the prefabricated wiring harness in the sanitary unit (cable tree)

In the future, sustainable installation solutions will consist of various and possibly hybrid systems based on high as well as low value forms of energy. In part they are connected on a neighbourhood level. In other cases they are decentralised on apartment level. Thus, the resulting wish list of technical services in the prototype is relatively long. Heat recovery from ventilation air and shower water, heat pump, multiple drain pipes, etc. are considered. This quickly leads to the conclusion that it makes sense to concentrate a large part of the installation facilities in the core of the apartment, where the individual installation components can be optimally attuned. Initially, apartments modelled after the prototype shall be climatised with passive measures, then with additional decentralised air systems and low temperature heating (and cooling). Furthermore, the apartments can initially be equipped with a low-voltage electrical system that can be connected to the solar panels on the facade and the roof without voltage conversion.

Core of the integration oriented product development of this prototype is the 'installation cluster & sanitary unit'. It comprises all components of the complex installation which is already connected during production. After placing the components, it is only a question of plug & play until the installation can be put to use. Thus, installations are not a goal in themselves but the means required for energy and comfort optimisation. At the same time, the user is put on centre stage: Windows can be opened and closed by the user as desired.

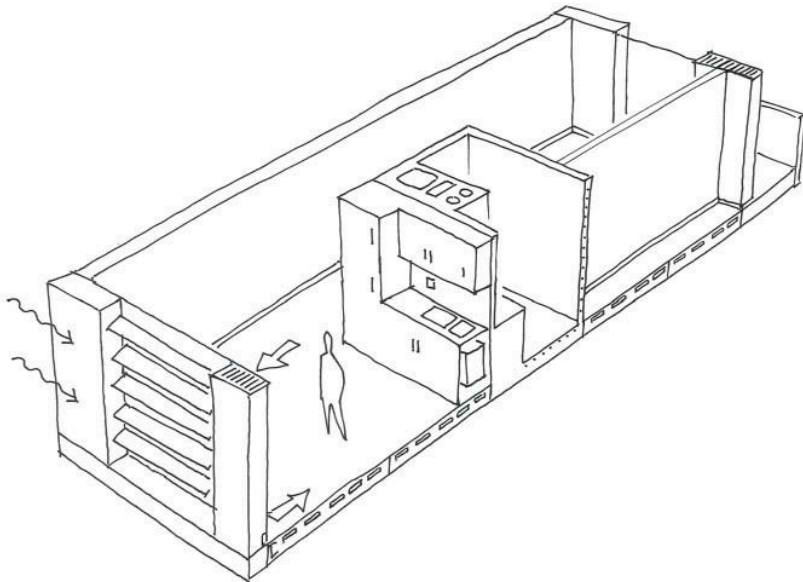


FIG. 51 One of the first preliminary designs of the concept house apartment with, amongst others, coupling of the sanitary units to the installations and the kitchen

The installation cluster is developed as one central beating heart according to up to date BIM techniques [signed with Revit], prefabricated and integrated. This creates the principle basis to reduce building defects and related very low performance in practice that still occur very often when such complex technologies are being connected in residential buildings. In any case, it is considered a step in the right direction. Reducing the number of building defects can be tackled with a good design, in the form of a material system of components and elements that have a mutual goal or function.

Another, possibly greater number of building errors results from noise in the communication channels; from miscommunication during the building process between the researchers, partners and sponsors, and from consequences for the whole due to inadequacy of one component or one supplier. Since the experimental process is not based on a strong hierarchy with firm rules such as obligations and penalties (as is customary in a typical building process), the process demands flexible manoeuvring in order to run as smoothly as possible. We leave it up to the reader of this 'Perry Winkle and the Rinkey Dinks' story to judge the building errors and failure costs of this experimental process. In addition to the installations, the core will also accommodate the sanitary facilities which are connected to the central ducting shaft.

One level up from that of the individual apartment, such a technical installations shaft permits limiting the length of various [ventilation] channels and piping [heating, sanitary, PV]. The location of the technical installations shaft influences the configuration of the different usage spaces in the apartment and must therefore be planned as early as in the preliminary design phase. The shaft strongly determines the floor print possibilities of the apartment.

The conclusion drawn from the preliminary design phase is that a central core or sanitary unit has the advantage that it lends itself extremely well for prefabrication. Thanks to the concentration of complexity in this part, the other building elements can remain rather simple, which benefits the flexibility of the building system. The dimensions [surface area and volume] of the technical installations space is then determined by the installation facilities that are to be included, including all couplings to piping and channels, the control panels, control elements and extra space necessary for placing and maintaining the installations. Therefore, early consideration of the configuration of the different systems and their interdependency is critical.

To restrict noise transmission from the installation facilities in the technical space to the other rooms in the apartment, acoustic measures have to be taken as well [sound-absorbing and vibration damping materials and fastenings, walls with a high surface mass, etc.]. In collaboration with the researchers and with help from a specialised subcontractor, Raab Karcher, a partner connected to the concept house from the beginning in 2004, takes on the challenge of the sanitary unit.

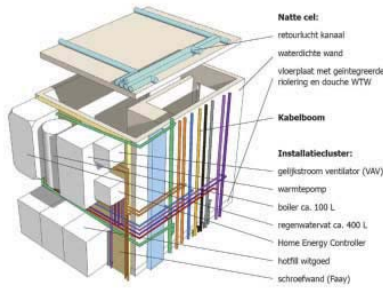


FIG. 52 Original concepts for the sanitary unit and a connected space for various technical facilities

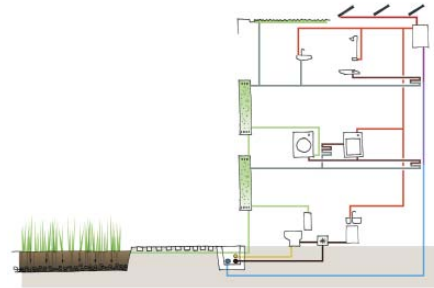


FIG. 53 Of the water and sanitary system

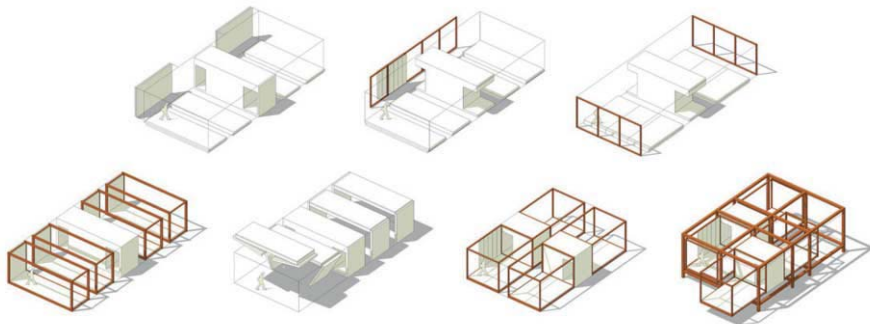


FIG. 54 Principle of the 7 developed concepts for the load-bearing construction of the building system

Raab Karcher wants to minimise the weight of the prefabricated sanitary unit. In order to limit the footprint of the technical room in the apartment, it is quickly decided to place the technical installations in a closet; considering sufficient space for the connections and adequate access by positioning it either in or at a circulation space or a storage space. Then, the goal of sustainable materialisation of the building system focuses on the sanitary unit: It will have to be certified 'cradle to cradle' (C2C). This means that all of the materials used must be able to be reused after the usage phase of the sanitary unit on an equal or higher quality level. This raises questions concerning the use of glue and putty as they are typically used in bathrooms. Material use and different water and sanitary systems are examined. However, before the details of the sanitary unit can be worked out, the final floor plan must be determined. Initially, the installation cluster is located inside the sanitary unit for the sake of flexible positioning and to save space. But to avoid placing electrical connections and branching points in a humid space, it is decided to reposition the installation cluster to the outside of the sanitary unit; inaccessible from a repeatedly hot and humid atmosphere. Thus, the first work drawings for the sanitary unit are only made in the second running year.

## LOAD-BEARING CONSTRUCTION SYSTEM

Seven different element and unitised building ideas were developed and evaluated for the load-bearing structure of the prototype system; with focus on design freedom for the architect, the degree of industrialisation and adaptability during the duration of use. The ultimate choice is an element building system with slender load-bearing walls that are constructed of steel columns and timber joists, offering a range of flexibility in terms of the wall infills. The system's free span of 7,5 m allows for spacious, freely to arrange storeys. The front facades are non-load-bearing and can therefore be filled in with various materials, the floors are realised in wood: A material which according to the researchers earns preference for sustainability reasons [extremely low CO<sub>2</sub> footprint].



FIG. 55 Model study of the originally chosen building system

Initially, the design team still presumes that, in terms of structural aspects, the load-bearing walls do not necessarily need to be placed exactly on top of each other, but could also be turned by 90 degrees; and that the sanitary units on the individual storeys also do not have to be located exactly on top of one another. But since, in practice, these ideas offer very few architectural surprises and cause quite a lot of technical and financial problems, this train of thought is abandoned. Vertical stacking of walls and sanitary units becomes a firm starting point. When wood skeleton construction company VDM was recruited in 2009 as partner for the shell construction, the design of the dividing walls and front facades of the apartment was adapted to a wood skeleton building system that the company is versed in. However, VDM adapts the floor concept of the concept house system as well. Even with floor spans of 7,5 m, this adaptation prevents the height of the storeys to be barely larger than in concrete constructions.

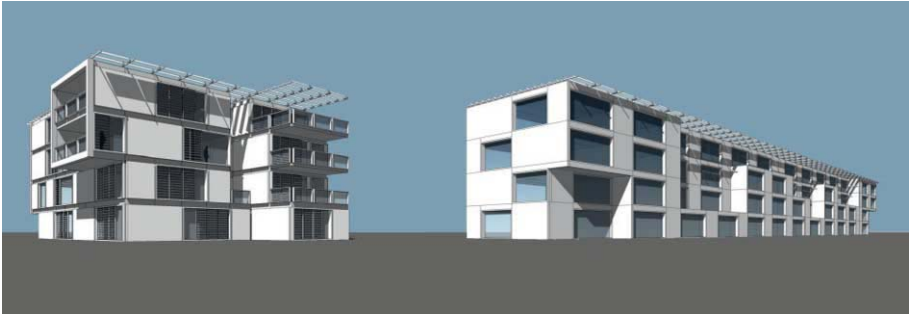


FIG. 56 Several early studies of the architectural possibilities the building systems offers



FIG. 57 Representation of various room configurations and room dimensions [however not combined] derived from the typological study

Using various narrow and wide room layouts, an extensive floorplan study examines whether the systems offers the promised architectural freedom. Since the system is developed for apartment buildings, the floorplans are also subjected to a 'Woonkeur' check [Dutch norm for apartments]. The system seems to be suitable for the realisation of one-person apartments of 50 to 65 m<sup>2</sup>, a more luxurious variant of 75 to 95 m<sup>2</sup>, and family apartments of 100 to 135 m<sup>2</sup>. Apartment complexes can be arranged in the shape of gallery, veranda or centralised site developments. Initially, maisonette typologies are included in the basic floorplan variants; however, they are discarded because interior staircases in the apartment take up too much space and because the concept does not seem to make a lot of sense in the context of apartment complexes with central staircases and the possibility to arrange the apartments all on a single level. It remains an idea for future development.

#### DAYLIGHT APERTURES

Another determining factor of the specific realisation of sustainability and zero-energy buildings is that of daylight apertures [ref. 4]. Window openings can provide for passive solar gains but transmission loss through [the glass of] the windows is always greater than through solid facade constructions. In order to comply with the passive house

norm, during the design phase the team decides to work with a window U-value of max.  $0,8\text{W}/\text{m}^2\text{K}$  (combined: thus for frame and glazing). This value is eight times higher than the guideline values for the heat transfer coefficient of dense parts (max.  $0,15\text{W}/\text{m}^2\text{K}$  for floors on full ground to max.  $0,10\text{W}/\text{m}^2\text{K}$  for roofs). Therefore there is reason to raise the quality level, certainly for large glass surfaces as they are common in the Netherlands, and unavoidable in combination with balconies.

From an energetic point of view, the apartment must be designed in a way that daylight can be exploited as efficiently as possible. This reduces electricity consumption for lighting. And the artificial lighting that is installed should exhibit a large light yield. This (preliminary) design phase also includes limiting transmission losses and using solar radiation gains through the same daylight openings. To achieve this, the initially chosen guideline values for window dimensions are approximately 6% to the north, 8% to the east, 28% to the south, and 13% to the west. With the footnote that most of the openings require sun shading. A guideline value of min. 50% is determined as solar energy transmittance factor (g). The implementation of a balcony (in the shape of a loggia) quickly determines that the most of the south-facing openings behind such balconies/loggia do not require sun shading. This is not true for the facade openings in the flat facade.

#### SUN SHADING

The choice of sun shading for the apartment depends on the individual location (and is therefore project dependent), even though an optimum (design) orientation for the prototype in its current location is generally determined. The aim is to integrate shading into the design such that passive solar gains can be use to a maximum in winter (low angle if incidence and considering possible shading from adjacent buildings), and that sunlight is shaded to a maximum during summer which in turn lowers the energy demand for cooling.

Besides reducing transmission losses, air tightness of the building envelope is the second important aspect when realising a comfortable and energy saving apartment. Well executed air tightness not only has a beneficial effect on the energy demand (by minimising infiltration loss) but also a significant influence on the acoustic performance. In addition, it guarantees improved thermal comfort because it prevents draught. And the risk of condensation inside the construction decreases because warm humid inside air escapes to the outside. Moreover, the combination of an airtight building with a controlled ventilation system is the best warranty for healthy, comfortable inside air quality.

#### OTHER DEVELOPMENTS

The concept house building system gets its general form in 2009. For the extremely ambitious goals that were initially set, practical solutions are forged into one overall concept. In broad terms, this concept is maintained across the duration of the project.



FIG. 58 The principle building system at the time of the development process in 2009

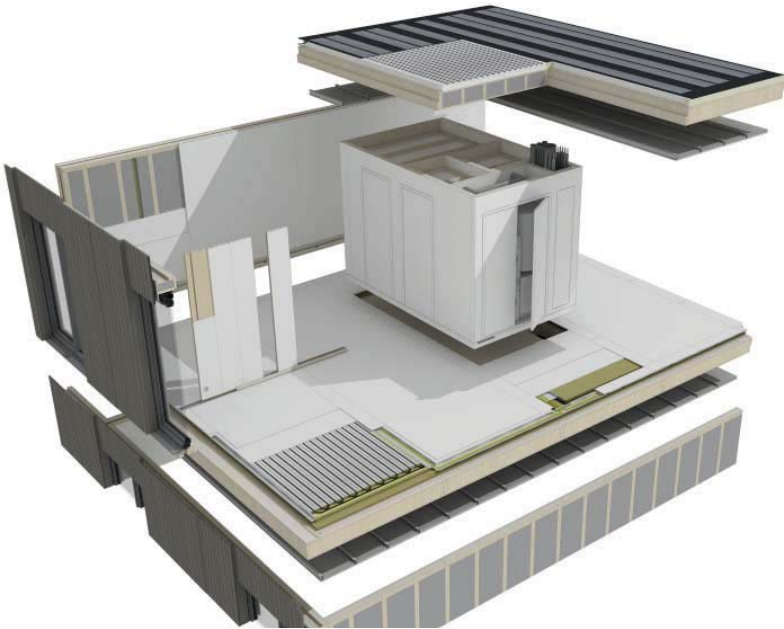


FIG. 59 Further developed system in 2011



It seems that in 2009, the first year, during which the integral system design is established, the same design is very foreign to many of the partners. The partners are each specialised in their respective products but have little experience with an integral approach, let alone seeing the importance of coordinating components. Typically, this is done by others [architect, contractor]. In order to involve them closer in the process, and to collaborate on essential issues of the project, the second running year 2010 starts with a session to re-discuss and re-determine the goals and priorities. Partners are allocated to each newly formulated part of the research.

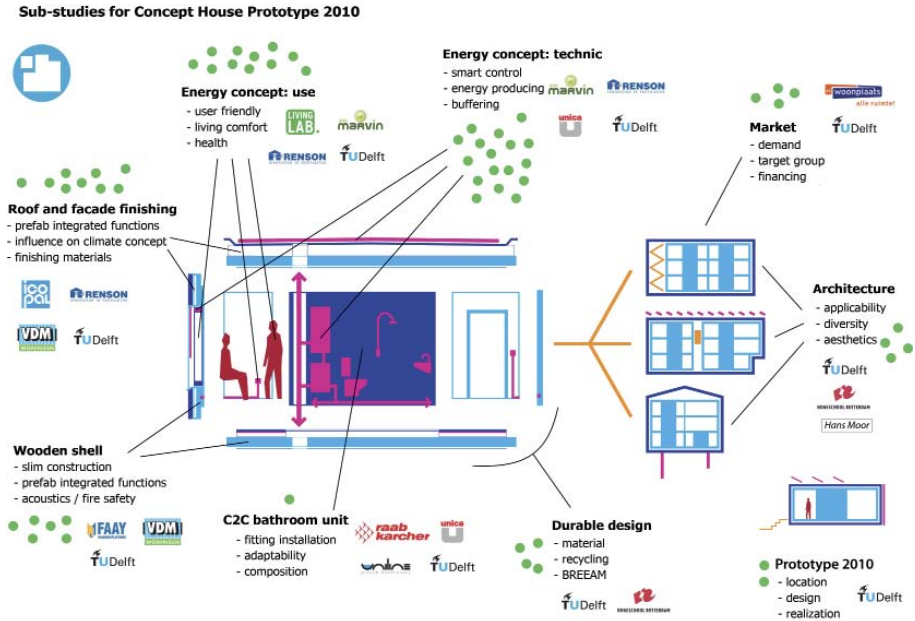


FIG. 60 Results of a workshop session with the industry partners concerning priorities in parts of the research, namely developments within the concept

### INTERMEDIATE PUBLIC PRESENTATION AT TRADESHOWS 2010 - 2012

At the end of each running year of the concept house prototype project, the exhibitions/tradeshows 'Building Holland' in Amsterdam or 'Internationale Bouwbeurs' in Utrecht offer the opportunity to present interim results and draw public interest. These venues also offer the possibility to address potential clients or partners; and they are a good means to fulfil self-imposed deadlines. Both tradeshows accept the concept house project with open arms. The concept house initiative gets free floor space. The experimental project is appreciated, and receives sufficient space to present itself to the building world. New brochures keep being printed. As early as the first running year, the team played with

the thought to build a prototype apartment and to display it at 'Building Holland' at the Amsterdam Convention Center, or even to assemble it during the show itself (3 days), after which it can be shipped across the water to Rotterdam or Delft in order to monitor it together with inhabitants. However, this remains a dream considering the limited finances of the project. But there are plans for project exhibitions that contribute to drawing the goal of materialisation a little closer. Thus, in 2010 there is the idea to place the prototype at the 'Bouwpub' building behind the Faculty of Architecture building, respectively as a 'landed' apartment for the RDM complex in the Rotterdam harbour. Dreams can indeed produce new realities. As shall be the case with the concept house.



FIG. 61 Based on the first definite design of the prototype, montages are made with possible locations in Delft on the 'Stylos' building behind the Faculty of Architecture



FIG. 62 Prototype projected in Rotterdam next to the RDM complex, where, after all, experiments are planned for living on water

Another option considered is a 'walk-in' model that presents the entire building system on a 1:1 scale, openly showing several important details, or displaying them separately. But by now another possibility to achieve the same goal has been developed; a digital model offering a virtual walk through the apartment. It is no longer necessary to create a material model of a prototype in order to experience a space. And details can be created separately.

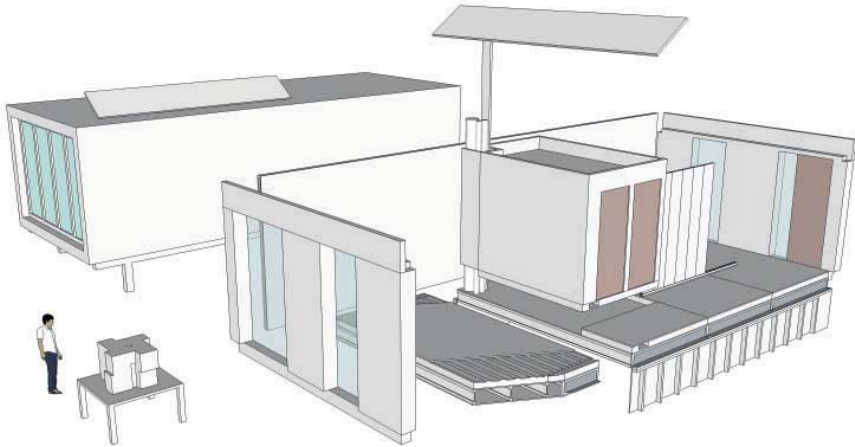


FIG. 63 Exhibition design for a 1:1 'walk-in' model of the building system to be presented in 2010

In 2009, not enough subsidies can be acquired for such work, whereby the financial burdens are entirely on the shoulders of the partners. This does not seem to be a feasible scenario; requiring an alternative setup. The researchers themselves create three models to explain the building system and variants of possible building typologies, as well as an extensive brochure and an 18 metre long display wall. Ultimately, no matter in what form, the knowledge gained is presented to interested parties during discussions and presentations.

At Building Holland 2010 the consortium receives enthusiastic reactions, and is addressed by ten new SME parties who are interested in participating in future developments. The Bouwbeurs 2011 in Utrecht is on the agenda for the following year. Here, the consortium wants to create an even bigger impact by exhibiting two mock-ups that show the most important building details on a 1:1 scale, made of the true materials. These mock-ups highlight two different details; one is a facade detail and the other a detail of the service shaft in the sanitary unit, the heart of the building system. On the outside, cross-sections of all the different types of walls, floors and piping are visible behind Plexiglas. There seems to be great building technical interest considering the many discussions taking place. The laws regulating energy performance do no longer mention thermal bridging. A thermal bridge is an interruption or local weak point of the insulation layer or connection at which higher heat loss and the risk of surface and/or inside condensation occur. Chiefly, the silence avoids a negative connotation. However, the technical problem

has not disappeared into thin air just because it is not mentioned any longer. Because, in practice, exactly these locations where three-dimensional connections need to be made are the topic of many discussions. Besides, two or three-dimensional transmission losses in a building can also be caused by linear and point-shaped interruptions that are inherent to the separating structure (timber framework, cavity anchors, spacers for glazing, etc.). If attention is actually paid to the elimination or at least minimisation of thermal bridges, improved connections and sealing as well as an appropriate execution, the mentioned problems can be reduced to a minimum. In the Netherlands, the term 'bouwknoop' (construction node) is often used in this context. Emeritus professor Jan Brouwer (1935, professor 1990-2000) is 'the hero of the bouwknoop', however, in the sense of technical design. Energy balance requires more thorough knowledge. The term covers "different locations in the building envelope or points where separations between compartments meet, at which extra heat loss can possibly occur, without having to do with illegitimate heat loss and/or condensation and mould problems" [Geysel et al., 2011]. This is the reason for the decision to build two of such essential construction nodes for the exhibition.

Together, the partners need to take another step in the detailing of the building system. It forces the consortium to think about specific connections and design solutions. It also forces them to work together in practice (as compared to the typical way of creating mock-ups that are developed on paper). It is important that the staff members of the drawing and production departments of the participating companies become more intensely involved. This process brings strengths and weaknesses to light that flow into the final detailing and production of the prototype, such as it is realised in December 2011. At the time of presentation at Internationale Bouwbeurs 2011 (February) the concept house building system has developed into a feasible concept. The Dutch press and trade journals regularly publish reports of the concept house during this period. At the exhibition, various materials sponsors, in addition to two new partners, show interest in participating, which makes it seem very possible to realise a completely functioning prototype apartment.

When Building Holland opens its doors again one year later, in 2012, the prototype in Rotterdam has already been built (except for the kitchen, furnishings and exterior landscaping), and almost definite results can be shown at last. More acquisition work is conducted to support a pilot project of the urban villa, which the industry partners can independently continue to work on upon completion of the project. In 2011 and 2012, the researchers of the concept house project direct their attention at completing the project, often by hands-on work, by looking for other materials sponsors, but also by anticipating the following phase of the development and realisation of the urban villa. The split between the backsides of the SME and the supporting services of the Faculty of Architecture costs a lot of energy, to put it mildly.

It proves difficult to keep the attention of the various stakeholders of the companies over the entire process. It is a side project for almost everyone, a project not yet really interesting in financial terms which therefore does not have high priority. Furthermore, it is a complex project: The diversity of partners is great and the goals are very ambitious. It is difficult to keep the resulting choices and directions of thought clearly in mind.

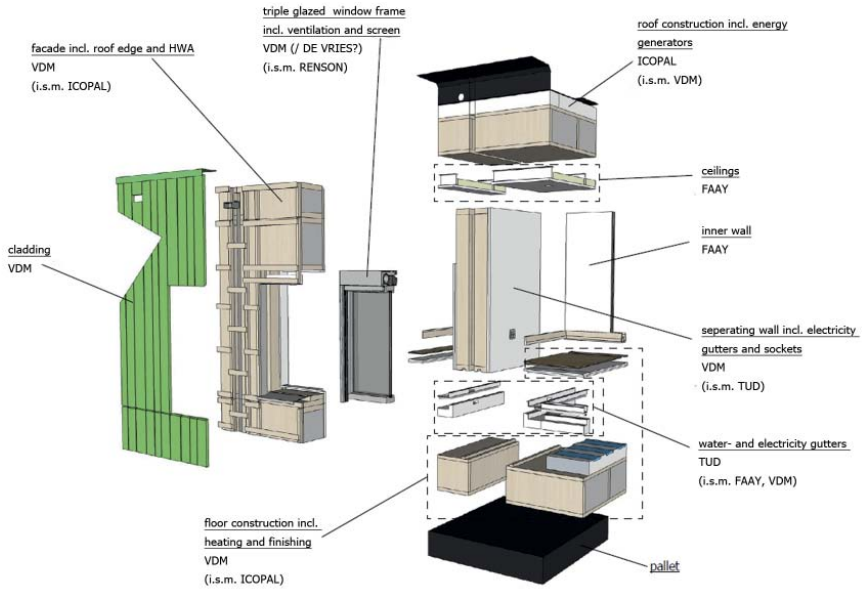


FIG. 64 Exploded views of two elaborated construction node mock-ups

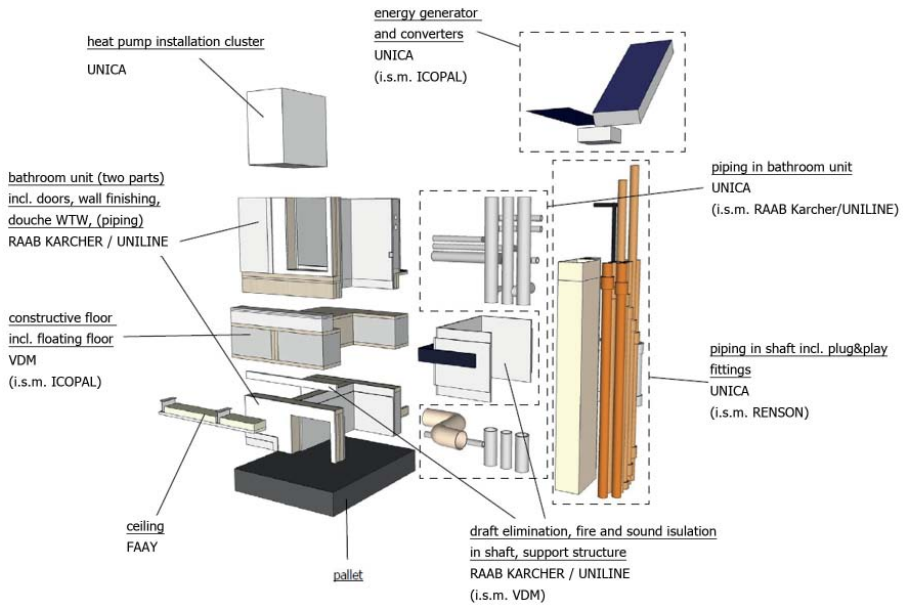


FIG. 65 Exploded views of two elaborated construction node mock-ups

And in the middle of the process, co-partners can leave or join as they please; something that certainly does not benefit the speed and efficiency of the process. Reports are not always written in detail, nor does everyone read them thoroughly or follow up on action items. Some discussions are repeated after a while; with the consequence that all parties find it difficult to meet the deadlines that quickly succeed one another. The researchers of the chair presume that, just like them, the companies should work intensely on innovation and repeatedly propose far-reaching ambitions and modifications; often outside of the actual core business of the companies. And on top of this, these [or variants thereof while maintaining the goal] must be realised in a very short period of time. The immediate consequence is that no one actually materialises them. Besides their other tasks, the two designing researchers that work on the project on a daily basis are not [fully] able to intensively and continuously accompany the partners. Another hope is that the link to education offers comfort and leeway for the partners. But the effort of the university students working on partial tasks does not deliver very interesting input for the project.

On the one hand, the 'broad horizon' pulls the mutual ambitions onto a higher level, but on the other hand it is rarely realistic, resulting in distance and incomprehension amongst the company staff members and the academics.

All of this is not surprising considering the tasks and goals that the design and research team of the chair has posed on itself and the consortium: Good information and reporting management as well as shared sets of drawings and specifications are needed. And the team tries to secure ample financial resources for product innovations and building prototypes from partners and subsidy grantees. It works on a marketable solution which must be supported by cost analyses, a business case and a marketing strategy. The aim is to develop individual and collective innovation and optimisation in the field of installation technology, building technology, production and assembly, logistics, costs and CO<sub>2</sub> footprint. Interesting architecture and urban design related solutions are researched. And the team wants to execute elaborate studies to quantify the environmental burden resulting from the entire lifecycle of the complete system. Research programs are developed for the prototype on a product and building level, and the team tries to organise collaboration with other expert groups, faculties, universities and higher education institutes. As with every intellectual process, the sum of the ambitions is larger than the competences, and it is almost inevitable that one has to gradually adapt to the typical melange of the process. It is an unavoidable given that one has to learn to deal with this.

All goals are being worked toward, successes are achieved on all different levels, but the team at the chair doing the daily work is small and has little time, too little specialised knowledge and practical experience to pull the cart in all areas. Nevertheless, the chair makes a brave attempt to force along extremely necessary integral innovations in the building industry. The overview, the arisen enthusiasm and the flexibility of the researchers prove to be of great importance for the process and therefore the results of the project. The coherence within the consortium grows with the years it works on the project. The involvement of the partners also grows, and at each company there is at least one person who feels personally responsible for the success of the project. In addition, the

involved partners have sufficient trust in the project to invest time and money and to regularly meet at plenary meetings. The partners get particularly involved when work is done on building the mock-ups and the prototype.





# 05 TECHNICAL DEVELOPMENT IN 2011

Research at the chair is directed at materialistic results of building products or buildings as products. Naturally, this includes the science of methods, the methodology. But the relationship between users and producers is the domain of the faculty of industrial design engineering; therefore it is subject of the 'Living Lab' phase of the prototype. The chair is object-oriented. The many changes during the design phase and the cyclic iterations result in the fact that certain items are repeatedly mentioned in various parts of this book; however, mirroring the process they return in an improved state of insight and functionality. In the concept phase, we therefore take a round to take stock of all aspects. And the same in the sketched design phase. And again in the final design and the tender and working drawings. Because this is how the engineering process works: Cyclic, and with an increasing focus on the expected goal of realisation and functioning.

## 05.01 THE BUILDING METHOD

After sub-research into reference projects and the main differences (advantages and disadvantages) of 2D and 3D modules, components and element building systems, the development process indicates that, considering the (previously described) starting points, element building or so-called 2D element building (no unitised building system) has the most potential to achieve the goal of broad applicability. The main reason for this is the possibility to realise multiple architectural building typologies, types of arrangement, building heights and widths and room dimensions with a single building system. And thereby to create the desired design freedom for housing corporations or developers as well as designers. The preference is to base all developed apartment types on two room

dimensions (5,40 m and 7,50 m). These are common room dimensions for apartment building that also facilitate adding parking spaces underneath the building. Two or three 90-degree parking spots between the load-bearing columns or walls on the ground level or in the basement. As described earlier, different apartments are designed with this building system, varying from 50 to 150 m<sup>2</sup>. In this way, project architects can vary the orientation of the different apartment toward each other; possible cantilevering and facade design; offering a unique character to each apartment block. The background is that the concept house consortium develops the principles, while adaptations and increases in scale need to be done by the market (by themselves, by their market oriented consortium or by others). In this case, adaptation architects are needed, while the chair first develops the system design and evaluates it by means of the prototype.

The most important aspects of designing the building system are sustainable materialisation, extensive prefabrication of elements (including installations), and preventing wet connections between the elements and the materials that the elements are made of: IFD building (Industrial, Flexible, Dismountable).

## 05.02

# SUSTAINABLE MATERIALISATION

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Currently, there are very many different methods and certificates that want to give an indication of the sustainability of materials and production processes. Many of these methods are based on the LCA (Life Cycle Analysis). However, it seems that different certificates evaluate certain materials differently. Which makes it difficult to choose a particular certificate. For the project in question, the choice is made in favour of the NIBE (Nederlands Instituut voor Bouwbiologie en Ecologie, Dutch Institute for Building Biology and Ecology). This sustainability index, which includes aspects such as work environment and environmental pollution, is also used for evaluations by BREEAM NL (Dutch version of BREEAM). All this results in an environmental score expressed in Euro's. The NIBE index comprises almost all conceivable building materials, facilitating easy comparability. In contrast to, for example, products with a cradle to cradle (C2C) certificate, of which there are not that many yet.

## EXTREMELY LOW FOOTPRINT WITH TIMBER AS CONSTRUCTION MATERIAL

The starting point for a low CO<sub>2</sub> footprint and general sustainability leads to choosing wood (timber) as the building material for the construction and a combination of mineral wool and isofloc (based on recycled used paper) as insulation material. Fire resistance and noise insulation values comply with above average requirements and comfort levels. In order to proactively address the common, often negative connotation related to timber constructions, and to also demonstrate that the exterior finishing of the apartment buildings is up to the choice of the designers, housing corporations and developers, the

exterior finishing is made of C2C certified tiles instead of wood. Other finishing is done in wood, 'vertical green' facade and dry mounted aluminium add-ons for [glass] balustrades and sun shading [aluminium with wooden louvres]. The latter components are all easy to dismantle at the end of their lifetime.

#### EXTENSIVE PREFABRICATION

Prefabrication of a sustainable building element involves more than merely considering material consumption. Many different parameters play a role for the design of the system. Frequently, these parameters contradict each other. This is inherent to building. Well illustrated by the design process of the sanitary unit. It is a search for optimum compromises. The most important aspects for the sanitary unit are as follows:

- C2C / wood skeleton construction;
- Extensive degree of prefabrication;
- Comply with 'Woonkeur' [Dutch certificate];
- Consumer oriented.

#### C2C / WOOD SKELETON CONSTRUCTION

Starting point is that the sanitary unit is realised as a C2C unit. Amongst other things, this means choosing sustainable and recyclable materials that can be easily separated.

To guarantee broad applicability of the building system the construction type of choice is an element building system. The main reason being the possibility to realise multiple typologies and dimensions with one and the same building system. And thereby achieving sufficient design freedom for housing corporations and designers. All of the apartment types that can be built with the system are based on two room dimensions: 5,40 m and 7,50 m.

And it is decided to realise the sanitary unit as a wood skeleton construction plated with Fermacell panels: Cement-bound wood fibre panels. In combination with the complex installations that are part of the sanitary unit [amongst which is a lot of horizontal piping] wood skeleton construction seems a very problematic construction system. It involves having to make a lot of ravelling and cut-outs in the elements. A very labour-intensive process. When the system goes in serial production, a number of these tasks should be automated. But the question arises whether in that case it would not be a better idea to work toward a shell-like panel construction, whereby the panels themselves are load-bearing instead of the timber frame construction with panels being mere filling options. This results in fewer obstructions for the piping as well. This is seen as advanced insight and as an idea for future iteration. Due to the many piping and ducting parts, the composition of the sanitary unit resembles the installations of a submarine.

## PREFABRICATION

Since a maximum degree of prefabrication is one of the presumptions, the finishing [of the sanitary unit] in the form of tiles is already done at the factory. The choice for tiles is made to comply with the wishes of the end-user [as they are assumed by the development team]. This remains to be an important aspect because the goal is to develop a commercial building system with as many application opportunities as possible. Tiling at the factory has a great influence on the construction of the sanitary unit. The unit needs to be made extra stiff to prevent the tiles from coming loose or breaking during transport and assembly. Therefore the construction of the entire sanitary unit is over-dimensioned. However, during the realisation of this first prototype there is not enough time to complete more than one finished experiment with tiles attached to the load-bearing walls with flexible glue, in order to gain insight into the technical boundaries of the tiled walls. Here, as well, we experience firsthand that experimentation should be better done in parallel, or preferably before the start of a project rather than during a running project.

## 'WOONKEUR' REQUIREMENTS

Conceding to the requirements of 'Woonkeur' [which is one of the starting points], the above mentioned over-dimensioning of the sanitary unit cannot be achieved by simply using a thicker framework. Since this would lead to the interior space of the sanitary unit being too small. Therefore, it is decided to use massive wooden Kerto walls. Even though this material consists almost entirely of wood, it also contains [non-sustainable] PU glue, and significantly increases the weight of the sanitary unit. Thus, there is room for further optimisation in a subsequent project.

During the scope of the process, more or different materials are selected for a few, very specific locations than what was initially considered necessary. Which does not comply with the C2C and sustainability aspects that the researchers had originally determined. The pragmatism to realise the prototype [with the available means and in the allotted timeframe] are the reason for these choices; being aware of and recording such potential points of optimisation is a nice challenge for future project phases or new projects.

The tiles are attached and glued in the traditional manner. Also discussed is the development of a tile system that can be applied and sealed dry together with the company Mosa; however, ultimately Mosa is not interested and not willing to free up money for this purpose. The team tries to find an alternative in the form of a glued tile system which – even though glued – can later be separated easily into its constituent parts. This is achieved by applying a glass fibre reinforced mat that allows for pulling all tiles of the support structure in one piece and easily removing the [ecological] glue. Two test setups are built to test this system, but since the results are not entirely satisfying the decision is made not to use it for the sanitary unit. The question is whether a tiled surface is the optimum sort of cladding for the interior of the sanitary unit or whether a different, thinner material would not function as well and be easier to apply. Such as glass, for example, or a new sort of bathroom wallpaper and/or nano finish.

Another consequence of the desire to fulfil all of the above-mentioned criteria and the fact that the sanitary unit should be entirely prefabricated is that it requires its own structural floor. For reasons such as sufficient stiffness during transportation and as foundation for the floor finish.

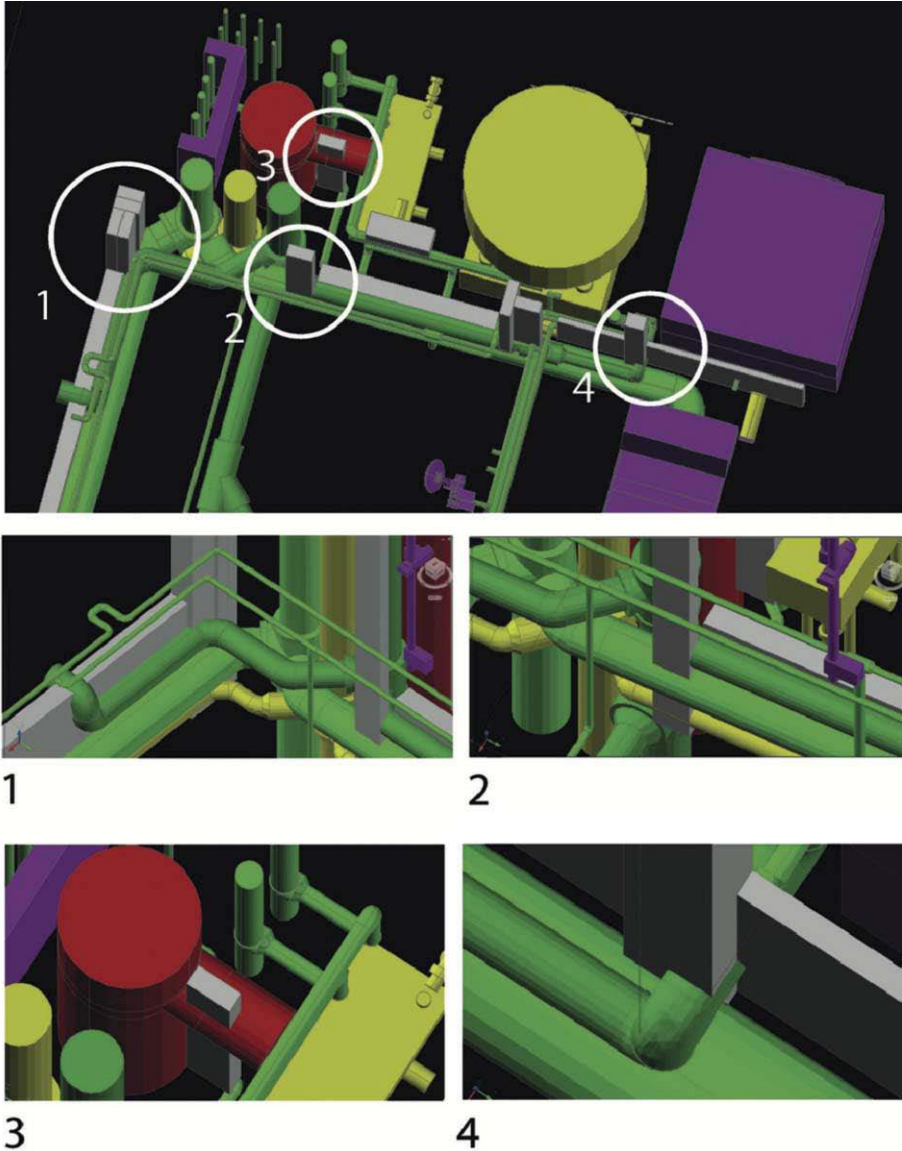


FIG. 66 Drawings displaying the conflicts between installations and wood skeleton construction in the sanitary unit / installation cluster

The shower in the sanitary unit has a shower drain heat exchanger [waste heat recovery] with an installation height of 120 mm. The shower drain ultimately determines the construction height of the floor of the sanitary unit. And since 'Woonkeur' dictates that the shower floor has to be flush with the rest of the floor and that an apartment may not have differences in floor height greater than 20 mm, this means that it also determines the thick floating floor of the entire apartment. This is another aspect that requires evaluation and maybe a completely different approach in a subsequent project. Thus it seems that dogmatically holding fast to each originally formulated criterion means to verge off target. In hindsight it might have been a better choice to dispense with the shower waste heat recovery, because not only the structural floor of the sanitary unit but the floating floor of the entire apartment as well could have been realised with a much lower height. This would have saved material and reduced the storey height.

Another option could be a slender steel construction forming the basis of the sanitary unit, providing sufficient stiffness. And it would offer material savings as well. Nevertheless, it is not certain that these choices would have been better. This can only be proven by comparison, including a calculation of the CO<sub>2</sub> footprint of the different concepts. Unfortunately, during the development process of this first prototype the researchers do not have enough time to do this. Thus, no comparisons are made. But they remain valuable suggestions for further research.

The ultimately developed and realised installation cluster is equipped with preparatory and installed facilities [heat pump, boiler, converters, fuse box, ventilation system, a. o.] and a completely furnished and finished sanitary unit [including triple waste water separation according to 'quality'], separate lavatory and kitchen connections. This makes it possible that almost all of the connected integrated and sustainable systems and techniques [PV systems, waste heat recovery from ventilation air, heat pump, etc.] can be used within one day after installation during assembly.

## FLOOR COMPONENTS

Several designs are reviewed during the development process of the floor. These are some of the criteria for the floor design:

Dimension related criteria:

- Room dimensions [centre to centre] 7500 mm
- Total wall thickness Max. 300 mm
- Span clearance Min. 7200 mm
- Storey height 3200 mm
- Total floor thickness Max. 500 mm
- Free storey height Min. 2700 mm
- Apartment depth 10,000 mm
- Element width 2500 mm

## ASSEMBLY

- Underfloor heating, prefabricated in floor element;
- Dry floating floor, prefabricated in floor element;
- Floor elements dry dismantable and reusable in case of demolition.

## LOADS

- Dividing walls  $0,5 \text{ N/m}^2 \text{ k}$
- Floating floor  $1,2 \text{ N/m}^2 \text{ k}$
- Variable load  $1,75 \text{ N/m}^2 \text{ k}$
- Variable point load  $3 \text{ kN}$
- Requirements related to strength and deflection conform NEN6702
- Residential building with a reference period of 50 years
- Safety class 3

## NOISE INSULATION

Comfort class 5dB higher than building regulation 2003 with respect to hard floor finishes.

- Contact noise insulation  $l_{co} \geq +10 \text{ dB}$
- Contact noise insulation measurement  $RA \geq 60 \text{ dB[A]}$
- Air sound insulation measurement  $L_{n,A} \leq 45 \text{ dB[A]}$

## FIRE RESISTANCE

- Floors and walls: 90 minutes

From the different designs, the fourth variant in figure 72 is chosen, the wooden channel plate floor. It seems easy to produce as a variant of wood skeleton construction producer VDM's own system. The floor elements consist of a layer of joists (height 244 mm) with 27 mm thick Kerto panels densely nailed to the top and underside of the joists. The panel on the underside provides for extra bending stiffness of the spanning element. A 7,2 m long span can thus be accomplished with a wooden and size-limited construction height (298 mm). The spaces between the joists are completely filled with cellulose insulation which contributes to thermal and acoustic insulation. Each element is equipped with two coupling joists, one for the upper and one for the lower side. When connecting these elements, these joists overlap and can be screwed together to create a stiff floor area.

## FLOATING FLOOR

A floating floor no less than 135 mm thick is placed on top of the floor elements. The height of the floating floor is derived from the dimensions of the floor of the sanitary unit. Even though in terms of acoustic and thermal insulation it could have been realised with a lower height, the thickness chosen offers ample room for channels which is handy during assembly and the installation of piping and ducting. The over-dimensioning also contributes to the flexibility of the apartment, allowing future generations of habitants to make radical changes to the room arrangement.

The entire build-up of the floating floor (80 mm Rockwool re-used compression resistant insulation, 30 mm underfloor heating system in EPS, 25 mm Fermacell) is dry mounted and disconnected, preventing all contact noise. The floating floor is only attached to the wooden subfloor with large screws during transportation and assembly. For upper, apartment-separating floors, an extra, freely suspended ceiling by Faay is installed underneath the floor. This ceiling provides additional acoustic insulation and ensures the required 90 minute fire resistance of the construction. Even though the researchers are trying to tempt the relevant partners to develop an intelligent ceiling that would be part of the prefabricated floor element as well as generating innovative solutions to implement electrical and ventilation connections, unfortunately Faay has little interest in doing so. Therefore, one of their existing system ceilings is used for the prototype. An entirely freely suspended system that is put in place onsite, based on steel I-profiles which run from wall to wall and are resiliently suspended from one centre point. In addition to the ceiling not being a prefabricated unit, the implementation of steel I-profiles also pains the researcher due to their large CO<sub>2</sub> footprint. Another aspect for innovation for the pilot project of the urban villa.

The next challenge for Faay is to give the ceiling, which consists of relatively small elements (600 mm centre to centre) a homogenous, seamless finish. Since ceiling systems are not usually perceived favourably in residential dwellings, the seams of the ceiling in the bedroom are filled with spackle to achieve the look of one large abstract surface. And the ceiling in the living room is even plastered in its entirety; a finishing method that truly contradicts the principle of 'no wet or glued connections'. This really displeases Mick Eekhout. Several times during the development process he declares that builders as well as habitants must get used to the fact that a prefabricated building must include a prefabricated ceiling, and not a ceiling that negates the prefabrication character by resembling a concrete part. Another issue for further development.

The floating floors are assembled entirely at the factory. The roof floors are completely prefabricated as well. Instead of mounting a floating floor, the roof floors include an ecologic EPS separating insulation mounted into the elements with a minimum height of 120 mm and a maximum height of 300 mm. In parts of the roof, the same dry underfloor heating system is installed as in the apartments. However, here it is used not as a heating system but rather a heat collector. It is covered with a bitumen layer, followed by amorphous, flexible PV panels that are mounted flat onto the bitumen. By cooling the PC cells on warm days by means of the underlying heat collector system, they will most probably work more efficiently. At the same time, thermal energy is drawn from the roof that can be used to regenerate the ground source of the heat pump. In winter, the PV cells can be slightly warmed – if necessary – so that snow and frost melt and the PV cells can deliver more energy. Taking measurements during actual use must show whether the amount of energy needed to warm the roof is higher or lower than the amount of energy generated. Both floor packages (apartment separating and roof floors) achieve an Rc value of approximately 9,5 W/m<sup>2</sup>K.



## WALLS:

A differentiation is made between two different types of walls:

- Apartment dividing walls;
- Facade elements.

The walls separating the apartments are constructed with wood skeleton construction elements with a centre to centre grid of 600 mm. An apartment dividing wall construction consists of two load-bearing wall leaves with an air space between them to prevent noise transmission from contact noise. The posts are 120 x 38 mm. Tightly compressed cellulose is placed between the posts, and a double gypsum board is mounted only on the interior side of the skeleton framework to provide stability and 90 minutes fire resistance. Including the air space of 50 mm between the two wall elements, an apartment dividing wall has an overall thickness of 350 mm. The facade elements are also constructed from wood skeleton construction elements, with siding on both sides. Here, however, the posts are wooden I-profiles, 250 mm high. On the inside, the siding consists of one OSB layer and one layer of gypsum boards; whereas [vapour open] DHF panels are mounted on the outside. Here as well, the cavities between the posts are filled with cellulose. None of the wall elements contains any foil, which means they are vapour open constructions. Morgo open façade fabric is attached on the outside of the wall elements, a vapour open water-repellent facade fabric. The walls have an  $R_c$  value of approximately 5,7 W/m<sup>2</sup>K [depending on the number and size of the window openings].

All walls in the apartment (constructive as well as dividing walls) are equipped with vertical electrical / data shafts and horizontal electrical / data skirting ducts. The existing Faay KBL system is used for the interior walls. Different concepts for the apartment dividing walls and facade elements are developed with the partners VDM and Faay, who have an interest in this topic. Criteria here are that the wall thickness may not increase (with reference to 'Woonkeur'), that acoustic insulation and fire resistance are maintained and that the walls may not sound hollow. A number of the developed concepts can be seen on the following page. Almost all concepts are based on no, or minimal, increase in wall thickness to comply with the requirements of 'Woonkeur'. In some cases, the production process must include turning the wall elements so that materials can also be attached to the other side. This is unacceptable to VDM; so these concepts are neglected. Another concept involves using an adapted Faay inner leave element instead of the stabilising siding that is standard use in the wood skeleton construction elements by VDM. This seems to cause production technical problems as well. Since there is no more time to further develop the above mentioned concepts or to find solutions for production related problems, but also because it is very difficult take VDM beyond known paths, even though we are only dealing with one innovative prototype, ultimately double walls are implemented in the prototype anyways. The majority of walls in the apartment are double leave walls with a 35 mm cavity. A part of the apartment is equipped with a double leave wall by Faay that consists of a flax core with shafts of 200mm [centre to centre] with a gypsum board finish. Beneath the inner leaves by VDM and Faay, an adapted standard electricity baseboard profile is used that was developed by the researchers of the TU Delft in cooperation with Faay.

For the electrical system, the team assumes 4-core flat cables that can be interconnected with connector blocks. Each cable can accommodate 2 groups. The skirting ducts are large enough that a connector block can be vertically inserted.



FIG. 67 Mock-up with apartment dividing wall [a.o.]

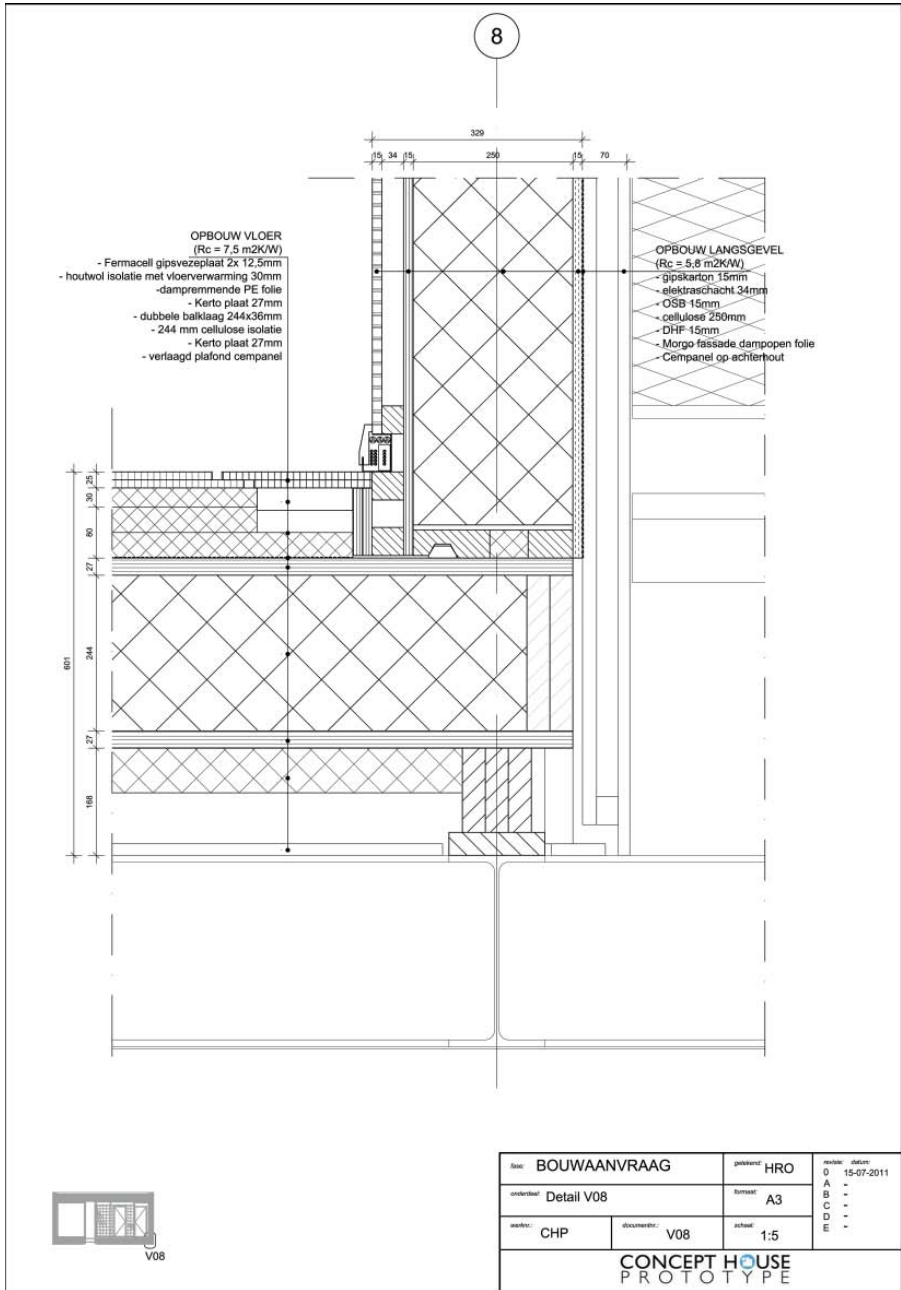


FIG. 68 Detailing including sanitary unit: stiff, slender, ducting, lack of space, installation cluster, triple sewerage, wood skeleton construction with a little bit of Kerto after all, dismantlable tiles, with a traditional appearance

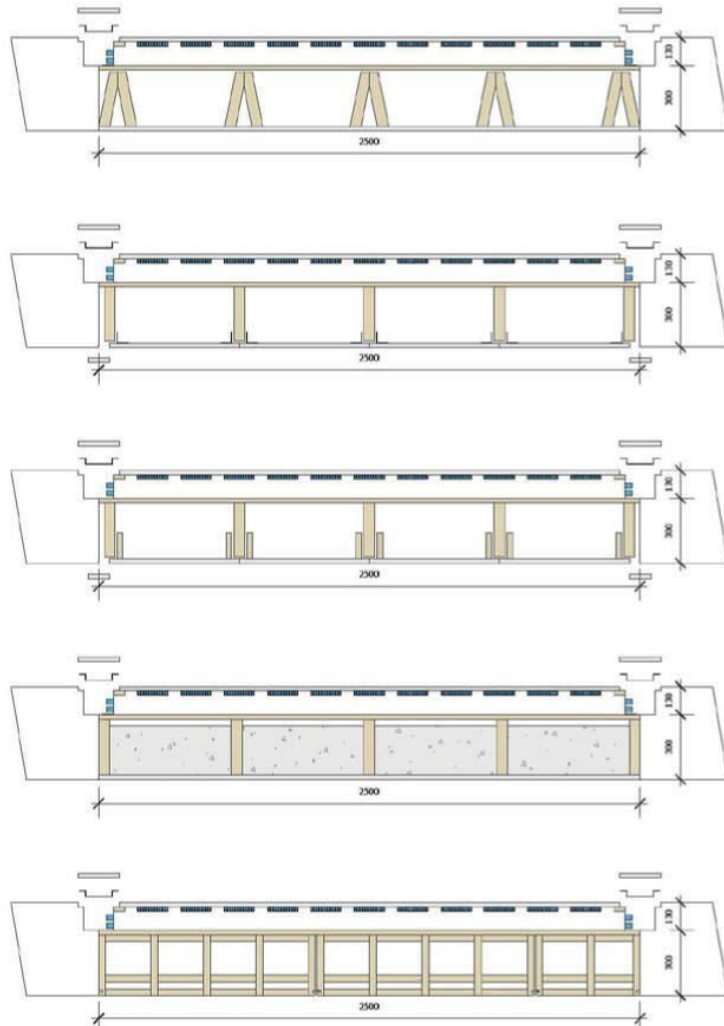


FIG. 69 Construction variants of the floor construction

#### SUSTAINABILITY MEASURES IN THE FINAL DESIGN

The sustainability measures taken in the concept building system are twofold: On the one hand they are directed at material cycles [with the goal of a low CO<sub>2</sub> footprint], and on the other hand at energy consumption [with the goal of being energy positive in use], subdivided into building site related parameters and building related parameters. With regards to the high energy related ambitions it is important to consider and principally determine the building related parameters [typology, volume compactness, plan set-up and compartmentation, daylight apertures, sun shading and materialisation] in a very

early phase of the development process. The background of the prototype design as a zero-energy apartment is optimisation following the new 'trias energetica' approach: First, progressive reduction with extensive insulation in facades and roof, and very economical appendages (lighting, home automation, toilettes, showers, etc.). Followed by energy recovery from available residual thermal flows (such as waste heat recovery from shower water and ventilation exhaust air, for example). And finally, maximising energy generation from renewable resources via available roof, façade and ground surfaces. Principally, the fundamental criteria remain the same throughout the elaboration of the final design. However, execution, engineering and dimensioning are mainly fine-tuned during this phase.

#### A MAXIMUM OF FOUR STOREYS FOR ENERGY-POSITIVE MULTI-STOREY BUILDING

During the course of the development and calculation process (based on EPC calculation and building physical similarity calculations), it becomes apparent that currently the maximum achievable energy-positive arrangement that can be accomplished with appropriate (available) methods and systems is a 4-storey construction. The main reason for this is the relatively small available roof (and ground) surface, as it relates to the energy generating roof with PV cells that must balance out a maximum number of energy-consuming storeys. From an energy viewpoint, renovating residential apartment buildings of more than four storeys seems like witchcraft!

During the first design and development phase of the prototype, important building site related parameters such as orientation and positioning related to sun and wind, the (micro) climate, ground, vegetation (present and planned) and the built environment (present and planned) cannot be considered – or in an abstract manner only – because the final building site has not yet been chosen. The abstraction is thus limited to applying the basic principles of so-called 'bioclimatic' or climate conscious architecture.

Climate conscious architecture tries to find the consensus between the design and the construction of an apartment, the climate and the environment and the habitants and their life rhythm. Energy economic apartments aim at achieving a comfortable indoor climate during the summer as well as the winter. During summer, it is all about shielding, minimising and exhausting: warm air must be kept outside, therefore the sun must be barred and excess heat must be exhausted, for example by means of night time cooling or seasonal storage. During winter, it is all about generating, storing and distributing: to capture thermal energy and to efficiently distribute it throughout the apartment. It seems necessary to conduct prior soil research on the assumed building site. This is done as soon as the location in Heijplaat becomes known. Another reason to do this as early as possible is that it should be used for a climate conscious architecture approach. It does not only provide a good indication of the geotechnical properties of the ground and its load-bearing capacity, but also of the storage capacity, permeability and geothermal properties onsite.

## REALISATION OF THE CONCEPT HOUSE DELFT PROTOTYPE

In addition, the ground has an influence on the air temperature at a given location. It is determined by the typology of the surfaces that receive incident sunlight. A plant covered ground promotes evaporation, which in turn keeps the air temperature low (or only slightly rising). A ground with high accumulating capacity stores solar energy during the day and emits it when temperatures fall, resulting in slower local temperature decreases. This is as true for water surfaces. These can store thermal energy as well and give them back when the air temperature drops via radiation and convection.

Apart from thermal energy, the reflection coefficient of the ground outside has an influence on the amount of light that can penetrate the building. This is known as the 'albedo' or diffuse reflection factor. Water surfaces can cause blinding and reduced visual comfort indoors. For the concept house prototype, the choice was made to separate the prototype from the ground with a steel substructure. This is done to prevent the suggestion of a ground-bound apartment or villa. Postulated effects in terms of temperature and reflection do play a role, but to a much lesser degree. Nevertheless, it is decided to improve the reflection coefficient of the ground – besides the paths that are paved with special bricks – by only using semi or non-hardened ground. Another factor, of course, being water management at the building site.

In order to promote closed materials cycles, the origins and health aspects of various materials were closely examined in the NIBE tables before choosing specific building materials. The choices are also based on the dismantling possibilities with regards to components and materials being reused later. The insulation materials cellulose, recycled rock wool and recycled EPS, as well as the EPDM used for the project, flax and Fermacell siding are reusable products, the ceramic façade tiles are dry-mounted and can be recycled according to a C2C certificate. All sewer pipes are made of easily recyclable PE; they can be connected without glue thanks to a special welding method. During assembly, PUR, putty and glues are used as little as possible – and if it cannot be avoided such as in the sanitary unit, products from suppliers with a DuBo certification (sustainability certificate) are chosen. The inside walls are attached to each other with a single dot of glue, thus easily dismountable; the floating floor lies loosely on the rock wool insulation; wall, roof and floor elements are screwed and taped to each other. And a triple sewerage is used so that waste water can be optimally cleaned or reused.

The energy required to produce materials is also considered in the evaluation. This explains the preference for wood products (solid wood, but I-joists and different types of panel material as well), and the limited use of steel, aluminium and concrete. Generally speaking, applying recycled materials has a positive effect on the energy consumption for production. Currently, it is still true that energy consumption during habitation is several times as high as that used during the building process. A lot is to be gained on the roof; the strategy used follows the previously explained trias energetica. In order to minimise the energy demand of concept house apartments, several measures (extensively explained in previous sections) are applied with regards to reducing transmission losses (very well insulated floors, walls and roofs and triple glazing throughout, gapseals, etc.), with special attention

paid to the [3D] building nodes. Each building node is elaborated in detail during the design and development process. Besides guaranteeing a continuous insulation layer it is also important to ensure air tightness. The airtight layers that come together in the nodes must be carefully joined. This is ensured by using foils and special tape on all seams. The design already incorporates the highest possible degree of practical feasibility, also concerning the process sequence. But the majority of these tasks can be done more carefully and under better conditions by the industry partners when they build the components. It is therefore necessary to follow up assembly by examining all joints and taping them. This is also true for the ceiling because it is a suspended ceiling. In this way, a continuous airtight layer is installed to guarantee good air tightness. The vapour barrier layer (building foil) on the inside of the insulation functions as air sealing; it runs uninterruptedly, especially in those areas where several building parts meet. The materials used to ensure air tightness have an air permeability of  $1 \times 10^{-6} \text{ m}^3/\text{m}^2\text{sPa}$  maximum, including all seams. Electrical connections and installation parts such as ventilation ducts are positioned within the airtight layer. Special attention is also paid to connections around the doors and windows.

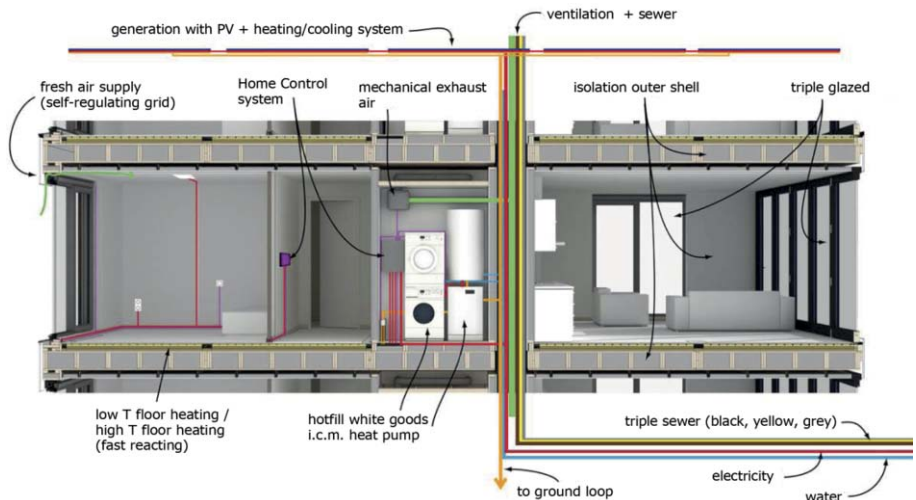


FIG. 70 Typical longitudinal cross-section of the concept house prototype apartment, with the different climate systems and connecting infrastructure

Typical weaknesses in this area are connections between interior and exterior walls, connections between the roof and/or floor and the interior walls. These details are ultimately resolved at the building site itself [possibly not entirely in compliance with the starting criteria of the project]. The choice is made for a continuous but controlled ventilation flow to guarantee healthy indoor air quality. This is accomplished with the Health box by Renson, which also serves waste heat recovery. This is with regards to a [very economic] demand-driven ventilation system with fresh air supply and single mechanical exhaust. The control [via the Niko system] is demand-driven by the user [and

an overrule function), coupled with an automatic control (triggered based on physical presence, CO<sub>2</sub> concentration, relative humidity). Special attention is also paid to internal thermal energy gains: Useful gains in the building from people, equipment, lighting et cetera. These depend on the users and are therefore difficult to quantify, but flow into the calculation as a fixed number. During winter, solar gains are an important contribution to minimise the energy demand for heating. Thus, they are exploited to the highest possible degree. Principally, the prototype is not ideally oriented since the living room does not face directly south. But since it is a corner apartment the side window does allow for solar light incidence. It demonstrates the flexibility of the building system. The goal is a light incidence factor (g) of 50% or more.

Upon ensuring maximum thermal energy gains it is important to exploit them as much as possible. Considering that the Dutch climate is characterised by relatively large temperature fluctuation throughout the day, the thermal mass of the building can greatly impact energy consumption. The factors determining whether a certain thermal mass will function well are high density, high heat capacity and the possibility to delay heat dissipation. The effective thermal capacity of the building structure strongly depends on the building method. However, here comes into play that the prototype is based on wood as construction material. The accumulation capacity of wood is lower than that of concrete. Therefore the (dry) floor consists of a double Fermacell gypsum board (with low-temperature heating beneath) and insulation. And the walls are also equipped with Fermacell boards for the same reason.

Usually, the mass can temporarily store excess heat that, due to gains from solar radiation or internal heat sources, occurs at peak moments. During a subsequent cooler period, the stored thermal energy can be re-dissipated to the inside spaces, allowing for a more stable inside temperature without the need for much extra heating. This effect does occur in the prototype, even if to a rather small degree (and utilising solar gains and storing them with thermal mass in a protected volume of space is very dynamic and difficult to predict, particularly as the floor construction plays a role as well). It is presumed that active cooling systems are unnecessary in the Dutch climate. However, the low-temperature heating in the floor elements can also be used as high-temperature cooling. The heating and cooling system is very economical due to the heat pump with ground buffer. Very economical options have also been chosen for lighting and electrical appliances such as LED lights and 'hot fill' washing machines. Furthermore, the electrical system is controlled with a home control system. It is obvious that the choice of consumer appliances and devices plays a significant role for the actual energy performance of the building. All devices should preferably have at least an A+ label, and if a tumble dryer is used, the energy for it should be generated with a heat pump. Coming back to solar gains (to be used as much as possible). Naturally, there will always be peak moments that can lead to undesirable passive heating (and thus a demand for cooling). Sun shading is necessary to prevent this, and therefore included in the project. The sun shading is located on the same plane as the glazing, whereby the solar incidence factor of the glazing (which is to be combined with the sun shading) lies between 0.15 and 0.85. The systems installed in this prototype are primary sun shading (firmly installed, structural sun shading such as roof extensions/



side walls at the balcony/loggia and recessed window frames], secondary sun shading [specially mounted exterior sun shading, automatic and/or home control system controlled moveable slat panels along the sideways south facade, and sun protection integrated into the bedroom windows], and finally tertiary sun shading [additional curtains on the inside].

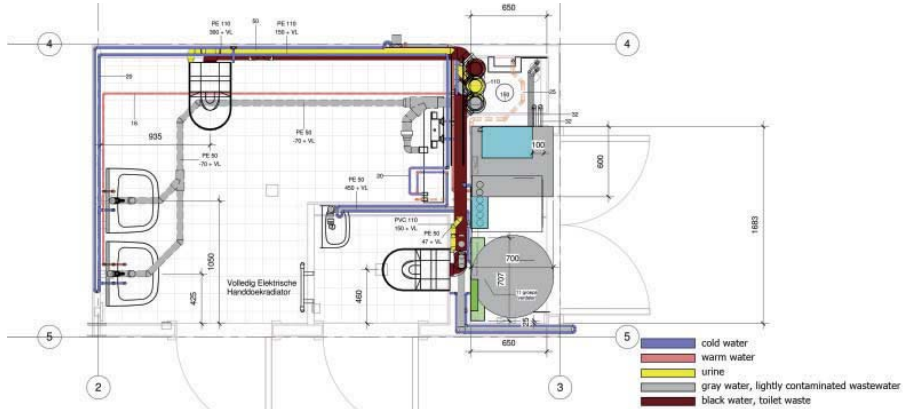


FIG. 71 Floorplan sanitary unit (Unica Installatiegroep)

Hereby, the control of the sun shading system is essential because it determines its efficiency. It is important that these systems are automatically controlled considering that most users react too late [when the building has already become too hot]. In order to prolong the lifetime of the sun shading it should include wind and rain sensors. Naturally, the automatic control can be overruled by the user to guarantee maximum user comfort. The home control system monitors energy consumption and provides feedback to the user to stimulate energy saving. Other possibilities to further minimise energy consumption are a central off-switch for all lighting devices and electrical outlets and automatic control of lighting and sun shading. In the future such a central controller should be connected to an intelligent storage device in electric cars and to other buildings in a 'smart grid'. Currently, much research is invested into smart grids; a promising aspect for the future. In addition to the above mentioned energy savings measures, electrical energy is generated on the roof of a concept house apartment building with solar panels that are integrated in the roofing. The energy can be harvested with an underfloor heating system which is integrated in the roof. Besides the energy-neutral arrangement thus realised in the prototype, the design of the system also emphasises the comfort experience of the inhabitant. The apartments have good acoustics, the air quality is very good and underfloor heating and cooling react quickly to changes in the temperature settings. Architects do not need to make concessions to the dimensions of the window surfaces, and it is very easy to place additional electrical outlets or switches. The system allows for relatively large room dimensions and a flexible arrangement, while solid and aesthetic materialisation prevents inhabitants from feeling like living in a systemised building.

## CENTRAL CORE

The core of the development of this concept house prototype is the 'installation cluster & sanitary unit'. It comprises all components of the complex installation which is already connected during production.

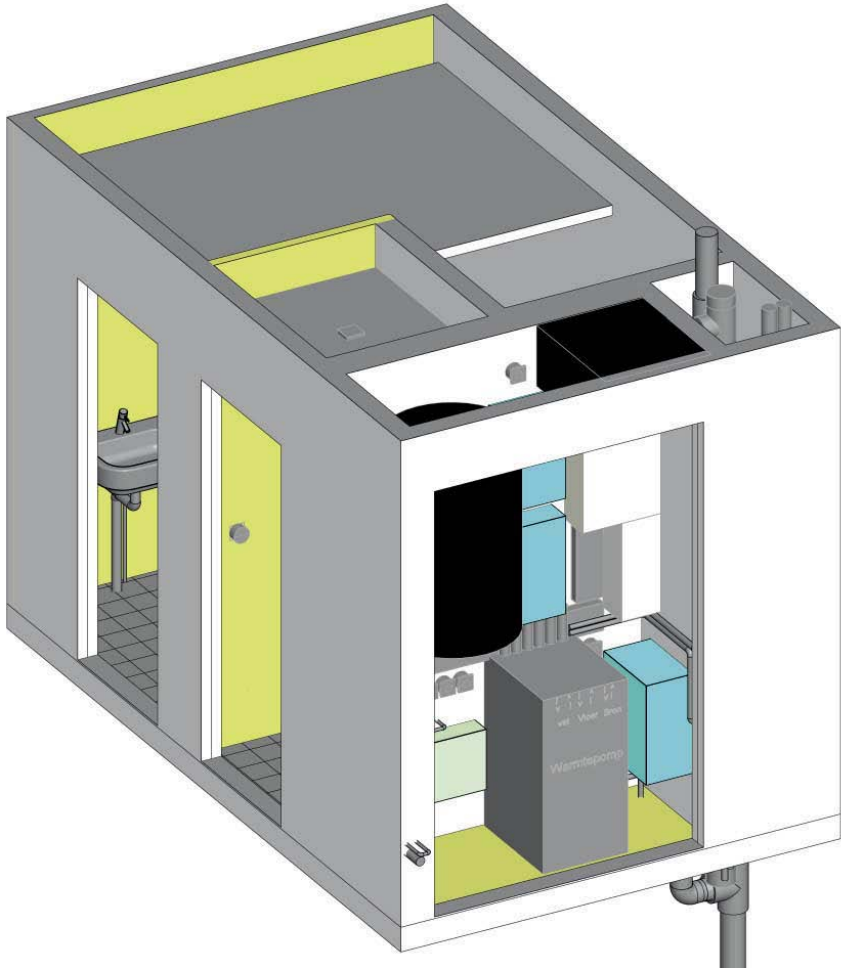


FIG. 72 BIM drawing sanitary unit (Unica Installatiegroep)

After placing the components, it is only a question of plug & play until the installation can be put to use. The principle is a mix of 'passive building' and 'active building'. Installations are not a goal in themselves but rather a means. In those places where energy and comfort

optimisation demands it, windows can be opened as usual. After all, the user stands at the heart of the matter; and the user is in charge. The installation cluster is developed as one centrally 'beating heart' according to up to date BIM techniques [drawn with Revit], prefabricated and attuned. The installation cluster, equipped with preparatory and installed facilities [heat pump, boiler, converters, fuse box, ventilation system, a. o.] and a completely furnished and finished sanitary unit [and triple waste water separation according to 'quality'], separate lavatory and kitchen connections, also makes it possible that all connected, sustainable systems [PC systems, waste heat recovery from ventilation air, heat pump, etc.] can be used within one day after placement.

#### EVALUATION OF THE DEVELOPMENT PROCESS OF THE TECHNOLOGIES USED:

Several other findings based on the ongoing process [which, too, fall under 'transition from a conventional building mindset toward a prefabrication and integral production and assembly mindset':

- During the assembly of the sanitary unit it becomes obvious that the Unica installation engineers are used to take measurements onsite and only then tailor-make the necessary piping etc.. This is not necessary if correct measurements are predetermined and communicated. And the workmen do not have to wait for each other's work to be completed;
- MdR [the building company for the supporting steel structure; which, by the way, does not form an official part of the concept house consortium] has initially included a camber in the steel structure onto which VDM builds the raw building shell. Luckily, VDM realises this in time: Otherwise the structure would have been built incorrectly, and VDM could not have built the building shell. The joists only come to lay straight if the total weight is placed onto them. VDM begins with the loose floor elements which need to be joined before the walls can be placed on top of them;
- VDM calculates with a weight for the sanitary unit of 1500 kg [the target weight during the earlier development and design process], whereas in reality it weights approximately 4000 kg [because of constructive changes but also because it was insufficiently elaborated in terms of dematerialisation];
- The detailing of the connections of the [relatively rigid and heavy] Solarlux façade framing [a new product in the Netherlands] on the VDM shell is realised too late. Which results in a lot of rework and, initially, inadequate joins;
- Good detailing of the cabling channel along the bottom of the inside walls based on the Faay model for the [exterior] wall elements by VDM is missing until very late in the game. Better attunement would have led to a [yet] better i.e. more similar execution of the two;
- With regards to the detailing of the inner wall leaves, the wishes [mainly] concerning flexibility are not considered in time, which causes problems for the installation engineers during the building process;
- As a consequence of less than optimum adjustment of the connection of the baseboard channels in the raw building shell, it is very difficult for Unica to lay cables and ducting through the conduits due to insufficient flexibility.



FIG. 73 Realised Solarlux folding facade

- The electricity channels in the floor are not well thought through. This results in an improvised solution with [relatively expensive] Niko switching material during the realisation phase;
- Faay's inner wall leave [test version] in one wall element of the hallway and the living room is drawn at a very late stage, and not checked against the installation drawing. The wall does not run all the way through to the front door where an important Niko switch must be placed;
- A flexible electricity network in the ceiling does not exist at all. The partner Faay, responsible for this part, does not want it, but Unica does. Ultimately, an inflexible traditional solution is installed;
- The cable ducting through the [outside] façade by VDM for systems and switches by Unica, Renson and Itho is realised in the prefabricated raw building elements with difficulty later. They are not easily accessible in the cempanel and ceramic exterior façade finishing.
- The lavatories are installed onsite rather than at the factory, with the result that this is less accurate;
- Faay uses very long screws when mounting the attachments between the inside wall elements and the raw building floor that might damage the underfloor heating if not carefully monitored. The exact position of the attachment fixtures must be determined ahead of time;
- In spite of fierce attempts by the project team of the chair [directed at Itho management], an integration of the Niko and Itho controls is not accomplished: Niko Home Control and Itho autotemp. The reason is Itho's company strategic point of view; with the result that

the algorithms are not delivered that would allow regulating the control of the heat pump via the Niko home control system as well. Thus, in addition to the Niko display there is a separate display in the Itho room to control the heat pump;

- At the last moment, the choice was made to install Renson ventilation exhaust channels in the individual rooms instead of the [originally planned] single exhaust in the central installation cluster/core;
- As a consequence of too late communication to Unica about the dimensions [and necessary implementation] of converters needed for the PV system and an additional distribution and compression barrel for the roof system, Icopal must adapt these in the limited space of the installation cluster at a very late stage, the initially well designed arrangement of the installation space must be reorganised;
- Unica has detailed and drawn the installation cluster too late. And realises even later that the distributor of the underfloor heating requires much more space than initially estimated. This means that there is no longer enough space for the white goods in the installation cluster. The original plan was to integrate them in the core as well. The layout of the installation cluster is adjusted several times over the course of the building process. The white goods now stand separately in the storage space adjacent to the installation room;
- The last piece of the rain water drainpipe on the front side of the prototype, behind the ceramic façade plating, is not linked sufficiently to a particular stakeholder. Thus, the materials have not been ordered in time to integrate it nicely;
- Icopal ordered too little material from supplier Danfoss for the underfloor heating, or does not handle the available piping and underfloor elements economically: All material is used up during prefabrication, which means that there is no material left for the [particularly important ] underfloor heating in the living room along the Solarlux facade. Thus, a solution must be improvised with separate [residual] material;
- The arrangement of the posts in the façade elements of the raw building by VDM with regards to the suspension points of the Mosa façade, to be realised by Justimax: VDM modifies the posts from what was determined and drawn by the staff of the chair without prior communication, which means that Justimax has to execute the drawings twice;
- One of the subcontractors has not done a good job when drilling the Mosa tiles for the outside façade: Other dowels are used than what is common practice [namely by Fisher]. And there seems to be a problem with the drill, because of which the entire series [complete facade: 120 m<sup>2</sup>] must be done anew. In the first batch, a number of the tiles broke at the suspension points, causing them to fall down;
- The Mosa product is C2C certified: Amongst other things this means that the tiles can be recycled while maintaining a relatively high degree of quality. The rejected first batch of tiles of the prototype are not sent back to Maastricht but rather removed by a Rotterdam waste processor. The failure is mainly caused by the drilling company, not by Mosa itself. It seems as if the ceramic base material does not yet have the desired quality level, or there still is too little responsibility taken for the end of life approach of their products;
- The design of the consoles for the structural sun shading by Renson is completed so late that the consoles cannot be produced in time, and must be assembled after the actual building process is completed [with a separate lifting ramp].

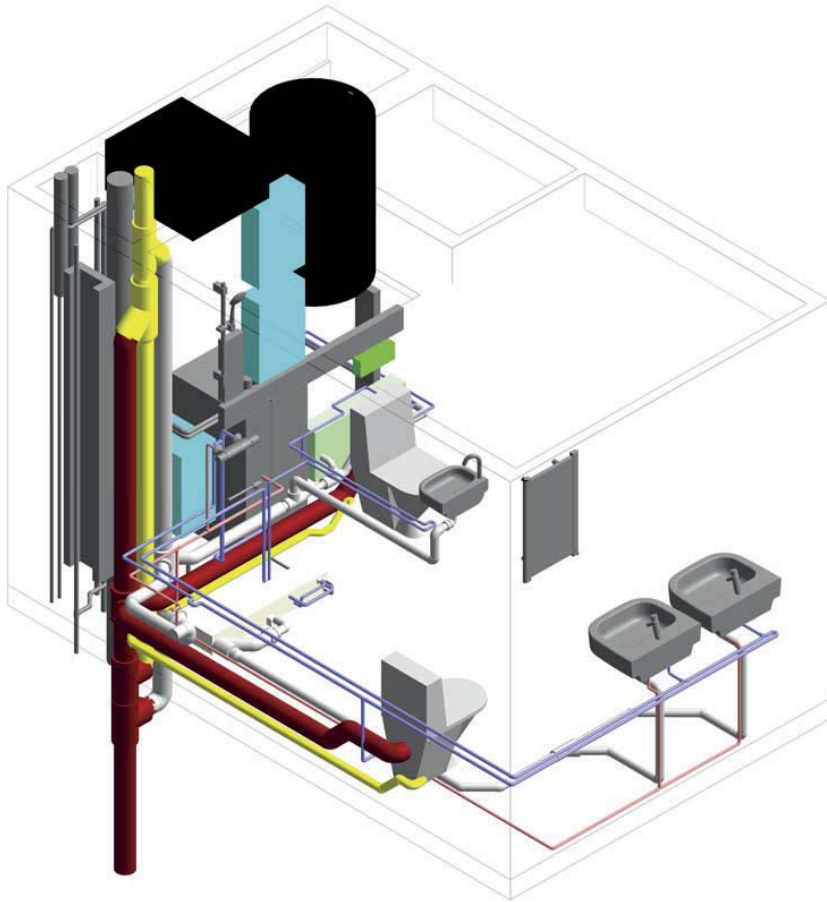


FIG. 74 Sanitary installations 3D BIM (Unica Installatiegroep)

- The architectural detailing of the roof edge is realised according to a design by VDM and Icopal. It therefore does not comply with the drawings. Amongst other things, one immediate consequence is that because VDM has executed the roof edge details differently, Justimax needs to adapt and shorten the perfectly prefabricated and pre-drilled aluminium omega-profiles with a grinder on-site;
- The connections of the Faay walls to the VDM raw shell is insufficiently detailed: PUR must be used after all. Also for the connection to the ceiling. Faay should be able to prevent this;
- Following the desire for smooth wall and ceiling finishes, the seams in the Faay walls and the ceiling must be filled in. However, the seams underneath the glass fibre coating remain visible. There is a general discussion about whether the seams in an industrial building system can remain visible or must be hidden;
- Since the building site and the prototype are so crowded, the workers do not feel the need to remove their garbage during the building process, let alone separate it, or to handle surface finishes carefully [such as the deck on the balcony, for example].

### MISCOMMUNICATION LEADS TO FAILURE COST

Please note that these issues are not listed to discredit the partners and sponsors, but rather to demonstrate that parts of the process are recognisably typical for the building industry. In this sector we speak of failure cost. And here is why: Many of the failure cost stem from miscommunication; they are never caused by one single party alone and therefore difficult to minimise. Thus, there is a lot to learn and a lot to gain. Unfortunately, each building process is different; again and again a lot of time and energy is lost before mutual trust is created, mutually accepted descriptions and drawings are generated, and the engineering work and actual execution can finally begin. The researchers also realise that the coordination and integration must be done even more stringently, with even more discipline and energy. This book is one of the few documents describing an experimental process; and very briefly at that. But even when merely reading about the process, the tenor becomes obvious. The social 'alpha' envelope around the technical 'beta' process demands a lot of attention.





# 06 'DELFT' PROTOTYPE IN CONCEPT HOUSE VILLAGE

Across the river from Rotterdam centre lie the old city harbours. Rotterdam's harbours keep extending westward to accommodate increasingly large ships. An area of 1600 hectare, where a transformation from industrial to residential functionality needs to take place until 2030. The city harbour area has an important strategic position in the ambitious goal of the 'Rotterdam Climate Initiative' in order to cut CO<sub>2</sub> emissions in half by 2025.



FIG. 75 The location of the RDM campus in Rotterdam in the village Heijplaat and white dot for prototype

The RDM campus of the Hogeschool Rotterdam and the Albeda College lies in the middle of the Rotterdam city harbour area, on the terrain of the former Rotterdam Drydock Company [where at first Dutch cruise ships and later submarines were built], and it also houses a number of pioneers looking for ways to fulfil the climate targets of the RCI. It is a space for cross-pollination for education and business without too stringent boundaries, which allows the involved parties to realise their visions for the future in an experimental manner.

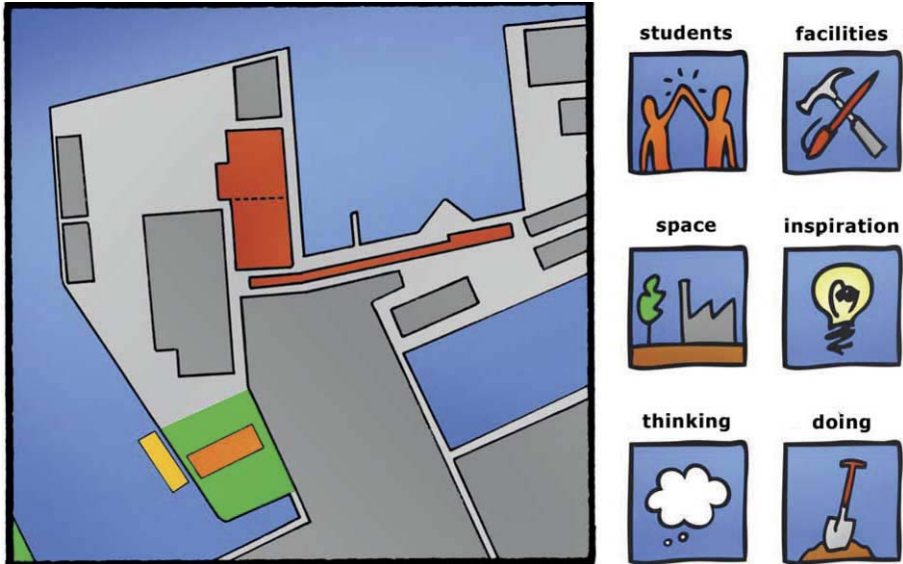


FIG. 76 Floorplan RDM complex

With the project concept house village, Cityports Academy Rotterdam, a collaboration between Hogeschool Rotterdam, TU Delft and Woonbron a. o. in the RDM Campus area focuses on the creative industry ; a hotbed where innovative living concepts, building processes and sustainable products can be developed, tested and demonstrated. Behind the RDM campus lays the former workmen’s village Heijplaat, of which Woonbron demolishes a part to plan new buildings that better suit our times. In this phase of transition, the concept house village facility literally provides Woonbron with the space needed for building experiments. The concept house village is expected to stay for eight years; buildings in the village may stay a maximum of five years. Considering the amount of energy invested in this first prototype of the concept house village it is called the ‘Delft prototype’; also to prevent confusion since more prototypes are to come. It is questionable whether it makes sense to maintain the temporality of the location for future prototype consortia that the village wants to recruit. A semi-permanent or permanent location would draw many more prototype consortium members. Certainly during these times. In 2011, obtaining the necessary building permits for this temporary single prototype has taken up about the same amount of energy as for a 60 apartment large building

complex. The promised flexibility with regards to temporary permits seems to remain a dream in the Rotterdam administration. A warning for future prototypes in the village to use the experiences of the Delft prototype and accomplish the process in half the time, with half the energy and half the money. [Wormack, 1990]. To quickly push temporality through bureaucracy. The project staff of the chair also loses a lot of time with these efforts.

The concept house building system and the idea for the concept house village are developed simultaneously with well established interaction between the two projects. Wim Poelman sets the pace. The Delft prototype is considered the first project, the key project in the development of the concept house village and receives extra support due to the pioneering role it fulfils in the village.

## 06.01 THE DEVELOPMENT OF THE PROTOTYPE DESIGN

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Even before the consortium begins with the development, initiator Mick Eekhout wants to develop a sustainable residential building system based on consecutive prototypes that weave together theory and practice. Business as usual for his own design & build company, where experiments, often preceded by prototypes, are executed successfully and applied around the world. It is normal procedure in the world of designing innovative components. However, in the building industry it is not. In Rotterdam it should be easy. But unfortunately reality is more obstinate; coming at you from all sides. Everybody plays for safety and the protection of their own agenda. It seems that the term experiment must be re-invented.

Following an unsuccessful attempt in 2009 to realise an actual prototype, the discussion is revitalised in October 2010. The building system offers several possibilities. The question is which of these should be implemented to find the proper balance between costs and benefits.

Based on the possibilities, the team at the chair develops four variants of different character and presents them to the plenary meeting:

- Option 1 has small room dimensions [5,4 m] and stands immediately on the ground;
- Option 2 has wide room dimensions [7,5 m] and a more spectacular and striking appearance;
- Option 3 also has wide room dimensions and a cantilever, and explicitly shows the apartment as part of a larger building;
- Option 4 combines most of the options – two different room dimensions, two naves and two storeys, a cantilever and a roof terrace.

A questionnaire filled in by consortium members shows the mutual opinion that the prototype should fulfil the following three main, equally important functions:

- A presentation of progressive building technology to clearly communicate the top performance that the consortium delivers and to draw [inter]national interest;
- A demonstration apartment which offers visitors an impression of the luxurious outer appearance and the comfortable sensation of a new standard in very sustainable apartment building;
- An experiment that the parties involved continue to adapt, and the building and habitation of which delivers insight into the field of building technology, installation technology and user experience.

The design of the prototype needs to find a good balance between the mentioned aspects. However, the function descriptions are not easily compatible. In spite of the expected added cost, there is a mutual decision for design variant 3 of figure 81: A spacious apartment with large outside space and wooden façade cladding, around which a scaffolding construction with textile covering suggests a larger building volume. At that time [August 2010] a request for subsidy is submitted to an energy research program of the Ministry of Economic Affairs [EOS:KTO]. Unfortunately this is rejected one month later because supposedly the project is not sufficiently innovative and commercial. Alas, the centre of gravity lies too much at the university instead of at one of the commercial business partners. Without this subsidy, the budget is too small and the project to build a prototype is put on hold yet again.



FIG. 77 Different designs of the prototype as a solitary unit of the 16-apartment urban villa

The attention shifts toward the two ‘mock-ups’ for the Bouwbeurs 2011. Here, the consortium receives a lot of positive feedback. Immediately following the exhibition, at a plenary meeting the team decides to revive the plan to build a completely functional prototype of a single apartment. The circumstances are positive: At Bouwbeurs, new partners and material sponsors have registered to participate in the prototype building. The RDM Campus promises financial support provided that the prototype can be built in 2011. Woonbron is ready to demolish a number of apartment blocks in Heijplaat so that a building site can be freed up in short term. Via the valorisation centre [in connection with the instigating function that TU Delft has within the Citiports Academy Rotterdam] TU Delft promises to stand guarantee for the budget gap so that a building application can be submitted shortly. Later, the decision to stand guarantee by the valorisation centre seems to have disappeared into thin air. Since the consortium partners are only contractually bound for a little more than one year more [until end of April 2012], it is uncertain whether Mick Eekhout’s dream will come true. A lot of effort is expected from all involved parties in order to accomplish the goal.

The realisation of the prototype is budgeted based on the agreement that the partners do not charge commercial prices. In order to keep costs as low as possible, the partners basically charge material cost only, with the exception of Unica and VDM who in their role as the main contractors for installations and raw building construction must perform a lot more work than the other consortium members. For parts that are not linked to a specific partner, all consortium members actively search for suppliers who are ready to sponsor the project; all expenses are registered and made public to all members so that everybody can review them. The first version of the open budget for the prototype in March 2011 adds up to € 208,000; the budget deficit of the project at that moment is € 88.000.



FIG. 78 Design proposal for the prototype mid 2011 [with two storeys not filled in behind cloth]

Simultaneously with the budget, the consortium also sets up a compact planning process, which allows all partners a good two months for the final detailing and for the last optimisations in the field of sustainable material use. In their naiveté, the researchers of the chair take on the role of architect as well as main contractor. In addition to the complete set of drawings they also work out the architectural detailing, prepare the application for the building permit and various utility connections, and work out the parts that are not linked to any partner such as the foundation and the sub-structure. The goal is to start construction preparations shortly after the summer vacation 2011 on the building site, where the prototype must be assembled and finished within a month starting end of September 2011.

In April 2011, the partners receive a preliminary version of the complete set of drawings on the basis of which each party can create its own final work drawings and can attune their process with those of the other partners. Unica is the only partner who adapts to the process very quickly and has the first drawings completed even before the summer. VDM waits until the very last details are resolved; completing the first drawings only in October 2011 and the work drawings as late as in November 2011. Thus, a number of adjustment problems only become known at a very late stage. Subcontractor Raab Karcher

also leaves their drawings very late, with the result that there are no correct drawings of the sanitary unit available at the beginning of production. The researchers resolve the problem by working on the detailing and production themselves. For many companies who are used to work with firm specifications and drawings, the cyclic manner of thinking and engineering seems inefficient.



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FIG. 79 The two consecutive proposals of the prototype with and without rugby goal (scratched due to cost)

The design and budgeting change in a number of points; due to two new partners, several sponsorship deals and design adjustments the budget comes to 181.000 Euro in May 2011; the total deficit is lowered to only 39.600 Euro. At that stage, the prototype has been reduced by one storey and the apartment complex is symbolised by a 4-storey high steel

arch construction [figure 79]. In a subsequent round of cost saving efforts, the arch of the rugby goal [introduced by Mick Eekhout to replace the storey-high scaffolding to illustrate the urban villa] perishes as well. However, the designers do hold on to placing the prototype at the level of an upper floor: From the inside the view implies being in an apartment of a [multi-storey] apartment house, and from the outside it is not easily associated with a solitary house. In addition, the raised apartment is a spectacular sight, emphasised by the cantilever of the interior balcony and the skewed position with regards to the intersection to underline the temporary character. But also to enable more passive heating with improved orientation and to stand out from the existing buildings that will be demolished shortly. The prototype has the floorplan of a spacious three-room apartment with central entrance; it is developed based on the generic building elements from the concept house element library explained earlier. The floors, facades, roof elements, sanitary unit, inside walls and plug & play connections for water and electricity are realised according to standard detailing. Furthermore, these elements are dry-mounted, and hoisting facilities remain present [hidden from sight]. Thus, everything is eventually usable so that the prototype can be taken apart after 5 years without greater damage.

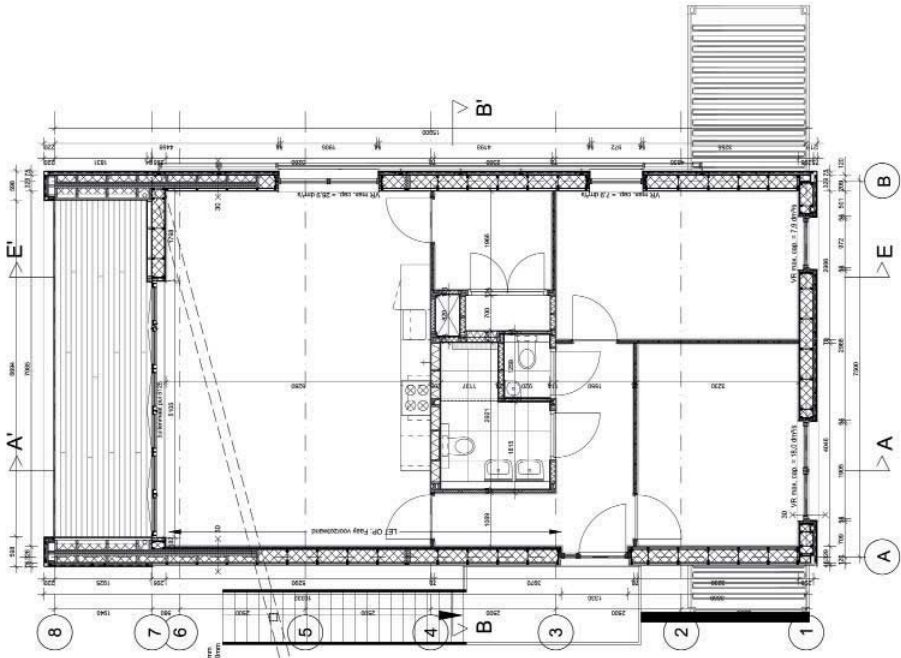


FIG. 80 Floorplan of the upper level of the apartment, with the container placed perpendicularly underneath

In addition to these standard solutions, the design of the prototype includes a series of project specific characteristics: The prototype is carried by a steel structure including a sea container that provides stability and storage space; the living room can be opened

over a width of 5 metres by means of a broad insulated harmonica facade (triple glass and six-fold sealing), realised by Solarlux during the course of the IPC project 'Add-on façade', led by Arjan van Timmeren within the chair. The façade is clad with a system of dry-mounted, C2C certified Mosa façade tiles 1,20 m wide. The south façade is characterised by structural sun shading with wooden louvers. No standard PV panels are mounted on the roof; instead the prefabricated roof cladding by Icopal comprises flexible solar cells that are produced off the reel. The loggia is finished with sustainable Robinia and the platform is also made off sustainable wood with FSC certificate. The balustrades at the loggia for a French balcony are very transparent; executed with recycled balustrade glass by Octatube. A green wall by Greenwave sits on the outside of the loggia. The interior walls and ceilings by Faay have a smooth finish to mask the industrial character of the system and give it a perfect appearance.

After a third new partner joined in 2011 and a subsequent round of cutbacks the project deficit remains at approximately € 20.000. On May 31<sup>st</sup> 2011, the dean of the Faculty of Architecture needs to sign a land agreement with the concept house village facility in order for Woonbron to be able to start demolition in time. The dean refuses to do this if the financial risk lies with the faculty alone. Therefore, all partners are asked for a final time to lower their cost by an extra 15% to sponsor the project, upon which the dean finally signs in June 30<sup>th</sup> 2011. An advance building permit is applied for in June 2011 by means of a concept application; it is agreed upon with the city of Rotterdam that an abbreviated process can be started before the final authorisation due to the temporary and the experimental nature of the subject of application. Ultimately, the building permit is issued with a seven-week delay due to questions about fire resistance requirements and the obvious contamination of the ground. To eliminate the risks of the ground contamination, Woonbron needs to add a 1 metre thick layer of clean ground; which is done hastily. In addition, a load-bearing capacity measurement shows that the ground at Heijlstraat is so weak that 27 metre long piles must be inserted in the ground; meaning that the original foundation plan with a dismountable 'foundation on steel' (simple and quickly dismountable concrete slabs on a bed of sand) must be changed. Assembly planning shifts from end of September to mid November and finally to the beginning of December 2011. Delivery is still anticipated for the end of 2011 as a requirement of the subsidy 'Pieken in de delta'. The set of drawings for the prototype are done in 3D CAD (Revit) as well as in 2D CAD (AutoCAD). Lodewijk van Es and M&R Advies work together with the researchers to generate a parametric library of elements of all integrated building parts, with which architects can design future concept house buildings. For the building permit, CBB Arnhem creates a non-parametric Revit model; but due to difficulties in obtaining information and time pressure the building permit documents are ultimately done based on the researchers' AutoCAD model. The Revit drawing can, however, still be used to optimise certain parts. Unica is the only main partner working with Revit. The drawings for the sanitary unit are done in Revit, the other ducting in the apartment must be drawn with AutoCAD. It remains in suspense whether the prototype can actually be realised or whether the team of the chair will throw in the towel considering the complexity of the process, the capriciousness of many involved who seemingly have their backs turned toward the project. There are times when no one really expects the prototype to come to reality.





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FIG. 81 Prototype in mid 2012: Viewed from the ground level and the balcony with green façade



# 07 ACTUAL PRODUCTION AND ASSEMBLY

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Prefabrication of the prototype building elements is mainly done in two separate production halls: At VDM in Friesland (Northern Netherlands) and in the name of Raab Karcher at Uniline in Weeze (Germany). VDM doubts until the last moment that the information necessary to start production is complete. But, under strong pressure from Mick Eekhout, it is decided to not delay building, so that it can be completed in 2011 and delivery can take place in December 2011 in accordance with the agreement with the concept house village.



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FIG. 82 Prefabrication at VDM

The factory in Germany has problems as well. Uniline fights issues such as understaffing and dissatisfied personnel. And on top of it all the director is unavailable for a long time due to illness. The design of the concept house sanitary unit is very different from other projects that are produced in Weeze, and the staff finds it difficult to read the drawings. And several mistakes need to be rectified that result from bad attunement with Unica and

Faay. In order to speed up planning, Jaap van Kemenade and Rutger Wirtz themselves are obliged to start production in the beginning of November and to see it through to the end. Materials are ordered too late, and not everything is always available. Improving is the name of the game.



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FIG. 83 Activities in the Uniline factory in Weeze (Germany) for the sanitary unit

On the building site, the earth to cover the contaminated ground is filled in during the second week of November. One week later, the researchers, now in the role of main contractor, move into an apartment close to the building site which is also used as a construction shed by the demolition crew. Demolition company Oranje as one of the sponsors provides a coffee machine and fencing. These little acts of friendliness boost the moral and help to compensate the inexplicabilities of the financial challenges.

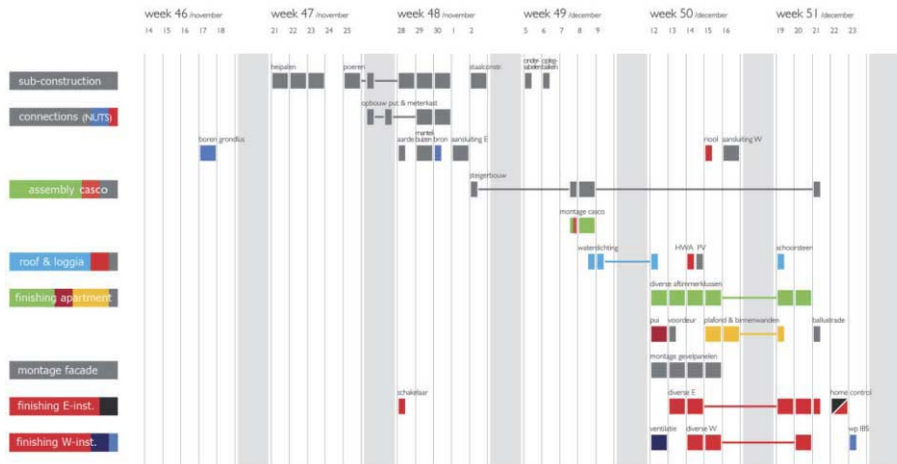


FIG. 84 Planning the activities onsite

The building permit is finally issued in the third week of November 2011, the lot is surveyed and measured, and the position of the piles is specified. Everyone is still a little tensed to see whether the trailer with the 27 metre long piles can get through the tight corners in Heijlplaat village. And the team worries that the neighbours might complain about the pile drilling work. However, the process runs without interruption. Under the watch of several partners and members of the RDM Campus project team the first pile disappears into the ground. Three days later, all 10 piles are driven into the ground and concrete foundation supports are poured in four days, also according to traditional methods.



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FIG. 85 Driving in the first pile (left), and laying the foundation in the conventional manner

In the meantime, the researchers at the chair build a pit with piping shaft and meter box in which electricity is connected even before building begins and water is connected during the building process. The steel structure is assembled on Friday, December 2<sup>nd</sup> 2011.

According to plan, the prototype is to be assembled, connected and finished within one week, starting Monday December 5<sup>th</sup> 2011. Unfortunately, the weather forecast before the weekend predicts rain and strong winds for the beginning of the week. Up to 8 Beaufort. Eekhout wants to continue, but VDM makes the final decision since they are responsible. Upon consideration with VDM it is decided to delay assembly for a few days. This decision means that all dates for installation and finishing agreed with the other partners need to be postponed, which puts several of them into difficulties due their own busy end-of-year schedule.

The weather on December 5<sup>th</sup> turns out better than predicted and does not hinder the work on the prototype. The weather forecast for the rest of the week remains about the same: the chance of rain will only decrease after one week and the strong winds are expected to stay as well. The only thing that can be said for sure is that the weather at the end of the year is always a risk factor for a building project. Based on the unreliability of weather

forecasting and the plan [and contractual requirement] to complete the prototype in 2011, it is decided not to delay the assembly any longer but to prepare for a start on Wednesday December 7<sup>th</sup> 2011.

However, on the morning of December 7<sup>th</sup> the weather is so bad that VDM considers sending back all transportation vehicles with their cargo still onboard. Ultimately they don't follow through with this plan, and the floors and the sanitary unit can be hoisted in during the afternoon in spite of strong winds. The raw building shell is assembled on Thursday and made watertight the same evening.



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FIG. 86 Several assembly steps during the first week of building with heavy rain and storm (between 6 and 8 Bft)

Following the orderly work done by (for the most part) just one partner, there are on average 17 people from 6 different parties present at the building site during the week starting Monday December 12<sup>th</sup>; half of whom work inside the prototype. In order to prove that the majority of the work is done in prefabrication – keeping the work onsite manageable – the leaders of the project adhere to stringent planning. It now is a typical building process.

Every day, a number of consecutive tasks need to be executed by different partners; which requires complex coordination. The usable space inside is limited due to materials being stacked for later use and because the drains and channelling between the floors are not closed yet. Fortunately, the workmen at the site understand the situation, but it is a challenge for everybody to complete the work in time. In short, it is the typical image of an average building site where many things must be done in a very short timeframe by people from different companies. The benefit of industrialisation is not yet obvious. Mick Eekhout keeps declaring that an industrial process must also be noticeably short. Even though this is an experiment, all eyes lie on the possible advantages of industrialisation. Thus it becomes a sport to keep everything closely to plan, and to realise it within the given framework.

From December 19<sup>th</sup> onward the construction site becomes a little calmer and all jobs get tidied up. On Thursday December 22<sup>nd</sup> the RDM Campus Christmas party is held on the prototype. The construction of the prototype is completed by the deadline, and aside from enormous delays in the beginning by Unica, VDM and the staff of the chair itself, the project is realised almost within budget. However, everyone appreciates the short winter break, not least Jaap van Kemenade and Rutger Wirtz.



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FIG. 87 The prototype at the time of the traditional roofing ceremony on December 22<sup>nd</sup> 2011

The apartment still needs to be finished and furnished and the garden needs to be established before the research program can begin. Again, the researchers must find sponsors; now to furnish the apartment and the ground level. Unfortunately this creates a major delay for the consortium: The official opening of the prototype is finally planned for and realised on October 5<sup>th</sup> 2012.





# 08 EVALUATION AND CONCLUSION

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Much has been written about the development process and the realisation of the concept house Delft prototype in this report. This publication aims at passing on the lessons learned to following generations of researchers, to the partners and sponsors and, essentially, to the SME of the building supply industry; for anyone undertaking a similar project. We realise that a similar history could be written for every remarkable building project, but that usually there is no time to do it. However, the process gives colour to our profession and makes building exciting. We also realise that in some cases the openness of this report emphasises the weak points of the process. We have to accept this. We made many mistakes and had to live with many unavoidable facts. And finally we ask ourselves: "Was it worth it? Was the entire process worth all the financial sacrifices, all the energy spent to sail against the wind?" As sailors we don't mind the wind in our face but it does not make life easier. We do want to record the entire process.

What have we achieved? That a material prototype of an apartment design has been built based on a number of starting points which seemed new in the beginning and gradually became very logical and normal during the course of the process. That it therefore is not impossible to build such a prototype. To realise a building that is industrially fabricated, has an extremely small ecological footprint, is energy-positive in use and can be built to medium height. It invites the following steps and iterations: Living, measuring, evaluating and learning, and improving the prototype on one hand, possibly with material variations. And on the other hand, advancing the process by later building a concept house urban villa and determining the scale-related effects of a small complex of apartments and the effects on urban design and area development. The preparations related to various attempts at urban villas show that it is extremely difficult to build a subsequent pilot project that is 'market conform plus'. Thus, the new obstacles on the way to realisation are already in place. However, we will keep them for the next adventure. We have listed the afterthoughts of this process as follows.

- Completing the prototype has been a step in the direction of a more sustainable and integrally cooperating building practice;
- Many challenges remain for commercial companies, universities and educational facilities; true collaboration and ambitious experiments are needed to come to positive results. It is difficult to get companies to participate in futuristic developments which are indeed formulated as part of the concept house goals. In order to achieve practical results when working together with commercial businesses you have to have a golden touch to build a complete apartment. This is a task that the parties are used to and that they have worked on with us with conviction and without exception;
- There is a mismatch between the level of ambition at the chair and the vigour of the innovation teams at the partner companies;
- In order to approach the building task in a truly integral and sustainable manner, many more participants are needed on a project basis to accomplish the work in the various disciplines. The reason is obvious: A research project requires a lot of attention and effort from the partners which takes away capacities from their running projects and therefore revenue and gains. The end result might be more innovative and integrated if the different companies clearly knew ahead of time how much work must be put into the project. All parties are unsure of the scope of the task. The same is true for the chair. Considering the fact that the supplying companies are also the project partners, this is a difficult political situation;
- From the outset (2008), the chair has not presented a strong and well founded vision of the system to be developed. Project leaders have come and gone, which leaves the participating companies with an impression of instability. Mick Eekhout does not continuously accompany the project but rather gives impulses now and then;
- External approval and finances strongly influence the possibilities. There is no way to keep an experimental process that is subject to continuously changing circumstances strictly according to plan. Experimenting and building cannot be friends;
- Often, very diverse practical and theoretical knowledge is needed to develop ground-breaking innovation. An ideal challenge for a collaboration between the chair and SME Building;
- In spite of fierce attempts by the researchers it proves very difficult to mobilise the knowledge and insight available in other areas of the university, and to link them to real commercial jobs. Partly, this is a financial question; but it is also due to the fact that the knowledge and expertise of a lot of university personnel in this field is not sufficiently up to date. Commercial life often runs ahead of the university;
- The project has gotten off the ground thanks to courage and persistence, characteristics typical for entrepreneurs but necessarily for the current mood at the Faculty of Architecture. In many cases, solutions to organisational and financial challenges have only been found during the process. If Mick Eekhout and the staff of the chair had not been as stubborn and had not behaved as 'product champions' or had not continued in spite of disappointments and resistance, the project would not have come to life;
- If more collaboration liaisons with other chairs are formed, the project can actually disintegrate due to its complexity and lack of leadership;

- Politics and diplomacy are always part of the game with the development and eventual realisation of such a project. Not just the product but also the context in which it must be realised and all the people who influence it. In order to progress it makes sense to look for likeminded people and keep close contact with them. The concept house village could be a platform to do this. But so are other platforms, such as ‘Boosting’ as well as ‘Barba House’.

## 08.02 THE COLLABORATION BETWEEN THE STAFF MEMBERS OF THE CHAIR AND THE PARTNERS

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- After the engineering process, Unica realises that the piping shaft which had not yet been detailed is very difficult to realise [i.e. to produce and assemble] due to the large number of different ducts and branching within an extremely small space;
- Uniline is not able to deliver high performance because the production involves different and more complex components than what the company is used to. In addition, the appropriate employees have too little time and make too little effort. This is resolved by the two chair staff members themselves who spend long work hours onsite for one week. This does teach them a lot about the working methods and appropriate tools though, and provides them with insight that comes in very handy at a later stage. But a well-meaning academic researcher is still no real builder;
- Together with the researchers, Unica and Uniline realise that ducting and construction intersect in a way that weakens the construction to an unacceptable degree. Thus, after engineering, the construction of the sanitary unit requires a significant redesign with regards to the production of the final prototype. Which in turn results in a considerable increase in material and weight;
- VDM proves to be reliable when it comes to achieving results within a given timeframe, even if with limited regard to aesthetic detailing and finishing. The company needs all aspects to be worked out completely before they start working. This results from lessons learned during the scope of the project;
- And it becomes apparent that not all parts of the project are covered by a designated partner; and that for some of these parts one partner thinks another partner takes care of them. Setting specific boundaries, allocating a specific party as responsible for a certain aspect and continuous communication about the smallest details is not done or not clearly enough communicated. This relates to an omission by the coordinating main contractor in the building team;
- Due to financial limitations this is done by the two staff members of the chair with: drawings for the mock-ups; work preparation and the production of the mock-up sanitary unit construction; adaptation and implementation of floor and wall ducting profiles, wall finishing, a mirror for a view of the roof in the mock-up facade; support for implementation of insulation materials and acrylic glass peepholes, electric connections; transportation and installation at exhibition, subsequent storage;

- It is obvious that with regards to the setup of the process, personnel planning and budgeting as well as execution, the function of the main contractor who simultaneously coordinates and integrates, is vacant. It needs to be filled without additional cost, from naiveté concerning the course of the process and without the knowledge that contractors usually have;
- The time and energy lag leads to the researchers having to conduct more execution work, and to leaving recording and reporting over to Mick Eekhout and Arjan van Timmeren.

## 08.03 DURING EXECUTION:

- The researchers leading the building process know the drawings to the core. This insight helps to prevent situations where different assembly teams hinder each other with their fast work. One example of where this goes wrong, however, is the duct in the south façade leading to the motors of the sun shading system: the subframe of the façade is mounted before the cables are laid which results in one of the ducts being blocked;
- The planning is very compact but therefore also very vulnerable: In many cases, time shifts in the process lead to extra work (unloading the trailers on the street, temporary storage of the Faay products, temporary locking of the prototype on the weekends, ...);
- The presence of a self-dependent work team (staff members and students of the chair, Hogeschool Rotterdam and the Albeda College) clearly proves its added value for projects with such tight planning and such a high number of tasks. Essentially, this relates to the coordination on the construction site and the free hands that every contractor needs;
- And a good working area makes work much easier. In the haste no one has or takes a lot of time to clean up or setup shop properly. The researchers take on these tasks during the building process as well. For future projects it makes sense to have the work area cleaned up every night. And designated work areas during the building process should be part of the design; as should be temporary storage space for building materials that are needed later in the building process;
- Building and finishing is done very quickly. But the original plan was one, not two weeks. The possibilities to optimise the schedule are mainly better work preparation and more complete prefabrication of components such as the sanitary unit, the floor and wall ducting profiles. All this relates to optimising execution; thus it is only indirectly related to the research goal of the chair. But an aspect that should be considered in the subsequent pilot project;
- The building system must be devised and evaluated in even greater detail. Several issues become obvious during the finishing process, some of which the workmen solve in a traditional manner with [very undesirable] PUR and putty;
- Many building details involve products from different suppliers. For the researchers it is important to stay informed about the materials used and work sequences to be able to work out the optimum form. This relates mainly to architectural design. For example the profiles of the window frames or roof edge detailing. But it is also true for building technical issues such as the distribution of posts in the walls, which determines how the

facade tiles are mounted and where the electricity ducts are placed. Often, this kind of information is only determined at a very late stage, resulting in stress, extra work and sometimes suboptimal results;

- And even if information is easily shared, it can still be difficult to achieve good results because the project leaders themselves do not always have sufficiently detailed information about their own production techniques. To prevent this, people working on the execution of the project must be included in the design process;
- The intended integration of building technical aspects has been accomplished rather well. Unfortunately the integration of installation components from different partners was not as successful: The heating can not yet be controlled with the central control panel, and the functions of a number of components overlap in the installation cluster;
- One difficult aspect of the concept to work with sponsors is that each company works according to their own methods, and prefers certain products or even works with a fixed product assortment. This increases the reality level of the development exercise but it does not always increase the innovative nature of the project;
- When optimising the system design, attention must be paid to the branching points of the electricity network and tool making in the floor, walls and ceilings. Coordination and integration of the installation components as part of the architectural components have high priority for a possible pilot project.

## 08.04 CONCLUSION

- The prototype has actually been built, which shows that mutual experimentation and innovation between the chair and SME Building are indeed possible;
- Innovating and experimenting in many areas at the same time should best not be stuffed into one single project with a fixed deadline. Experimenting and building should be separated, or at least be conducted consecutively;
- Each new building team of individual members needs time to get to know each other and ‘matching time’ to trust each other and learn to think alike;
- The democratic nature of unrelated and independent parties working together requires a self chosen hierarchy with a budgeted lead for the execution, for example a subcontractor with the appropriate mandate;
- The main problem with many components is that the principle is not fully developed before the application is decided on, but that principle development and application choices intertwine. The books on methodology by Eekhout clearly differentiate between the development process of standard products, system products and special products. In this project, we are dealing with system products typically developed in two design rounds: first designed and developed as a system, and only thereafter designed and developed as an application;
- The relatively small scale of the prototype in combination with the large number of diverse innovations, the democratic hierarchy of independent partners and sponsors, and the

lack of discipline for research and development at the SME companies lead to a – very changeable – process, which is difficult to oversee even by the chair;

- And still, the experiment is worth the effort and deserves to be published in this scientific report, not to repeatedly dwell on the sore points of the process but to learn about the nature of such a process internally and externally before delving into a similar adventure;
- A future period of a concept house urban villa merits a stricter leadership, not only to be able to better control the partly experimental process, but also because of the financial concerns involved. Even better would be to conduct experimental engineering and possibly building prototypes before the actual building process; and only to start building when all components are developed to maturity;
- Only young, stubborn and driven engineers with certain building experience, but not yet corrupted by typical building discipline fit into development projects of this sort – projects with an experimental prototype as the final result;
- With this project, the chair demonstrates that innovation in the building industry with a platform of SME partners is possible. Together with 9 other chair holders from 3TU. Bouw [all busy in the field of building product development], the chair is open to stimulate innovation with SME;
- Product development in the building sector should best happen in an incremental manner: step by step. Small improvements, in short succession, so that progression will eventually take place;
- This experiment is a big step for the co-makers, but just a small one toward the mandated energy-neutral residential building in 2020. The possible future pilot project of the urban villa is the next step toward this goal;
- In spite of strong headwinds it was an educational process which provides insight into the building industry and how an experimental process can be set up better;
- The chair has pursued its ambition and has built the prototype. Mick Eekhout is determined to continue until an urban villa is realised following the same principles. Until approximately 2015, Mick Eekhout's retirement.

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# SOCIETAL / SOCIAL / CULTURAL / SCIENTIFIC CONTEXT

## SOCIETAL/SOCIO-CULTURAL CONTEXT

The essence of sustainability for future building tasks, the basis for the concept house: The environment is the accumulation of requirements for life. Today, buildings play an increasingly important part in this. As a designer, you can loath or embrace this fact. The 'accumulation of requirements for life' is characterised by the fact that it actually changes continuously or that it is subject of continuous transformation.

A built environment that is based on sustainability and thus not only on 'durability' must be able to follow this process of 'continuous transformation'. The process of growing and possibly shrinking, the process of using and the accompanying changes must serve as the basis for every plan, as if it was a living being with its own metabolism. Continuing transformation is the only momentum for durability in the sense of sustainability, which in turn is an important component of quality of life.

In our opinion sustainability-conscious architects and urban planners build in a way in which human interference with nature adapts to the inherent cycle of nature as much as possible. This means withdrawing as few raw materials and fossil energy resources as possible from nature and, in addition, to add as little permanent waste to that same nature. Closing cycles and reusing waste, waste heat and waste water are the most important criteria.

Besides the much talked about and positively as well as negatively regarded globalisation there is an increasing emphasis on the necessity to be able to accommodate changes. Current societal processes that play a role in this context:

- Increasing emancipation, ageing, multi culturality and individualisation of society;
- Proceeding scale differentiation, administrative decentralisation, internationalisation and globalisation;

- Continued transformation, economic-technological renewal and modified tasks in the public sector.

The increasing emancipation of individuals and groups as well as general individualisation have an influence on people's needs, while an increase in scale and internationalisation are important trends that change our orientation. Over the last decades a large part of environment-oriented developments are coined by an upcoming awareness that demands the credo "Think global, act local" to be put at the basis of all solutions. But on the other hand, this is precisely the problem: To create awareness amongst today's society. The importance of sustainable use and the relationship between one's own actions and global effects on the environment, be it in the short or the long term, is difficult to see or understand for many. In this context it is essential to resolve and explain advanced sustainability aspects of our living situation, particularly as they relate to the target group of starters and the elderly i.e. care-oriented apartments.

Against this background it becomes more and more necessary to inform people about the consequences of their own actions. In time, this will happen before acting, and thereby avoid negative consequences, but it can also happen after acting [provided that the consequences are monitored and are restricted to the initiator]. Often this leads to an appeal to provide insight into the actions on a level that is closer to the people. And thus it is on these lower levels, close to the end user, that the best and most extensive sustainable and/or energy-saving or even energy-generating concepts are realised. In itself, this is logical: After all, in this case user and owner often are one and the same, resulting in the fact that incorrect actions are immediately experienced by the owner himself, which leads to either changing one's behaviour or finding other [sustainable] solutions. But it also results from the fact that the task of building apartments in a very sustainable manner still requires more space [and investment]. Thus, the need to conduct research about functionality and the way these users handle the new techniques and systems necessary to achieve the sustainability targets.

The true transition or [building] task toward sustainability actually lies in a different area: That of stacked apartments, a compact [existing] city. Apartments with limited space for ducting and installations but also for [relatively] limited budgets. And it is here where it gets a little more difficult [in a technical but also a social sense] to close the cycles while maintaining constant comfort and still trying to offer optimum flexibility.

'Cradle to cradle' [2002], a philosophy introduced by Michael Braungart and William McDonough, provides an interesting guideline. Cradle to cradle or C2C assumes that sustainability and growth can strengthen each other. Sustainability is not a limitation or threat but an opportunity. The development of the first Delft prototype followed this guideline as much as possible but it was not considered mandatory for every single part. The latter way of thinking is necessary if certified building components are not available and also in connection with the involved industry partners who, in some cases, work according to different guidelines for scientific evaluation of the materials and systems used by them with regards to comprehensive sustainability and health. It is becoming increasingly important to change the current tendency of the previously mentioned

lifetime becoming shorter and shorter [lifetime related to a particular function]. Because you can make a building or an environment as sustainable as you want; if they only last for twenty years this is much less sustainable than a building or environment that is not considered sustainable in the typical sense but that does last and function for 50 or even 100 years [and thus is 'durable']. Hence the growing importance of 'being able to react', or even better to be able to anticipate changes in buildings or the environment proactively [Van Timmeren, 2006]. In what ever way we look at this; based on a single day [different solar angle and solar radiation, wind direction] or based on a lifetime [accommodating new functions, new user etc.], sustainability is closely connected with the manner in which buildings can react to changing circumstances; through usage or 'ambient factors' such as climate changes, for example increasing rainfall, increasing prices for raw materials and the demand for green energy sources that form the concrete translation from world problematic to the occupational field of architects, urban planners and engineers.

'Green' building projects from the last few years show two ecological topics that keep coming back: Efficiency improvement of [existing] systems and the integration of natural and artificial environmental technologies in architecture. For the latter, the focus is shifting toward integration of sustainable measures in the building envelope and toward intelligent installation systems that control essential 'flows' [energy, water, waste/material].

Besides energy, water, materials and green, there is one more pillar in the sustainability framework: social processes. It is necessary to break through the deadlock of the control and management [and comprehension] of the essential infrastructures: a central, minimal 'back-up infrastructure' with privately controlled [semi-autarkic], user friendly technologies and sub-networks is a much better solution than the current, mostly impersonal central techniques and infrastructure. The goal of such an alternative approach will be robust patterns with a morphological resistance as a requirement to be able to build with a diversity of collective and private clients who are able to persist.

'Surplus' and 'flexibility' are important means to allow for simultaneous development and transformation; essential sustainability aspects over a long period of time. On a building and property level to provide users with the space to adjust their buildings and/or outdoor areas to their current life and development phase; on the level of public spaces as reservation for future facilities and for possible phasing during realisation. The guideline involves the use of gentle transitions and the integration of space for 'bottom-up' processes of informal self management and participative building.

Hereby the 'roadmap' includes employing it strategically if we are talking about new building, as an icon and boost for renewal and as a catalyst of social and economic renewal, of emancipation and value creation. Building technology and material consumption shall decrease to a post-war adage of minimum material and maximum functionality, while handling fossil fuels with care. Preferably based on cyclic approaches such as Cradle to Cradle [Braungart & McDonough, 2002] and Regenerative Design [Tillman Lyle, 1994]. And at the same time, land use is intensified. High-rise building, vertically adding onto existing buildings and deepening the infrastructure and parking facilities are all measures that will be

employed more and more often [Bosch et al., 2010]. Simultaneously, we proactively address the contamination issue, for example caused by automobility, by introducing intelligent couplings (interfaces), such as 'vehicle to grid', whereby energy from electric cars is tapped by buildings and vice versa [Beella et al., 2010]. Hereby, correct control of the storage behaviour of cars shall balance out fluctuations in the electricity network, and the serial storage capacity of vehicles themselves can be used as a buffer for peak moments. In this context it is also important to view the concept house as part of the development toward larger scale projects. A recent study by Planbureau voor de Leefomgeving [2012] (planning office for the environment) showed that a combination of building and area related rules are the most efficient manner to limit CO<sub>2</sub> emissions from the built environment. It results in greater CO<sub>2</sub> reduction than employing only building related measures such as insulation or efficiency improvements of heating installations, or only area related measures such as using residual heat, geothermal energy or heat and cold storage.

Applying all profitable building and area measures prevents 15 to 30% of the CO<sub>2</sub> emissions derived from the built environment by 2050. The size of the percentage depends on two factors: The energy price and the cost invested in energy savings measures. It is questionable whether large and infrastructural investments to advance energy transition actually matter. Energy is on a level too low to efficiently control it. Therefore, comparable households, next to each other in almost identical apartments can consume very different amounts of energy. Maarten Hajer (director at Planbureau van de Leefomgeving): "I expect more from intelligent energy metres that let the habitants influence their own behaviour and consumption. Considering the rising energy prices, users will need these more. In addition, my opinion is that it is not so much about separate intervention but rather a combination of logical and appealing modifications that automatically change behaviour and energy consumption, use cleaner technologies and improve the quality of life. I am thinking of selectively condensing urban areas, stimulating the use of bicycles as is done in Copenhagen, and promoting electric cars in the city. With selectively condensing I mean to intensify those areas in a city that truly offer the potential to make a difference. For example, within an ideal bicycle distance, a radius of 8 kilometres around the centre". [Dubbelling, 2012].

## SCIENTIFIC CONTEXT

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Attention to materials, water and energy saving by reducing the demand, improving efficiency and using renewable resources has always been self-evident for the (environmental) research tradition [Brezet, 1994]. Since the Nineteen Eighties, much research has been done regarding the influence of the environment on our living together and mainly as it concerns the built (living) environment. A large part of research is restricted to partial aspects whereas the most important factor for the future of our living together is that we

are dealing with an integral issue. It quickly becomes clear that the real solution can only come from an integral approach.

Research projects about environment related energy, water and waste (material) flows generally still hold on to the existing compartmentalised subjects. Many well-intended initiatives become stuck in thematic and effect-oriented solutions without achieving a certain degree of integration or added value of the environmental measures. Talking about specialisation legitimates scientific and policy-related compartmentation. The different 'specialists' then maintain the sectoral mindset.

The consequence of which is a lack of connectivity, i.e. interweaving of different scale levels and (chiefly) sub-techniques with each other; victimising user friendliness and therefore the user directly (comfort, health/wellbeing, etc.) and indirectly (cost, dependency, 'resilience of the system', etc.). This 'old school' compartmentation seems to dwindle. However, 'new' compartmentation arises [Meyer, 2003], topics in isolated circuits and institutions take on a life of their own, each with its own network of experts and facilities; resulting in inevitable confusion and fragmentation in the public sector.

As part of the developments around the Delft prototype and comparable running concept house projects in the concept house village in Rotterdam, such as Active Reuse House, HOTT House, Passive House, Maskerade, Wijk van Morgen, the goal is to break through such compartmentation and to investigate the abundance of solutions.

Meanwhile, quite a number of front runners have undertaken to develop (and sometimes realise) energy-neutral pilot projects. The pitfall for innovative building projects is that they are entirely oriented toward technical masterpieces in the field of energy saving, and hereby tend to forget that some needs to be able to live in these projects comfortably. And that such apartments need, of course, to be affordable. There are too few example projects that demonstrate how an energy-neutral apartment can create a healthy and comfortable indoor environment at acceptable monthly cost. If we did not have to consider the user, we could indeed create much better energetic designs. However, if we do not do it for the user, we do not need to do it at all!

Thus, it is all about finding the balance between energy savings and the needs of the user. This research emphasises energy savings in combination with a healthy and comfortable indoor climate and acceptable monthly cost. A good technical solution that is too expensive makes little sense for the user.

Many energy-neutral front runner projects are based on energy neutrality on the building level. The user's consumption is not factored in. And it is indeed a difficult aspect since every user has his/her own pattern of behaviour. But it is important for energy-neutral living to know what the influence of this user behaviour is. That is one of the reasons for the explicit decision to have different sorts of people living in the concept house Delft prototype for a certain amount of time, and to measure and evaluate various aspects during these phases of habitation. Another aspect in this context is subsequent research in the risk of

the so-called 'valley of death'. This term describes the risk of failure if a prototype does not achieve general market acceptance. If a prototype is not positioned well in the market or if insufficient information is available on how to actually use the prototype, then it will be very quiet around the concept and the product will not find any takers. In the building industry, the opinion prevails that pilot projects and programs are executed only once. Often, a final report is written that shares part of the experience, but then it usually becomes quiet. It is difficult for others to develop a follow-up prototype because pieces of information are missing. And it is very difficult for the market to reproduce this building concept.

Part of the problem is caused by the following: Since innovative building concepts use different ways to express the goal and different methods to judge the results, a comparison is almost impossible. The problem is twofold. The decision makers of the initiative phase of a building project do not know when and why they can apply a specific building concept. On the other hand, the front runner cannot clearly position the building concept in between all the other concepts on the market; resulting in the risk of 'valley of death'.

That is also one of the reasons why the concept house Delft prototype is to be followed up by an urban villa consisting of 12 apartments in Winterswijk. And to be accurately monitored and compared together with the named projects that are part of a TKI process [top sectors policy innovation, sub-part energy in the built environment]. Since these front runner projects, amongst them the prototype, often consist of innovative solutions, they are not considered in most sustainability standards. The reason being that most sustainability standards use a scoring system for measures instead of basing them on performance. Therefore, within the framework of this project, research is done to identify in how far applying certain measures in an evaluation system results in insufficient opportunity to prove the particular impact. Furthermore, the performances that are indeed considered in sustainability standards are generally only calculated. But the essential issue is, of course, the actual delivered performance. This is the basis for an appropriate comparison of the focus and the impact of an innovative building concept.

The second element that can draw a prototype project toward the valley of death is that the experiences of a building concept are usually insufficiently recorded. This is true for aspects concerning the design and building process as well as for technical solutions. This report hopes to make a contribution to remedy this. In addition, international comparisons as part of the InterREG SUSlab project (North-western Europe) and the formulated TKI research.

Hereby, the lack of a general theory of sustainability is indeed a problem. Namely the role of the building sector and the development of the built environment: The connection between local and global sustainability is characterised by insecurity and ignorance. In the traditionally conventional building sector, developments all too often follow paradigms, which leads to a development with a fixed end point as alleged 'ne plus ultra' [Timmeren, 2006]. And this can slow down attempts to pursue better alternatives. Explicating the underlying societal needs and finding instruments that facilitate the interconnection between the development and building process and the spatial development and related infrastructure with the changed societal goals, and a different way of handling 'public issues' such as



energy, water and possibly even materials and nutrients. One of the problems is that environmental and economic issues are fundamentally different in nature. Environmental problems are often diffuse. The problems are distributed across a larger area or averted to the future. Economic issues on the other hand are more concentrated. This is the case, for example, with [utility] facilities that are considered a 'common [necessary] good', such as energy supply. Through market-listed privatisation, assets go to certain actors who run very little risk [of investment] with regards to the cost of the project. Specific sectoral demands can be very different from general economic demands. The one-sided representation of interests can slow down renewal. New ideas that do not connect well with today's needs will not be taken seriously as quickly.

However, the situation is improving; not least because of the privatisation that has started in several sectors. Dictated by market demands [competition], private organisations or enterprises are actively 'redesigning'; adapting their interests and needs in a more environmentally friendly direction. The necessary phase of 'rethinking', providing for further integration of future economic and present-time environmental interests is still beyond the mindset of these parties. For the present, this remains to be the obligation of the authorities and science.

Within this context, the concept house is a first step, an integral 'redesign' of state-of-the-art techniques and materials/components for a targeted building project.



# THE INTENDED LABORATORY WORK

During the period from October 5<sup>th</sup> 2012 (official opening) and the contractually agreed upon date of dismantling on 30<sup>th</sup> of November 2015, the concept house Delft prototype will be used for research and development, following two directions:

- From the Faculty of Industrial Design Engineering for research within the framework of the Sustainable Labs North West Europe (SUSLab NWE) under leadership of Professor Dr. ir. David Keyson;
- From the Faculty of Architecture for research and development within the framework of the prototypes under leadership of Professor Dr. ir. Mick Eekhout; developing and creating prototypes in the Bucky Lab and related activities;
- From the Faculty of Architecture for sustainability related development and research under leadership of Professor Dr. ir. Arjan van Timmeren; mainly measuring and evaluating the energy consumption for (temporary) habitation under comparable living circumstances in the prototype for guests (no rent), partly under leadership of Dr. Truus Hordijk.
- From the former partners and sponsors of the concept house consortium for further development of the prototype as a building, in the sense of replacing and improving existing parts of the Delft prototype in collaboration with partners and sponsors.
- From Concept House Village for deliberation and discussion with students, potential interested parties for new concept house prototypes, for the arrangement of ‘the New Village’ of Heijplaat of which the concept house village is part of, and its current and future inhabitants.

Ad 1: The program of the SUSLab is published in the brochure ‘Concept House Heijplaat Rotterdam’ by Sustainable Labs North West Europe. See [www.Suslabnwe.eu](http://www.Suslabnwe.eu).

Ad 2: Prototype development at the chair. There have been a number of suggestions to extend and improve the current prototype:

- The front of the container could be equipped with a glass façade with double doors for easier access to the interior space of the container, which houses a room with an exhibit about the concept house urban villa and concept house village;
- An elliptical, insulated glass outside wall could be mounted underneath the current prototype, consisting of glass panels that were rejected to be used for the Fletcher hotel on the highway A2 near Amsterdam (because of a producer's bankruptcy and stepping over to a different kind of coating). Function of the space: Exhibitions, meeting place, thus semi-public, and independent of the apartment on the upper floor. Coordination Mick Eekhout a.c.j.m.eekhout@tudelft.nl. Design and realisation by students working in the Bucky Lab under leadership of Dr. Marcel Bilow. The glass panels are available as of November 2012; the prototype exercises in the Master education of the Buckylab are organised two times a year. M.bilow@tudelft.nl. Application depends on the final location of the Delft prototype, amongst other things.

Ad 3: Sustainability evaluation according to Arjan van Timmeren: the intent is to compare the calculated energy consumption of the prototype with that of actual apartments, by letting a number of habitants who live in similar 'real' apartments live in the Delft prototype for a certain amount of time, and comparing the actual apartments with the prototype with regards to habitants' behaviour; and then comparing the prototype apartment with calculated assumptions derived from the prototype design. Dr. Truus Hordijk (associate professor chair of building physics, architecture) has indicated that he would like to participate in this research.

From the Faculty of Architecture, the following research topics and development processes are proposed on the level of city/neighbourhood + technical functionality:

3.1 Evaluating energy consumption; to evaluate the development process (coordination and integration) and the production/building process;

3.2 Individually evaluating building product innovations.

- Sanitary unit/installation cluster;
- Solar energy generation, sun shading + home automation;
- Comfort/building physical aspects;
- Living green wall (CO<sub>2</sub>, PM10, etc.).

3.3 Further developing and applying building product innovation to the prototype

- Sun shading alternatives (in collaboration with Bucky Lab, ongoing);
- Living green wall alternatives (in collaboration with TKI, requested);
- CO<sub>2</sub> comfort facade (configuration passive zones ict??? energy/CO<sub>2</sub> consumption/production);
- (in collaboration with Solarlux, promised);
- Energy storage and generation (renewable) integrated into the façade (in collaboration with Oskomera, promised).

Portfolio Research Concept House Village	People-product	Building & end-of-life	Technical function
City/district	<ul style="list-style-type: none"> <li>• Involvement of residents in arranging Heijlpaat (relation IKS) and choice of sustainable measures</li> <li>• What is the potential of collective sustainable facilities and services?</li> <li>• How do sustainable measures contribute to social interaction?</li> <li>• What would a district oriented energy feedback system look like?</li> <li>• Comfort and experience of public spaces and social interaction</li> </ul>	<ul style="list-style-type: none"> <li>• Determine crucial elements for local metabolism</li> <li>• Determine potential location for innovative infrastructure</li> <li>• Optimal ecological infrastructure and social-technical organisation</li> <li>• Supply and dispose of building materials</li> <li>• (Re)use of local materials</li> <li>• Possibilities for energy-exchange and storage on district level</li> </ul>	<ul style="list-style-type: none"> <li>• Extent of energy exchange and storage</li> <li>• Link E-mobility</li> </ul>
Building	<ul style="list-style-type: none"> <li>• Involvement of (future) users during the development of apartments / houses</li> <li>• Comfort and experience of residence</li> <li>• Influence of behaviour upon the e-performance</li> <li>• Habitation of residence</li> <li>• Which adjustments are made or desired (extent of desired flexibility)</li> </ul>	<ul style="list-style-type: none"> <li>• Evaluation of permit, construction and end-of-life process (planning, accommodation partners and costs)</li> <li>• Quality of the building</li> <li>• Possibilities for energy exchange and storage on district level</li> </ul>	<ul style="list-style-type: none"> <li>• Optimization level of measures (one or multiple apartments)</li> <li>• Energy performance during different seasons</li> <li>• Maintenance during the experiment</li> </ul>
Installation-/product	<ul style="list-style-type: none"> <li>• Routines concerning management of energy and sustainable sources and comparison to previous living situation</li> <li>• Comfort and experience of installation and interfaces</li> <li>• Habitation of installations, interfaces and products</li> <li>• Influence interfaces and associated services on acceptable sustainable measures</li> </ul>	<ul style="list-style-type: none"> <li>• Quality installations and facilities</li> <li>• Flexibility / adaptability installation and facilities to residents</li> </ul>	<ul style="list-style-type: none"> <li>• What is the energy use per family member?</li> <li>• What is the explanation of the variation in energy use? (social-cultural, building and facilities / products)</li> <li>• Maintenance installations and products</li> </ul>

FIG. 88 Intended research following mutual deliberation in concept house village 2012

Ad 4: Solarlux has offered to build a sliding wall on the inside of the glass balcony screens for free, as a prototype of a renovation wall for upper storey apartments. Since this impacts current consumption, this offer is presently postponed.

Ad 5: Meetings, discussions and visits will be coordinated by the faculty of industrial design engineering, headed by Professor David Keyson and coordinator associate professor Sacha Silvester. [s.silvester@tudelft.nl]



# PARTNERS, SPONSORS AND BIOGRAPHY RESEARCHERS

The prototype is the fruit of a collaboration between the chair and 10 partners from SME Building:

- VDM;
- Unica;
- Icopal;
- Itho Daalderop;
- Faay;
- Niko;
- Raab Karcher;
- Renson;
- Solarlux;
- de Woonplaats.

Seven in-kind partners:

- CBB;
- Danfoss;
- Lodewijk van Es;
- MdR advies;
- Hans Moor Architects;
- Uniline;
- Architectuurcentrale Thijs Asselbergs.

And thirty material sponsors:

- Albeda College;
- Bruynzeel;
- CRH;
- Drooghmans;
- Dura Vermeer;
- Forbo Eurocol;
- Fermacell;
- Global Solar;
- Greenwave;
- Justimax;
- Kingspan Unidek;
- Kramer Group;
- Luinstra;
- Mastervolt;
- Mosa;
- Koen Mulder;
- Novatio;
- Octatube;
- Oranje;
- Philips;
- Prokom;
- Relius Systexx;
- Rockwool;
- Roval;
- Schilders^Scool;
- Woonbron;
- De Vries Kozijnen;
- Zadkine.

Mick Eekhout [1950] is professor Product Development, a chair that he holds since 1991 with at least 0,4 fte. Education in design methodology of building products, building systems and building components; research in the field of new materials and unbreakable glass Zappi, free-form technology Blobs, and the development of concept houses. He has written 12 books, and another 8 are on the list to be completed. More than 300 published articles. Writes columns for Cobouw. Was the motor behind 3TU Speerpunt Bouw from 2007 until 2009. Graduated in 1989 cum laude with the dissertation 'Architecture in Space structures' and completed his education at the Faculty of Architecture in 1973, also cum laude. Started his own architecture firm in 1975 and ran it for eight years, after which, from 1983 to the present, he started and directs the 'design & build' company Octatube, 70 employees, specialist in light-weight roof and façade constructions, often experimental, developed in Delft and applied throughout the world. a.c.j.m.eekhout@tudelft.nl.



Arjan van Timmeren [1969] has worked in practice as well as in science since the beginning of the Nineties, nationally and internationally. In 2006, he graduated cum laude at TU Delft with research into the optimum scale of preservation of the water, energy and nutrient flows in the built environment. Since 2012 he is professor at the chair Environmental Technology & Design at the Faculty of Architecture, TU Delft. Van Timmeren has a rich scientific career and is specialised in the integration of sustainable technology in buildings and area development. Prior to this, and in addition to his practical work at Atelier 2T and various architecture firms [Renzo Piano, Italy; Jesus Arribas, Spain; Gunnar Daan, NL and Karelse VdMeer, NL] he has worked at the TU Delft in the department 'Building Technology', first at the chair 'Climate Design & Sustainability', and from September 2009 until September 2012 as UHD at the chair Product Development. [avantimmeren@tudelft.nl](mailto:avantimmeren@tudelft.nl).

Jaap van Kemenade [1982] studied Industrial Design Engineering in Delft with a special focus on custom work and user experience. Shortly after his studies he was drawn to the research project concept house at the Faculty of Architecture as researcher, where, in addition to his drive for renewal he also had to put his organisational talent to work. As an industrial designer he knows the quirks of working in a building team like no other, particularly if the team members are not yet used to each other. Process leadership. But also knowledge of the industrial discipline, which is direly needed in the world of architecture. In addition, he knows installation and can roll up his sleeves and do-it-himself, if needed. This has certainly helped with the end result of the process. Van Kemenade now works as freelanced designer and is active in the cultural sector. [jaapvkemenade@gmail.com](mailto:jaapvkemenade@gmail.com)

Rutger Wirtz [1982] studied architecture at the Faculty of Architecture at TU Delft. He got his Bachelor degree at HTS in Tilburg. In his profession as an architect he is most fascinated by the combination of technology and concept, and of practice and theory. After working for different architecture and building technology companies during and after his studies, he was drawn to the research project concept house as a researcher, where he occupied himself with elaborating the building system and designing and building the prototype. Wirtz currently works on architecture projects under the name of RRAW architectuur. [rutgerwirtz@gmail.com](mailto:rutgerwirtz@gmail.com)



# CALL FROM 3TU TO SME BUILDING

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Will the SME Building suppliers participate in research and development to help create a new future?

It has already been five years since ‘Bridging the gap’, the research master plan by 3TU Speerpunt Bouw (Spearhead Building), was published. [Eekhout et al, 2009] For a long time after that it was very quiet. Finally, on October 8<sup>th</sup> 2012 3TU.Bouw was officially launched. In the meantime, much has changed in the relationships in the building sector. Where ‘Bridging the gap’ indicated a new, society-related direction for academic building research, research now should better be directed toward looking for a promising future together with the companies in the building industry. By helping the building industry to overcome the recession, or, if this lies beyond the power of the researchers, by offering the building industry a perspective for the time after the recession. The 3TU Bouw faculties not only open up toward society but also toward the future of the building sector. “The wind-shield is larger than the rear-view mirror”.

[Citation from Harry Hendriks, director Philips Nederland in a joined interview with Mick Eekhout in: Van Wijk, 2010].

The building sector is rightly worried. In 2013, more than 60% of Dutch architects are unemployed. In the years to come, the builders must also find a balance considering a significant reduction in job opportunities. Consequently, in five years time the building sector will no longer be as large as in 2008, the apex of the economic building explosion. Which, for the main part, seemed to originate in the post-war reconstruction period. Do Dutch private partnership companies still have sufficient funds for the building sector? It makes sense to explore the future of the built environment in the Netherlands in 2040 by reasoning toward the future of society, the role that the built environment plays therein, and finally the intervention that the building industry must undertake to adapt the built environment to the needs. In this manner, the building sector will be able to accommodate real demands and not market delusions. Of course there will be many more

complex influences in the far future; with the possible conclusion that a reliable outlook is impossible. But still, studying offers a lot of insight. The conclusion that the building sector might have to shrink significantly is not impossible either. And that we will invest much less in new buildings and much more in upgrading and renovation of the existing building stock.



FIG. 89 Research collaboration between public authorities, the business community and the university ]. 'Government says: valorisation!, Industry says: fast and cheap and University says: fundamental research'. Cartoon: Auke Herrema

At this point in the concept house Delft prototype report it is good to know that the professors of 3TU.Bouw[producten] reach out to the building supply industry to jointly develop a vision of the future. A future that is easily influenced by societal problems and challenges. A future for which we the best that all Dutch researchers have to offer. They will apply themselves as a Research Club Sandwich.

## COLLABORATION WITH RESEARCH PARTNERS

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First of all it must be noted that the Dutch building research, of which 3TU.Bouw research is only one part, serves to increase insight into many aspects of building, to advance the state of the art, to accomplish greater efficiency in building innovation, to realise a better cost/quality relationship, and to strengthen the export activities of Dutch private partnership companies.

Building research comprises a number of parties that conduct research in different ways:

- 3TU, the technical universities;
- TNO (independent research organisation), ECN (Energy Research Centre of the Netherlands) and the GTI's (Groups Technical Installations);
- The HBO's / Polytechnical universities;
- NL Engineers: the engineering companies;
- BNA: the architecture firms;
- SBR: Stichting Bouw research (foundation building research);
- CUR, CURnet;
- Private research institutes.



FIG. 90 Model Club Sandwich of collaborating researchers

## RESEARCH FOR THE BUILDING SECTOR IN A 'CLUB SANDWICH' MODEL

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Each of the institutions has a slightly different goal. If we were to translate the research domains of these institutions into slices of bread, each with a different topping, stacked on top of each other, we would get the image of a sort of 'Club Sandwich'. Then, for each societal challenge, one segment can be cut from the club sandwich, in which all players are represented with their particular part, their specialty in the research.

## TOWARD A GENTLEMEN'S AGREEMENT FOR INTEGRATED NATIONAL BUILDING RESEARCH

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At the same time it seems unavoidable that the different research players in the club sandwich define their own characteristics, their strengths and weaknesses, and indicate how they want to collaborate in consortia in the area of building research. The leaders of these institutions [CvB 3TU, deans, HBO committee and directorate, directorate TNO Bouw, chairman NL Engineers, chairman and directorate BNA, directorates SBR, CUR etc] should be able to come to a gentlemen's agreement which formulates everyone's competences, outlines everyone's limitations, and documents the rules for integral collaboration. This leads to the goal to respectfully work together with other research players based on one's own strengths if and when job opportunities occur, paid or unpaid. The competition is not in the Netherlands but in foreign countries. We will need to offer the building sector in the Netherlands a better cost/quality ratio. We will need to make the Netherlands and the building sector stronger, better adapted to the requirements and desires of society, as well as more efficient, with export being one of the measurable mileposts.

The collaboration between the above mentioned eight parties that conduct research which the supply industry itself does not do in its design & engineering departments, must rise to a national level. It is necessary because all eight parties are restless, they move up, down and sideways and integrate, hoping for more revenue or at least maintaining the current levels. While revenues generally dwindle for everyone. 3TU.Bouw must link itself to companies. TNO undertakes more projects. The engineering firms also do general research. The architects have their 60% unemployed brain power that can be applied creatively for component design & development. SBR and CUR are linked to the revenue of the building sector. If revenue declines dramatically, action must be taken to replace the lost income. But generally speaking the threshold between project and product oriented businesses and the research oriented institutes must be lowered, to benefit the Netherlands as a whole, with the insight and knowledge that researchers have but which is not applied in practice.

It is time that the eight parties each describe their strong and their weak points, their opportunities and threats. To drive each other on and to openly communicate. And finally to come to a casting with far less overlaps and to ignore slight irritation rather than to develop oneself in the current era. Who takes the initiative? Who takes over the lead? 3TU.Bouw? The bond of suppliers: NVTB? In any case, the chair does its best within the small tension span of a mini-academic company. The chair product development with its professor who has one leg in academia and the other firmly planted in the industry builds a bridge between these two worlds. But the research conducted in academia is different from the direct product development done in the industry. It is much more fundamental than application-oriented. In principle, the first phase of the concept house was very fundamental or broad. Academia must conduct research that is not done in building practice. We must not compete. Even though the building industry has little interest in fundamental aspects, it can be said that we are creeping toward fundamental research. Because our colleagues from the other TU Delft faculties are looking at the Faculty of Architecture with pity; the best of the colleagues are almost Nobel Prize winners. OK then, the Faculty of Architecture as well as the Faculty of Industrial Design Engineering are indeed very application-oriented. Nothing fundamental. It is thus a question of looking at the issue comparatively. But in the meantime they are very curious as to what we are busy doing. Renowned nano-technologist Professor Dr. ir. Cees Dekker of TU Delft, Faculty of Applied Science (Physics), does indeed conduct fundamental research, but has no idea of potential application in the industry; in our case the building industry. Can he increase the strength of the nano layers to a degree that we can use thinner glass, glass that does not break or if it does break heals itself? Self healing glass? He has no idea about this. We do not either but if we keep bugging him with this sort of questions, there might just be self healing glass in five years. This is the power of designing. Of dreaming and thinking and the determination to succeed, no matter how much headwind you are running into. These are the challenges that the chair lives on. Great ambitions!

In the meantime, short-winded work needs to be done as well. And this concept house prototype development began with the chair's prerequisite that first of all various components should undergo revolutionary innovation before everything was to be fitted together to see whether the manifest components will work as a unit, as an apartment or, in the case of an urban villa as an entire complex. This was clearly one step too far ahead, an ambition that could not be realised short term with the small group of people working on it. Thus, we concentrated on selecting components that together should bring knowledge, ability and insight – in short: science – a small step further by means of coordination and integration. The professional field of bringing together components to form the artefact of the whole, of the apartment or of the apartment complex essentially is a field of expertise that belongs to the chair 'Architectural Engineering' under Professor Thijs Asselbergs. But he has his hands more than full with educational tasks. Thus, upon intense deliberation, the chair product development has decided to strive for this high speed [individual] product development toward component integration to the artefact of the apartment. By involving Thijs Asselbergs in the process, certainly with regards to the larger scale aspects such as multi-storey apartment buildings and the neighbourhood of the apartments, in short: the 'built environment'. But let's return to the general considerations.

## THE PRODUCTION CHAIRS AT 3TU

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### CONDUCT FUNDAMENTAL RESEARCH

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In general, and in international comparison the Netherlands spends shamefully little energy on developing fundamental knowledge by means of research. This is as true for the building supply industry. Nobody will say that the Netherlands leads the way in this context. In the meantime, fundamental academic research to advance the field of expertise has indeed become a young but growing tradition. Nonetheless, the chairs busy themselves with fundamental aspects of applied business. The basis for this are dissertations by doctoral students as well as theoretic books written by the current professors. Professor Dr. ir. Wim Poelman (now U Twente) wrote his dissertation about the match between supply and demand with regards to developing new materials. Mick Eekhout (TUD) has written two books about the methodology of developing standard system products and special building products. Professor Dr. ir. Jos Lichtenberg (TUE) wrote his dissertation about sustainability in building technology. Professor Dr. ir. Joop Halman published many texts on the 'Platform' development method, a method to reach a certain development by working together with companies, and then to continue separately. Thus, the eight building product chairs of 3TU. Bouw have a solid fundamental basis.

The research staff of the eight Dutch chairs of 3TU. Bouw[producten] is very small, as previously mentioned. New projects shall be staffed with the best university graduates who have demonstrated a scientific attitude. Besides those, young PhD's who have demonstrated that they can self-sufficiently conduct a scientific process under supervision of the professors, are very good candidates for fundamental project research. At this moment of the development at the faculties their work contracts are ended immediately after graduation due to the deans' opinions on financial issues. They might be able to succeed on a professional level as scientifically experienced post-docs who combine thorough knowledge in their field with the courage to tread new paths.

But in general it can be said that the scientific field of building product development is still in the fledglings stages. The first professor for this area of expertise [Eekhout] was employed in 1991. It is a professional field that derives from the practice of designing, developing and researching new building products. Thus, there is a strong relationship between theory and practice. In one way or another, all professors have experience with the practice of product development. There is no gap between practice and theory, and if there is it can be easily bridged. It would be good to establish a permanent relationship between the supply companies grouped under the umbrella organisation of the supply industry NVTB and the 16 umbrellas beneath it, and the 3TU building product chairs. Practice is challenged to do this.

Such as was begun in 1988 with the setup of Boosting [see [www.boosting.nl](http://www.boosting.nl)] by a select group of architects, industrial design engineers and producing companies for the building industry. Many initiators of the first hour – Jan Bouwer, Mick Eekhout, Marcel Vroom and



Thijs Asselbergs – still play their role in this area of expertise. Originating in the Boosting enthusiasm, four PhDs and eight professors were employed at the 3TU's. For as long as 25 years, Boosting has been the front runner in this area. The 3TU.Bouw [producten] wishes to suggest broadening this in a scientific sense ['Boosting Science'?)

## THE DOMAIN OF BUILDING PRODUCTS

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Meanwhile time passes by. The economic recession is not changed by the downfall of one cabinet or the emergence of another. There are still many international reasons that require the Dutch building world to face a different future than the one we expected until recently. The many different parties in the building sector are all busy exploring and charting what they can expect in the future. The building sector in its entirety, under the lead of its politically minded chairman Drs. Elco Brinkman of Bouwend Nederland is busy working on its future. In Bouwend Nederland the main contractors dominate the game. In total, their revenue added up to 70 billion Euro in 2009. The share of the building supply industry, under the umbrella of the NVTB under Director Dr. ing. Peter Fraanje, was 30 billion. Contrary to typical proceedings, the force of the supply companies is barely noticed by the media. The knowledge and insight of 3TU.Bouw could be well used in favour of the building supply industry. Supply companies in the Netherlands are partly autonomous, partly part of larger organisations, and a good share is part of large international commercial enterprises. These enterprises make their decisions regarding research & development in their headquarters outside of the Netherlands. Thus, the Dutch umbrella organisations do not have a lot of reach. Unless one takes the 'Danone effect' into account. With support of an extraordinary Dutch research infrastructure in Utrecht and Wageningen, Wim van Gelder, former CEO of Nutricia and scientist, succeeded in establishing the worldwide applied Danone research at the University of Utrecht in an institute and building specially built for this purpose. Thus, even with an international enterprise, it is indeed possible to establish decentralised research facilities outside of the headquarters in areas where research has an optimum chance of thriving. The 'Danone effect' could also hold value for the international building industry. But this means that the relevant scientists and the infrastructure must be available. That is the goal of this chapter: To show that the united chairs of 3TU.Bouw [producten] together are indeed capable of developing innovative research & development in collaboration with the industry. That they really want this, and that they call out to the supply industry to participate. The issue is not whether the chairs will survive; they are stable in their small formation. But the issue is for the Dutch building industry to use sufficient brainpower to jump over the recession.

The supply industry in particular is based on technical specialisation. In the building supply industry, the 3TU.Bouw faculties also recognise their technical counterpart in practice. This argumentation leads to a perception of the technically innovating building chairs at the 3TU and lets them look for their match in the supply industry.

In this argumentation, the domain of the 3TU Speerpunt Bouw [producten] is consciously set up at a narrower scale to offer quicker results and to show that a smaller echelon of 10 professors can much more easily score in a match between demand and supply than the large 3TU Speerpunt Bouw echelon of 80 professors. The chairs of the 3TU.Bouw [producten] work in the same manner and mindset as 3TU Speerpunt Bouw is described in the brochure 'Bridging the Gap', but in the smaller domain of the supply industry.

Even though over the past three years the management of the universities had a hard time to make a decision about the future of the 3TU Speerpunt Bouw, the need to form a 3TU. Bouw block in the field of building products is so great that this initiative for a 'matching game' is established and driven along by Mick Eekhout with a total of 8 chairs and 10 professors behind him. It seems logical that the same initiative could be started by the professors of Bouw[constructies], Bouw[installaties] and Bouw[informatica] (Building constructions, installations and informatics). In this manner, groups of likeminded 3TU. Bouw professors could find their match from respective demand partners in the building sector. Such a bottom-up initiative could also show other groups of university building chairs how the route toward a 'match' between SME demand and 3TU supply of building research could be conducted. In this case we usually speak of a SME approach. The building sector had a turnover of 70 billion and 400.000 people in 60.000 companies, and the supply companies had a turnover of 30 billion. Imagine half of the supply industry being oriented toward building products, and the other half toward constructions, installations, and informatics. That would mean more than 15 billion turnover on the demand side, and 85.000 people in 13.300 companies available for the segment of building products. Traditionally, every SME dossier is a 'headache dossier' for valorisation by the 3TU's. Since there are not just a few players who know precisely what they want. But I would like to repeat that 3TU. Bouw[producten] wants to open up toward the building industry, wants to integrate with SME in research consortia, and thus stimulate the building sector by jumping the recession.

# SEPARATION OF 'BARE PROPERTY' AND 'USUFRUCT' OF THE DELFT PROTOTYPE

Agreement to separate the 'bare property' and the 'usufruct' with regards to the concept house Delft prototype, built in Heijplaat, Rotterdam. Proposal by Professor Dr. ir. Mick Eekhout, chair holder product development and project leader concept house prototype.

January 10<sup>th</sup> 2013

- 1 The concept house consortium had the concept house set up at Corydastraat in Heijplaat Rotterdam;
- 2 Financing is established with a financial contribution from all consortium partners during 2011/2012, the subsidy 'Pieken in de delta', primary money stream support from the staff of the chair product development, payments in kind from 30 sponsors, and concessions from the concept house village;
- 3 The partners and sponsors are prepared to relinquish their contributions and shares with a waiver (to be defined) in favour of the chair product development. Partners and sponsors have access to the Delft prototype as a side product of the companies for the benefit of their clientele. Of course, such activities need to be coordinated well;
- 4 The Delft prototype is the property of the chair product development, the professor of the chair is project responsible, and the dean of the Faculty of Architecture, Professor ir. Karin Laglas, is authorised to sign;
- 5 The Delft prototype shall be used as a laboratory for research and developments linked to architecture and industrial design engineering;

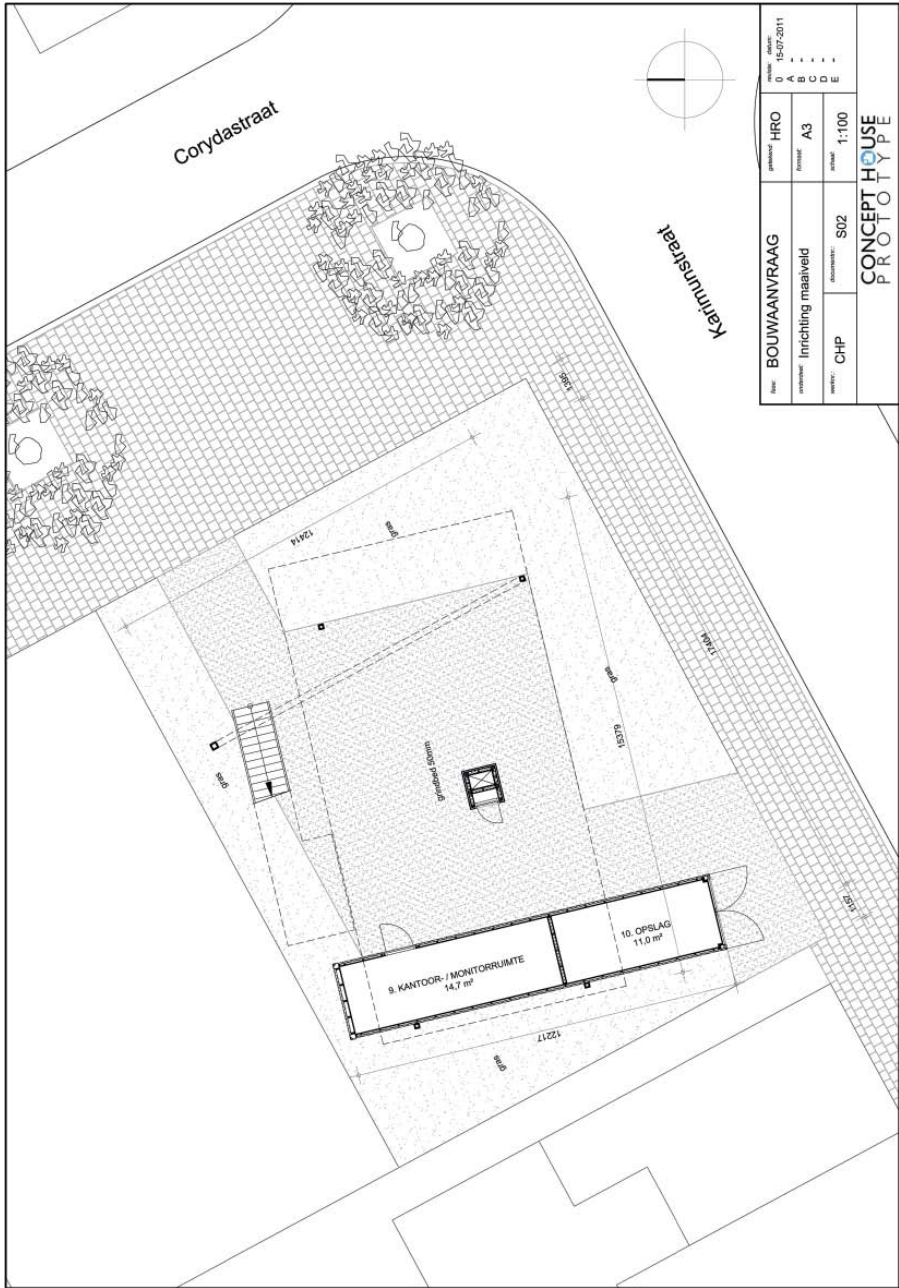
- 6 In the future, the chair product development shall promote and stimulate that parts of the concept house are further innovated and possibly replaced by the involved consortium partners and sponsors; additional architectural work shall be made possible, for example by students and staff members of the chair;
- 7 In coordination with the architecture chairs product development and environmental technology & design' of Professor Dr. ir. Arjan van Timmeren, architecture-related chairs wish to participate in research in the field of energy balance of the prototype as an evaluation via measuring and comparing it with the assumed starting points. The two chairs can utilise the prototype for meetings and appointments;
- 8 As one of the sponsors, the Faculty of Industrial Design Engineering has realised the furnishing and the financing for the opening of the prototype;
- 9 Professor Dr. ir. David Keyson as leader of the European SUSLAB NWE research is permitted to use the prototype as a laboratory environment ('Living Lab') for research conducted by staff members and students;
- 10 Part of the research involves test-habitation by guests over certain periods of time, without this being a rental situation; with the goal of monitoring the use and the users of the prototype;
- 11 Possible research should not damage the interior or exterior of the Delft prototype. All fixings must be reversible and invisible after use;
- 12 The SUSLab manages and controls the use of the prototype; the Faculty of Industrial Design Engineering allocates a considerable amount in its annual budget for the period from October 5<sup>th</sup> 2012 until November 30<sup>th</sup> 2015 for management and maintenance;
- 13 The two faculties thoroughly deliberate to allow for initiatives from both sides that would like to make use of the prototype;
- 14 This period will end when the prototype will in principle have to be removed in 2015. Different end-of-life scenarios are conceivable, listed according to preference:
- Preferred solution is reuse onsite, prolonging the laboratory phase;
  - Alternatively, sale and habitation onsite;
  - Reuse at a different location in the concept house village as a laboratory
  - Sale and habitation by buyer respectively;
  - Dismantling of the prototype and transportation of the total unit across the water to a new location on the TU Delft campus, where the prototype would again be used as a laboratory for research of a nature still to be decided.
  - Free (public) sale of the prototype with the goal to re-assemble it somewhere else for habitation.
- 15 After removal of the prototype, the building site needs to be brought back to its original state;
- 16 In the case of selling the prototype, the revenue minus the cost for removal and converting the building site to its original state shall go to the chair product development or the chair environmental technology & design, respectively the Faculty of Architecture, with the goal to reinvest in research related to the prototype;
- 17 The agreement between the concept house consortium and TU Delft of March 2011; the agreement consortium and facility from June 30<sup>th</sup> 2011 and the land agreement from 2013 are linked to this agreement. The provisions from these agreements will be respected.

APPENDIX F

# BUILDING PERMIT --- DRAWINGS



FIG. 91 Site plan



titel:	BOUWAANVRAAG	project:	HRO
datum:	15-07-2011	ontwerper:	inrichting maatsveld
schaal:	1:100	locatie:	A3
status:	CHP	document:	S02
		<b>CONCEPT HOUSE PROTOTYPE</b>	

FIG. 92 Layout ground level

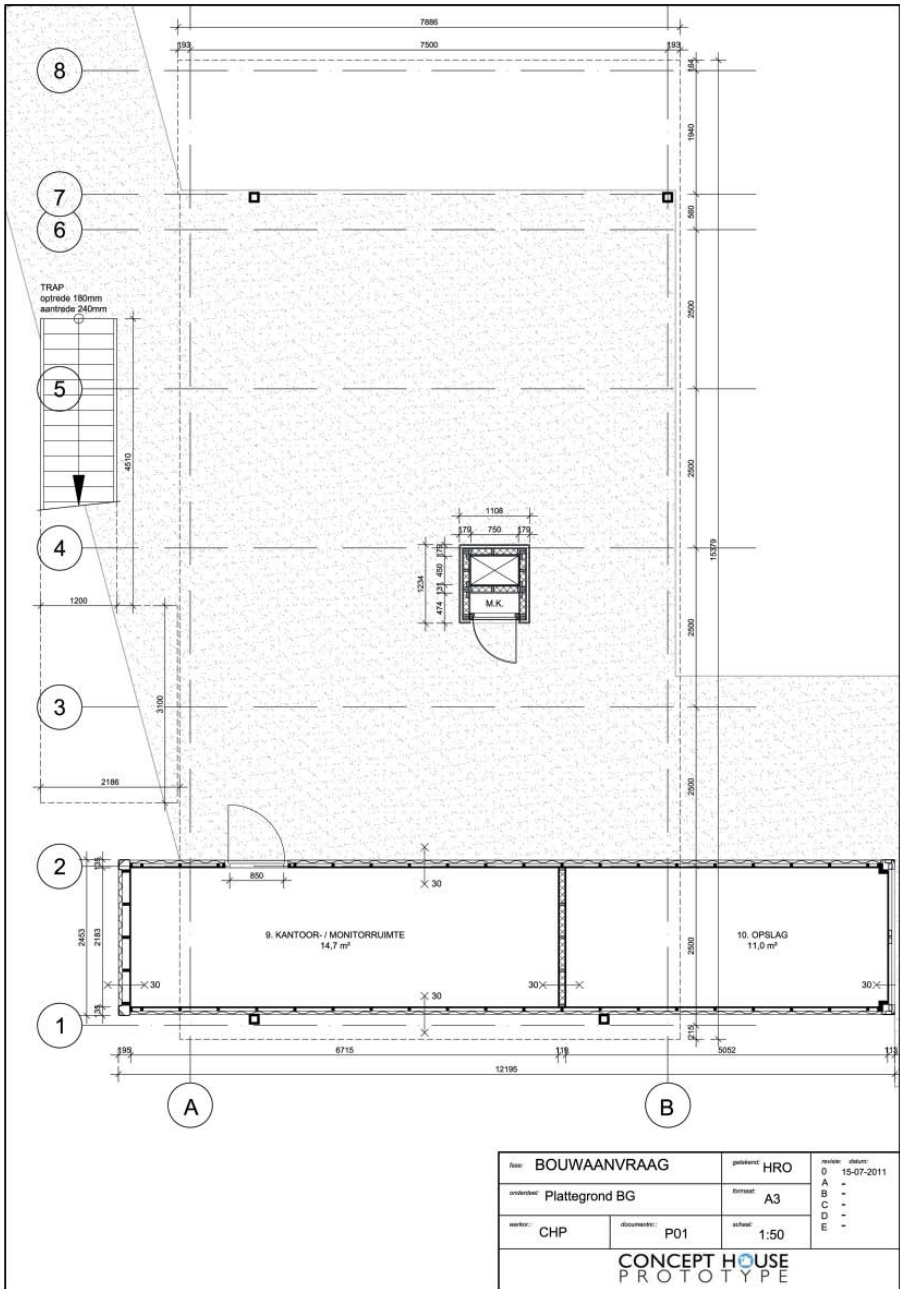


FIG. 93 Floorplan ground floor



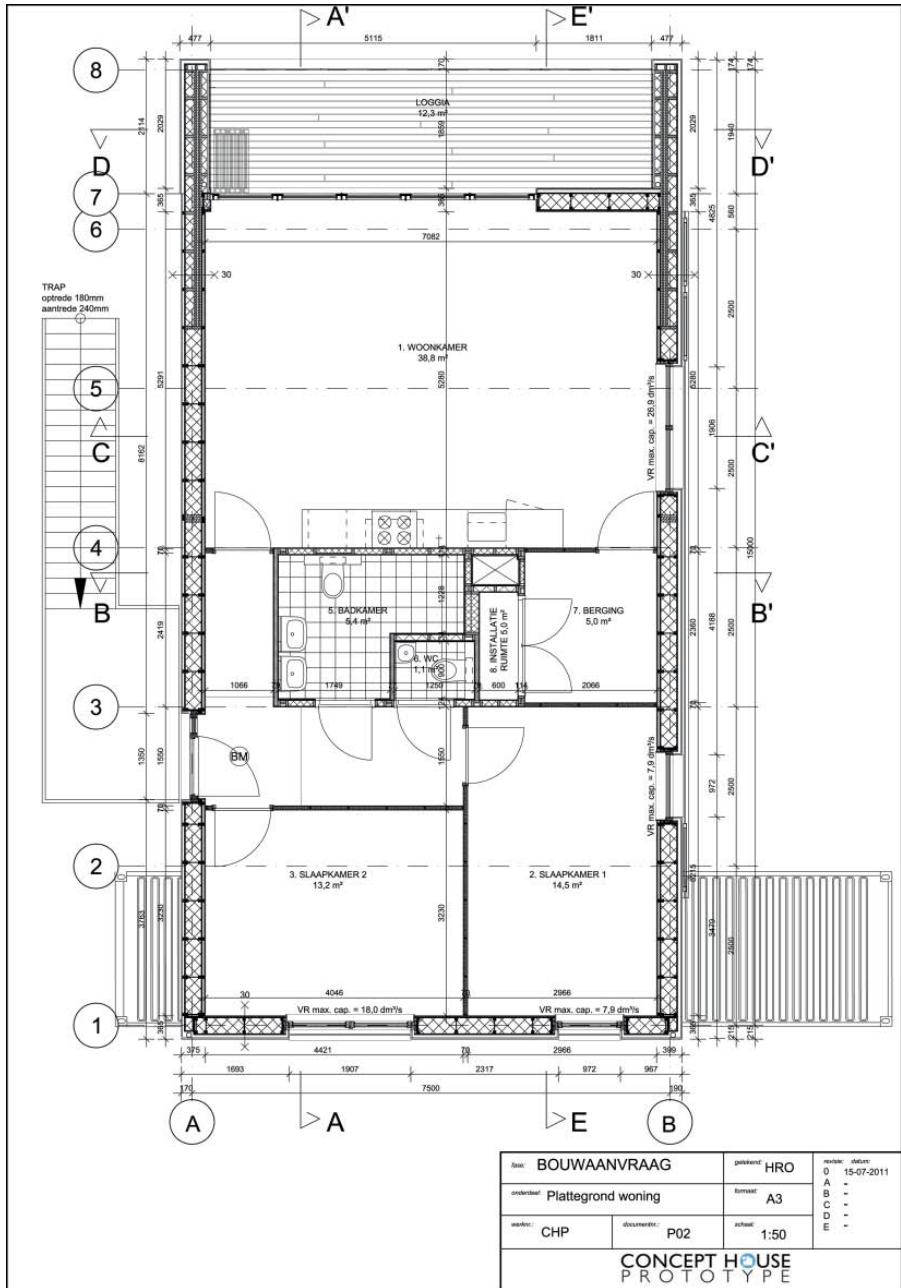


FIG. 94 Floorplan apartment

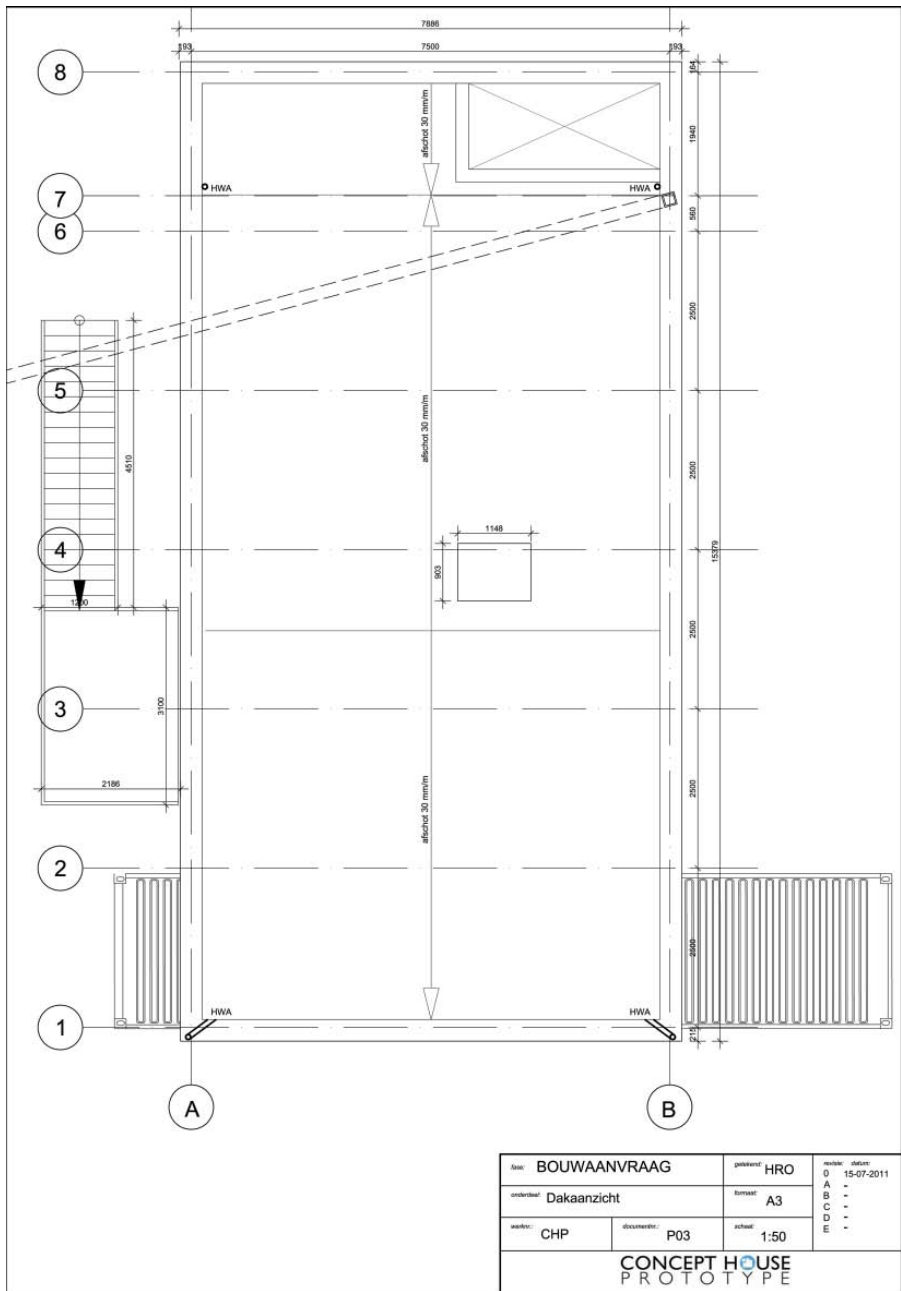


FIG. 95 Roof elevation

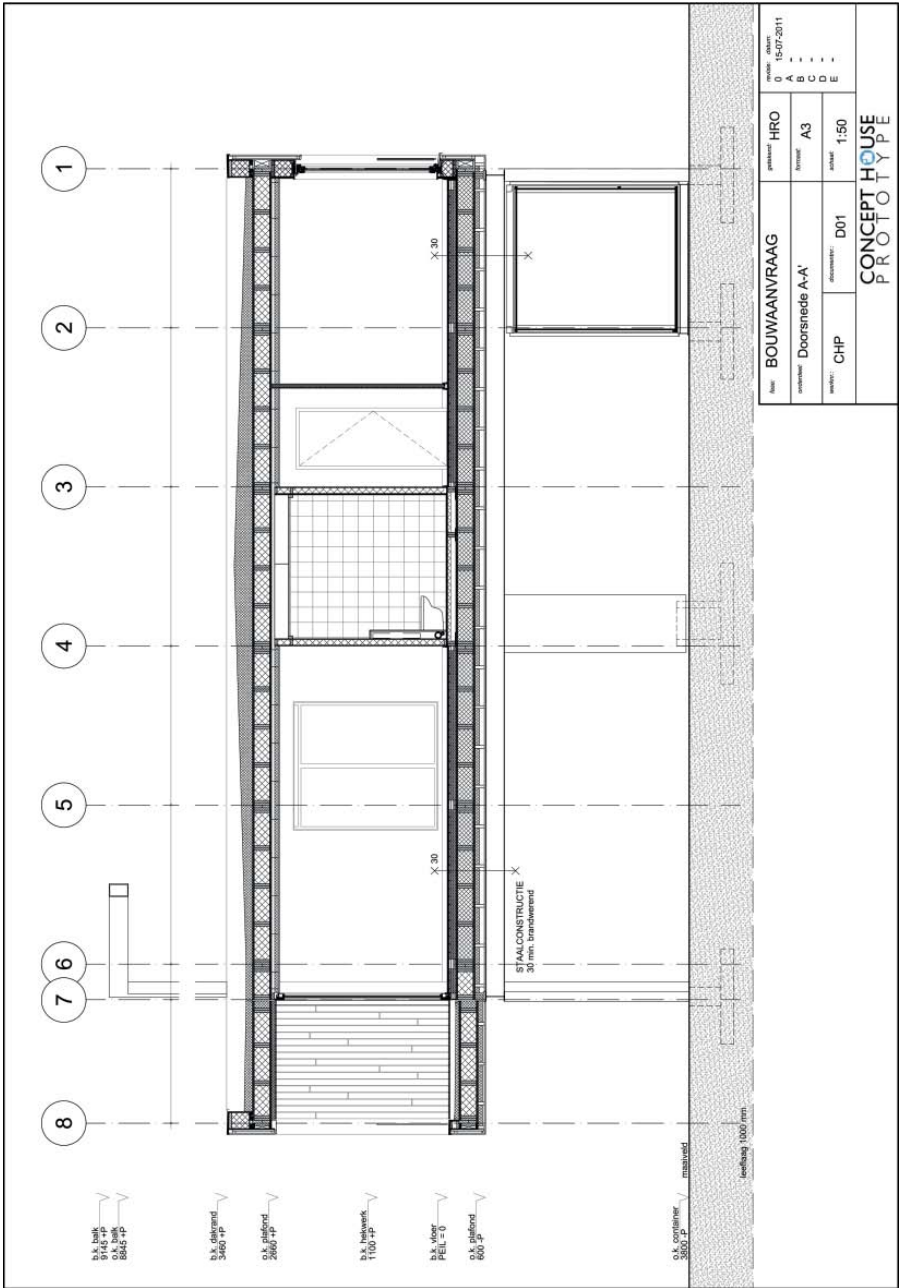


FIG. 96 Section A-A'

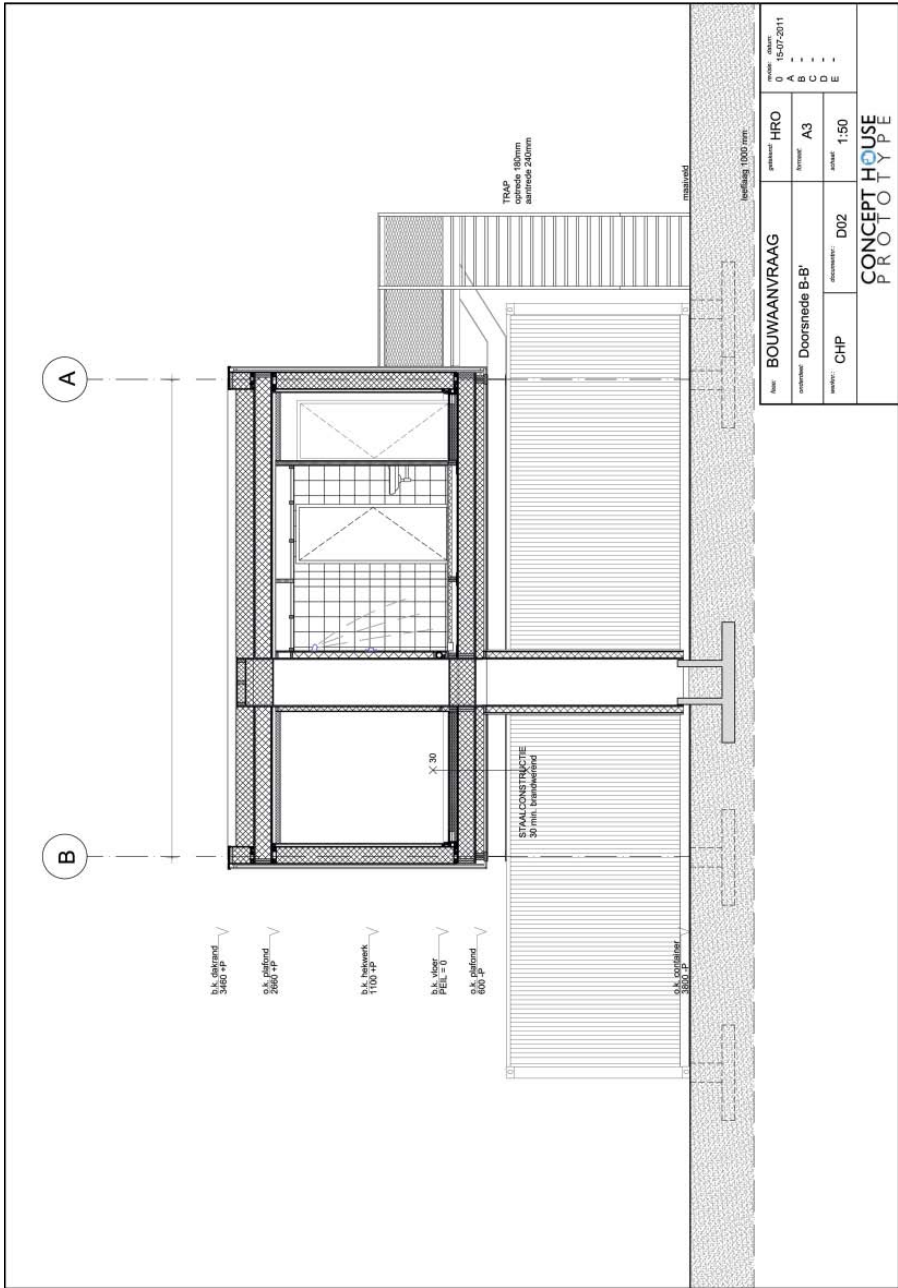


FIG. 97 Section B-B'

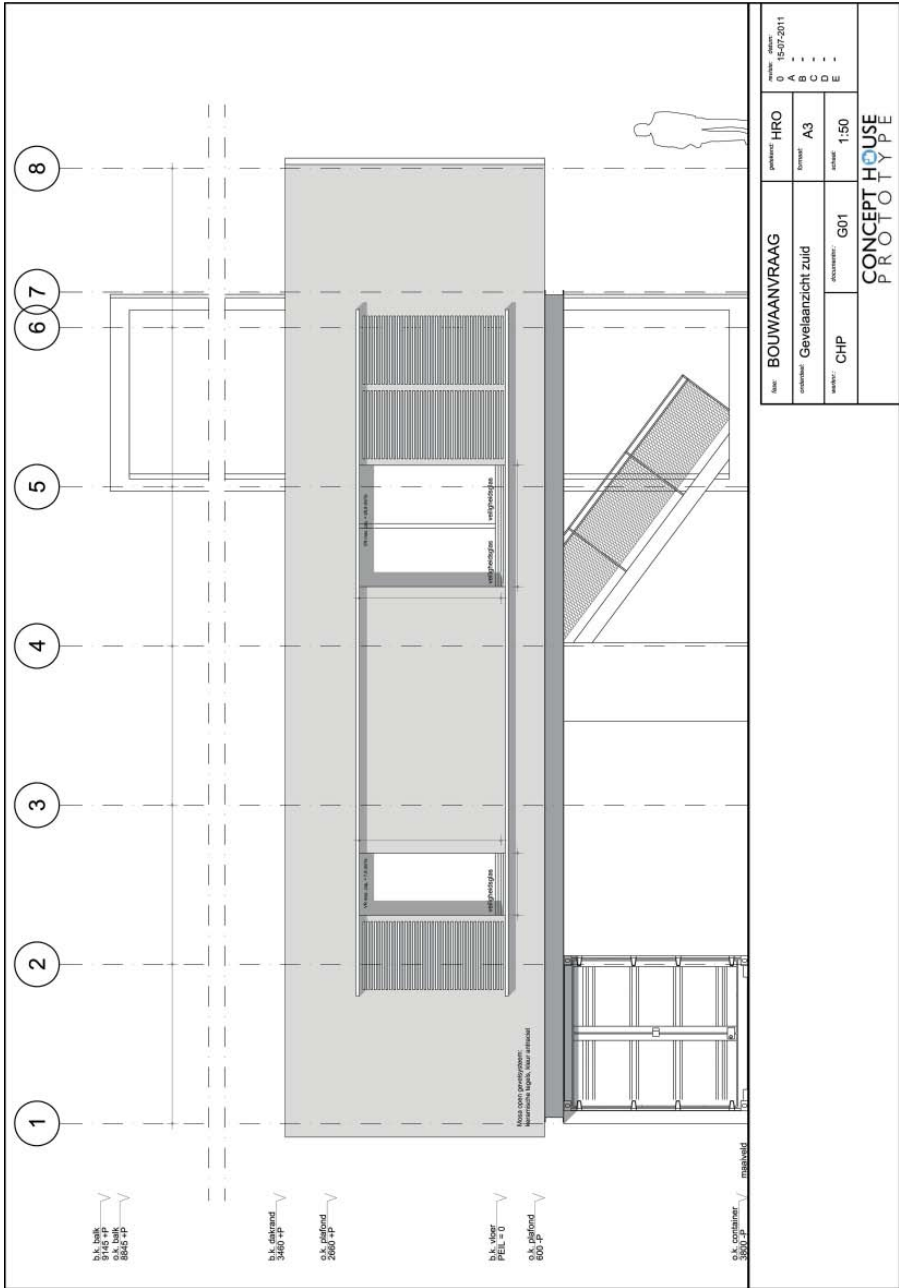


FIG. 98 South elevation



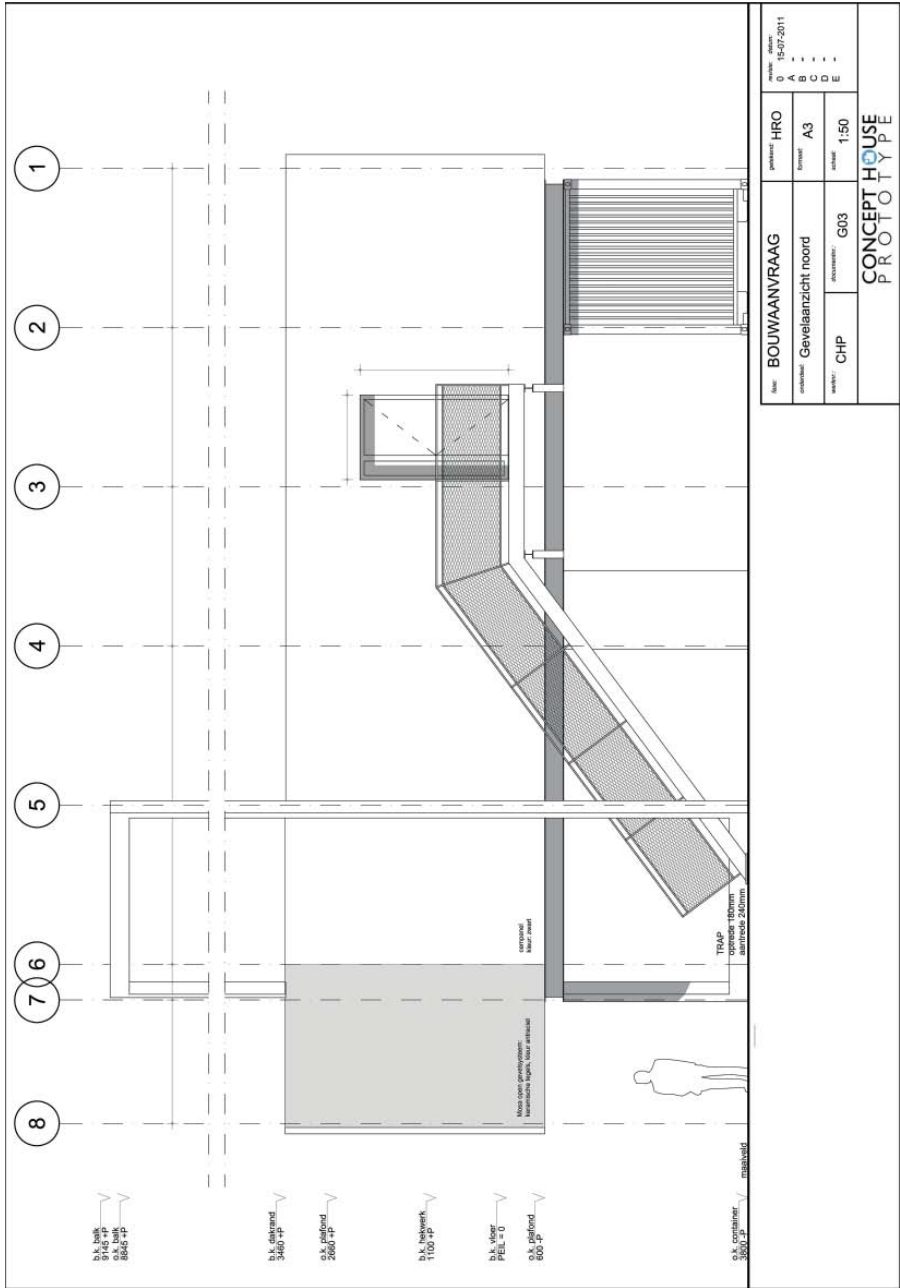


FIG. 100 North elevation

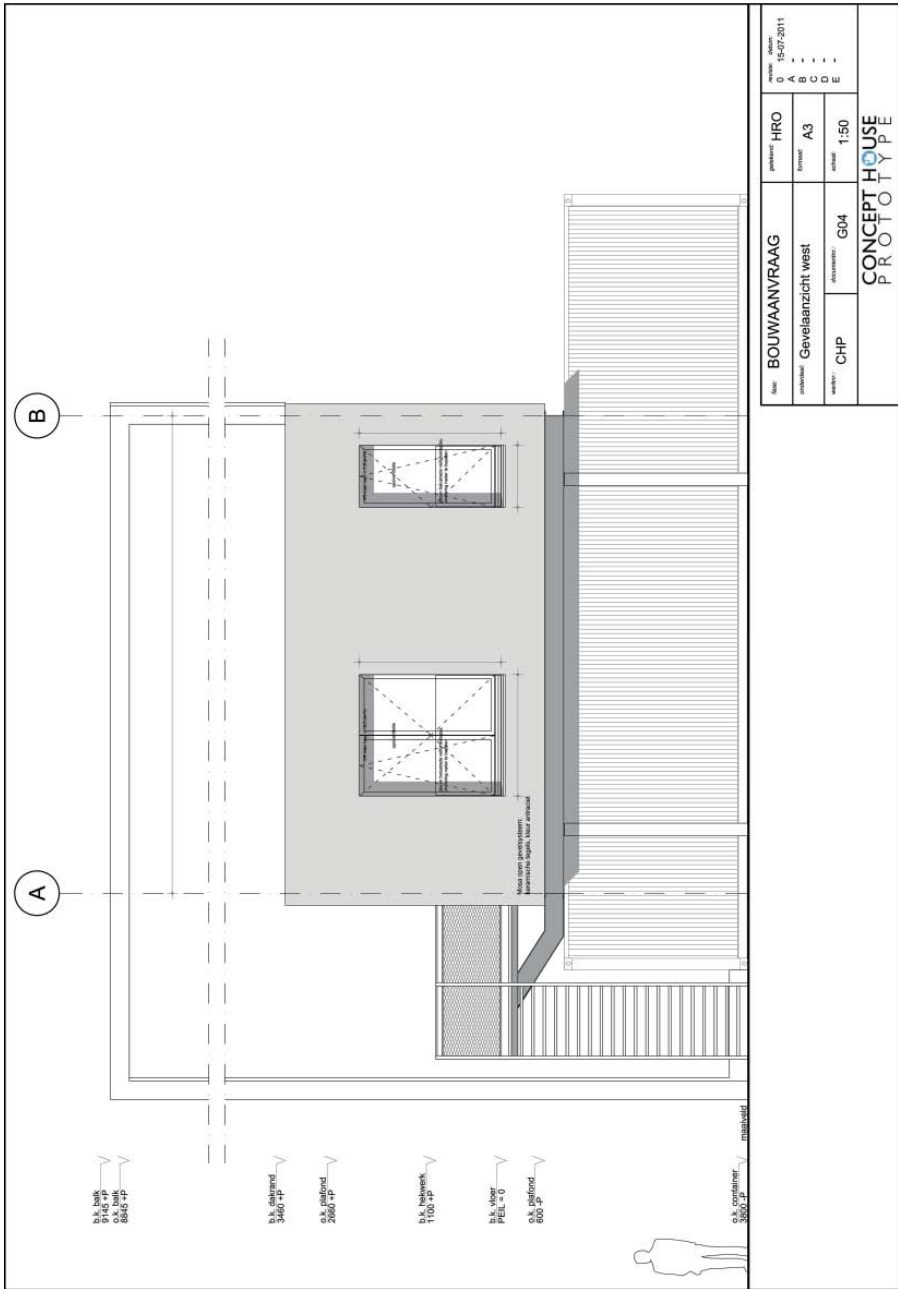
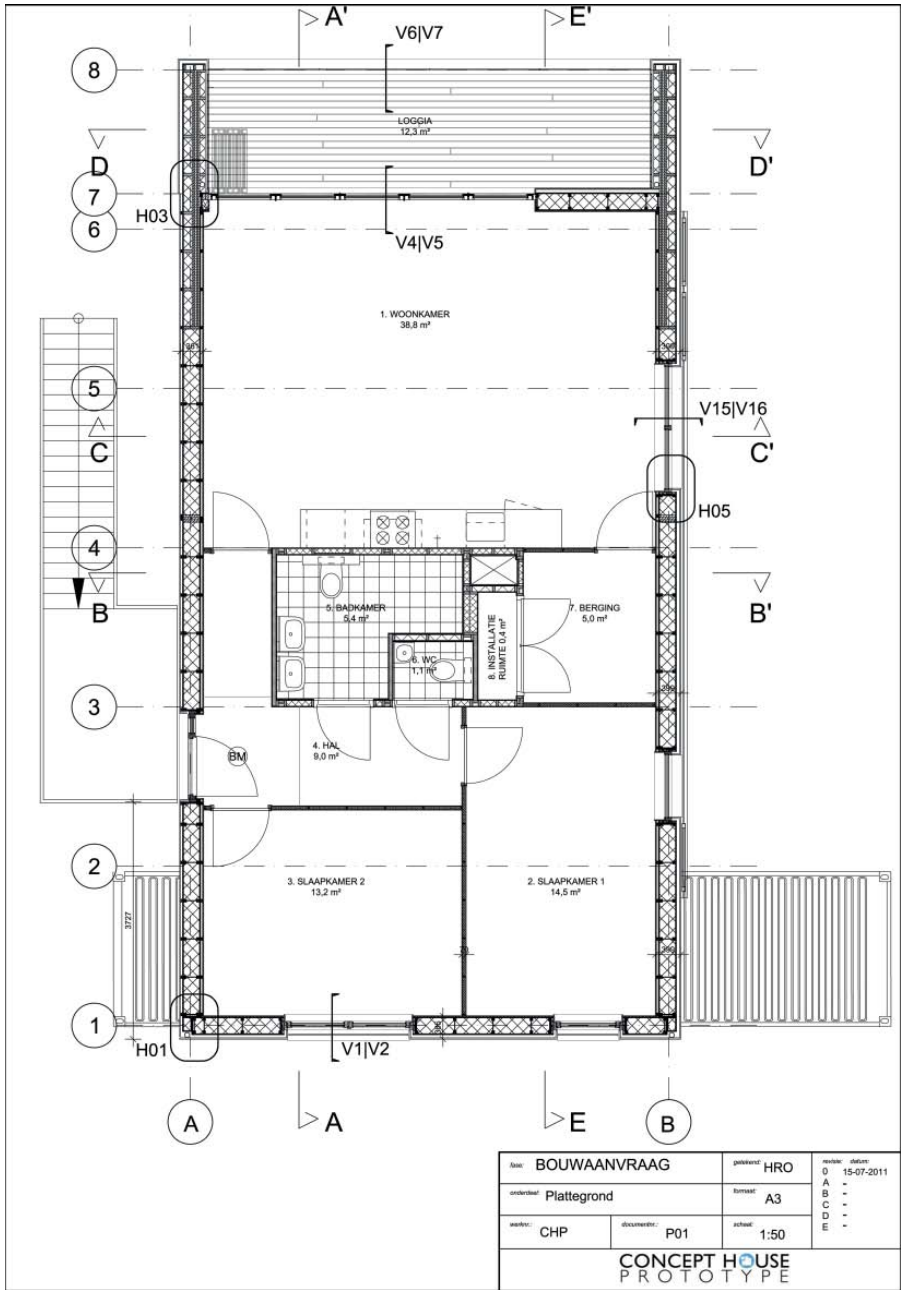


FIG. 101 West elevation





type:	BOUWAANVRAAG	project:	HRO	revisie:	status:
onderwerp:	Plattegrond	formaat:	A3	0	15-07-2011
serie:	CHP	documentnr.:	P01	A	-
		schaal:	1:50	B	-
				C	-
				D	-
				E	-
<b>CONCEPT HOUSE</b>					
PROTOTYPE					

FIG. 102 Floorplan

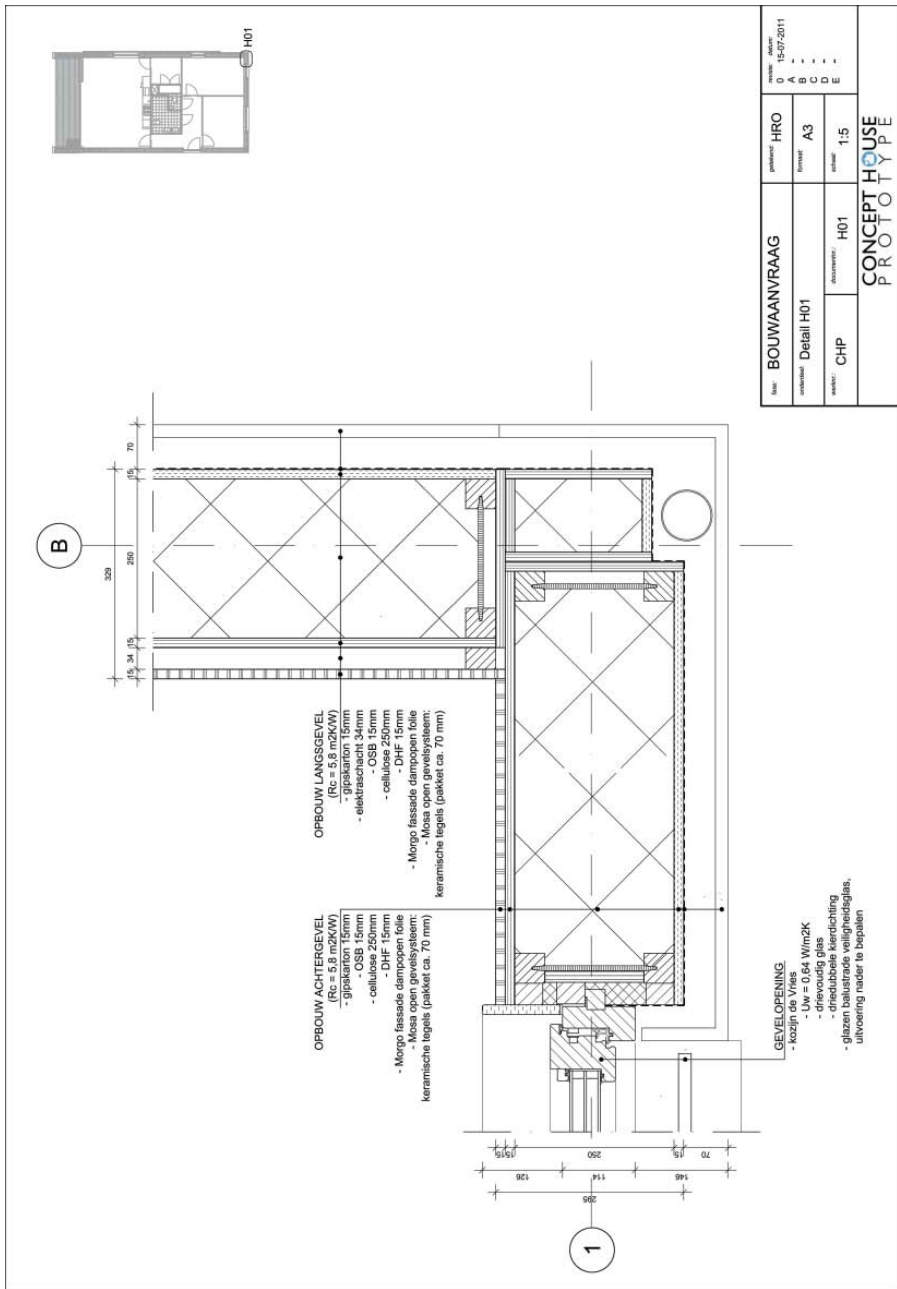


FIG. 103 Detail H01

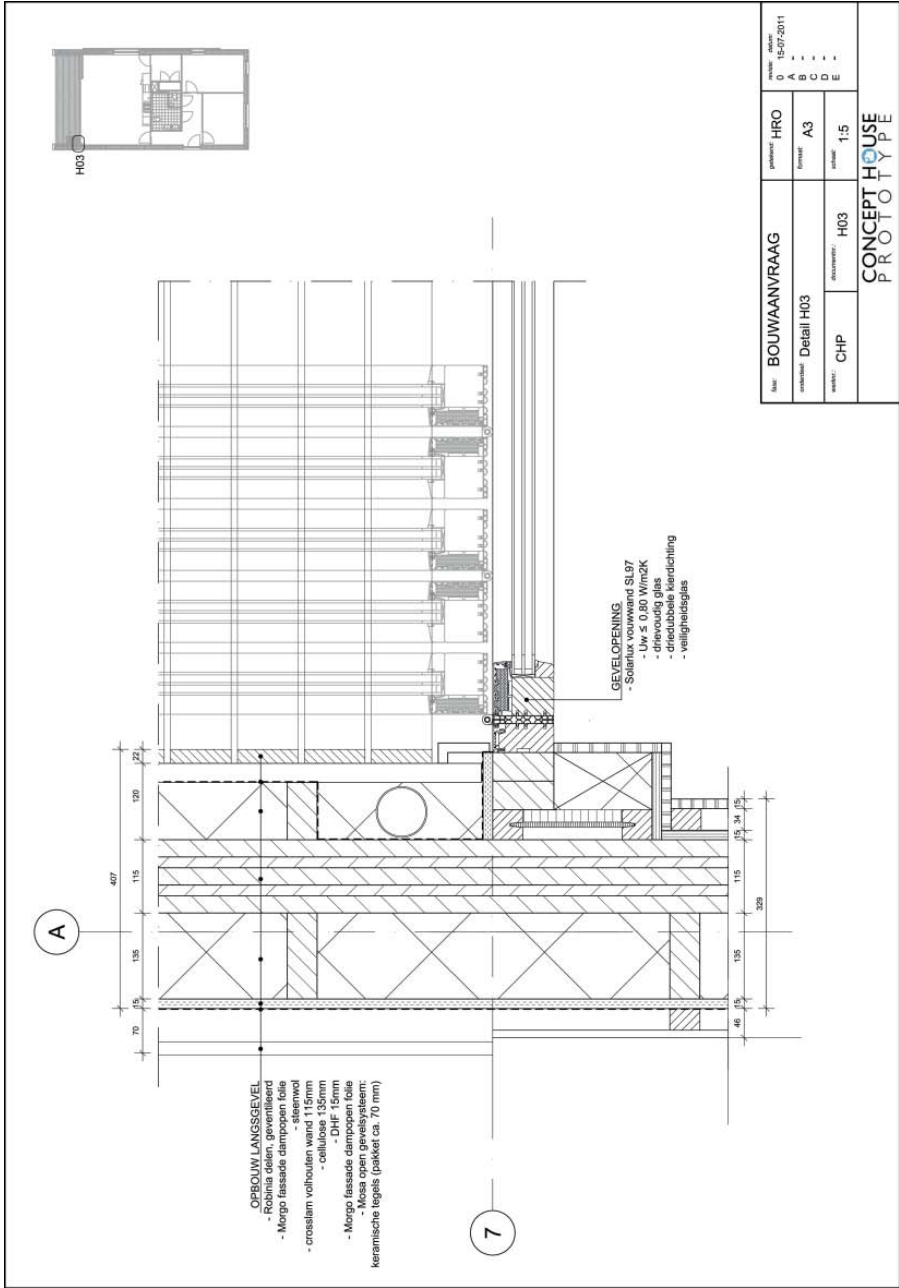


FIG. 104 Detail H03

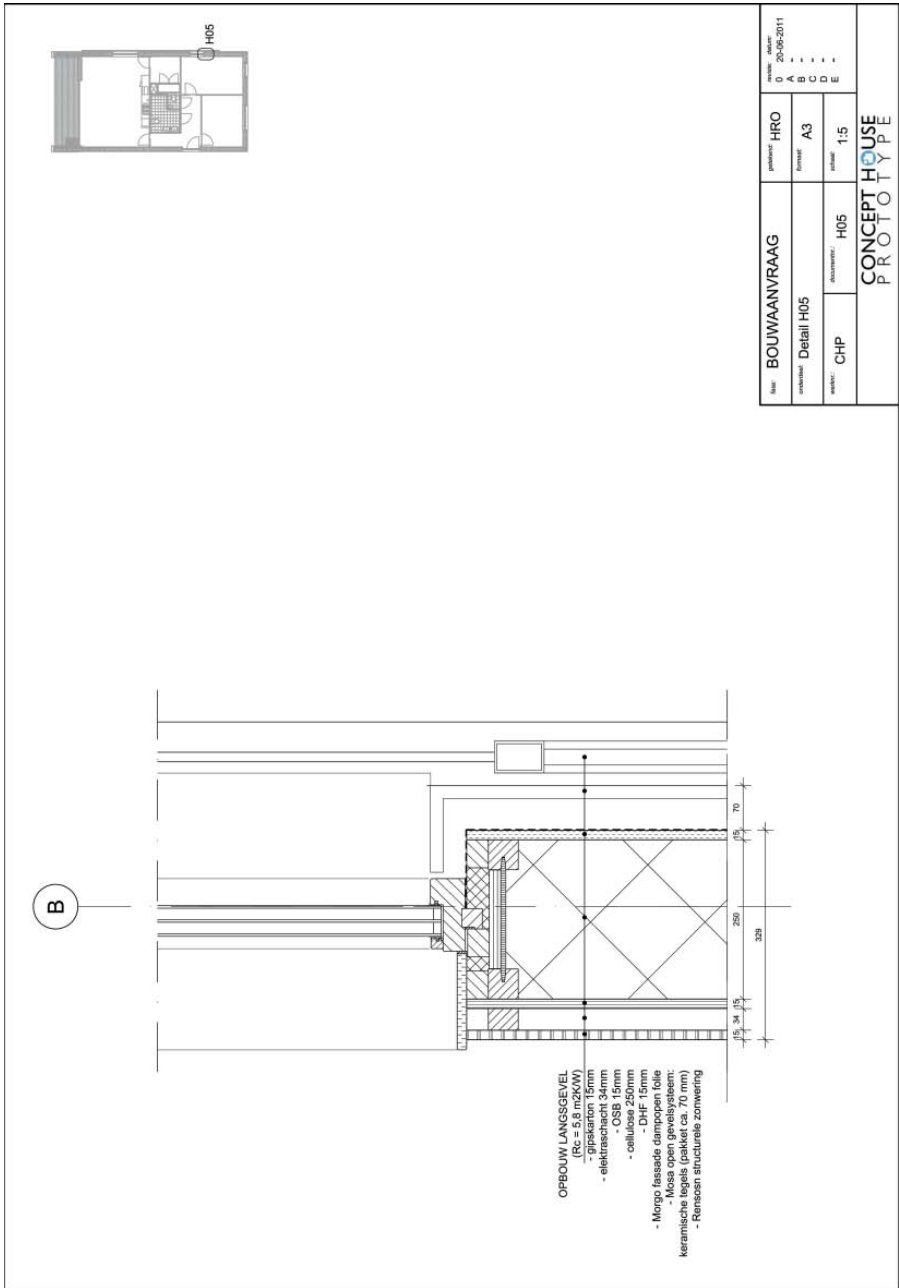


FIG. 105 Detail H05

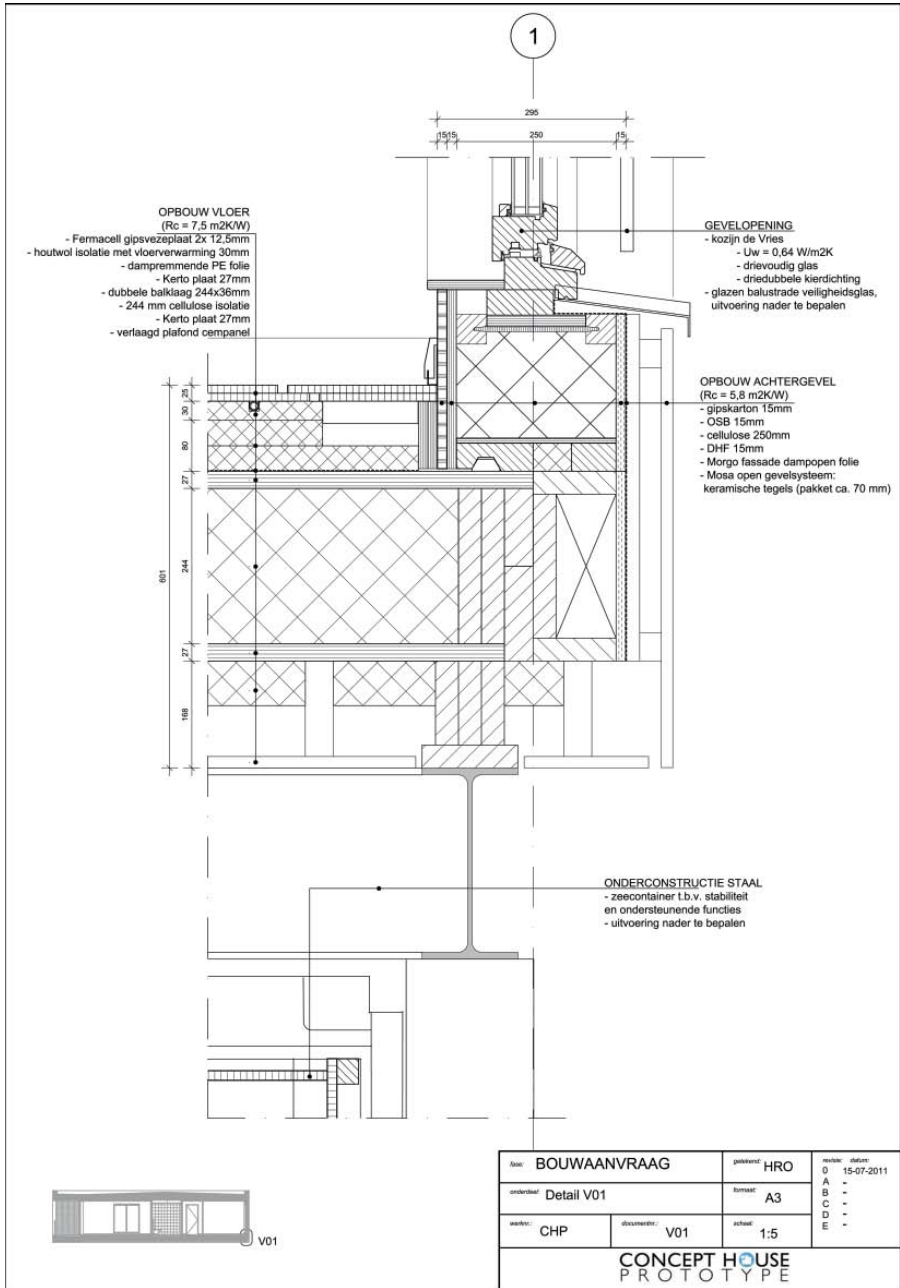


FIG. 106 Detail V01

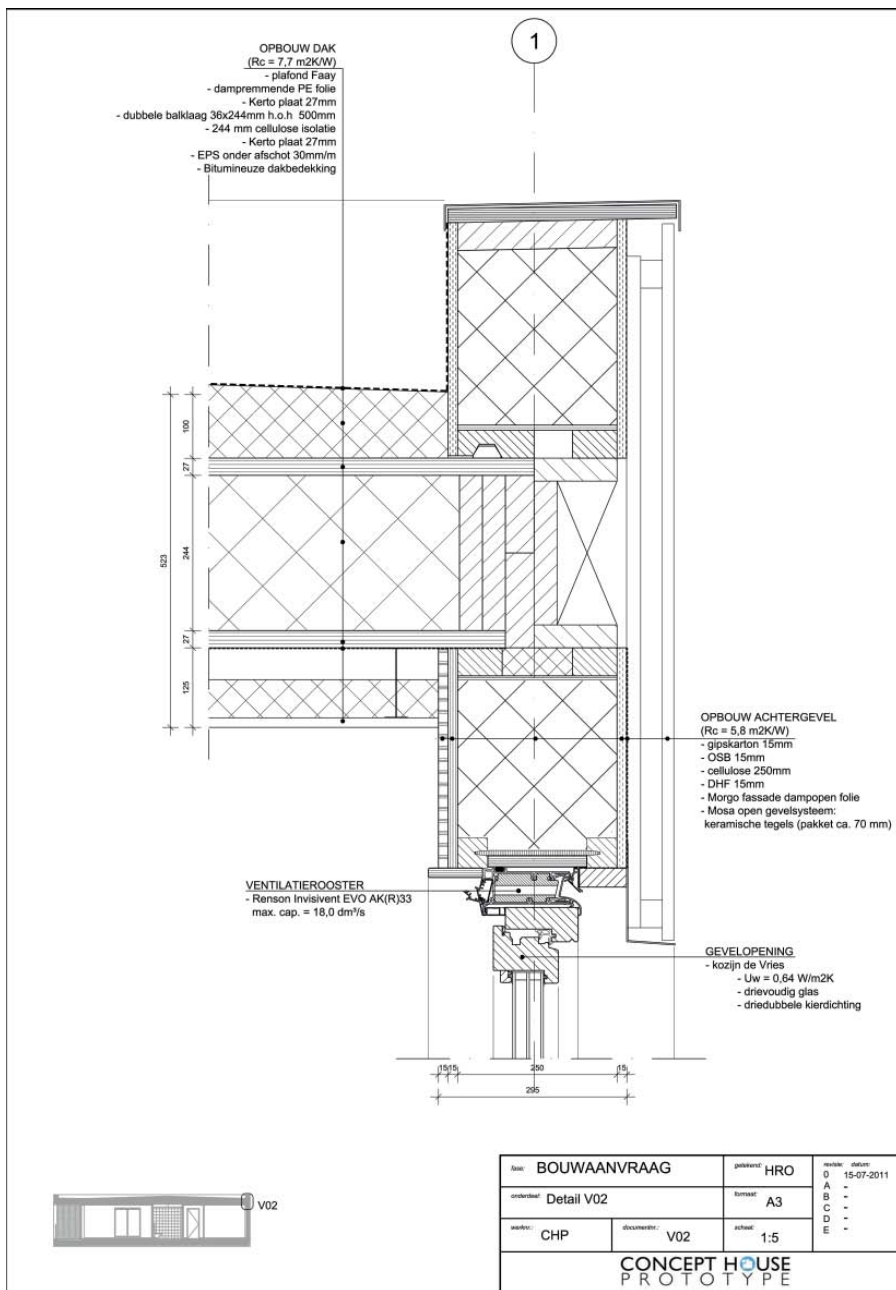


FIG. 107 Detail V02

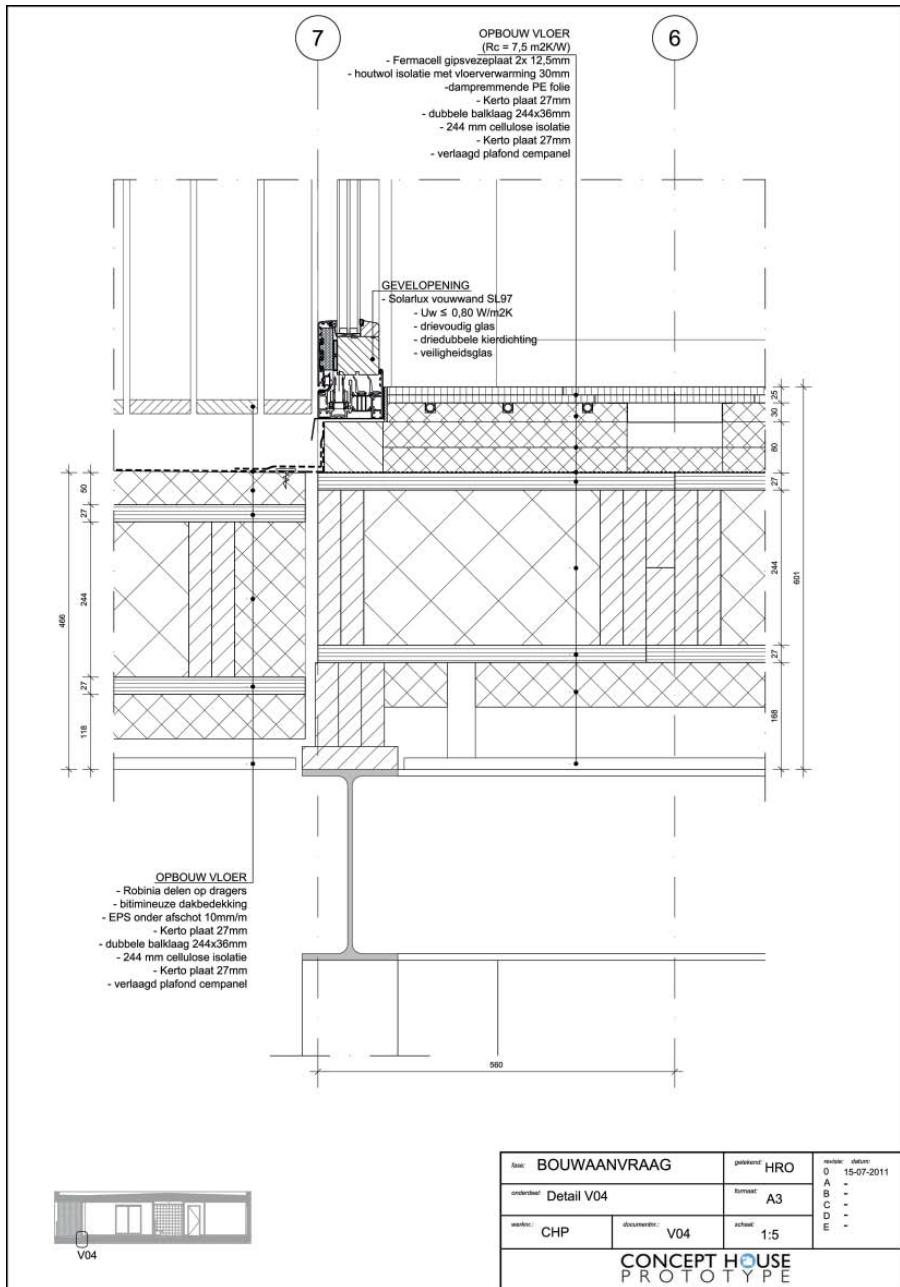


FIG. 108 Detail V04

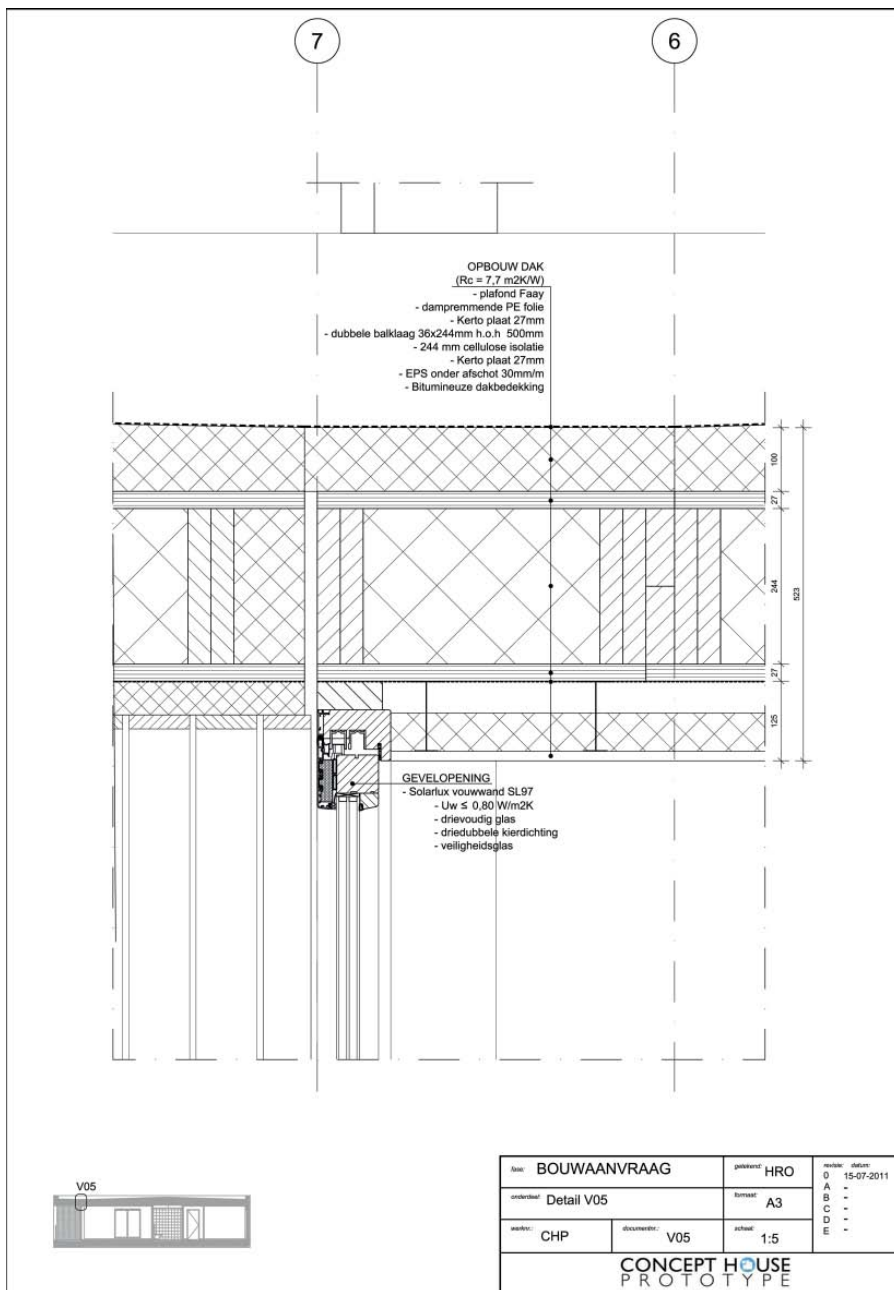


FIG. 109 Detail V05



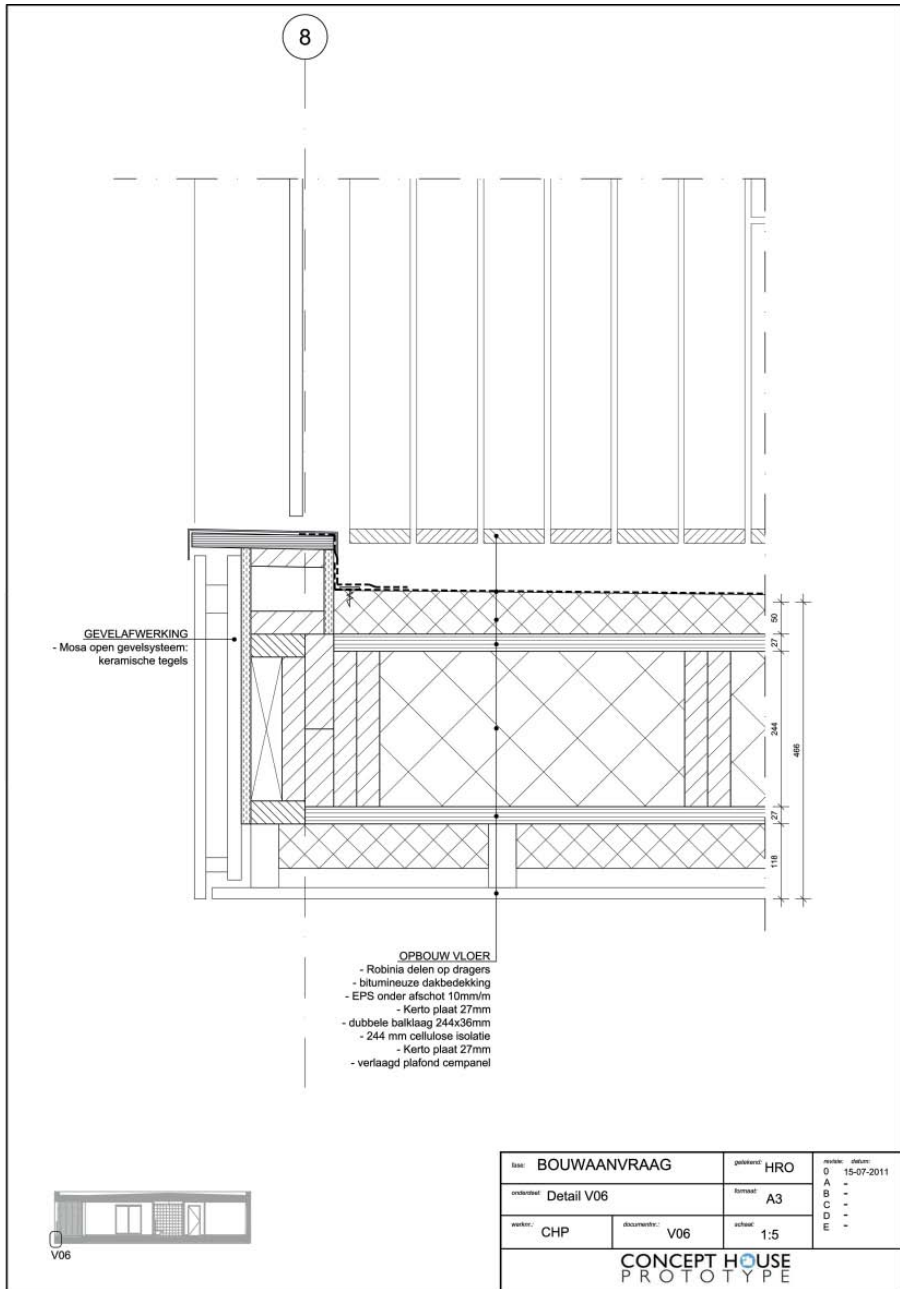


FIG. 110 Detail V06

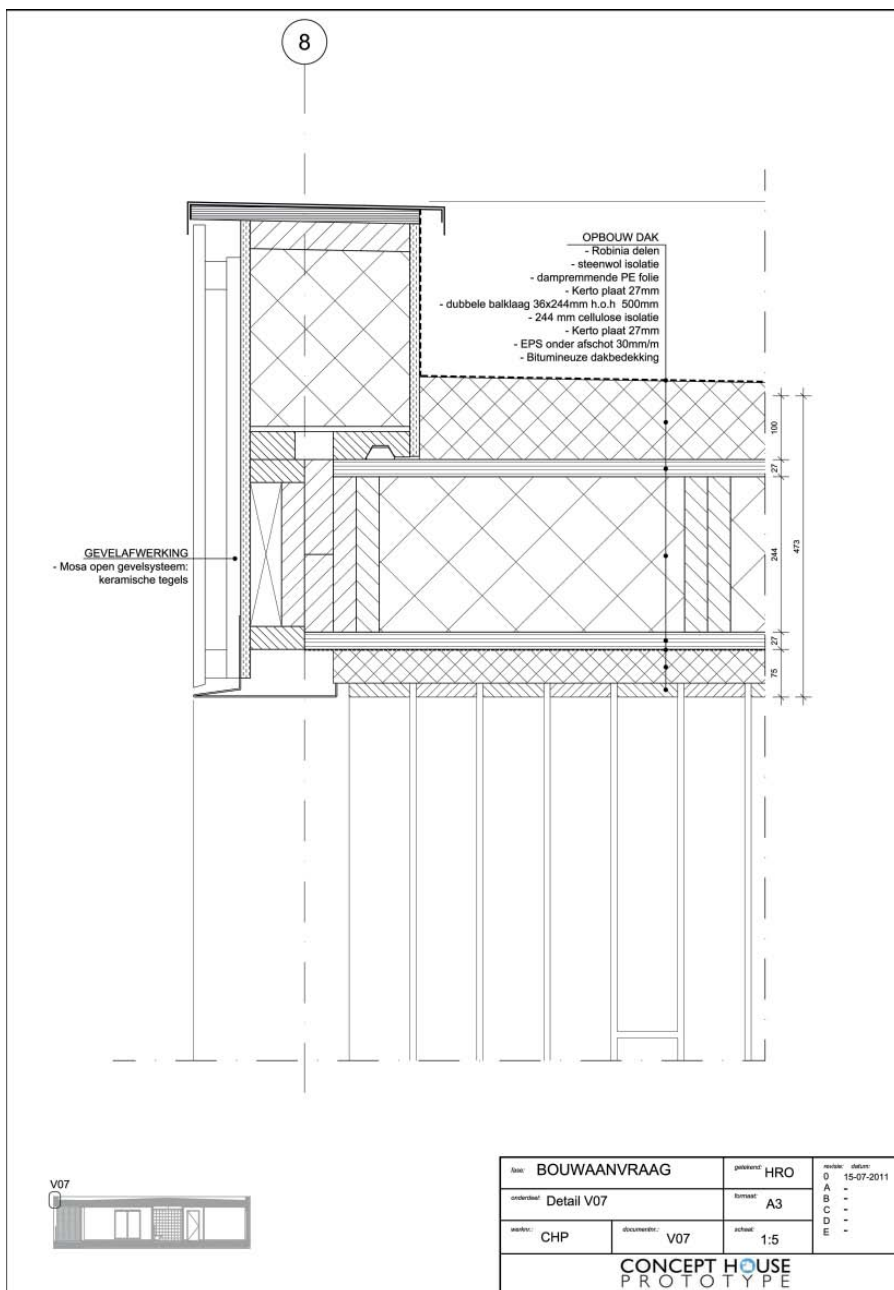


FIG. 111 Detail V07

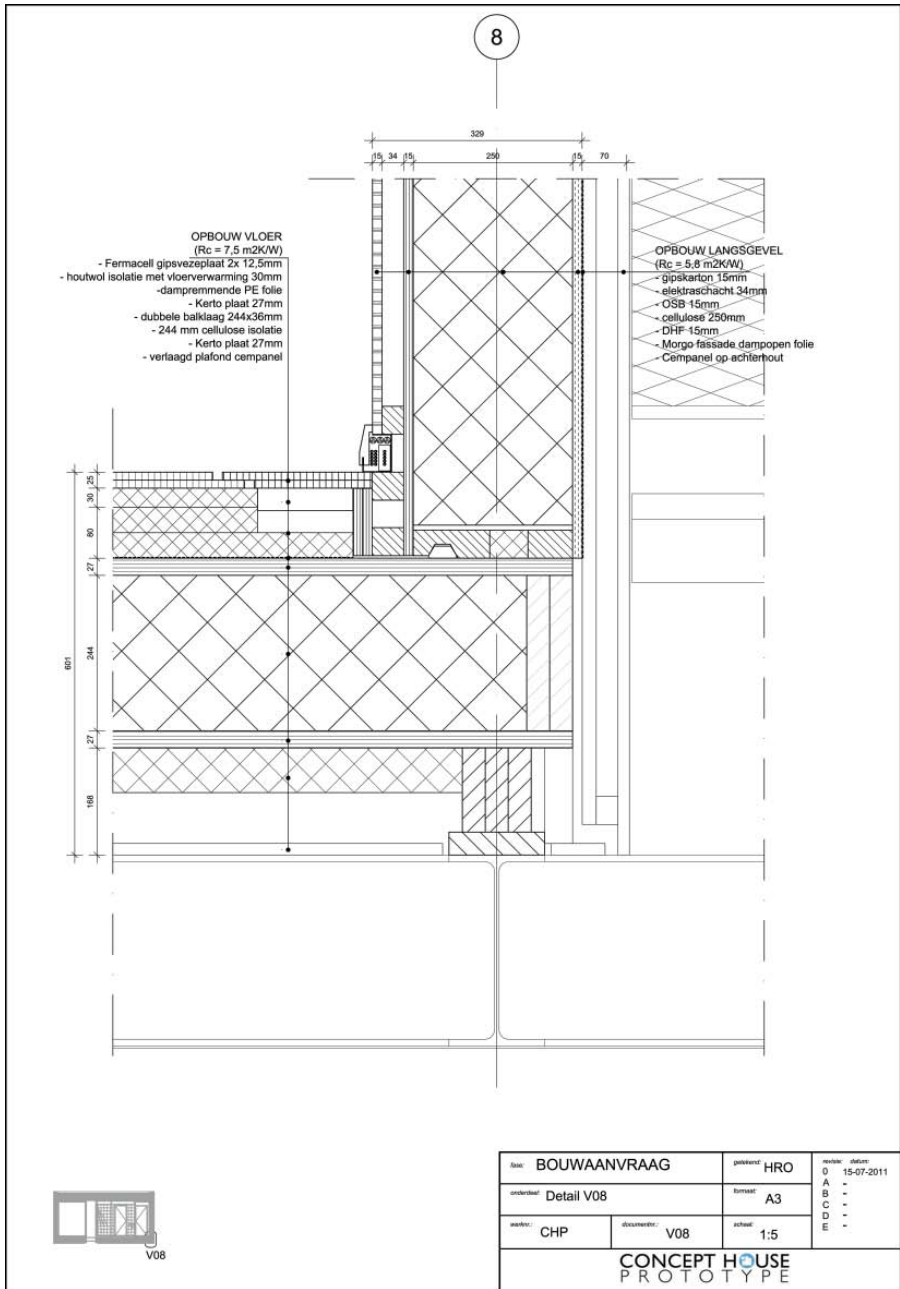


FIG. 112 Detail V08

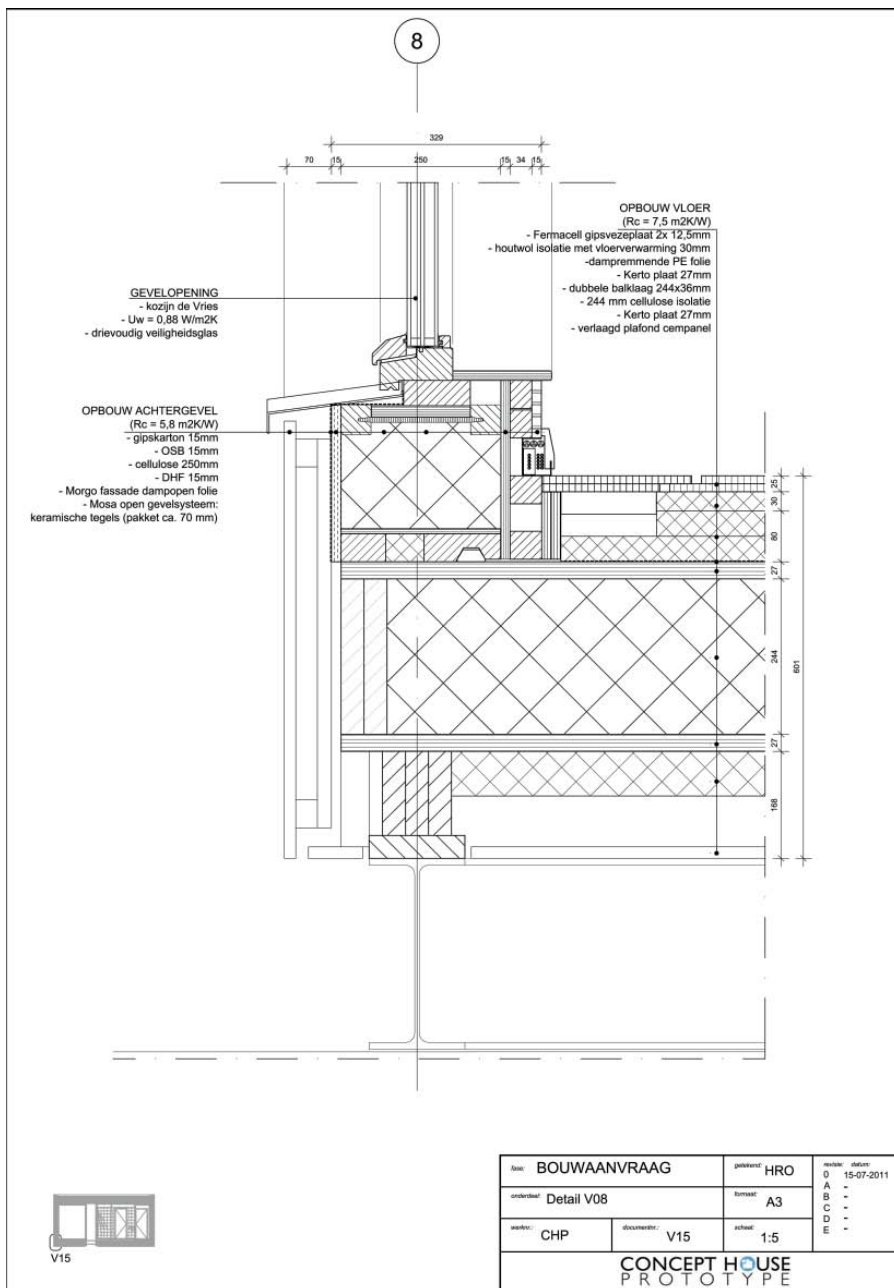


FIG. 113 Detail V08

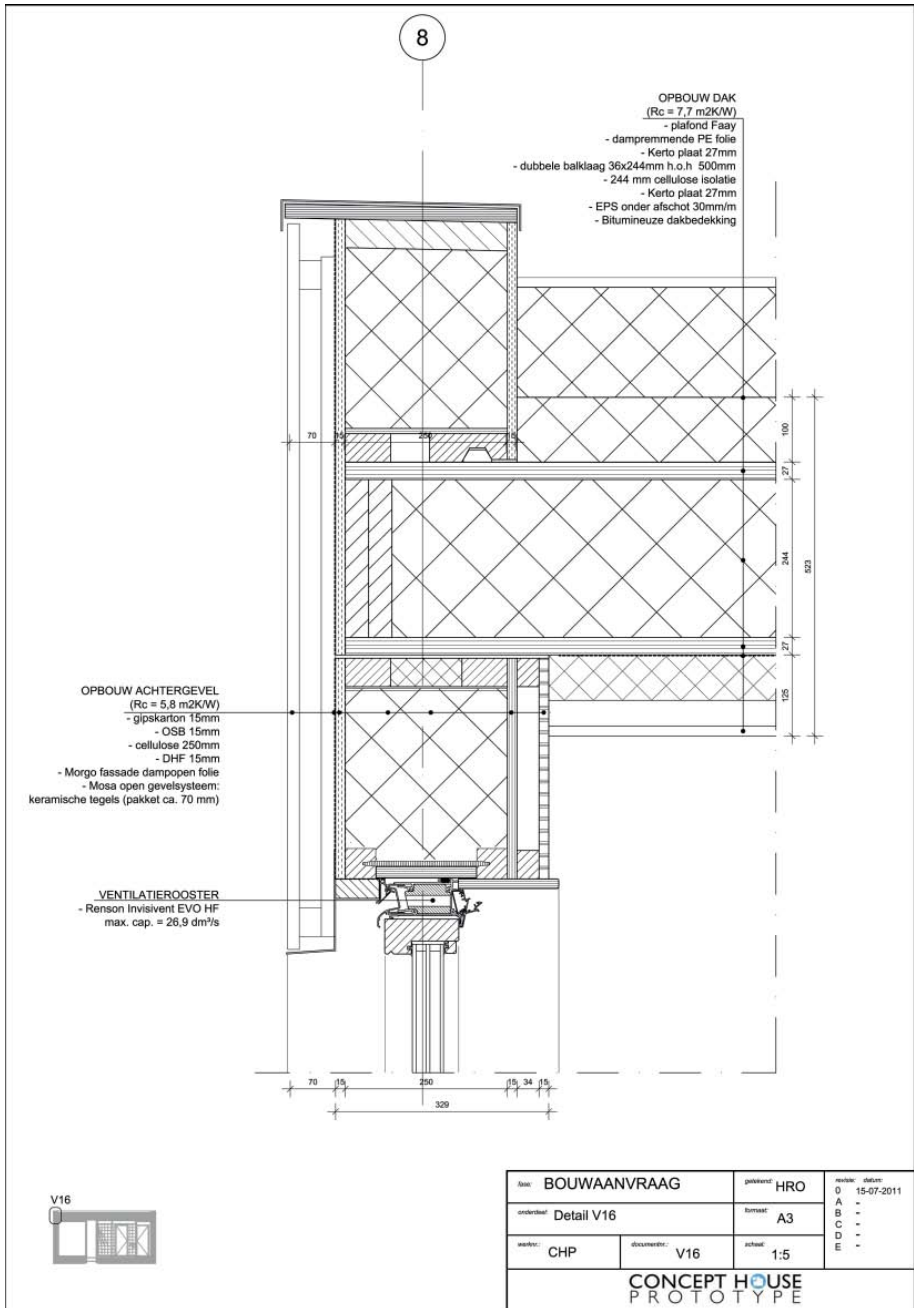


FIG. 114 Detail V016

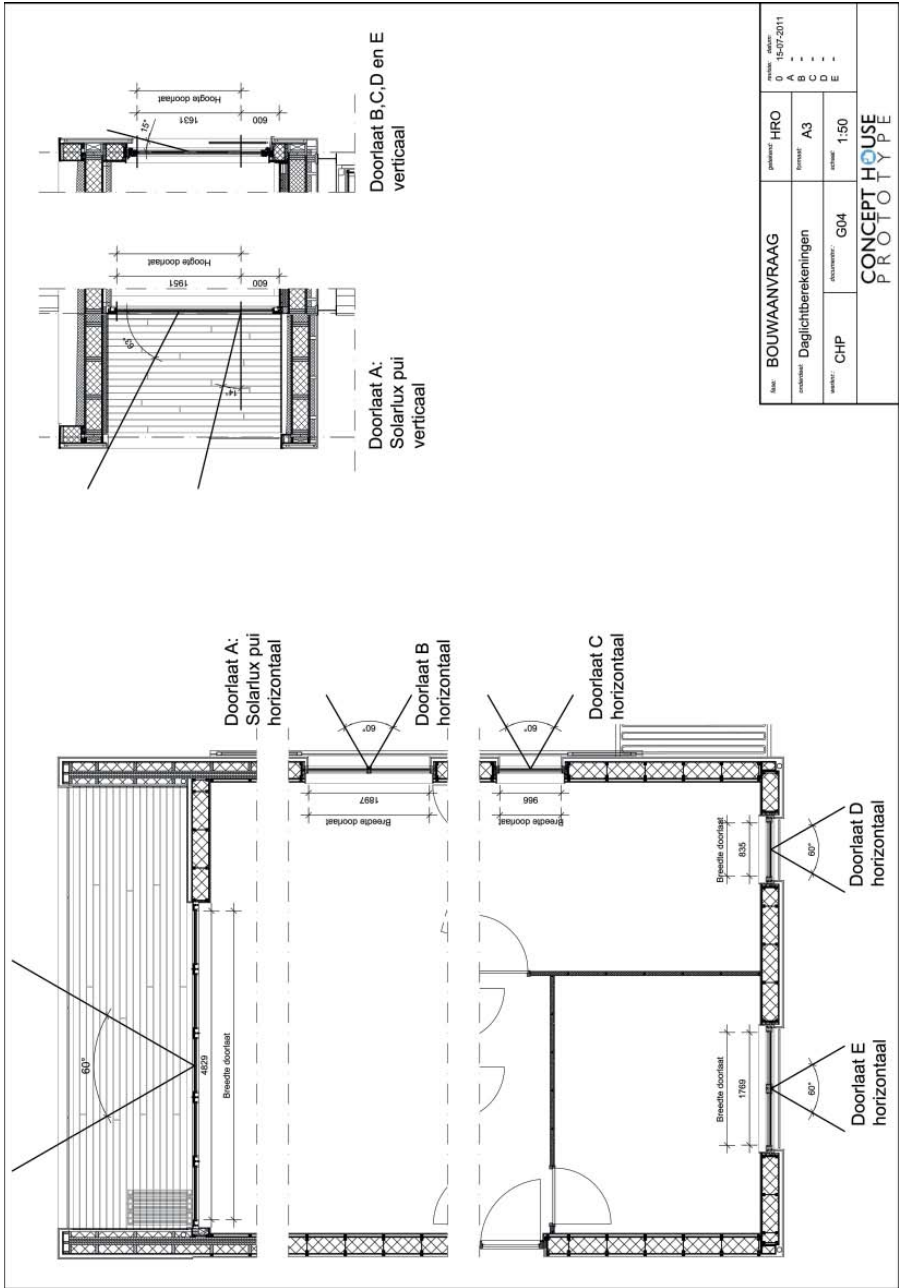


FIG. 115 Daylight calculation

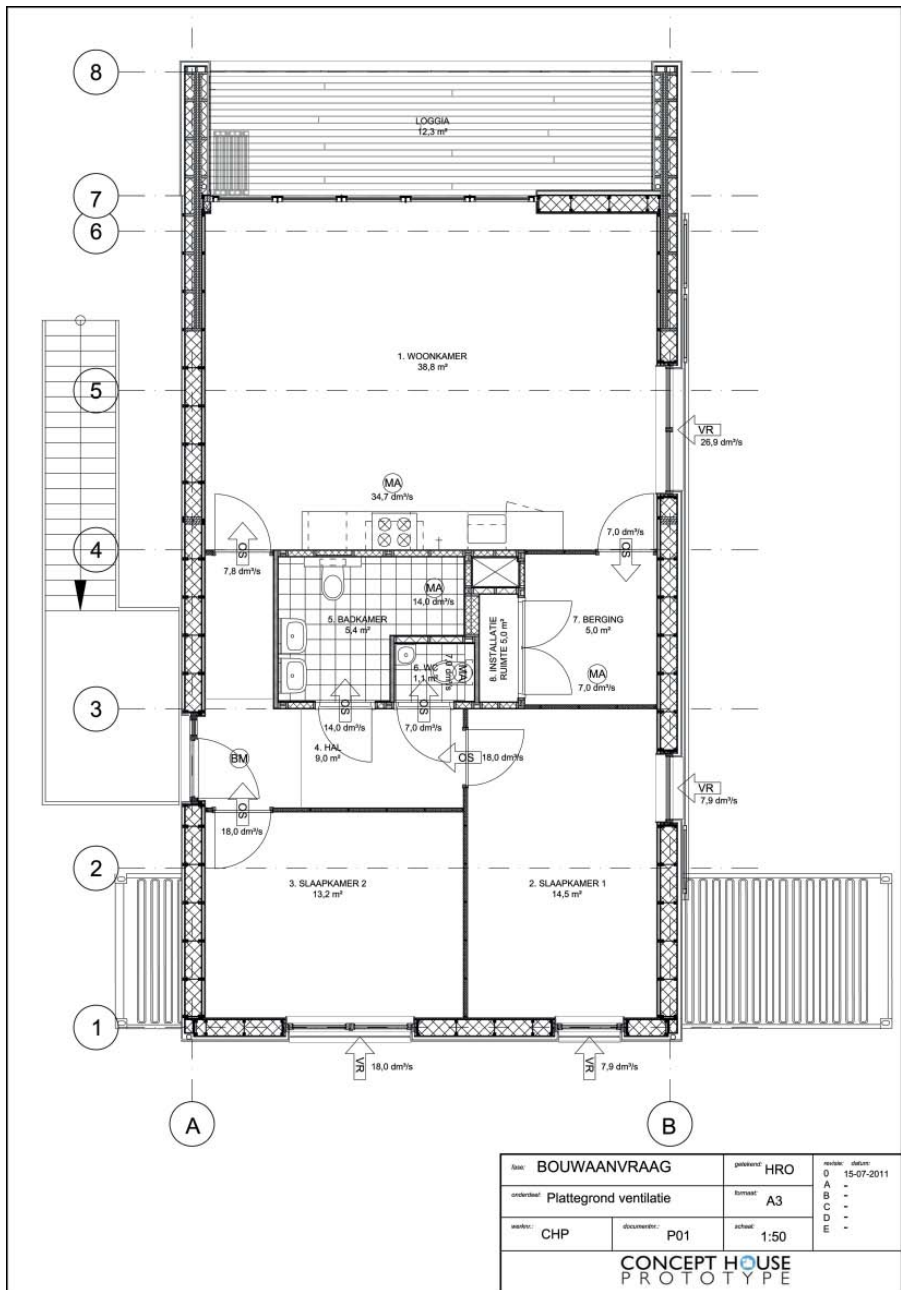


FIG. 116 Ventilation plan





# 10 EPILOGUE



Hugo riemusP

## 'AN ADVENTUROUS TRIP WITH MANY COURSE CHANGES'

I read this realistic account of the realisation of the Concept House 'DELFT' Prototype from the point of view of an outsider. I was active at the research institute OTB (research, education and consultation in the fields of housing, building and built environment) since 1985, and from 2003 onward at TU Delft, Faculty of Technology, Policy and Management. The distance between that faculty and the Faculty of Architecture and the Built Environment, where between 1960 and 1985 I was student, researcher, professor and dean, made it difficult for me to place the Concept House 'DELFT' Prototype as a research object. Understandable in the sense that Mick Eekhout stated it was no research project but rather a development project. The aim was to develop energy-positive multi-storey housing. Logical from the point of view of the chair Product Development. In a very practice oriented manner Mick Eekhout's scientific domain was situated between designing and making on one hand and generalising to achieve a "little more science" on the other. The problem statement at the basis of the development and realisation of the prototype seemed to be: Developing an industrially manufacturable energy-positive apartment and the coordination and integration needed to turn a collection of individually developed parts into a systematic whole for a multi-storey apartment building as an artefact.

The development focussed on the processes of designing, developing and integrating an industrial apartment as an artefact. Obviously the perspective has been adjusted in the meantime. In the beginning the primary objective was to develop a rational, industrial real-estate product; later the goal comprised an energy-positive apartment system. In part due to the fact that associate professor Arjan van Timmeren took over the leadership of the project. Initially the project was aimed at the target group of starters. By the way, market

demand was not analysed ahead of time, at least not in the scientific way I was used to. Income level and rental amounts were not specifically taken into consideration. The project was aimed at starters and yuppies. However, from 2008 onward the building market fell quiet in a recession. At that time, the target group had better been comprised of older couples and retirees, not in the city centre but in broader, more rural areas.

The developed system proved optimally suited for a maximum of four storeys in the form of energy-positive timber frame construction which resulted in a small ecologic footprint. The lateral dimensions allowed for spans between 5,4 and 7,2 m and a large number of floorplan variations; typically 3 to 4 room apartments. The realisation cost for the experimental single apartment prototype was approximately € 410.000. This amount included the salary for two staff members working on the development [extern] paid by the chair, materials and components, development of new components [bathroom]. All of the necessary financial means were acquired externally. Ten partners paid the salaries, subsidy was granted as part of the program 'Pieken in de Delta', and 30 material supplying companies participated as sponsors. With a target price of € 150.000 a small series of 16 apartments forming the Urban Villa would require an extra € 30.000 in connection with the installations and ducting needed to achieve an energy positive status; in the long run a larger series of Urban Villas could result in cost reductions down to approximately € 130.000 – 140.000. The project team also participated in the tender for the Lakenplein in Leiden [Portaal housing association]: 60 apartments (75 m<sup>2</sup>) for € 125.000, but the rock bottom price was not yet realisable for the social rental market with this pilot run. Strengths: comfortable, slightly luxurious; weaknesses: the prototype consists of only one single apartment. An urban villa with 16 apartments would have provided a better picture due to the serial effect.

Above all the design and realisation process seemed to be a question of improvisation: plans had to be adjusted repeatedly, and every new round offered surprises. Mick Eekhout acknowledged this: there were many loops, hesitation amongst various parties, certainly because there was not one single, financially driven leader but rather an academic research group. The composition of actors changed constantly. In several cases, one actor was succeeded by another. This had to do with the nervousness of the partners. Initially they really did want to participate but after two years many of them were called back by their board of directors, caught up by the recession.

The Delft Prototype contributed to the objectives of the 'Pieken in de Delta' program. It was the first prototype built in the Concept House Village for which the subsidy was granted: a delivery room for experiments. In the meantime there are three Concept House Prototypes in the Concept House Village in Heijplaat, Rotterdam.

The Concept House Delft Prototype fits in the research program 'Green Building Innovation' of the Department Architectural Engineering & Technology' at the Faculty of Architecture & the Built Environment. Upon completion the apartment was intended to be used as a research laboratory for the behaviour of human/machine: Living Lab by the Faculty of Industrial Design Engineering (IDE), and to be lived in. This opportunity has been utilised

a few times but it seems that measuring and comparing the results with the objectives has not gotten its due yet. Good feedback has not been provided. This must still be done. Professor David Keyson of IDE managed the prototype as a Living Lab, with students regularly working on sub-developments on machines; often related to controlling energy. One graduate worked on a 10-liter water shower system. In the beginning, living in the prototype did not require gas and electricity, given average user behaviour. A group of four students lived in the prototype for a week: in spite of irons, washing machines and refrigerators they conserved some of the energy, see TU Delft Delta May 2013. The emphasis lay on sustainable energy: solar cells on the roof, warm water in the roof for underfloor heating and a ground loop for room temperature. The experience and evaluation of households having lived in the prototype have barely been reported or published. In principle this was not part of the building process, but it was part of the user process Living Lab as it is used today. Measurements of the temperature comfort level were taken by means of apps [IDE research].

The dean of the Faculty of Architecture & the Built Environment at the time, Professor Karin Laglas, experienced the project as a 'headache dossier' and wanted an end to the project. She saw subsidies of € 100.000, granted on condition of a scientific report, evaporate when the external staff members could no longer be paid from the budget of the project. Mick Eekhout did not have any employees at the chair left who could write the book. Thus he wrote the final report himself. The subsidy was then granted according to the agreement. The financial department of the university now wanted to close the project quickly and shied away from maintenance cost. By the way, all of above mentioned managerial complications took place after the building was furnished and opened.

The end-of-life issue was recognised by the participants of this experiment as well. According to Mick Eekhout the best end of life would be to dismantle the prototype from the columns in one piece, to transport it by ship and reinstall it elsewhere in the Western Netherlands. An alternative could be to transfer it to a different location within the Concept House Village and to later sell it on the private market. Transferring it to TU Delft as a research laboratory is another option [for example to the Green Campus of Professor Ad van Wijk]. As sustainability came to play a more central role in the research ambitions, dismantling and possible reuse of the prototype gained in importance.

All in all the report 'The development and realisation of the Concept House 'DELFT' Prototype' was fascinating. It entailed a very detailed description of the development and realisation process and of the prototype that was the result of these processes. The development of the prototype crowned an eight year long process, initiated by a request from the building industry, fully externally financed, with the chair Product Development aiming at creating industrialised housing. The Concept House was seen as an artefact, a system of systems, an orderly collection of sub-parts that together function as a system, as one product. The intention was undoubtedly good but the execution left a lot to be desired.

The report seems to provide a rather representative picture of the Dutch building industry, of the realisation processes of real estate and of the state of the art of research and development in architecture. A similarly truthful report is rarely published; more often than not hushed up and forgotten. The result is clearly visible, but the path to get there was an adventure, a bumpy ride.

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