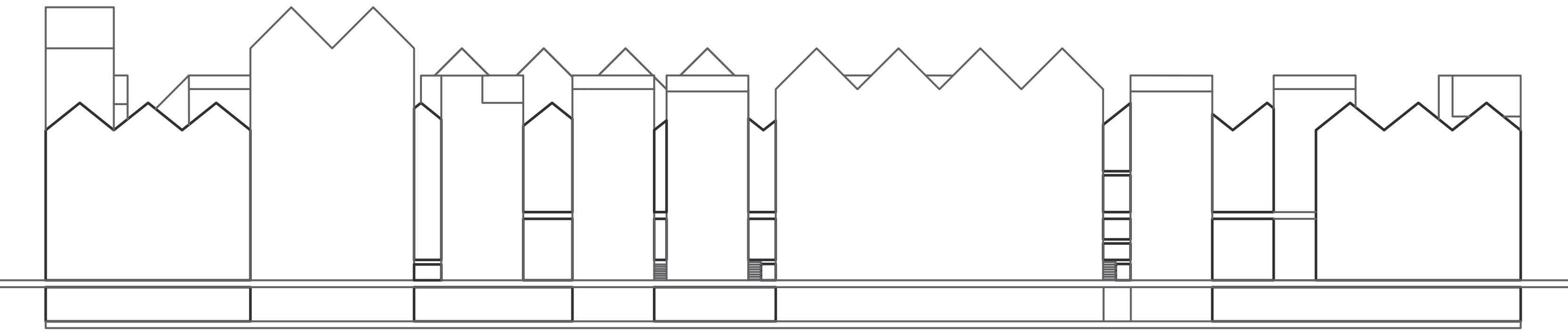

Urban Dwelling-Scape

Process report

ma4_ark34_2011
Cecilie Breinholm Christensen

HOME

(DWELLING IN PROCESS...)

*“a home cannot be produced at once;
it has its time dimension and continuum,
and it is a gradual product of the dweller’s
adaption to the world”*

[Pallasmaa, 1995]

TITLE PAGE

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Cecilie Breinholm Christensen

Synopsis

This report documents the process of the thesis project on 4th semester of the Master at Civil Engineering in Architecture & Design, Aalborg University.
The project is concerned with the themes of dwelling and sustainability; more specifically how the qualities of the detached single-family house can be combined with the qualities and sustainable benefits of living in a dense urban context at the harbourfront in Aarhus.

Ackowledgements

Thank you to *De Bynære Havnearealer*, Aarhus Kommune, for contributing with digital maps of the harbour area of Aarhus, and for their kind response to questions regarding the area.

Also thank you to Carsten Hoff, Architect MAA, for sharing his experience with housing projects, specifically the project *Fremtidens Etageboligformer* from 1978 and thank you to (previous) *Centre for Housing and Welfare,* Sociological Institute, KU, for their contribution with articles.

CONTENTS

INTRO

Title Page p. 7
Contents p. 6
Motivation p. 12
Project brief p. 16
Tools and methodology p. 20
Reader's guide p. 24

ANALYSIS

Theoretic context
- home & dwelling p. 29
- contemporary lifestyle p. 37
- sustainability p. 42
- energy and comfort p. 48

Physical context
- place and history p. 62
- topography and typologies p. 66
- climate p. 70
- functions p. 68
- paths and connections p. 69
- characteristics and materiality p. 72

PROGRAMME

Dwellers p. 76
Room programme p. 78
- functions
- connections
Architectural quality p. 82
Vision p. 84

CATALOGUE

Cases p. 88
- Kartoffelrækkerne, Copenhagen, DK
- 8-tallet, Ørestaden, DK
- VM-bjerget, Ørestaden, DK
- BedZed, London, UK
- Odham's Walk, London, UK
- Borneo-Sporenburg, Amsterdam, NL
- De Citadel, Almere, NL

- sustainability - architectural expression p. 92
- dense living p. 94

Spatial principles p. 100
- gradual transitions

CONCEPT

Urban scale
- physical context p. 107
- the villaroad p. 108
- part/totality - the kasbah-idea p. 110
- landscaping p. 112
- final concept p. 113

Building scale
- landscaping - common individuality p. 114
- the kasbah-idea - light conditions p. 116
- indoor climate and energy p. 117
- the villaroad p. 119
- final concepts p. 123

DETAILING

Urban scale
- spatial organisation p. 127
- infrastructure the villaroad p. 130
- materiality p. 132

Building scale
- spatial organisation p. 134
- facades - materials and construction p. 136
- facades - energy consumption p. 140
- facades - indoor climate p. 142
- energy and indoor climate p. 146

OUTRO

Conclusion p. 150
Reflections p. 154
References p. 156
- primary
- secondary
- illustrations

APPENDICES

Appendix 1 p. 167
Construction details

Appendix 2 p. 170
Indoor climate and heat balance, Bsim

Appendix 3 p. 176
Light indoor climate, Velux Daylight Visualizer

Appendix 3 p. 178
Energy consumption, Be10

INTRO

MOTIVATION

There are several motivation factors for working with the themes of dwelling and sustainability. First of all, the personal motivation factors are a general interest in the interaction between people and between people and the environment. **The home constitutes the border between public and private**, and as a result the home has a great impact on the way which people meet society. It is the place, where the child has its first encounter with the world, and the home frames family life, where values, traditions and culture is passed on from one generation to another. **Moreover, the home is where most of us spend the majority of our time**. Thus, it influences on the general health and well-being of its inhabitants, both physically and psychologically. This again influences the performance and behaviour of the inhabitants in all other aspects of their life, e.g. at school and at work. [Lawrence, 2001][Benjamin, 1995]
In this way, the architectural profession has an important task in providing the housing, which constitutes the physical frames for people's homes, and it is of course relevant to investigate how this can be done in an optimal way.

It seems however, that there is a disagreement between professionals and layman in what an optimal dwelling is. According to the Danish population, **the detached single-family house is by far the most preferred housing typology**. It is on the top of the housing hitlist and has been so for many years – and probably will be for many years yet to come. Among the things people value is the ownership of the house, the freedom to decide and to be able to walk around the house. Also, the neighbourhood has a great impact on the choice, as people like to live among people, who share the same values, they like to be able to relate to their neighbours, even though they may not necessarily have any social contact with them. On the other hand, they also like to have a hedge and some distance to their neighbours, they value the privacy of the detached house. And of course, they value their garden and terrace and the closeness to green areas in general. [Jensen, 2008][Kristensen, 2010]

Ill. 12a Home-making of the single occupant

But among architects and planners, there has always been an adversion towards the detached single-family house, especially the standardised ones. Neighbourhoods of this kind of housing are considered unattractive and distasteful among many architects and planners due to the many varying styles and expressions. These neighbourhoods are considered to be anti-social and people living there to have an individualistic, and egocentric lifestyle. A more objective and unbiased critique relates to sustainability, where this housing typology is considered an un-sustainable way of living characterized by a too high energy consumption and too high need for transportation. [Kristensen, 2010][Arkitekten, 1976][de Waal, 2011]

Also, most of the detached single-family houses are owned by couples who bought them in the 1960's and 70's, where the majority of them were built, and consequently their children has already left home. This means, that it is difficult for young families to enter the housing market, since they cannot afford to buy a house in the urban areas, where they have their job, and social network. So the "dream-house" is for many just a dream, which they cannot realize. [Kristensen, 2007]

Ill. 13a A typical horisontal villaroad

Moreover, **the detached single-family house is not sustainable**, and already when these houses were constructed in the 1960's -70's it was discussed, whether this was actually the best solution towards a more sustainable development. Sustainability is, of course, a broad and imprecise concept, and it seems like the term is applied on almost every ambitious project, without taking the time to consider what it actually implies for a project to be sustainable. Sustainability includes a lot more than lowering the energy-consumption and planting a tree, it is a way of thinking and consequently it should be implemented in a much more broad sense already in the projecting and planning of a project. It is a fact, however, that there is a need for a more sustainable development, if the present economic growth and urbanization is to continue, both on social, environmental and economical level. [Arkitekten, 1976][de Waal, 2011]

Ill. 13b A vertical villaroad

Seen in this perspective, the detached single-family house fails to meet the demands for sustainability on several levels. At a social level, the basic idea of the detached single-family house is not very social in terms of equality and fellowship and the aforementioned economic aspects hinders social mobility. At environmental level, the detached single-family house has a big use of resources, both in terms of materials and in terms of energy consumption for the household as well as for transportation. Moreover, it spreads out over the open land, which impacts on biosystems and nature in general. At economical level, the expensive detached single-family houses further hinders economic mobility. It keeps economical strong people strong, and makes it more difficult for people without a large economic capital to get into the housing market.

In this respect **it would be more sustainable to live compactly and dense in an urban environment**. Dense living implies less need of transportation, less energy consumption and less use of resources in general, more variety and social contact and a mixed use of functions, which enables a maximum usage of the city area. Also, the city corresponds better to a late-modern lifestyle, which is characterized by mobility, flexibility, globalization and variety. People are constantly on the move and constantly connected, nothing is taken for granted and everything is for discussion. Consequently, it seems like there is a mis-match between the ideal house of most of the population and the way they actually live their lives, and that the detached single-family house is a somewhat anachronistic housing typology.

However, since this housing typology has such a massive success in the population, it cannot be neglected by professionals. The architectural profession has to relate to the things people value in the detached single-family house as starting points in their critique towards this housing typology.

Part of the discussion, is the practice at many architectural offices, seen through internships at two different architectural offices in Denmark and the Netherlands respectively. **In the architectural development of a project there is mostly drawn upon tradition and prevailing techniques,** as economy is a necessary part of reality in a company, where there is little time to research. Moreover, **there is little awareness** of sustainable approaches among decision-makers in the building industry. [concito.info]

Personally, it is experienced that the enhanced qualities of the detached single-family house does not necessarily conflict with a more dense housing typology. By up-bringing in a semi-dense area of row-houses, a common house and different communal activities such as work days and dining together, the experience is that this does not compromise with the feeling of privacy and ownership of the single dwelling. On the contrary, the best is obtained from both being part of a small community with shared facilities and having individual dwellings with private gardens.

Ill. 14a Sustainability

Consequently, **the overall personal motivation factor is the strong belief in the possibility of a sustainable life in a dense urban context in combination with a high quality of life as enhanced in the detached single-family house**. There IS a solution of combining *home* with *sustainability*, but there is also a need for showing such solutions, both towards laymen, contractors as well as architects and planners in order to challenge prevailing prejudisms concerning sustainable and dense living, but also concerning the quality of life in the detached single-family house.

There is a need for action and for discussing and investigating more sustainable alternatives to present methods and design processes. It may be more expensive in the short run, but in the long term it is a necessary step to take. A key element in this development is the integrated design process, where environmental aspects has to be implemented from the beginning in order to achieve a high performance in sustainability in integration with the functionality as well as the aesthetics of the architectural design.

According to the previous listed motivation factors, the overall problematic, which is investigated in this project, is, **how the integrated design process can be used for designing dwellings, which combine the positive values and aspects from the detached single-family house with a more contemporary and sustainable way of life in a dense urban area – to re-invent the detached single-family house in a sustainable, urban context.**

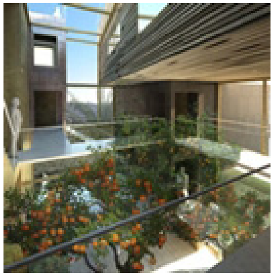
Ill. 15a The detached single-family-house in an urban context

PROJECT BRIEF

To guide the project, point of departure is taken in project briefs from contemporary architecture competitions, which focuses on the sustainable development of our built environment.

The Europan competition is an annual European architectural competition for young architects under the age of 40 with sites at several locations all over Europe.
In 2010 one of the sites was in Lisbjerg close to Aarhus as part of a new masterplan for the area. The solution should show how sustainable housing with varying sizes, ownership and demographic groups could be designed, with the use of sustainable building materials, more specifically industrialised wooden components. The design should be dense and compact and the project should encourage new housing typologies, by reflecting contemporary needs of individualisation and demands for privacy in the dwelling. The project should be perceived as a small village in the overall masterplan, and should contribute to a greater conscience and care for the surrounding environment, where the occupants get to feel a sense of belonging. [arkitektur dk, 2010]

The Europan competition for 2011 is inaugurated on February 28th 2011 and the topic is *"resonance between territories and ways of life - what architectures for sustainable cities?"*
The keywords are *identity, uses* and *connectivity* where the competition programme argues that in the quest for sustainability it is essential on planning level to develop the connections and interdependencies between areas, regardless of scale. *"The sharing of created spaces and access to the different municipal services promotes social relations between citizens."* Concern should also be taken regarding the horizontal growth of cities into unbuilt land by limiting this tendency, thereby protecting natural resources and biodiversity while enhancing the urban territories. The specific sites of the Europan 11 competition ask for solutions which proposes an environmental development strategy, where the projects should have a potential to evolve, taking into account the specific identity of the location and the scale of the site. In order to achieve this, the architect needs to consider aspects ranging from planning and landscape, as wells as environmental and economical factors in synergy with the architectural solution. Consequently, three scales have to be taken into account: the global strategic scale, the ideas scale and the scale of the urban and architectural project. [europan-europe.com]

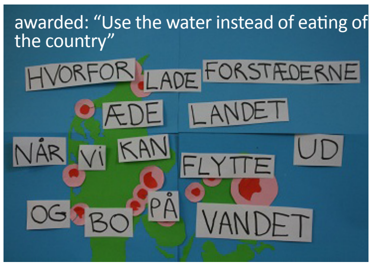


Ill. 16a
Europan 10, Lisbjerg
1st prize: *Together - apart*
by Kaspar Bjørn and Troels Dam Madsen


1st prize: “Favourite dwelling”


1st prize: “Living dense does not necessarily imply”


awarded: “Live denser - life will be easier”



awarded: “Use the water instead of eating of the country”


awarded: “toleraCITY”

Ill. 17a WInning proposals of “Show us how we should live - dense”

Another competition is called “Show us how we should live - dense” (translated from Danish), and the goal is to make visions for sustainable ways of living densely together. The competition takes its points of departure in the fact, that most Danish people would prefer to live in a detached single-family house, and that this is not very sustainable. It would be more sustainable to live compact in the cities, but this, however, also has disadvantages like noise and pollution.
Consequently the competition aims to challenge our culture, mentality and way of life, to investigate our willingness for change, to put our preferred housing typology into perspective, to ask about our use of resources and to contribute with realistic proposals for a paradigm shift in housing ideals.
Concretely, the competition proposals were to be handed in as short movies, showing visions of how we can organize our dwellings and cities in a way that increases quality of life and makes it more attractive and achievable to live and work dense in a sustainable way - thereby challenging the Danish dream of the detached single-family house. [botæt.dk]

The concrete architectural design of this project will deal with the beforementioned problematics by incorporating essential points and concerns.

Inspired by the competition in Lisbjerg, Aarhus, it is the goal that the architectural design solution entails:

- variation in dwellings (size and ownership)
- new housing typologies (individualisation and privacy)
- a small village in the overall urban fabric

From the competition “Show us how we should live - dense”, following points are extracted, where the architectural design solution should:

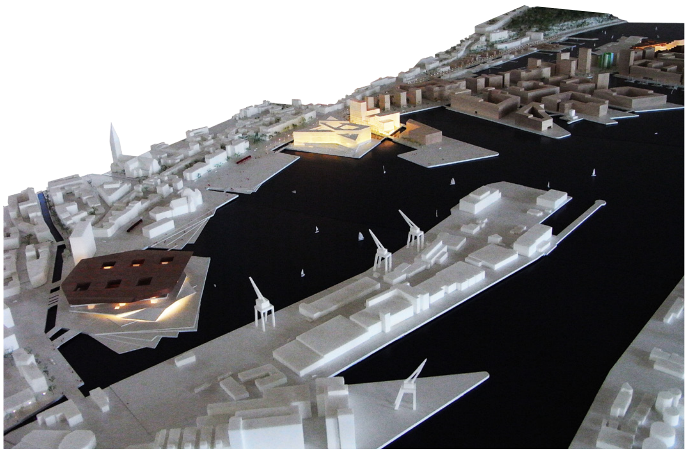
- putting our preferred housing typology into perspective
- envision how we can organize our dwellings and cities in a way that increases quality of life and makes it more attractive and achievable to live and work dense in a sustainable way

And finally, from the Europan 11, the architectural design solution should:

- relate to the keywords of *identity* and *connectivity*
- limit the tendency of horizontal growth
- have a potential to evolve

SITE

The project site is situated at the harbourfront in Aarhus, where the former industrial harbour is to be transformed into a new urban area with a mix of residential, commercial and leisure activities. First stage in this redevelopment is the Northen harbour area, which is situated very close to the city centre of Aarhus. The site chosen for the development of the architectural solution in this project is as close to the city centre as possible, at the most Southern part of this new plan (see ill. 18a below).
Another reason for choosing this location, is the opportunity to become part of the discussion of the future development of the city and how we should inhabit urban areas. The architectural design of this project will propose one solution to this problem, and by publishing it on the web-page of this new area (debynære-havnearealer.dk) it has the possibility to contribute to this interesting debate.



Ill. 18a Picture of 1:500 model at the office of "De bynære Havnearealer" at the harbour in Aarhus

The Northern harbour

The vision for the Northern harbour area is to become a lively, versatile and attractive urban area on the edge of the bay, which can emphasize Aarhus nationally as well as internationally. It should be a good place to live, an interesting place to work and have a multitude of recreational and cultural possibilties for both the inhabitants of the city as well as visitors. The fusion of commercial, residential and leisure functions should result in a lively centre for everyone, with respect for people, environment, architecture, infrastructure, business and economy.

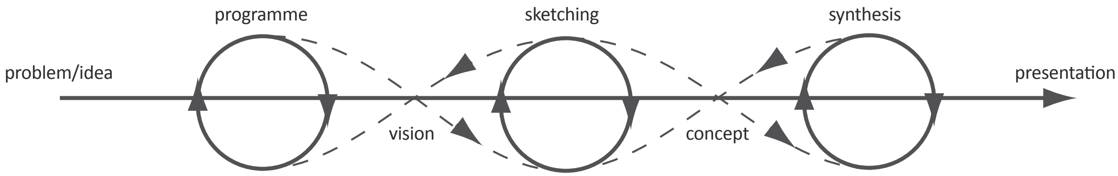
Two key elements in the new masterplan are a promenade along the original coast line of Aarhus for pedestrians and cyclists, and a maritime city square in close connection to the existing central city squares around the cathedral. Another important aspect is the mix of functions in order to obtain an urban city-like area. Consequently, the 80.000m2, which are to be built in the area, should have a division of 50/50 between residential and commercial functions, and with recreational areas in between. Moreover, there should be a variety of housing typologies and minimum 25% of the housing should be affordable.

It is the intention that the area should acommodate 7.000 inhabitants and 12.000 workplaces, with the workplaces centralized along the central accessway, which leads from the existing city centre to the area (see ill. 191 on following page). Consequently, the buildings here are tallest and decrease in height towards the water, in order for the housing to get closer to the water and to get a better possibility for a nice view over the water. All parking is planned to be underground, and the infrastructure in general should be of very high quality with focus on public transport to and from the area.[denstoredansk.dk,B][wikipedia.org][debynærehavnearealer.dk]

Ill. 19a Map 1:25000 of Aarhus with the new plan for the harbour area

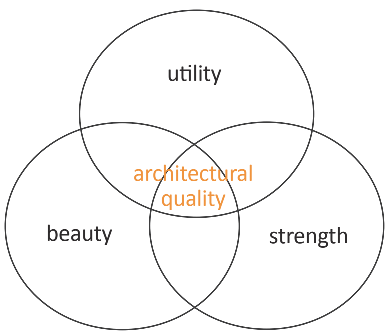
TOOLS AND METHODOLOGY

This project is carried out at the Master of Science in Architecture at Department for Architecture, Design and Media Technology at Aalborg University. The main method used at the engineering educations at Aalborg University is Problem Based Learning (PBL) where focus is on the Integrated Design Process. This method builds on the 5 phases: 1) problem and idea, 2) analysis and programming, 3) sketching, 4) synthesis and 5) presentation. It is an iterative process, as the phases overlap each other and interact on different levels, as different parameters, analysises and decisions lead back and forth within the process. The illustration below reflects how the different phases connect and how the process is alternately widening and narrowing as the project progress.

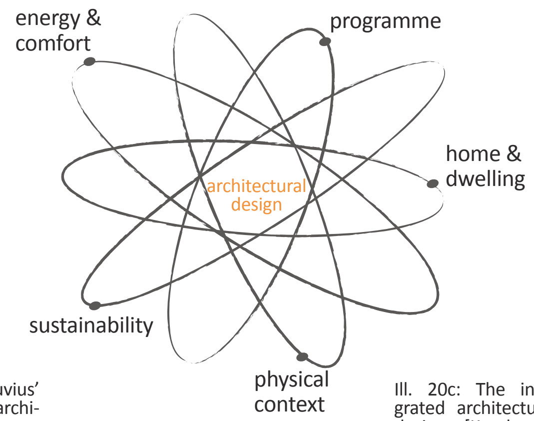


Ill. 20a: The iterative design process
[Knudstrup, 2005]

The Integrated Design Process is inspired by the Roman architect Vitruvius, who argues that qualitative architecture is a result of three equally important aspects: utility, stength and beauty. In this project these aspects cover the themes of sustainability, energy and comfort, home and dwelling, the programme and of course the specific location of the project, the physical context (see ill. 20c.). The solution should integrate and reflect these aspects equally in the overall architectural design as different layers of the design, both on a functional, technical as well as aesthetic level. [Knudstrup, 2005] [Topp, 2010][Jensen, 2011]

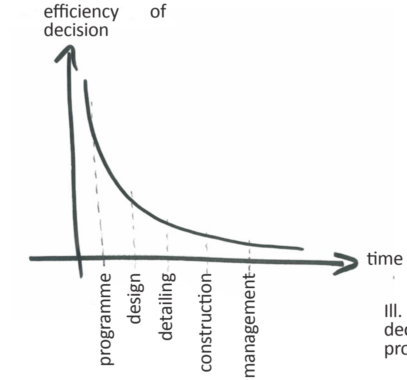


Ill. 20b: Vitruvius' definition of architectural quality



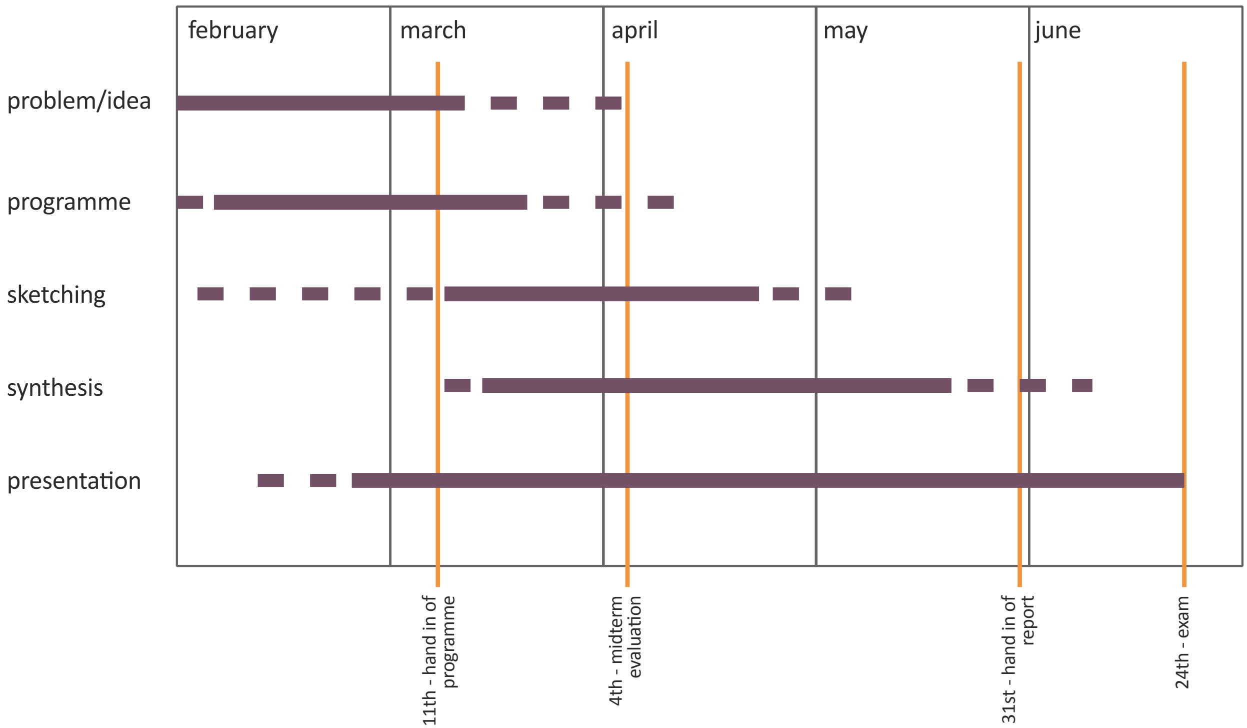
Ill. 20c: The integrated architectural design [Knudstrup, 2005]

As mentioned earlier, the integrated design process is a key element towards a building design with high sustainable performance. The earlier implementation of sustainable aspects, the more efficiently these can influence on the sustainable performance of the final building (see ill. 21a.). [Topp, 2010][Jensen, 2011]



Ill. 21a: Efficiency of a decision in the design process [Topp, 2010]

In order to adjust an iterative process to a linear time plan of the project period, the different phases are overlapping and running continuously over a large part of the period. The sketching phase for instance is initiated already in the early stage of the project, while the analysis is still being done, and continues into the synthesis phase, where the final detailing of the project is carried out.



Ill. 21b: The iterative design process implies overlapping of the project phases

Ill. 22a: Scheme of the tools used to solve the different tasks of the phases

	TASKS	TOOLS
problem/idea	project research + conclusions - theoretic context	literature, internet, article + case studies supervision/discussions writing analogous (pen + paper) digitally (Open Office + Adobe Creative Suite) visualising - 2D-sketching analoguous (pen + paper) digitally (Adobe Creative Suite)
programme	project/design research + conclusions/design parameters - theoretic context - physical context - rooms + functions - case studies	
sketching	design development - sketching (plans, elevations, sections, details) - physical modelling - digital modelling - initial calculations	literature, internet, article + case studies (study trips) supervision/discussions writing analogous (pen + paper) digitally (Open Office + Adobe Creative Suite) visualising - 2D-sketching analogous (pen + paper) digitally (Adobe Creative Suite) - 3D-sketching analogous (physical modelling) digitally (SketchUp + Revit) calculating - spreadsheets (monthly + daily average, ventilation spreadsheet) - Ecotect with Radiance - Be10 - Bsim
synthesis	design detailing - exact drawing (plans, elevations, sections, details) - physical modelling - digital modelling - exact calculations	
presentation	design documentation - 2D-visualisations plans: floorplans single unit, 1:50 floorplans connected units, 1:100/1:200 floorplans site, 1:200/1:500 situation plan, 1:1500/1:2000 elevations: elevations single unit, 1:50 elevations site, 1:200/1:500 sections: sections single unit, 1:50 sections connected units, 1:100/1:200 sections site, 1:200/1:500 sections area, 1:1500/1:2000 details: details single unit, 1:10/1:20 details connected units, 1:10/1:20 - 3D-visualisations physical and digital modelling - diagrams - final calculations BE10 Bsim	literature, internet + article studies supervision/discussions writing analogous (pen + paper) digitally (Open Office + Adobe Creative Suite) visualising - 2D-sketching analogous (pen + paper) digitally (Adobe Creative Suite) - 3D-sketching analogous (physical modelling) digitally (SketchUp + Revit) calculating - spreadsheets (monthly + daily average, ventilation spreadsheet) - Ecotect with Radiance - Be10 - Bsim

In the different phases of the project different tools to integrate both the aesthetic, functional and technical aspects of the design will be used. The level of integration of the aspects and themes in the project will however vary with the different project phases, which reflects in the tools used in the phases. The connection between project phases, tasks and tools used to solve the tasks is illustrated in the scheme to the left (ill. 22c).

The tools reflect a diversity of working methods, which again reflects the iterative and creative design process towards the integrated architectural design solution. In the first phase a primarily analytical approach is used, where the sketching phase is more intuitive and analogous. Here empirical investigations and experiences will be used to a higher extent, e.g. study trips to Copenhagen, Berlin and The Netherlands, where buildings that relate to the problem of this project will be visited. However, these need to be combined with analytical and technical tools in order to facilitate decision-making and progress of the project. Specifically, aesthetic solutions will be weighed against performance regarding indoor climate, energy consumption and the possibilities of "home-making" (which will be explained further int he chapter Home and dwelling, p. 29).

Ill. 23a: Scetch of Odhams Walk, London

"Drawing is a form of communication with oneself or with others. For the architect it is also, amongst other things, a working tool, a way of learning, understanding, communicating, transforming; a way of designing." Siza, 1997, in [French, 2008]

READER'S GUIDE

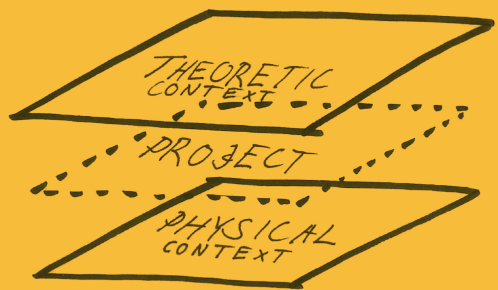
This report documents the process of the project duration. As explained in the previous chapter, the process itself has not been a continuous linear course, but has been looping between the different phases of the project – however, for the readability and understanding of the project, the report presents the process in a logic, chronological way as one linear process. Consequently, there may be some jumps in "real project time" between the different chapters, as the phases have been overlapping and things have been worked on at the same time.

The report is divided into chapters reflecting the different phases of the process. First the analysis is presented, followed by the programme and catalogue which form the basis for the sketching phase. This is documented afterwards, concluding in the concept of the design and followed by the detailing of this concept in the synthesis-chapter. Finally, there is an outro-chapter with a conclusion and assesment of the project, and the last chapter is the appendices, which document different calculations done during the process.

References are done using the Harvard-method as [author, year] e.g. [Kristensen, 2008] when using literature or articles, and when using web-pages as [root] e.g. [botaet.dk]. If there is used more than one reference with the same root or author and year, they are listed with a letter e.g. [Kristensen, 2008, a] or [botaet.dk, a]. In the back of the report the full references are listed alphabetically and by type of reference (literature, articles, webpages etc.).
Illustrations are referred to by page-number and a letter e.g. "Ill. 19a" for the first illustration on page 19. A reference-list for all illustrations is listed in the back of the report.

Ill. 25a: Visualisation from the final solution of the entrance to the site

ANALYSIS

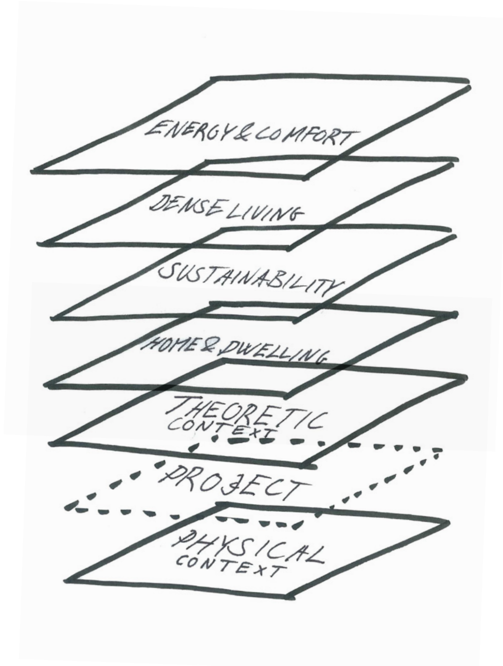


Ill. 27a: The analysis is split up into a theoretic and a physical context analysis

The analysis is carried out to form a basis for the project. It is partly carried out as theoretic research into themes related to the project, and partly as an analysis of the concrete, physical context of the project area at the harbour in Århus, Denmark.
Architectural quality is discussed in a summation, where it is explained how the different themes in the analysis will be dealt with in the design of dwellings at Århus Harbour with a high degree of arhictectural quality.

THEORETIC CONTEXT

The investigation of the theoretic context of the project is split up into different themes. First of all, a closer look at the concept of "home" and dwelling in general is made - what is a home and how is the home related to the physical dwelling, which is what will be the focus of the architectural design in this project. Moreover an overview of Danish housing tradition is given in order to get an understanding of the background of the detached single-family house. Subsequently, peoples perceived qualities of this housing typology are extracted.
In order to put the detached single-family house in perspective, a study of how people live their lives today is carried out. This gives an overview of different lifestyles and consequently different orientations when choosing where to live and what to live in. As one of the main themes of this project is sustainability, this is of course studied in order to get hold of the concept and the different aspects of sustainability. Finally the aspects of energy and comfort are discussed in relation to sustainability. In relation to the project of designing housing at Aarhus Harbour, it is considered relevant to research, how a dwelling is made into a home. What are the ingredients of a "home" and how can the architectural design of a dwelling make the optimal frames for this.



Ill. 28a: The theoretic analysis is further split up into different themes

HOME AND DWELLING

The concept of home

The word *home* has a history dating back to the Viking Age, where it is seen in different variations used in different languages, like e.g. Middle English *hom*, Dutch *heim* and Old Norse *heimr* [dictionary.com]. The use of it has always had something to do with dwelling and affection [Brink, 1995], however, the concept of *home* cannot be taken for granted in any given context, but is a complex, multi-dimensional and ambiguous term [Lawrence, 1995].

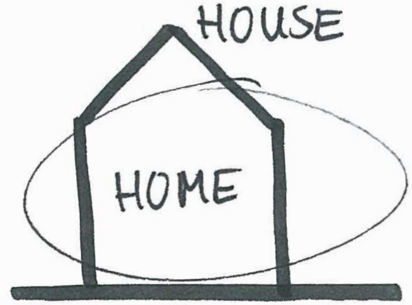
When one looks up *home* in a dictionary there are a wide variety of explanations, connotations and different meanings of the word. This is illustrated by the following different definitions of "home":

"a house, apartment, or other shelter that is the usual residence of a person, a family, or household." [dictionary.reference.com, a]

"man's dwelling, residence and gathering place for family or cohabiters together with depository for personal belongings." [denstoredanske.dk] (translated from Danish)

"place, where one lives" or *"the place and the people who live there"* [Høimark, 1996] (translated from Danish)

Home can both be used as a noun, an adjective, an adverb or a verb and is often confused with the nouns *house*, *dwelling* or *residence*. However, these are not necessarily the same, but are very often two aspects of the same thing. Where the dwelling is the concrete, physical place of residence, then the home is the more abstract content of the dwelling. Consequently, the last definition listed above is probably the most accurate, as it separates the meaning of home from the meaning of house.



Ill. 29a: The house as the container for the home

The interesting question is then, of course, what makes a house into a home. And alone by saying this already implies, that the home is the result of a process, it is not some finished product. Architects are often more concerned with the physical aspects of a home – the house – than with the psyche and soul of the home, which is really what makes the house into a home. Nevertheless, it is the house's ability to become a home which matters to the people, who are to live in it. One might say that the home is the individualized dwelling, it is an expression of the dweller's personality and patterns of life. [Pallasmaa, 1995][Westman, 1995] According to Heidegger, to build is to dwell, and to dwell is to be in it's deepest sense. It is the way in which we human beings are on Earth, which means that it is essential for man to build in order to dwell. [Heidegger, 1951] This implies that the dwelling has to make space for the dweller to be able to transform it into a home, by personalization of the house, the dweller has to "build".

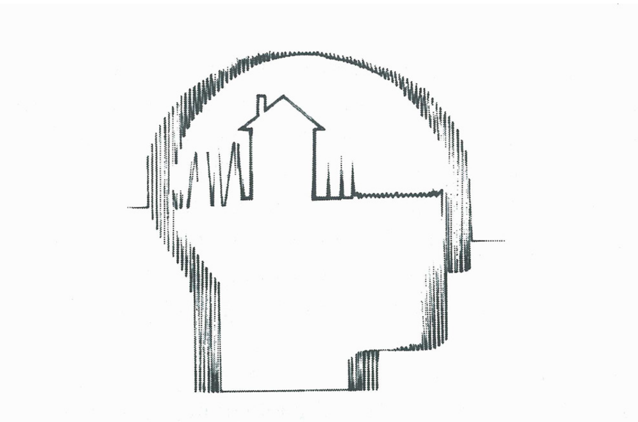
"It is evident that home is not merely an object or a building, but a diffuse and complex condition, which integrates memories and images, desires and fears, the past and the present. A home is also a set of rituals, personal rhythms and routines of everyday life. And a home cannot be produced at once; it has its time dimension and continuum, and it is a gradual product of the dweller's adaption to the world."[Pallasmaa, 1995, p. 133]

Another aspect is the social importance of "home", which be seen as a two-way mediator between public and private life. It both reflects the individual personality of the dweller(s) to the outside world, but also strengthens this personality inwards. Consequently the dwelling has to represent, reflect and embrace the daily life of its inhabitants, in order to become a home. [Pallasmaa, 1995][Westman, 1995]

Ill. 30a: The home is not necessarily bound to one place and not necessarily to a place at all. The home can be extended to include a whole country or region or minimized to a single photo or other symbolic things.

In Juhani Pallasmaa's article from the anthology "The Home" [Benjamin ed., 1995], he talks about the intimacy of home and the emotional aspects of home. He explains how the home can be seen as a psychic image of our mental well-being, where we both need a storage space for pleasant memories (the attic) as well as one for unpleasant memories (the cellar). Furthermore, he talks about three mental or symbolic elements as the main ingredients of home:

1) elements that are founded in the deep unconscious bio-cultural level, such as the entry and the hearth
2) elements related to personal life and identity, such as various memorabilia and inherited things
3) social symbols which are intended to give certain images and messages to outsiders, such as signs of wealth, education, consumerism etc. [Pallasmaa, 1995, p. 139] (see ill. below)

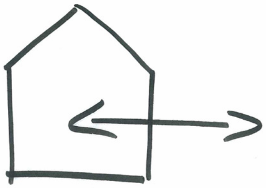


Ill. 31a: The home as a psychic image related to memory and emotions

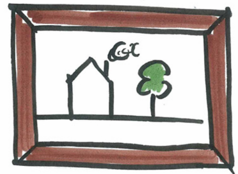
The home should also be seen in relation to routines and rhythms of daily life. It has a practical dimension and is related to acts and verbs rather than objects and nouns. For example, the act of looking out of the window from inside the house constitutes the feeling of being home, the act of entering the house constitutes the feeling of coming home etc. [Pallasmaa, 1995] As Amos Rapoport describes there is no thing, no x, that can be added to a house in order to make it into a home. Instead, "...x refers to a set of relationships between people and important systems of settings of which the house may be the primary setting or anchoring point." [Rapoport, 1995, p. 45]. These relationships and settings vary with different people, cultures, geographies etc. However, something common is that the feeling of home always involves a positive evaluation of an environment. [Rapoport, 1995]
Bror Westman argues that it is movements that constitute the home. He argues that, in order to understand a specific culture, one has to understand how people move in that culture. Movement has got to do with space and time, and he explains home as the place that takes place. And, moreover, what takes place for a specific period, a specific time. It is "a turning point consisting of turning points for the movements of humans." [Westman, 1995, p. 69].

According to Tomas Wikström, who has carried out a survey of different inhabitant's relation to their dwelling and the surroundings, there are six major concerns to take into regard in relation to the constitution of "home-feeling". These are: 1) safety, shelter, 2) going out and coming back, 3) autonomy, 4) domestic routines, 5) neighbours and 6) to be rooted [Wikström, 1995]. These sum up most of the previously mentioned aspects, and can be viewed as design parameters in the design of dwellings, which people can make into homes.

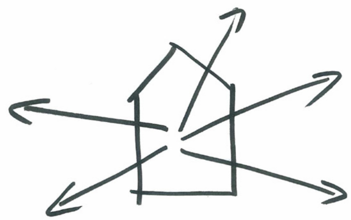
safety and shelter



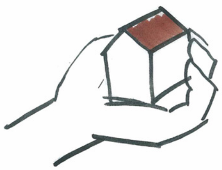
movements



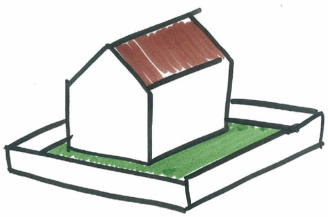
embrace symbols, rituals and emotions



to be rooted



autonomy and freedom



privacy

neighbours and neighbourhood

Ill. 32a: The seven parameters important in the constitution of a "home-feeling"

Conclusion

The concept of "home" is a complex and ambiguous term, which cannot easily be defined. It is related to the place, where people dwell, the dwelling, but the dwelling itself is merely the physical container of the home. However, it is important for us people to dwell, since this is the way which we live on Earth. And to dwell is to build. This corresponds with the importance of personalization of the dwelling by the dweller self. A home is not some finished product, but a result of a process, an expression of the individual dweller's personality and patterns of life. The home has to be understood phenomenologically as related to emotions, symbols and rituals as well as routines and rhythms of daily life. This should be embraced by the dwelling in order to both strengthen the self-image of the dweller inwardly as well as reflect the identity of the dweller(s) to the outside world. An important aspect of the home-feeling is the movements of the dwellers as a constituting part of the home. Movements are results of space and time, and dwelling is something that takes place in a specific time, it is an act rather than an object.

As an architect, it is not possible to design a "home", but merely a dwelling, which the dweller can make into a home. However, it is possible to provide the dwelling with as good conditions as possible in order for the specific dweller to be able to make the specific dwelling into a home. The dweller has to be provided with optimal conditions for the "home-making-process" to happen, to make way for this. The following parameters, inspired by the previous research, are used as guide lines in the process as indicators of what is important in the constitution of "home-feeling"

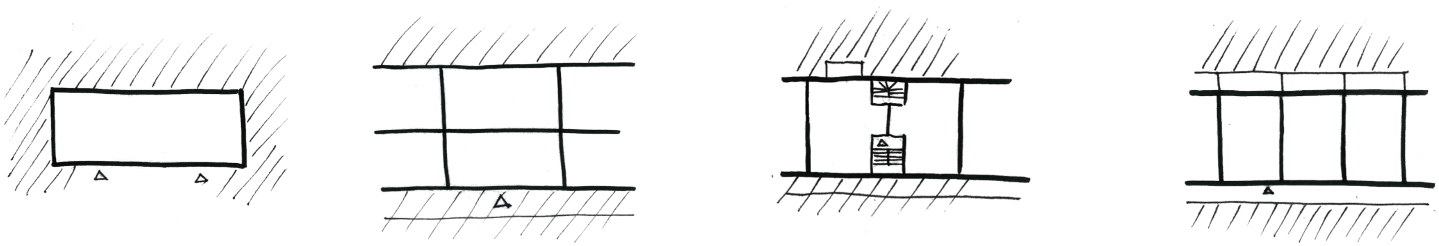
- safety and shelter
- movements
    - going out and coming back
    - going to and from
- autonomy and freedom
- privacy
- neighbours and neighbourhood
- to be rooted
- should embrace symbols, rituals and emotions of the dweller(s)

Ill. 33a: The dwelling as a physical, objective space on one hand - the house - and a phenomenological, emotional space on the other hand - the home.

The Danish single-family house in a historic context

In order to make optimal conditions for the dwellers to make themselves a home, it is necessary to understand the dweller. Since this project takes its point of departure in the detached single-family house, which is the preferred type of dwelling in a Danish context [Jensen, 2008], it is important to understand this housing typology. To do so, the historic background for this housing type is investigated.

The following housing typologies are generalized and consequently named in accordance with their main characteristics in opposition to the other housing typologies mentioned.



The long-house is the basic, traditional type of dwelling in Denmark since before the Viking Age. This typology is characterized by a longitudinal orientation, often with one entrance placed in the middle of the house or with two entrances placed symmetrically. This typology is used in traditional Danish farms as well as in castles and manor houses [Ørum-Nielsen, 1995].

The market town house is the further development of the long-house typology. As towns gradually grew, houses ended up forming continuous rows, defining the streets of the town and constituting the border as well as the link between public and private space. The houses adjusted to each other, being one storey high with the pitched roof facing the street thereby allowing for maximum daylight in the street and the garden on the other side. [Ørum-Nielsen, 1995] [Bredsdorff, 1945]

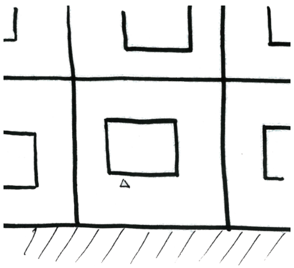
The city-apartment building is known since the 17th century. Like the market town house it forms continuous rows defining the streets of the city but is usually 5 stories high. The square housing blocks surrounding an inner yard, the "karré", is a result of industrialization and the idea of better housing with light and air for everyone. However, the uniform layout of the single apartments with the front to the street and the back to the yard resulted in big differences in the lighting conditions for the different apartments. [Elling, 1945][Rasmussen, 1945]

The slab is a further development and modernization of the city-apartment building. The uniform orientation of the free-standing slabs between green areas resulted in equal amounts of light and air for everyone. The typology is a result of technical development, where ferroconcrete made it possible to open up the facade and attach balconies. [Rasmussen, 1945]

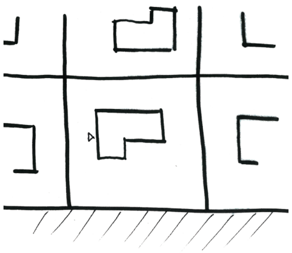
Ill. 34a: Historic overview of the main dwelling typologies in a Danish context

This overview shows that there seems to be a basic Danish house-type. The long-house has evolved into the market town house, which has grown higher into the city-apartment building, but is also translated into the row-house. Another movement is the detached single-family house, which has evolved into the standardized "parcelhouse". In Western culture, it seems there is a tendency to discard tradition in favour of innovation and creation of new concepts [Laurens, 2011], but it is important to remember that the concepts developed over a long period of time have proved able to adjust to changing needs in use and climate. Of course, this should not result in replication or nostalgia for the past, but merely for a conscious use of inspiration from tradition. Danish housing tradition implies consideration for human scale, adaptability to change, community sense, respect for individual privacy, of order and variety and an ingrained sense of involvement, of belonging and of feeling home.

"The role of architecture is to establish a framework that allows people to participate in developing and building their home and its neighbourhood..." [Ørum-Nielsen, 1995, p. 263]

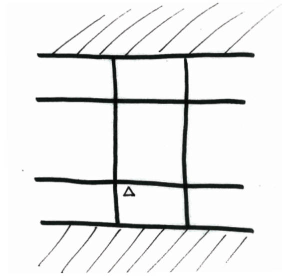


The villa is a result of an escape from the overcrowded cities of the 19th century. It was only the richest part of the population who could afford to move away from the city, and neighbourhoods like Hasseris in Aalborg arose just outside the city borders. The villas became increasingly fantastic and complex in their designs, until the modernization and functionalism of the 1930's which led to a much more clean and abstract expression. [Jørgensen, 1945]



The detached single-family house is a relatively new typology in a city-context. The "parcelhouse" was founded in the years before First World War, where neighbourhoods outside the original borders of the cities were layed out as affordable parcels for the middle-class. People did not understand the abstract aesthetics of functionalism, and wanted to express their individuality, which resulted in a mix of styles in these neighbourhoods. [Langkilde, 1945][Stephensen, 1945]

The detached single-family house of the 1960-70's was a result of increasing wealth in the population and poor housing quality of the post-war period [Kristensen, 2007]. The standardized single-family house was made for the nuclear family and a central element was the "pistol hallway", shaped like a pistol, which connected the entrance to the rest of the rooms in the house. Most children got their own room now and most of the "parcelhouses" are built in this period. [DR2, 2011][Jensen, 2008]

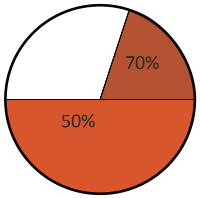


The row-house is a compromise between the apartment building and the villa, maintaining the connection between house and garden, but being smaller on behalf of common facilities. It became popular in the 1970's and 80's, but originates in the market town house-typology. For a long time this typology had low esteem, maybe due to the fact that social housing was build like row-houses. [Fisker, 1945][Ørum-Nielsen, 1995]

The detached single-family house today

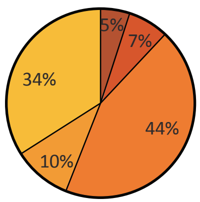
Even though it may seem very arguable and logic to continue the long tradition of building row-houses, it is an undisputable fact, that the detached single-family dwelling is by far the most preferred housing typology in Denmark. Consequently, it is investigated which preferences people have concerning housing in general. What they value when they choose how and where to live. This is put into perspective by looking at different lifestyles, which may explain the choice of the detached single-family house over other types of housing.

In general, there are high housing standards in Denmark. People have good, large and expensive homes and spend more and more of their income on their homes. The detached single-family house is the most common house type in Denmark where approx. 50% of the population lives like this. However, 70% of the population would choose to live in a detached single-family house if they could.

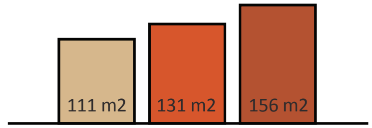


There are approx. 1,1 million detached single-family houses in Denmark, and almost 44% of these are built between 1960-1980. This corresponds to 450.000 houses, which is an amount equivalent to the total amount of new-build houses during the previous 100 years. This period is also called "the Middleclass' exodus from the cities ", where 1,5 mio people moved to a deatched single-family house. Consequently this movement is bigger than the urbanisation of the 19th century industrialisation. Only 5% of the detached single-family houses have been built after 1990. [Lind and Møller, 1996][Jensen, 2008]

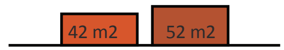
- 1940: 34%
1940 - 1960: 10%
1960 - 1979: 44%
1980 - 1989: 7%
1990 - 2008: 5%



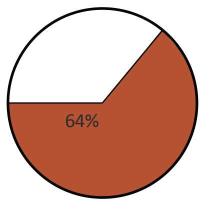
The new-built houses, however, grow bigger and bigger. The average size of new-built detached single-family houses have grown from approx. 131m2 in the 1960's to approx. 156m2 in the beginning of the 2000's. The average housing area in Denmark in general is 111m2, so people living in detached single-family houses have considerably more space than the average Dane.

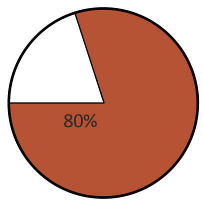


The average housing area per occupant in Denmark in general has gone from 42m2 in 1980 to 52m2 in 2009, and the Danes is the people in the world with the largest housing area per occupant.



The distribution of people living in detached single-family houses show that approx. 64% of the people living there do not have kids, and that approx. 80% of the people living there are couples. However, it is also a fact that many of these couples are 50-64 years old and that they have been living in their houses since they were built in the 60's and 70's. [botæt.dk][Jensen, 2008][Kristensen, 2007]





Ill. 36a: Facts and figures of the detached single-family house

Contemporary lifestyle

Nowadays, the home is seen as a stage upon which one's personal life and family are displayed. This is especially seen in relation to the detached single-family house, where one has rich possibilities of self-staging and of displaying one's consumption. Definition of identity has moved from the public space to the private, where consumerism has become a way of signaling status and position in society. This is e.g. seen in the organizational lay-out of new-built houses, where the multifuntional and practical rooms grow bigger and bigger and get more and more importance on behalf of the purely represensational rooms. The kitchen has grown and melted together with the living-room to become the most important room in the house. [Kristensen, 2007][Jensen, 2008]
These characteristics seen in housing can be applied on contemporary life-style in general. In a globalized world without limits or borders in time nor space, where everything has become possible, it can be difficult to navigate. Nothing is for certain anymore and everything can be and is discussed. There is a loss of common ground, values are constantly changing and the right choice today may be the wrong choice tomorrow. But that does not matter too much, because a choice can easily be altered, nothing is fixed. This results in people easily feeling uncomfortable and lonely. It is easy to get lost in the dynamic and mobile world of today, and people feel at home everywhere and nowhere at the same time. There is a higher degree of search for the sublime, the perfect, because it has actually become attainable, and people are competitive, artistic, sporty and freedom-loving individualists, who has to self-stage themselves in order to be distinguished and identified among the others. Additionally, contemporary life-style is very visually oriented, everything is at display and it is important to see and to be seen. [Ærø, 2001][Skyum, 2011]

Ill. 37a: The world is connected

In relation to choice of living, there are three general modalities characterizing the way which we choose. Either people choose according to a pre-modern modality, a modern modality or a late-modern modality.

Ill. 38a: Characteristics of different modalities

Through research [Ærø, 2001] it has shown that the pre-modern and modern modality are still dominating the way we choose where and how to live. This might explain why so many people have the detached single-family dwelling as the ideal way of living. First of all, this is considered to be the top of the housing market, it is connected to the upper part of society and consequently to wealth and status. Moreover, it is considered as the "normal" way of living, it constitutes the standard for "the good dwelling". This is seen in relation to the nuclear family being the "normal" family, the normal way to live one's life. However, the ideal of the standardized nuclear family is a construction of the 1950's - 70's, which fitted well with the standardized houses and apartments built at that time. This is not reality today, where about twice as many marriages end in a divorce (ca. 45%), than in the 1950's and 60's (ca. 20%) [statistikbanken.dk]. The reason why this is still an ideal, is maybe due to the fact that many people grew up this way, and the nuclear family in the detached single-family house consequently gives a feeling of safety and belonging. This is confirmed by the fact that 60% do not consider alternative possibilitites when they are deciding where to live, they do not question the choice of living in a detached single-family house. In a society where there are no fixed and certain values this is a way to find a sort of security and comfort. [Ærø, 2001][Jensen, 2008][Kristensen, 2007][Kristensen, 2010]

Values in housing today

The detached single-family dwelling does not only give the owners a feeling of safety and security. There is more to it. It is a tool for defining the identity of the inhabitants and consequently it is important to have ownership, and the freedom to decide what to do with the house, even though most people do not actually do anything. Also, it is important that it is children-friendly, which means that it should preferrably be in one level and situated in a calm, secure and green area with other children families. It is important to be able to show the house to guests and neighbours. This also correspond to the importance of the neighbourhood in general, where people put stress on the reputation of the neighbourhood and that the people living there share the same way of living. It is important for people that there is somehow an agreement of "good taste", social structures and ways of doing in a neighbourhood. However, there is not a wish for a high degree of socializing, but privacy and the ability to choose the degree of social contact is valued. Of course it is also very important that there is a garden surrounding the house, keeping the neighbours at a distance, and with a terrace connected to the combined kitchen and livingroom, since the terrace is the outdoor livingroom. Concretely, there are some main qualities put forward both concerning the house itself and the surroundings, as well as some things, which people would like to add to their house, if they could.

Ill. 39a: Happy family life

Main qualities:

- combined kitchen/living-room connected directly to terrace
- no leftover space for hallways etc.
- a healthy and sound house built of good materials
- separation of adult- and children "departments"
- one-level, practical with small children
- 2 bathrooms
- common familyroom centrally placed

Qualities of surroundings:

- forest/nature
- green areas (children friendly)
- big garden, but easy to maintain/keep
- existing garden, no need for everything to grow from scratch → privacy from the beginning
- no noise form neighbours
- good infrastructure (institutions, grocery shopping, footpaths)

MISS:

- cellar/deposit
- (bigger) utility room
- larder
- common house for parties, workshop etc.
- a nice view
- more children bedrooms (than 2)
- bigger children bedrooms (min 14 m2)
- office/guestroom
- bathroom in connection to adult bedroom

The previous has shown what the ideal is concerning housing and way of life for most Danes. However, it is only about 50% of the Danes that actually realize this ideal and move to a detached single-family house. There is consequently a large group with a mis-match in their preferred and actual way of living. The reasons for not moving into a detached single-family house are partly due to a wish of maintaining closeness to the city. This is connected to economic reasons, since the detached single-family house is an expensive housing typology, and even more expensive in the urban areas. Other reasons are the big responsibility of maintenance, and the fact that some people would actually not feel at home in a neighbourhood with this housing typology anyway. These people correspond more to a late-modern modality, and value closeness to the city with its culture-life and shops, they use the home as a base, a stop, on their way out into social life/society and prefer to live close to others.

Ill. 40a: the detached single-family house

Conclusion

The standard detached single-family house, the “parcelhus” is the product of an evolution of the Danish single-family house, dating back to the 30’s, which became very popular during the 1960’s and 70’s, when most of these houses are build. However, the detached single-family house is still an ever so popular housing typology and does not seem to become less popular. On the contrary, it seems to have been able to evolve together with changes in life-style among the population. Most of its popularity relates to the dream of the detached single-family house in the suburbs, which is maybe just a dream for many people. Partly because there is a shortage of this housing typology in the cities, which makes it too expensive and consequently too difficult to obtain for most people, but also because it actually does not reflect the mobility patterns of today’s society and contemporary lifestyle. Buying a house binds people economically for several years, and it is difficult to move away from a detached single-family house, once one has settled there. Another problem concerning the detached single-family house is related to sustainability. It is not a sustainable housing typology.

Consequently, there is a need for a higher degree of variation in the housing stock and for a more flexible housing typology. Especially there is a need for quality family housing, which reflects the mobility patterns that characterize society today and matches a contemporary late-modern life-style in general. A new housing typology which combines the best from the detached single-family house and the city apartment in an urban context. The detached single-family house characterizes the preferred type of housing and what people wish for their place to live, but this has to be combined with sustainable concerns and re-defined in a denser urban context.

SUSTAINABILITY

Sustainability is one of the most used buzz-words in arcihtecture today. Everything has to be sustainable, and the term is applied almost everywhere. Often it implies that a specific building is energy-efficient in use, but it can also be applied to e.g. the ecological societies of Christiania. In order to get a better understanding of the term, it is investigated in relation to the original meaning of the word, its origin and the history of the concept and further, how it can be used and assessed in relation to architecture, more specifically in the design of sustainable dwellings at the harbour area of Aarhus.

Word origin and history

as a verb: *to sustain* (used together with an object)
to support, hold up, bear, undergo, endure, keep up, provide for, uphold, confirm something

origin: 1250-1300; Middle English *suste(i)nen*, Anglo-French *sustenir*, Old French/Latin *sustinere*: to uphold, support, endure from *sub* up from below + *tenere* to hold.

In short to sustain means to support something and keep it in existence, to maintain it and supply it with necessities, and keep it from falling or sinking. [dictionary.reference.com, b]

as an adjective: sustainable
as a noun: sustainability

Definition

The concept of sustainability is - like the concept of "home" - a very complex and ambiguous field. A definition of sustainability is for the first time given in the World Comission Brundtland-report "Our Common Future" from 1987 as

"sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

The overriding political concept of the report was sustainable development, as a way to deal with the future necessary growth and development in the world. Another message from the Brundtland-report was to think global, but act local, which indicates that even the smallest parts play an important role in the overall picture. [isover-bogen] [un-documents.net][regjeringen.no]

Background

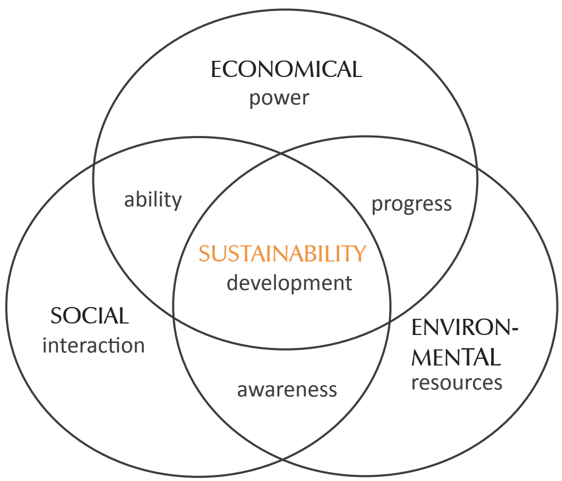
The concept of sustainability, however, originates from a Western context and can be seen as a consequence of the industrialization of the 19th century. Since then, there has been continuous economic growth and globalization as well as a growth in population which has resulted in growing urbanization. Nowadays, more than half of the world's population live in urban areas.
There can be traced several sustainable concerns, since the beginning of industrialization and urbanization. One example is the awareness of the importance of good dwellings, light and air for everyone in the beginning of the 1900's, especially seen in Denmark and the North of Europe in general. Since World War II there was an increasing awareness of economical sustainability, and during the 60's and 70's social and environmental sustainability was also put on the agenda. Especially after the Oil Crisis of '73 where the world learned, that the reserves of fossil fuels are not going to last forever (see timeline below.).

In Denmark this resulted in a growing awareness of the energy consumption of buildings. One of the results of this was the "peak-hole-architecture" as the Building Regulation of 1977 limited the allowed window area of bulidings. The amount of insulation in buildings has also increased since then, which has resulted in the outer walls of buildings loosing their function as load-carrying elements. This can e.g. be seen in Tinggaarden by Vandkunsten from 1978, which showed that the exterior could instead be made as a light cladding, as it was only to function as the climate screen of the building. Tinggaarden is also part of another result of the increasing sustainable awareness in society: the dense-low-movement of the 70's and 80's, where a lot of projects emerged focused on building dense and low dwellings with limited private in- and outdoor areas. This was on the other hand compromised by more common facilities.
[Edwards, 2010][Hansen, 2010] [Herzog, 2007] [Lauring, 2010]

Despite the increasing awareness of the energy consumption in the 1970's and focus on communities and the dense-low-movement, this was also the period of mass-construction of the standardised detached single-family house. However, already at this time, it was discussed whether this typology of housing was actually the best answer to future housing, and if it for example should be build with more flexibility for future alterations and possibilities for splitting it up into more households. [Arkitekten, 1976] One result of the 1970's is, however, that the energy consumption for heating in buildings has been lowered considerably, while the energy consumption for electricity has increased. So even though it seems that things have not changed since then and that it is the same discussions going on today, the awareness among people on energy consumption has helped to lower this. [Lauring, 2010]

- 1962 *Silent Spring*, by Rachel Carson
- 1972 *Limits to Growth*, by Club of Rome
- 1973 Oil Crisis
- 1980 World Conservation Strategy- IUCN
- 1983 World Commission on Environment and Development
- 1986 Chernobyl
- **1987** Brundtland Commission and Montreal Protocol on Ozone Layer
- 1992 Rio World Summit
- 1997 Kyoto Conference on Global Warming - UN
- 2000 The Hague Conference on Climate Change -UN
- 2002 Johannesburg Summit on Sustainable Development- UN
- 2006 Helsinki Conference on Carbon Trading and Global Warming - UN
- 2007 Bali Conference on Climate Change - UN
- 2008 Poznan Conference on Climate Change and Carbon Trading - UN
- 2009 Copenhagen Conference on Climate Change - UN

Today, the Danish Building Regulation still focus on the energy consumption of buildings, which account for approx. 50% of the total energy consumption in a European context [solar charter]. The requirements are becoming more and more strict and the goal is to reach an energy consumption of nearly 0 (as there will always be some degree of energy use) by the time of 2050 on EU-level. However, since the 70's the energy consumption for space heating has decreased by approx. 20% while the energy consumption for electricity has increased by approx. 70%, and 160 % in office buildings. This is among other things due to the increasing reliance on electronical appliances in our everyday-life, a development, which does not seem to change in the future. This indicates, that there is still a need for awareness of the energy consumption, but instead of focusing on the heating demand, there should be focused more on electricity. This is reflected in the Danish Building Regulations by the multiplication of electricity with a factor 2,5. [Lauring, 2010] [Jensen, 2011, a]



Ill. 44a: Sustainable development

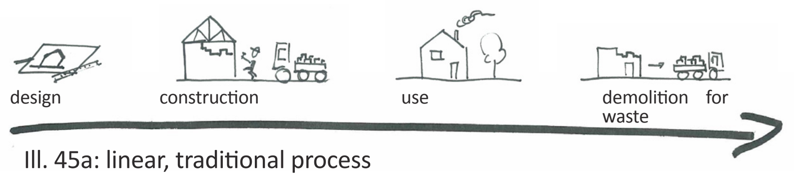
The focus on sustainability and sustainable development has not decreased over the years – on the contrary. Globalization and urbanization is not decreasing in the years to come, and also not the population growth.
Economic growth is closely related to an increasing demand for energy, where 1% economic growth in gross national product corresponds roughly to 1% increase in energy requirements. However, in the developing countries, an economic growth of 1% requires more than just 1% increase in energy. The use of fossil fuels today account for 80% of the total energy consumption in the world, and this is a problem. First of all because ressources are scarce. (Concerning Denmark, the oil in the North See will be used by around 2050.) Second of all, because the use of fossil fuels has a great impact on our climate. The use of coal, oil etc. for producing energy pollutes the air, soil and water and disturbs natural environments. Another fact is global warming. Over the last years an increasing amount of green house gasses in the atmosphere is found, and an increase in the global temperature has been observed. Worldwide this causes glaciers to melt, increasing water levels and very extreme weather conditions in general. It has not been proved, if this is directly related to the use of fossil fuels, which emits the beforementioned green house gasses, but it does certainly not have a positive impact on more extreme weather conditions – on the contrary.
Consequently, it is necessary to apply a more sustainable approach to the use of energy, if we want to continue the present development of economic growth. There are two main aspects to this: the use of less energy, which implies a more efficient use of the energy, and an increase in use of renewable energy, instead of the reliance of fossil fuels.
Architects and planners play a major role in this respect, since it is in the design and layout of buildings and environments, that sustainable actions has the greatest impact. Since most of the population already live in the citites and more will come, it is important to come up with integrated concepts for the spatial use and development of urban areas, especially concerning mobility patterns. The city should be seen as a symbiosis, it is a self-contained and long-living organism, where the constant processes of modification and deconstruction should follow the natural cycles of renewal [Herzog, 2007]

Operationalization

The definition of sustainability given in the Brundtland-report is relatively imprecise. This makes it widely applicable and easy to relate to a lot of different sectors and fields, but it also means that there is a need for some operational principles, a “translation” of the term into more specific tools and techniques, in order to apply the concept of sustainability to the context of architectural design and the building industry in general. As a step towards the operationalization of the concept of sustainability, it can be split up into the three aspects of environmental, social and economic sustainability.

Environmental sustainability
can be seen as the need for a more responsible use of natural resources, and a more balanced interplay between humanity and nature, in order to respect and keep natural systems alive.
Social sustainability
can be seen as the need for an understanding and awareness of the social processes that rule society in order to implement a global sense of resposibility.
Economic sustainability
can be seen as the need for economical development and consumption to be kept at a level, where Nature is not being overexploited and being trated as an economic externality. It should create surplus and technical knowledge on a self-reliant and sustained basis. Sustainable development is not always the most profitable one in the short run, but will be in the long run of development.[http://www.un-documents.net]

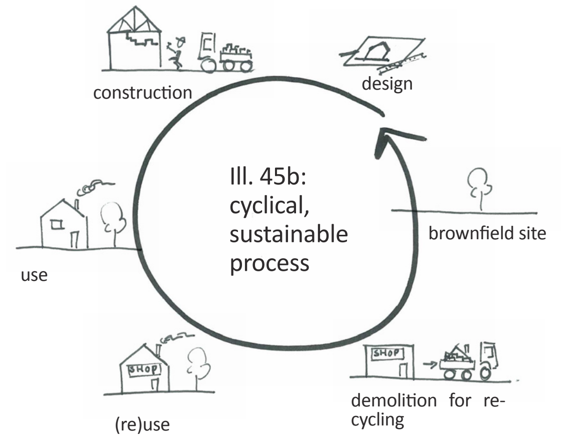
Consequently sustainability has to be met on more levels than just that of energy, and and more aspects have to be considered.



Ill. 45a: linear, traditional process

Life-Cycle Assesment (LCA)

The Danish Building Regulations mainly focus on quantifiable aspects like energy and comfort in relation to the indoor climate, whereas other approaches are more qualitative and have a more broad perspective and consider the whole life-cycle of buildings. An assesment method which has this broader perspective is Life-Cycle Assesment (LCA), which stresses the importance of the life-cycle of the building and a cradle-to-cradle approach. It is a holistic approach to the built environment, taking the aspect of time into regard, but also puts impact on a basic understanding of sustainability and sustainable development.
As an example, energy should not only be considered in relation to energy consumption in use, but also the embodied energy in materials, energy for transportation of materials, energy used for the construction of the building, as well as energy used for the eventual demolition of a building should be taken into regard. And not only the building process itself is important to consider – also the process before the actual building, the design process and everything related to this should be taken into regard.



Ill. 45b: cyclical, sustainable process

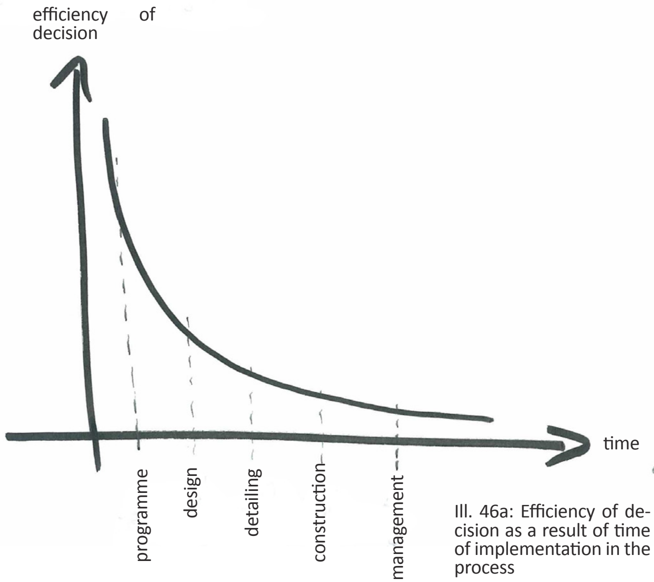
Integrated design

In relation to the implementation of sustainable aspects in the building process the Integrated Design Process proves itself very useful. The earlier in the process a sustainable approach is taken, the more effective it will be and the higher level of sustainability can be achieved (see ill. 46a.)

Moreover, passive techniques should be used before active techniques, as these are more sustainable, both in terms of lowering the energy consumption and in terms of using a cleaner type of energy. The priorities towards a sustainable and energy-efficient design are:

1) reduce demand
2) utilize renewable energy sources
3) apply efficient use of fossil fuels

[Topp, 2010][Jensen, 2011][Heiselberg, xxxx}



Ill. 46a: Efficiency of decision as a result of time of implementation in the process

	Heating	Cooling	Lighting	Ventilation	Design tools
Step 1: basic design	conservation	heat avoidance	daylighting	natural ventilation	Primary ex: orientation, shape, size, openings.....
Step 2: climate design	passive solar	passive colling	daylighting	natural ventilation	
Step 3: design of mech. systems	heating system	cooling system	electric light	mechanical-ventilation	Technological ex: solar cells, mechanical ventilation, high technology...

Conclusion

In relation to sustainability, there is still a need for action, if the present development and economic growth is to continue while maintaining the present standard of life. There are several aspects towards a more sustainable development, but a key area is energy and natural resources. The concern for energy consumption applies especially for the built environment, since most of the total energy consumption is spent in the areas of buildings and transport. There is consequently a need for architects and planners to consider and implement a more sustainable approach in the development of our built environment.

In relation to the concrete assignment of designing dwellings at Aarhus Havn, this will be done by a broader and more holistic approach to sustainability, than the one put forward in the Danish Building Regulation, BR10, which has a main focus on energy consumption. Consequently, the aspect of Life-Cycle Assesment will be taken into regard during the sketching. The energy consumption, however, will be assessed in accordance with BR10, in order to ensure, that the requirements stated here will be met.

ENERGY AND COMFORT

Even though this project aims at a holistic approach toward the concept of sustainability by considering more aspects than just that of energy consumption of the building in use, this is, however, an important aspect to consider. As the situation is now, energy used to run buildings account for approx. 50% of the total energy consumption in Europe. In comparison, transport account for 25% of the total energy consumption. But this is not necessarily the way it has to be. Several projects with low-energy buildings show that it is possible to limit the energy consumption considerably down to passive house, 0-energy or even active house-standard (see illustrations to the right). [Herzog, 2007]

Most of these projects also have focus on the indoor climate in relation to the lowering of the energy consumption. These are two sides of the same thing, as the use of energy in a building is closely related to occupant behaviour and the comfort level of the occupants, e.g. in relation to space heating and ventilation [Topp, 2010].

In the building Regulations this connection is clearly expressed:

> *"Buildings should be constructed, so unneccessary energy consumption for space heating, hot water, cooling, ventilation and lighting is avoided, together with obtaining satisfactory health related conditions."*
> (translated from Danish) [ebst.dk, a]

Ill. 48a: Comfort House in Vejle

The passive house is a German concept developed in 1990, which aims at a minimalization of the energy consumption for space heating as well as for technical appliances. This is done by keeping the passsive heat in the house as well as making use of the passive energy from the sun. in a Danish context this conept has been tried out at the Comfort Houses at Vejle.

Ill. 48b: Kingspan Lighthouse BRE-center, UK

0-energy is not a well-defined term, since it both covers buildings, that have an annual zero energy consumption and buildings which have a zero-carbon footprint. The former is obtained by lowering the energy consumption as much as possible, and then covering this by the production of clean, renewable energy on or at the building, e.g. from photovoltaic cells on the facade or roof. If a building is to have a zero-carbon footprint, this has to apply for the whole process of the buildling, which means that both materials, energy, transport etc. has to be taken into account.

Ill. 48c: House for Life, Lisby, DK

Active-house standard is when the building produces more energy, than it uses. To the left is shown the active house, House for Life, situated in Lisby at Aarhus and designed by aart architects for VKR holding.

In short there are three things influencing on the energy consumption of buildings. These are 1) design, 2) services and 3) occupants. Research shows, that in apartments with the exact same layout and design the energy consumption will vary considerably due to differences in occupant behaviour. Different people have different comfort levels, but another influencing factor is the fact, that there is a difference in awareness of the connection between occupant behaviour and energy consumption. Another consequence of this, which is important to keep in mind, is the fact that the actual energy consumption of a building in use often shows to be higher than the predicted calculated energy consumption, sometimes up to 40%.

This, of course, only sports the effort to design buildings for as low energy consumption as possible, but also to keep the whole lifetime of the building in mind, and to design it for easy use and coherence between design and occupant patterns and needs. Research has shown, that in cases with an automatic control system of the indoor climate, like e.g. in "House for Life", it has proved too difficult for the occupants to understand this system. There is a risk that it becomes something strange and extern, and that the occupants loose the sense of being in control in their own home.

In general, occupants are more satisfied with the indoor climate and prone to accept changes, if the changes are predictable and if they have a possibility to control the indoor climate themselves, even though the actual, objective conditions are not optimal. Also, they value if they can alter the indoor climate quickly in response to their eventual changed conditions. Consequently, there is a need for an empatic system, which takes human behaviour into regard, and a need to be able to overrule the system. Moreover the occupants have to learn how to use the building in order to keep the energy consumption low. [Andersen, 2011][Brunsgaard, 2011][Hauge, 2011][Entwistle, 2011][Jensen, 2006]

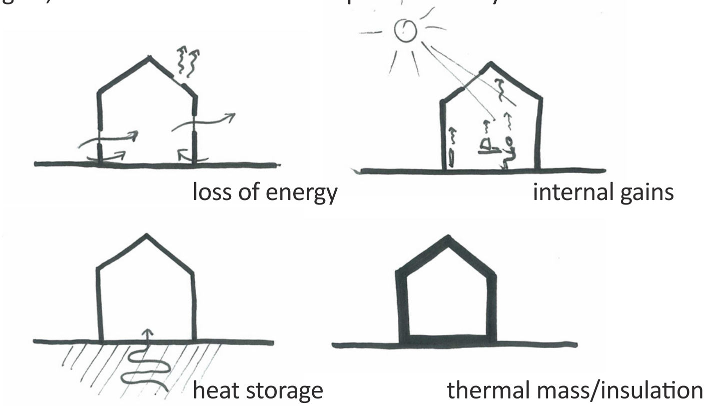
In relation to the concrete assignment of designing family dwellings at Aarhus Harbour, it is very relevant to take the close connection between comfort and energy into perspective. The physical comfort level can be concretized into specific requirements for the indoor climate, stated in the building regulations (BR10), which again has to be balanced with the predicted, calculated energy consumption of the single dwelling. This can be used as evaluation tools in the development of the overall architectural concept of the project. In order to obtain a high level of comfort and a low energy-consumption in an overall attractive architectural design, it is, as previsouly mentioned, absolutely necessary to integrate all aspects into the design from the beginning. [Topp, 2010][Jensen, 2011] Consequently various tools will be used during the design process to evaluate the different architectural concepts in relation to each other. These tools will be specified in the following, where an overview of the specific requirements concerning the energy consumption and indoor climate will be given.

Ill. 49a: Ecological Houses, Skejby, DK

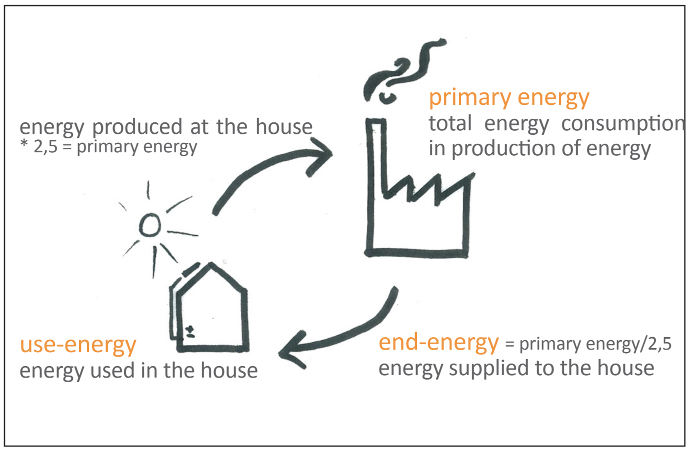
The Ecological Houses at Skejby were supposed to have a very low energy consumption, among other things due to the use of passive solar heat by the un-heated glazed "sun-spaces" of the facade. However, it showed that the occupants used this space in a different way than intended, and consequently they used a lot of energy on heating this space. [Lauring, 2010]

Energy

The following chapter takes a closer look at the specific energy requirements in the project. Everything uses energy, including buildings. Loss of energy happens by transmission, ventilation and infiltration. Gain of energy happens by solar radiation or internal heat gain from people or equipment. In order to minimize the energy consumption, the goal is during the cold period of the year to first of all minimize the loss and secondly to increase the gain, and vice versa in the warm period of the year.



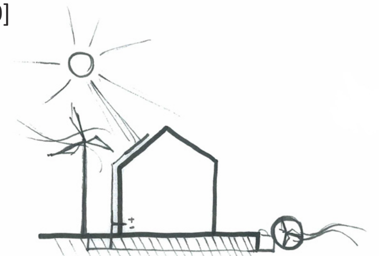
Ill. 50a: Diagrams of aspects related to the energy consumption of a building



Ill. 50b: Principle of calculation of primary energy

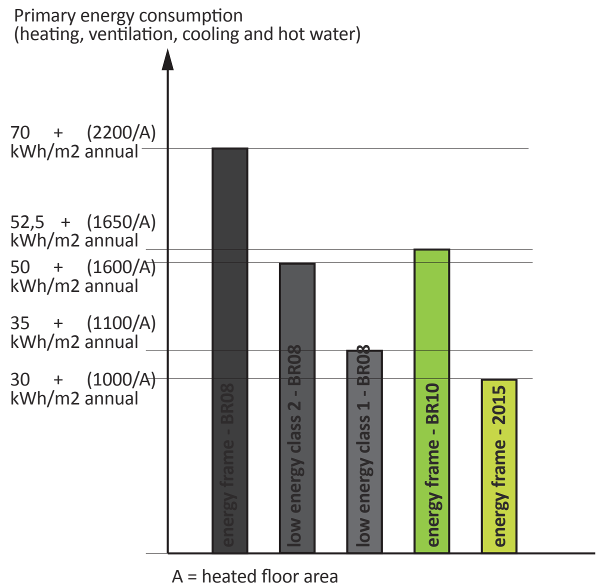
BR10
As this project takes its point of departure in a Danish context, the Danish Building Regulation will be used for assesment of the energy consumption. The requirements in the Danish Building Regulation concerning energy consumption are becoming more and more strict, and the perspective is what correspond to passivehouse standard by 2020 [bolig for livet]. Since Dec. 30th 2010 a new building regulation has been taken in use, which replaces the previous from 2008, and which tightens the requirements concerning indoor climate, energy consumption and the efficiency of electrical equipment.[ebst.dk, b][rockwool.dk, a]

The specific requirements concerning the energy consumption does not only cover the actual use of energy in the building, but also put up requirements for the climate screen and the installations. Consequently, there are four main elements to consider: 1) the energy frame, 2) air tightness 3)heat insulation and 4) transmission loss. The energy frame gives a value for the maximum allowed predicted primary energy consumption in the building. This covers the total demand for added energy for heating, ventilation, cooling, hot domestic water and eventual lighting (only for offices and institutions). [rockwool.dk, b][energiforumdanmark.dk] As this is the primary energy demand, it should be weighed in relation to the type of energy used. Use of district heating is multiplied by a factor 0,8 (for 2015-low energy standard), while electricity should be multiplied by a factor 2,5 since the production of electricity is more damaging to the environment than that of heat. If electricity from renewable energy at the building site by e.g. solarcells or windmills is produced, this should also be multiplied by a factor 2,5, in order to balance the calculations.[ebst.dk] [Jensen, 2006][Topp, 2010]



Ill. 50c: Diagram of different ways to exploit renewable energy

Maximum allowed energy consumption



Ill. 51a: Comparative table of the maximum allowed energy consumption in the Building Regulations of 2008 and the current from 2010 respectively. [energiforumdanmark.dk]

Maximum allowed infiltration

	max. air change rate (l/s/m² at 50 Pa)
standard class 2010:	1,5
low energy class 2015:	1,0

ll. 51b: The requirements concerning air tightness gives limits for the maximum allowed infiltration. This is evaluated after construction of the building by a blower door test, where the municipality should put up requirements for measuring of the air tightness in minimum 5% of new constructions. [Jensen, 2006][Brunsgaard, 2010][rockwool.dk, b]

Maximum allowed transmission coefficients

Building part	U-value requirement (W/m²K)
Exterior walls and walls towards earth	0,30
Partition walls towards unheated rooms	0,40
Horizontal division towards unheated rooms	0,40
Ground deck, crawl space floor and suspended floors	0,20
Floors with heating over cold rooms	0,50
Ceiling and roof	0,20
Windows, skylights and exterior doors	1,80

Ill. 51c: The requirements concerning heat insulation gives maximum allowed values for the transmission coefficients for all building parts towards the exterior and unheated rooms, as well as maximum allowed values for the linear thermal transmittance. [rockwool.dk, b]

New construction - requirements for transmission loss (W/m²)

	standard class 2010	low energy class 2015
1 storey	5	4
2 stories	6	5
3 stories and more	7	6

ll. 51d: The maximum transmission loss gives values for the the total loss of energy through the climate screen. [rockwool.dk, b]

As concrete tools there will be used monthly average spreadsheets during the sketching process. Only the energy needed for heating will be taken into regard, as there will mainly be used natural ventilation for cooling which does not require any added energy. The spreadsheets will be used for comparison of different architectural solutions, rather than focus on minimizing the calculated energy consumption for one solution. The documentation of the predicted energy consumption for the final architectural solution will be made with BE10.

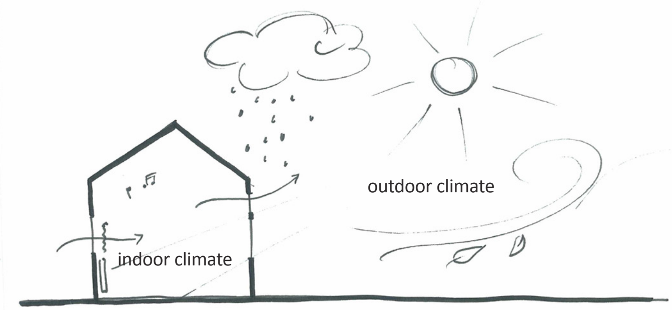
we spend 90% of our time indoors. In the Danish Building Regulations it is stated that:
"Buildings should be constructed, so that the intended use of the building in rooms where people stay during a longer period, a healthy and safe indoor climate can be maintained to a satisfactory standard." [ebst.dk, c] (translated from Danish)
This is of course a very broad and imprecise definition, why there is a need for some operational principles and requirements. The health related part of the indoor climate includes comfort an wellbeing, where the goal is of course to be in comfort. This is obtained in a "feel-good building", characterized by

- thermal comfort
- indoor air quality
- acoustics and sound
- ligthing and outlook
- privacy and safety
- space and materials

A feel-good-building should be designed for interaction instead of seclusion and the building systems as well as the building materials should be empatic and take occupant behaviour into regard. Consequently the building should be adaptable over time. A steady indoor climate is not always a goal.

In general, the indoor climate can be split up into a physical and a psychological indoor climate. The psychological aspects of being in comfort are more difficult to implement directly, since there are no concrete requirements to follow. However, this aspect will be kept in mind in the sketching process. The physical indoor climate is easier to deal with, as it can be measured, and consequently incorporated in the design process as evaluation tools of the design. [Jensen, 2006]

The physical indoor climate is related to the thermal, atmospheric, acoustic and light indoor climate. It depends on the occupant behaviour, that is the activity level of the occupant and the clothing of the occupant, on external building related factors, and, of course, on the outdoor climate - both on macro- and microlevel. The outdoor climate determines the need for heating and cooling and limits the possibility to make use of daylight for passive lighting and the wind for natural ventilation. In general, the sun is the main force of the outdoor climate, and consequently it varies with different climate zones and different times of year and is difficult to change or control. But it is possible to control how the indoor climate responds to the outdoor climate. In the following an overview of the different aspects of the physical indoor climate will be given. Since focus in this project will be on the light climate, this is elaborated more than the other aspects. [Jensen, 2006][Steen-Thøde, 2008][ebst.dk]



Ill. 52a: The indoor climate is dependant on the outdoor climate

Thermal indoor climate

The thermal indoor climate deals with the aspects influencing people's heat exchange with the surroundings, first of all the temperature of the surroundings.

"Buildings should be constructed, so that, under the intentional use of the building in the rooms where people stay during a longer time, there can be maintained health related satisfactory temperatures under consideration for the human activity in the rooms " [ebst.dk, c]

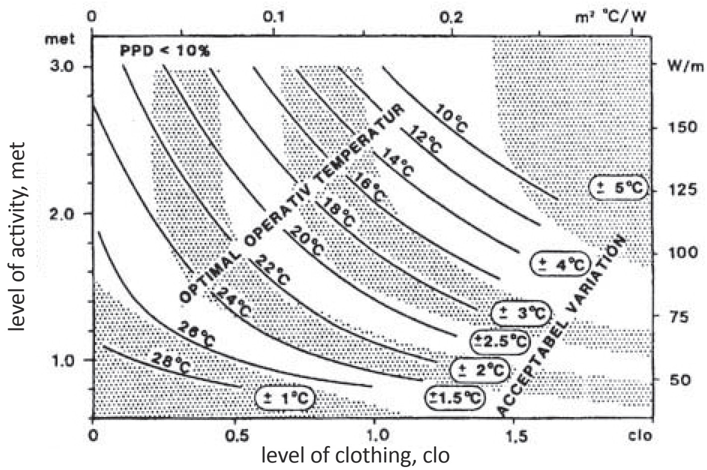
The physical surrounding environment affects humans thermally by conduction, convection or radiation. The operative temperature is used as an expression for the uniform temperature of the air as well as the surrounding surfaces, which would cause the same emission of heat from the body as the actual conditions [Jensen, 2006]. The body has to be in thermal balance, so that the heat produced in the body equals the heat lost from the body. Consequently, the operative temperature has to correspond to the comfort temperature, which is an expression for the optimal room temperature for a person doing a given activity at a given clothing-level. Furthermore, there should not be any local discomfort, e.g. draught from windows.

The evaluation of the thermal indoor climate is done according to PPD (Predicted Percentage Dissatisfied) as a function of PMV (Predicted Mean Voting), which is an expression for the expected mean evaluation of the indoor climate. The comfort temperature is given as an interval of temperatures, which depends on the level aimed for in the specific project – the higher level, the smaller interval, that is, the more precise the predicted calculated comfort temperature has to be (see ill. 53a.). [Jensen, 2006][Steen-Thøde, 2008]

As the focus in this project is on the light climate the thermal indoor climate is aimed at a level B, which corresponds to a PPD of less than 10% for general influences (overall temperature) and a PD under 5% - 20% for local influences (draught, air temperature difference, surface temperature of floor or radiant asymmetry). Level A is the most dififcult to reach, and is equivalent to a PPD of less than 6%. The specific values of the operative temperature in the different rooms in the dwellings are read from the table below as

operative temperature winter:	24,5° +/- 1,5°
operative temperature summer:	22° +/- 2°

[DS474E, 1995][CR1752, 1998]

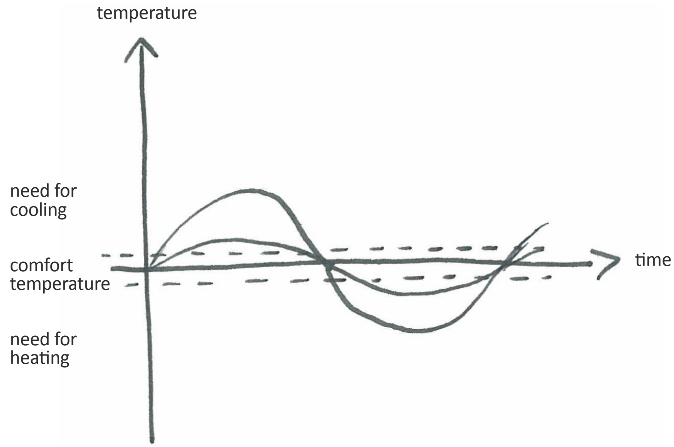


Ill. 53a: table showing the connection between the operative temperature range, the activity level and the level of clothing [DS474E, 1995, p.17]

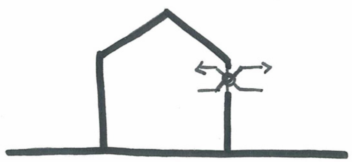
Concerning passive techniques for controlling the thermal indoor climate, it is first of all the goal to minimize temperature swing. This is primarily done by insulating the walls. Secondly, overheating should be avoided, which is mostly a problem during the warm period of the year. This is best done by external shading, since the rays of the sun should not reach the windows, where they will cause heating of the interior space. However, during the cold period of the year, the solar radiation can be useful for space heating in combination with use of thermal mass. Consequently, the shading can with advantage be designed so that it allows for solar radiation during this period. Next, natural ventilation can be applied for removal of excess heat.

Active techniques include district heating and mechanical ventilation for removal of heat. Mechanical ventilation can with advantage be combined with heat recovery, since this minimizes the energy consumption for heating of the intake air.

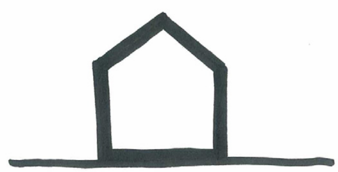
As concrete methods to evaluate the thermal indoor climate daily average spreadsheets will be used, during the sketching process. This gives an estimate of over temperatures and consequently if the comfort temperature can be reached. The spreadsheets will be used for comparison of different architectural solutions, rather than focus on obtaining an accurate value that meets the requirements for one solution. The documentation of the thermal indoor climate for the final architectural solution will be made with Bsim. [Jensen, 2006] [V. Jensen, 2010]



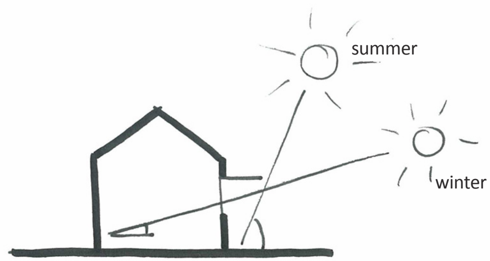
Ill. 54a: The comfort temperature is defined as a range of maximum allowed temperature swing



Ill. 54b heat exchange



Ill. 54c thermal mass/ insulation



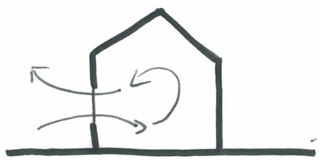
Ill. 54d solar radiation

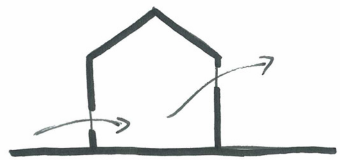
Atmospheric indoor climate
The atmospheric indoor climate is the totality of components in the atmospheric air with affection on the surfaces on humans, first and foremost the airways. Aspects influencing this are: gasses and fumes, steam, particles, micro organisms, smells and atmospheric electricity [Jensen, 2006]. Again, like the thermal indoor climate, there has to be mass balance – the incoming air has to equal the outgoing air. A main tool for controlling the atmospheric indoor climate is ventilation. According to the Danish building Regulation buildings should be ventilated [ebst.dk, d].
"In residential rooms as well as in the residence in total there should be a supply of outdoor air of at least 0,3l/s pr. m2 heated area. Kitchens should be supplied with a cooker hood with exhaustion over the cooker." [ebst.dk, e]

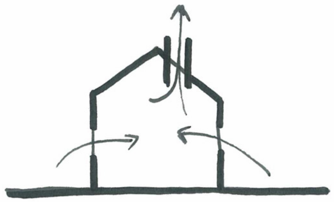
This is a minimum requirement for the ventilation, and the actual needed ventilation rate should consequently be calculated for each room. Since the ventilation is both a tool for controlling the thermal as well as the atmospheric indoor climate, the ventilation rate both depends on the eventual occurrence of overtemperatures during the year, and the occurence of CO2 in the air by occupancy. Consequently, the aspect demanding the highest ventilation rate decides the required value. The specific requirements for the ventilation rate in the different rooms in the dwellings are listed in the room programme on p. 79.

Ventilation
There are different techniques for ventilation of rooms. In general these can be split up into passive and active techniques, where passive techniques are of course the most sustainable, since they do not require any energy consumption. Consequently, there will mainly be used natural ventilation, and mechanical ventilation will only be applied during winter time, where the outdoor air is too cold to use for ventilation. In this case heat recovery will also be used in order to minimize the energy consumption for heating of the incoming ventilation air.

Natural ventilation can be applied in several ways (see ill. 55a-d). It works either by thermal buoyancy, which is driven by differences in air density, or by air pressure, depending on the outdoor conditions.


Ill. 55a One-sided ventilation


Ill. 55b Two-sided ventilation


Ill. 55c Stack-ventilation

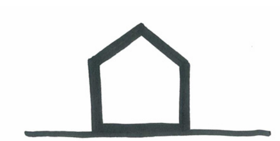

Ill. 55d Combined ventilation

Various spreadsheets will be used as concrete tools both for the calculation of the needed ventilation rate (in relation to either the occurrence of over temperatures or the amount of pollution in the air) and for the evaluation of different architectural solutions during the sketching process (see appendices xx. On pp. xx.). The documentation of the atmospheric indoor climate for the final architectural solution will be made with Bsim.[Jensen, 2006][Topp, 2010]

Acoustic indoor climate

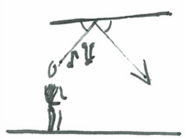
According to the Danish Building Regulations *"Buildings should be planned, projected, constructed and organized so that the users are ensured satisfactory sound conditions"* [ebst.dk, f]
This concerns the building's ability to insulate from un-wanted noise, from both outside and eventual neighbouring rooms or buildings, as well as the buildings ability to deal with the dispersion of sound within the specific rooms of the building. The reverberation time of a room has to be fitted for the function of the room (which again depends on the occupants and the activity), so that the sound does not become noise, and the amount of insulation has to be able to prevent noise from outside the room.

Reverberation time depends on the dimensions, materials and interior elements of a room. As domestic spaces often are relatively small and decorated with furnishes and paintings, the reverberation time is usually not a problem. However, if spaces are designed with a big volume, cubic dimensions or hard surfaces the design should be checked for acoustic conditions according to wave theory. For this project the reverberation time is not considered an aspect, where special concern has to be taken during the design process. In relation to sound insulation, this is also not considered to be a problem, that has to be taken in special consideration during the design process, since the sound insulating characteristics of the building parts are closely related to the heat insulating characteristics of the building parts. [PHK/Kirkegaard, 2009]

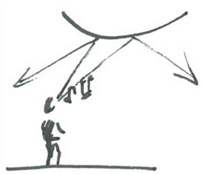


Ill. 56a insulation

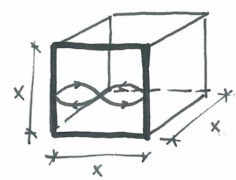
Ill. 56b sound reflection of concave surfaces



Ill. 56c sound reflection of plane surfaces



Ill. 56d sound reflection of convex surfaces



Ill. 56e sound reflection in box-shaped room

Light indoor climate

This project focuses on light, as this is closely related to both the energy consumption of a building as well as the comfort of the occupants, but also to the perception of space and consequently the phenomenological experience of the dwelling, the home. The use of daylight reduces the use of energy for artificial lightning, and both the physical and psychological wellbeing of humans is directly related to daily access and exposure to daylight. The light depends on the area and placement of the openings and plays a great role in the overall perception of a room. If the light conditions are not good, the occupants are more likely to evaluate the overall indoor environment negatively. Also, the late-modern lifestyle is very visually oriented, and consequently it plays a great role, how things look, which is mainly determined by the light conditions.

Good light conditions depend just as much on the quality of the light as the quantity. Strong spotlight and light from several directions easily results in a shadowless environment, which makes it more difficult to perceive threedimensional objects and the texture of surfaces. This is easier to perceive with light from only one direction, where the light becomes broken down into several nuances from light to darkness, and the environment consequently gain more plasticity. This gives more variation in the light and adds atmosphere to the room. [Brorson, 2010][Anvisning203]

Ill. 57a The sun is the primary source of energy

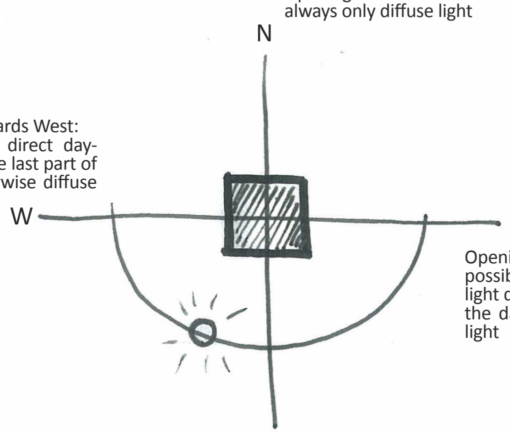
When speaking of daylight, there are generally two main types:

Direct daylight:
light from a sunny, clear sky which gives strong contrasts between light and shadow and a more dramatic effect.

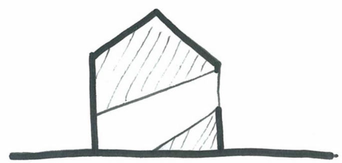
Diffuse daylight:
light from an overcast sky, which gives a general light that blurs the difference between light and shadow and consequently evens out contrasts.

Taking this aspect in regard, the orientation of openings has a great influence on the incoming daylight, in relation to the sun path over the day:

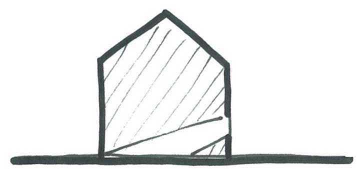
Another factor is the placement of the openings in the wall. The higher placement of the openings, the better dispersion of the light into the room. A rule of thumb is that the distance from floor to the upper edge of the opening multiplied by two, is the distance of light dispersion into a room (see ill. 58b-d). The lower the openings are placed, the more directed, the light will be, which can create desireable effects for various functions. Another tool for the dispersion of light into a room is to use light and reflective surfaces, which will work as reflectors of the light, especially if the openings are placed directly adjacent to the surfaces.



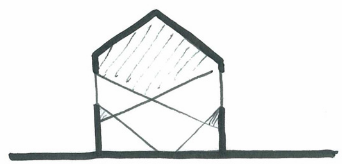
Ill. 58a: Character of light from different directions



Ill. 58b: light dispersion from openings placed high



Ill. 58c: light dispersion from openings placed low



Ill. 58d: light dispersion from openings at two sides

Requirements

The Danish Building Regulation states that *"Work rooms, living rooms, residential rooms and common access ways should have a satisfactory light, without causing an unnecessary heat load."* [ebst.dk, f] Satisfactory light of course depends on the function of the room and which activities should take place in the room, why it is mostly related to the amount of light in a room. The daylight factor indoor should be minimum 2%, that is a daylight level on 2% of the outdoor light level, and there is also a demand for being able to look out on the surroundings. One of the main reasons for these requirements is the fact that the amount of daylight has a great influence on the needed energy for artificial lighting, as earlier mentioned.

In this sense, use of daylight is a passive technology and use of artificial lighting is an active technology. Of course, the use of daylight cannot be applied when the outdoor conditions are not suited for it, but a lot can be done by orientation and area of openings. In this respect the side-effects of daylight should, however, also be taken into consideration. Solar radiation does not only bring light, but also heat, which means that direct light on glazed areas can cause a great heat gain, because glazed areas have a high transmission coefficient. Consequently, there will also be a great heat loss through glazed areas, if there is no direct light on them, e.g. in Northern directions. This should of course be taken into account when placing openings, where the need for daylight should be balanced with the risk of overheating and heat loss. [ebst.dk, g][Rasmussen, 1957][Pedersen, 2009]

In dwellings, there is in general not a need for a strong work light, but rather a need for light that creates an intimate and cozy atmosphere. This depends, however, on the different functions of the room, and consequently the specific requirements for the different rooms in the dwellings are listed in the room programme on p. 79.

In the project Ecotect with Radiance will be used in the sketching process for evaluation of the daylight level for comparison of different architectural solutions. The documentation of the light climate for the final architectural solution will be made with Bsim.

Conclusions

Energy consumption is an inevitable aspect of a sustainable building design, as the energy used for running buildings currently make account for approx. 40% of the total energy consumption. Presently, the techniques used for energy production has a great impact on natural resources and are consequently not sustainable. It is simply not possible to continue the present development, if we are to maintain the same level of development and standard of life. Therefore it is necessary to minimize the energy consumption as much as possible, and to apply the use of renewable energy instead of fossil fuels. The fact, that this discussion has been going on since the 1970's does not make it less relevant to take action.

However, the focus on the energy consumption of buildings should be balanced by other sustainable aspects, as mentioned in the chapter on sustainability (see p. 42). Moreover, it should be considered in close connection to the indoor climate and the comfort of the occupants as inseparable aspects. The indoor climate plays a crucial role in the comfort of the occupants, and the responding occupant behaviour has a great impact on the energy consumption of the building.

Consequently, the architectural design of dwellings at Aarhus harbour should provide a good indoor climate for the wellbeing of the occupants, which should again be balanced with the predicted energy consumption of the building design.

Ill. 61a: User behaviour plays a big role in relation to energy consumption

The predicted primary energy consumption for the architectural design solution of this project should fulfill the requirements for low energy class 2015:

primary energy consumption: 30 + 1100/A kWh/m² annually

A good indoor climate is in this project defined for the four aspects of the physical indoor climate:

Thermal indoor climate

level B:	< 10% PPD	
	operative temperature winter:	24,5°C +/- 1,5°C
	operative temperature summer:	22°C +/- 2°C

additionally there should be max
100 hours > 26°C and 25 hours > 27°C

Atmospheric indoor climate

Air change rate should be > 0,3 l/s + exhaust in the kitchen

CO_2 amount in the air < 1000ppm

(The specific requirements for the single rooms will depend on the actual design of the room, where either the thermal climate or the amount of CO_2 in the air will be deciding. Consequently this will be specified later in the design process.)

Acoustic indoor climate

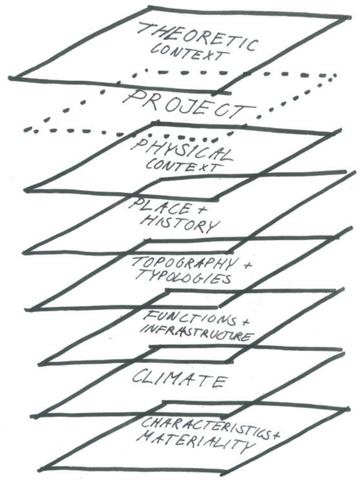
The acoustic indoor climate should be satisfactory, which will be evaluated for the different architectural solutions during the sketching process based on experience.

Light indoor climate

DF > 2% + outlook from all rooms for longer stays

PHYSICAL CONTEXT

The site is located at the harbour area of Aarhus, which is again situated at the East coast in the centre of Jutland, the part of Denmark being connected to the mainland of Europe via Germany.
The investigation of the physical context at Aarhus Harbour is split up into different themes, in order to get an understanding of the physical aspects of the site. First the history of the city and harbour of Aarhus and how it has developed over years is looked into. Then the topography as well as the different building typologies of the site and its surrounding area is investigated, in order to get an idea of what the design of this project has to relate to concerning the existing buliding mass. The surrounding area is also investigated regarding existing functions, traffic and infrastructure in general, and of course the climatic aspects of sun and wind for the specific area are documented. This gives an idea of the possibilities of using passive techniques for e.g. lighting and ventilation in the architectural design of dwellings at Aarhus Harbour. Finally, a look at the experience of the site and the harbour area in general by visual connections to and from the area, as well as materials and surfaces of the area is looked into.



Ill. 62a: the physical context analysis is split up into different themes

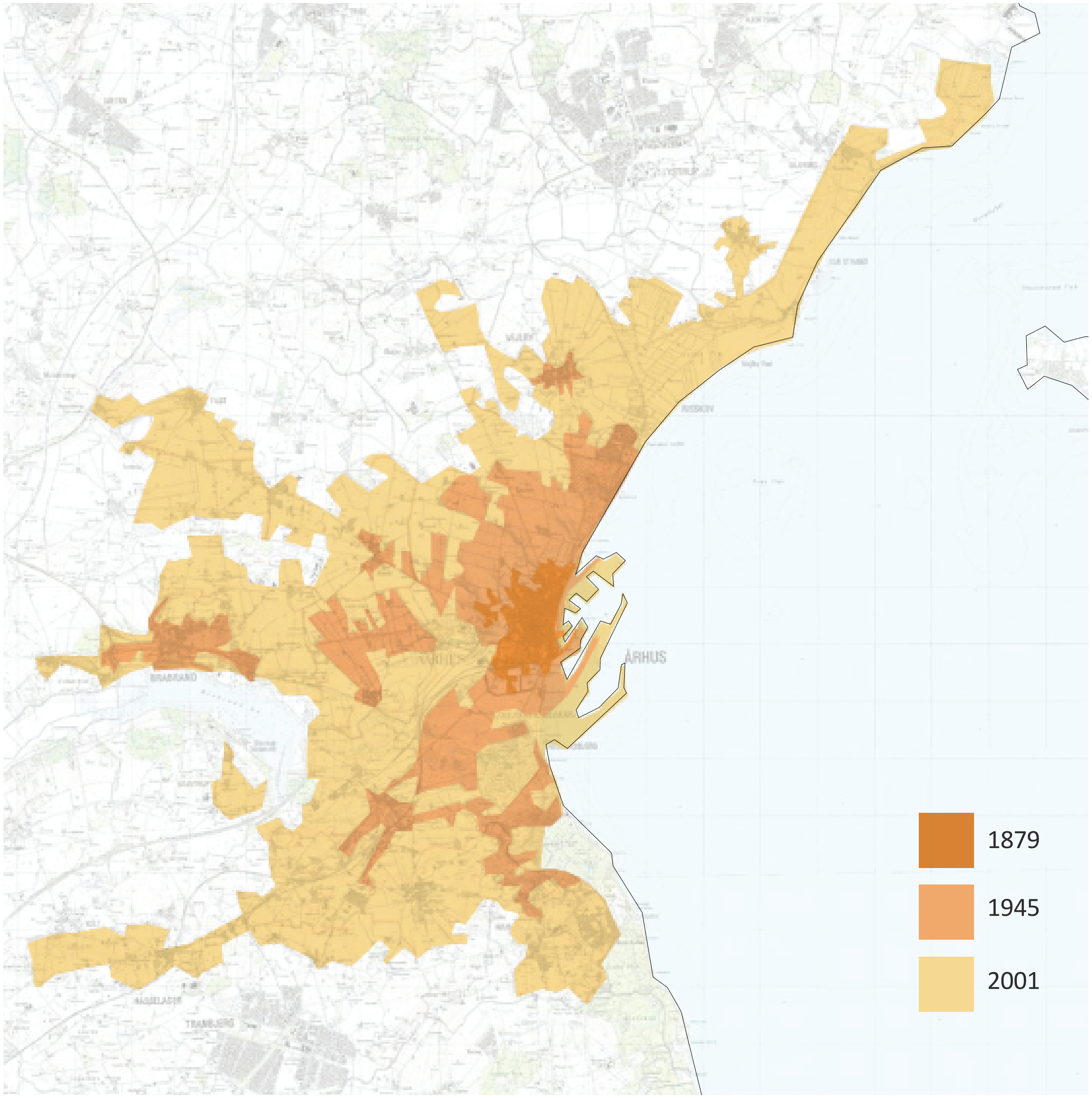
Ill. 62b: Location of Aarhus in Denmark

Ill. 62c: Aarhus is the capital of Jutland

Ill. 62d: Location of site within the city of Aarhus

PLACE AND HISTORY

The city of Aarhus has approx. 240.000 inhabitants and is the largest city on Jutland, and the secondlargest city in Denmark since the 1870's. It is also the second oldest city in Denmark, where the name *Aarhus* comes from *Arus* (1231) which is made up from the Danish *å* (stream) and the old-Danish *os* (estuary), later *hus* (house). Thus, the name indicates that the city is situated at the estuary of the Aarhus stream into Aarhus Bay and the Kattegat. Aarhus dates back to the 900's as a city and has had a bishop since 1065. It has grown due to the beneficial location for trade and shipping and officially obtained market town privileges in 1441. The extensive growth of the city in the 19th century and up to present state is primarily due to improvement of the roads, the harbour and the establishment of railways. Most of the public buildings of Aarhus are from late 19th century and the first half of the 20th century which is of course reflected in the expression and styles of the buildings, which represents Art Nouveau, neoclassicism, functionalism and modernism. [denstoredansk.dk,B][wikipedia.org]

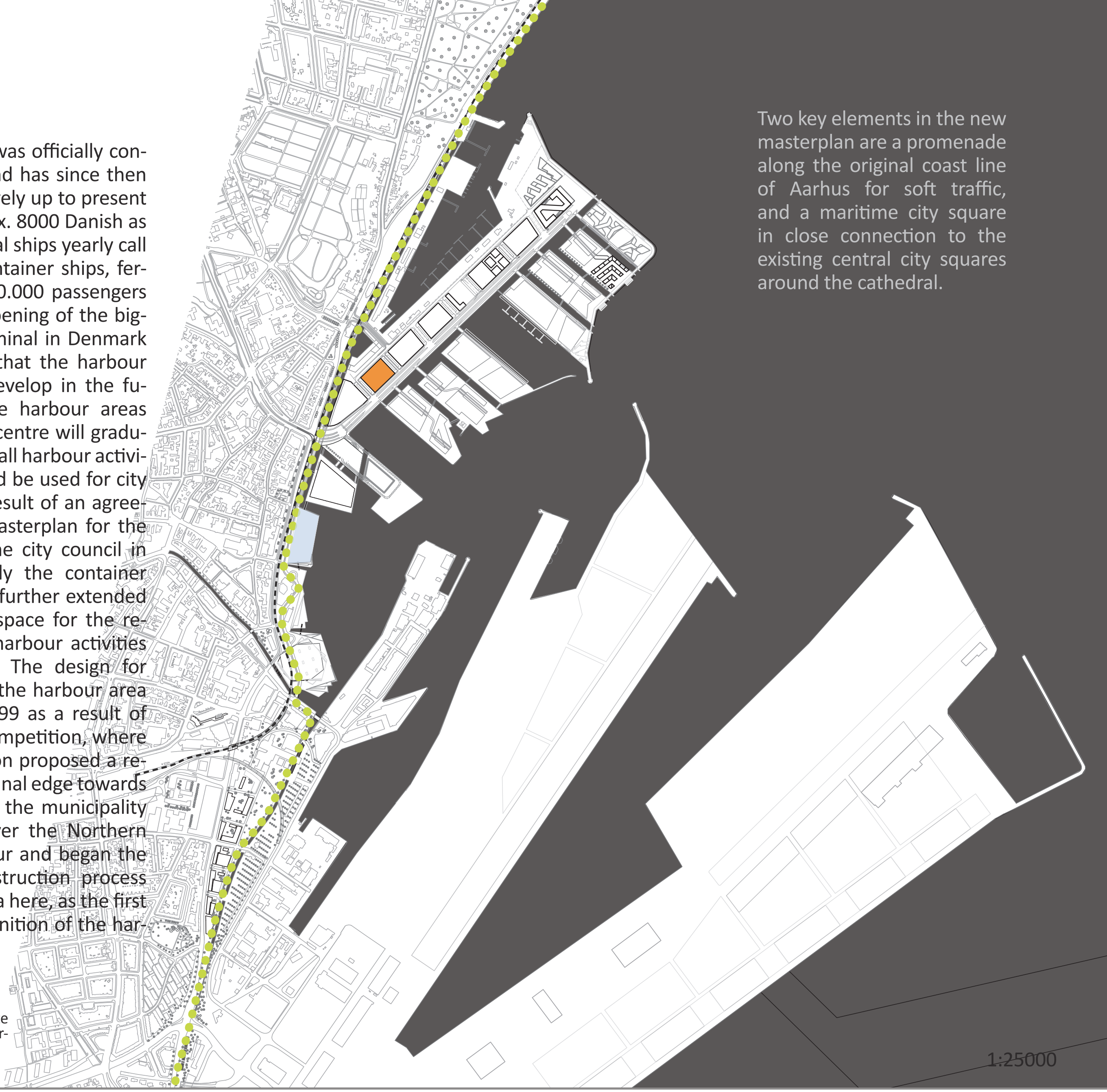


Ill. 63a: Growth of Aarhus through time

The harbour

The harbour area was officially constituted in 1861 and has since then developed extensively up to present state, where approx. 8000 Danish as well as international ships yearly call into port, both container ships, ferries and approx. 30.000 passengers on cruisers. The opening of the biggest container terminal in Denmark in 2001 indicates that the harbour will continue to develop in the future. However, the harbour areas closest to the city centre will gradually be emptied for all harbour activities and will instead be used for city purposes, as the result of an agreement on a new masterplan for the harbour area in the city council in 1997. Consequently the container terminal has been further extended in order to make space for the removal of existing harbour activities from these areas. The design for the masterplan of the harbour area was decided in 1999 as a result of an urban design competition, where the winning solution proposed a re-creation of the original edge towards the water. In 2007 the municipality of Aarhus took over the Northern part of the harbour and began the planning and construction process of a new urban area here, as the first stage in the re-definition of the harbour area.

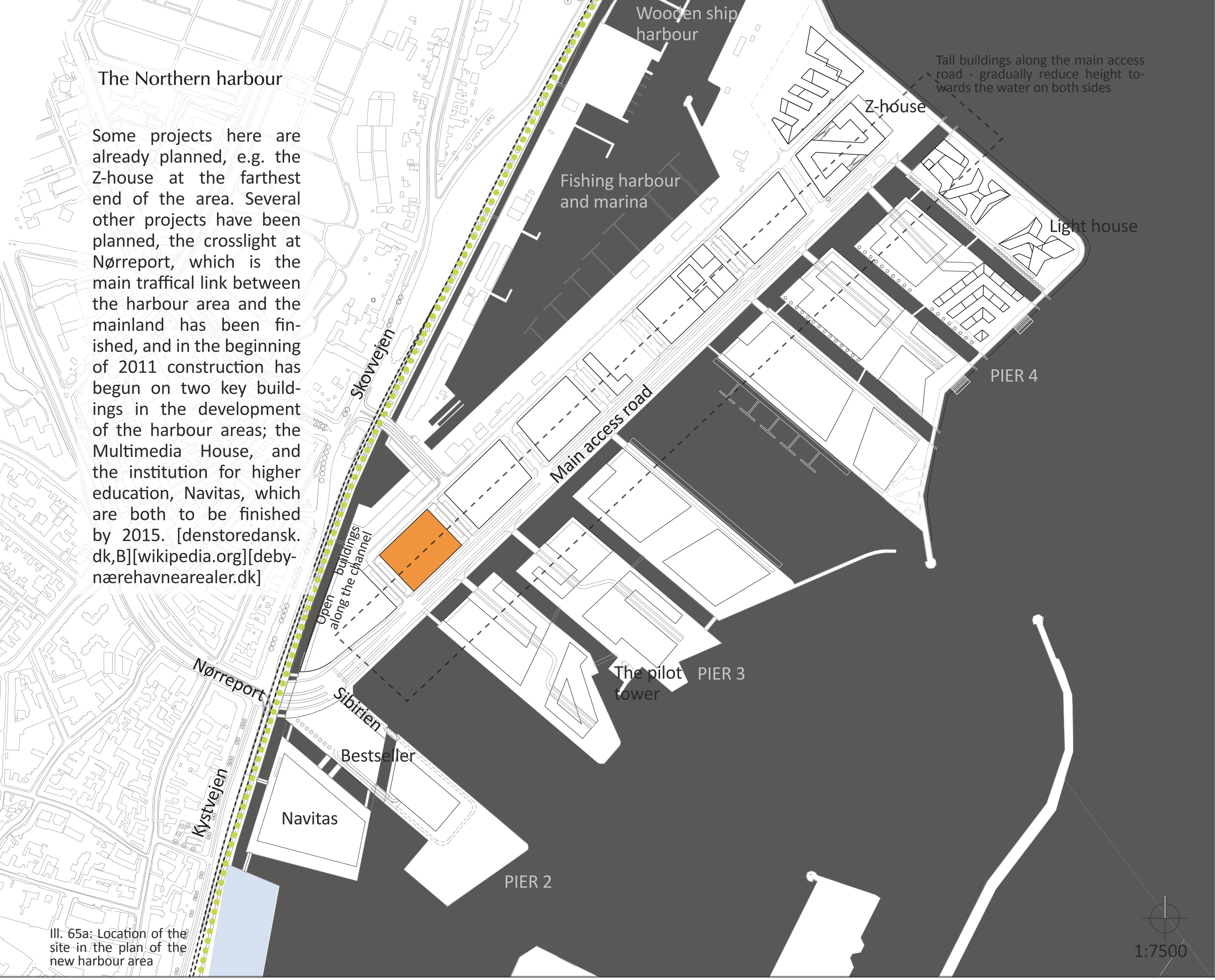
Two key elements in the new masterplan are a promenade along the original coast line of Aarhus for soft traffic, and a maritime city square in close connection to the existing central city squares around the cathedral.



Ill. 64a: Location of the site in the plan of the new harbour area

The Northern harbour

Some projects here are already planned, e.g. the Z-house at the farthest end of the area. Several other projects have been planned, the crosslight at Nørreport, which is the main traffical link between the harbour area and the mainland has been finished, and in the beginning of 2011 construction has begun on two key buildings in the development of the harbour areas; the Multimedia House, and the institution for higher education, Navitas, which are both to be finished by 2015. [denstoredansk.dk,B][wikipedia.org][debynærehavnearealer.dk]

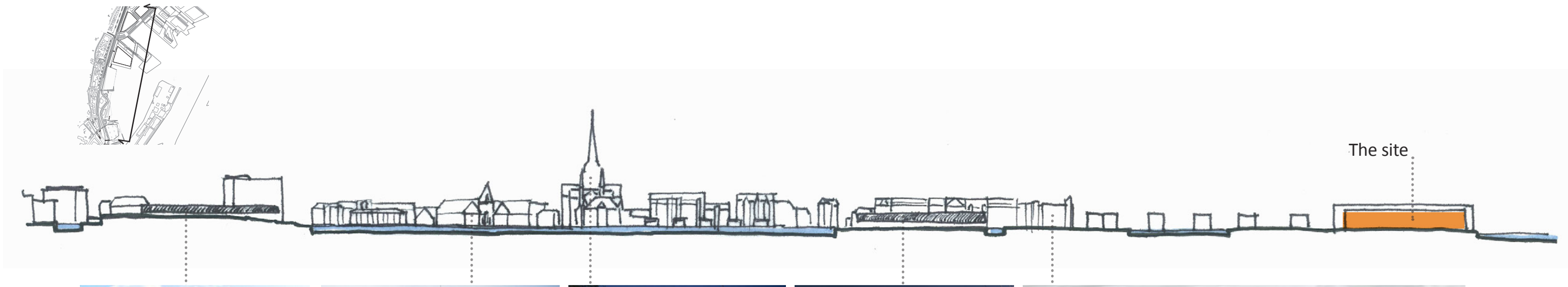


Ill. 65a: Location of the site in the plan of the new harbour area

TOPOGRAPHY

The topography of the site is dominated by the meeting of city and sea, which the sketch of the harbourfront below clearly demonstrates. The view from sea is that of a "city wall" constituted by a row of typical apartment block buildings characteristic of the Danish cities. In front of this the relatively flat harbour area is stretched out, thereby making the city wall visible. In the middle of this sight, the cathedral clearly marks itself, acting as a landmark and point of orientation. Two new significant buildings are going to flank and frame the view of the cathedral, which is also being emphasized by the empty space of the new maritime city square in front of it. The site of this project has a relatively anonymous placement to the North-East of this scenery, but should not distract this significant central composition.

The principle cross-sections at the site show how the connection between the city and the harbour will be. Or rather not be, as the Kystvejen, the railway as well as a new canal are going to separate the city and the harbour area.However, crossings for pedestrians and cars at several central points will be made. The separation of the city and the new harbour area gives the possibility of defining the new urban area on its own conditions, where it does not necessarily have to relate to the buildings in the central city. However, the significant city wall should be visible from the new harbour area in order to connect the two areas visually.



Urban Media Space by the architectural company Schmidt, Hammer & Lassen, an architectural company based in Aarhus, is going to house the main library of Aarhus as well as other citizen facilities and services.

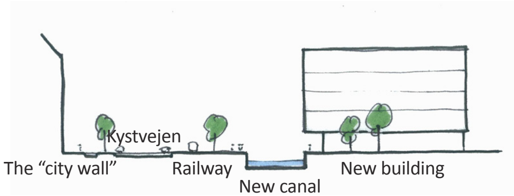
The toll house, "Toldboden", by architect Hack Kampmann was constructed in 1897 and is now functioning as the student house of Aarhus.

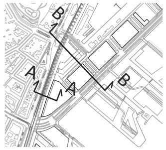
The construction of the Sankt Clemens Cathedral began from the end of the 12th century. The remarkable tower with its copperclad spire, which can be seen from almost everywhere in the city centre, was added during the 15th century and got its present look in 1931.

Navitas Park by Kjaer & Richter, an architectural company based in Aarhus, is going to house an innovation and education centre for engineering, among others marine engineering.

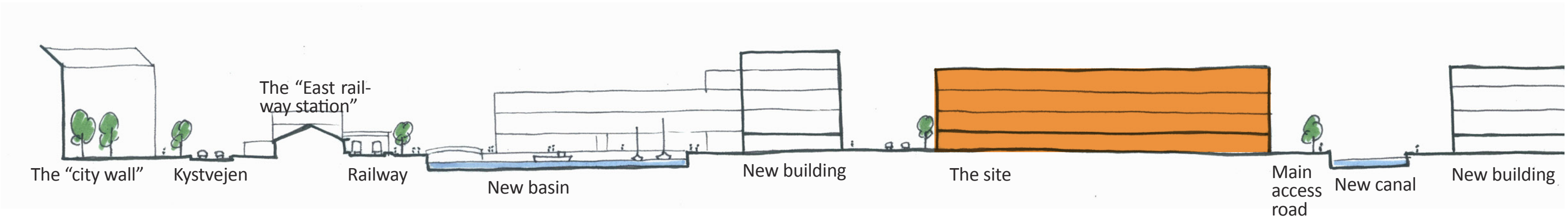
Along the Kystvejen, apartment housing constitute a visual city wall towards the harbour area. The facades of the housing welcomes people who arrive to Aarhus from the seaside and gives the first visual impression of the city.

Ill. 66a:Elevation of the harbourfront seen from the water towards West.





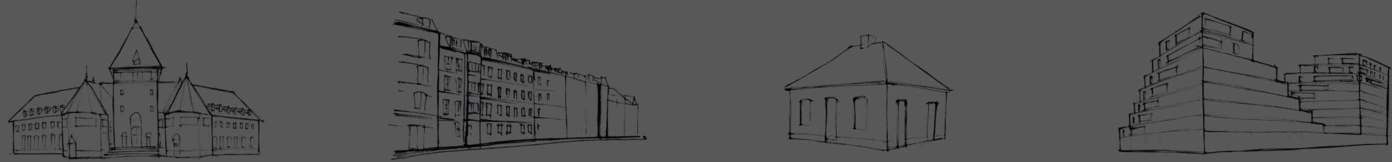
Ill. 67a: Principle section A-A



Ill. 67b: Principle section A-A

TYPOLOGIES

Ill. 67c: Characteristic building typologies in the surroundings



The historic building

E.g. the cathedral, the "Toldbod" and the railway station, which are significant buildings that act as landmarks in the urban fabric. They convey the history of the city and the functionality of the area.

The city block building

Is found everywhere in the centre of the city, where they from continuous rows defining the streets. This give a rhytmic impression of the streets, where each building preserves its individuality as a part of the totality of the street.

The small harbour building

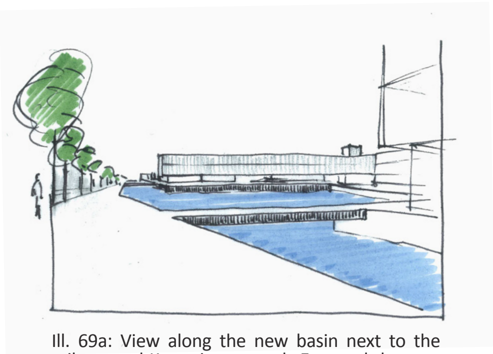
Is found scattered around the harbour area, but are to be torn down before construction of new buildings. However, they convey an impression of the history and functionality of the harbour area.

The modern city block

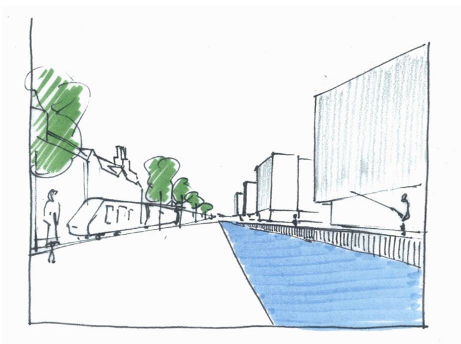
Is found in the new plan for the harbour area. One overall design and expression for a whole block, which gives this typology a more individual and self-centred expression. Does not necessarily relate to other buildings in the area.

Ill. 68a: Main functions in the close surroundings

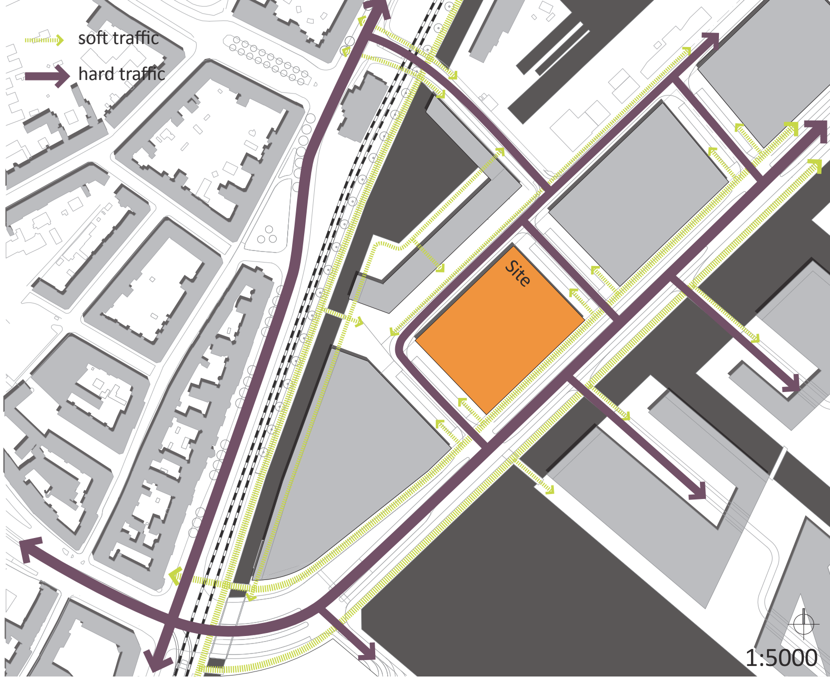
PATHS AND CONNECTIONS



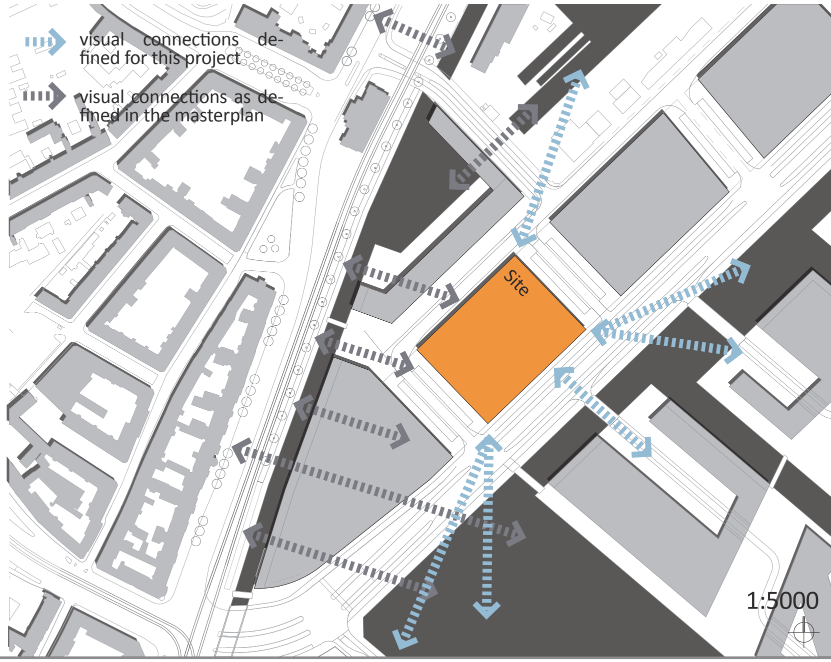
Ill. 69a: View along the new basin next to the railway and Kystvejen towards East and the new building next to the site.



Ill. 69b: View along the new canal next to the railway and Kystvejen towards North-East and the new basin next to the site.



Ill. 69c: traffic and physical connections between the surrounding area and the site



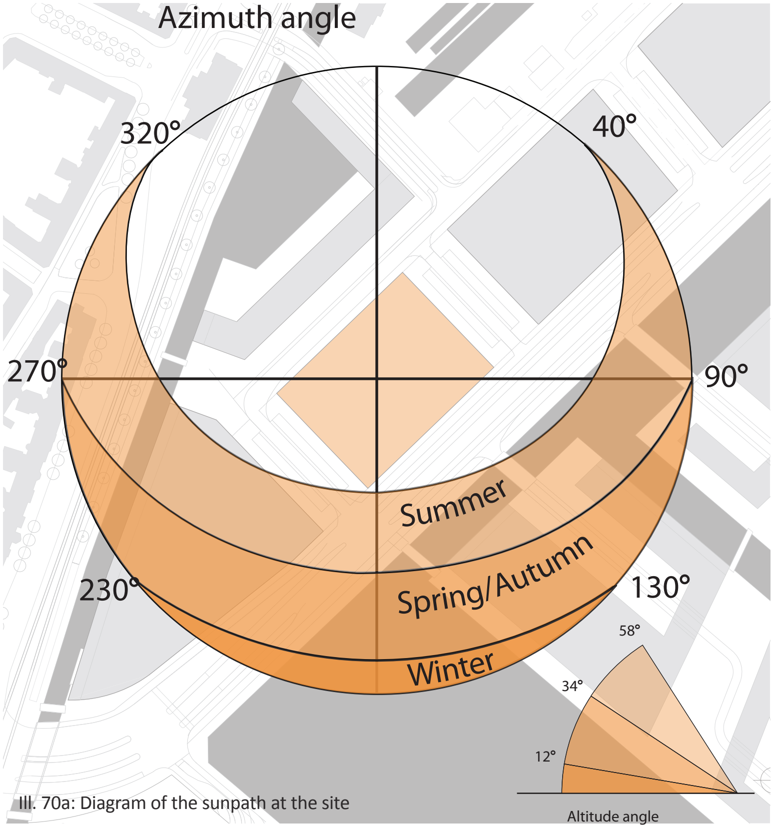
Ill. 69d: visual connections between the surrounding area and the site

CLIMATE

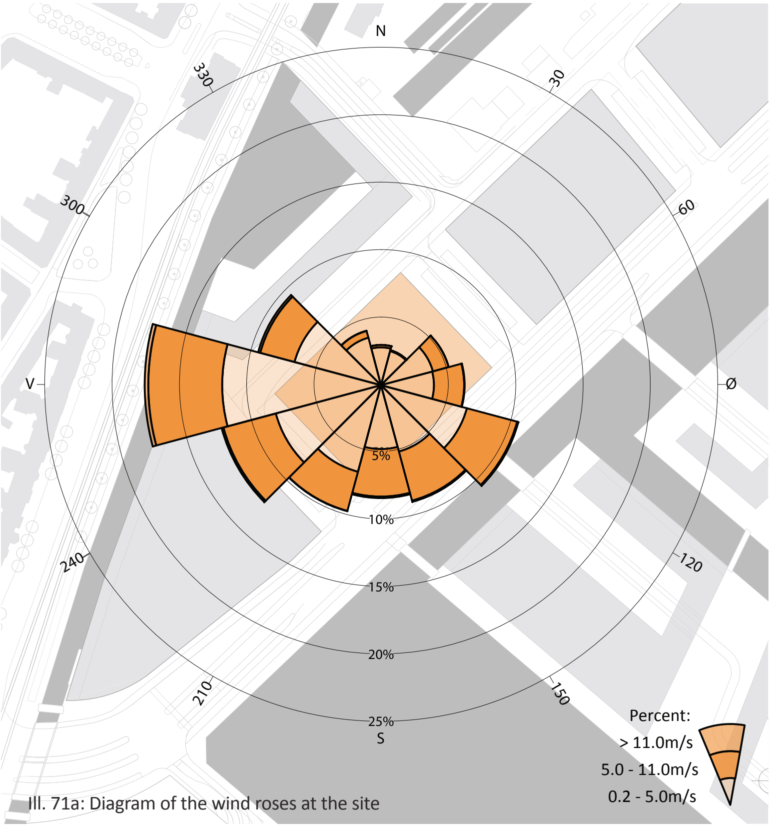
The site is located in Aarhus in the middle part of Denmark, which is a Nordic country with a temperate coast climate. This means that the lowest temperatures normally occur in Jan-Feb, with average day temperatures of around 2°C, and the highest temperatures in July-Aug, with average day temperatures of around 20°C. The average yearly precipitation is approx. 700mm distributed over approx. 120 days, where most fall as rain and some as snow during winter. Consequently there are good possibilities for collecting rainwater for use in households. There is also possibility of making use of solar power, e.g. by photovoltaics or solar cells. However, in order to get maximum use of these, they should preferably be placed at an angle of incidence of 45°, due to the low angle of the sun in Denmark. Even though there are relatively few hours of sun in Denmark, photovoltaics work quite good in the cold climate here, as they need to be cooled down in order to work the most efficient. [dmi.dk]

Sun path

Due to the Northern location of Denmark, there is a big difference in the position of the sun over the year. Consequently there is also a big difference between the intensity and amount of daylight over the year. During the Winter there is a limited amount of daylight, due to the small azimuth and altitude angles (50° and 12° respectively), while there is very short nights during the Summer due to the relatively big azimuth and altitude angles (140° and 58° respectively). However, in Winter the intensity of the sun can feel quite high, since the sun is very low in the sky and consequently the angle of incidence is quite small.



Ill. 70a: Diagram of the sunpath at the site



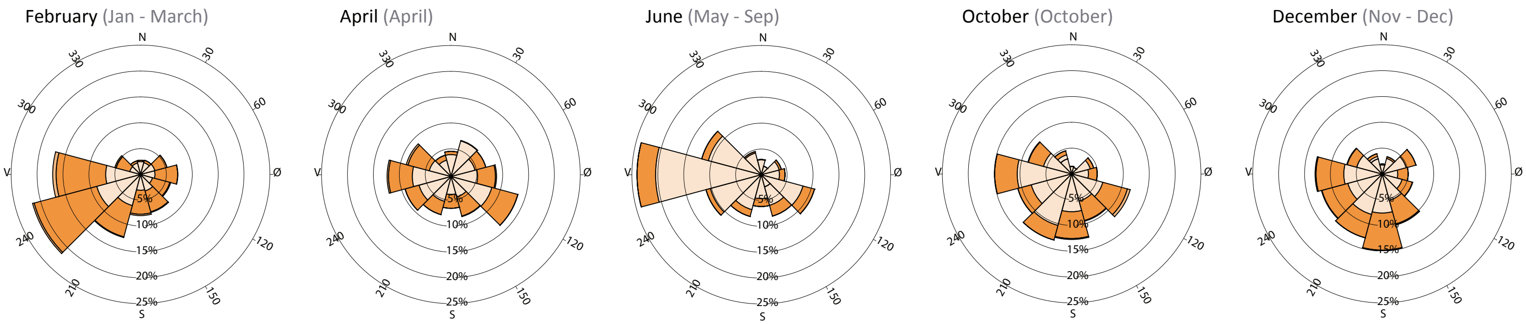
Ill. 71a: Diagram of the wind roses at the site

Wind

From the shown wind-roses, which are based on measurements at Ødum ca. 20 km North of Aarhus, it is clear that West is the predominant wind direction annually. However, there are big variations over the year as the five wind-roses below show. A common characteristic throughout the year is however, that there is rarely wind from a Northern direction.

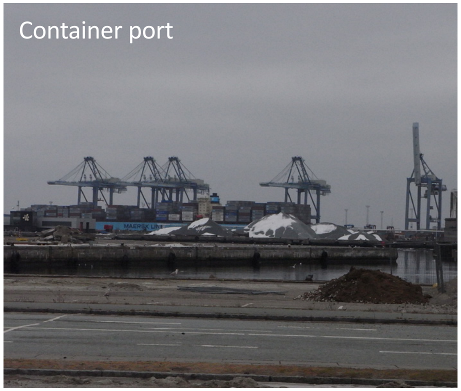
Concerning the specific site, it is located at the Eastcoast of Jutland with the city of Aarhus to the North and West. Moreover, the topography of Aarhus is sloping upwards from the harbour area, which means that the site is relatively sheltered from wind from these directions. Towards East and the open water the site is relatively exposed, with only a few buildings to shelter. Towards South the site is more or less directly exposed, which may be a problem from October to December, where there is relatively much wind from a Southern direction.

There is a risk of turbulence at the site, as the Western wind have direct passage to the harbour area via the big road Nørreport. A report on the predicted wind conditions at the new building Navitas to the South of the site shows, however, that there will probably not be great problems with the wind conditions in the close surroundings of this building, but that special concern should be taken at corners of big buildings, where there may be heavy winds. [Cappelen and Jørgensen, 1999][Rasmussen & Lauridsen, 2010]



CHARACTERISTICS AND MATERIALITY

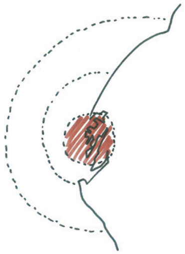
The general impression of the area, as it is now, is that of an industrial area, where all coming and going is meant for cars and heavy traffic, and where there is little concern for human scale. However, some details and smaller areas make space for stays...



Ill. 72a: Photos from the site taken March 3rd 2011

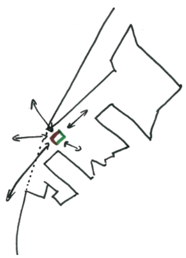
Conclusions

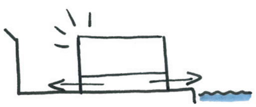
URBAN FABRIC
Aarhus has previously expanded inland, but expansion into the harbour area makes it possible for this area to connect directly to the very city centre of Aarhus. This brings an obvious opportunity for the sustainable development of the harbour area in a dense city context.



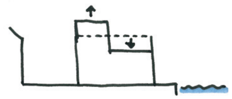
IDENTITY
The re-development of the harbour area should maintain an own identity of the area, which relates to the tough and industrial characteristic of the harbour. Nevertheless, the harbour area should be stitched together with the existing city centre in order to strengthen the connection between the two areas. The building typologies in the new area should, however, relate to the typologies of the existing city centre, with their concern for human scale and individuality, but re-interpreted to a contemporary expression as in the already planned projects in the new plan for the harbour area.

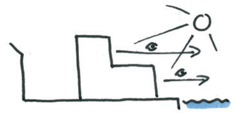
CONNECTIVITY
By the central position close to the main access point to the area, the site has the possibility of becoming an important link and to strengthen the connection between the existing city centre and the harbour area. Consequently, the specific site of this project should act as a physical as well as visual attractor both towards the harbour area itself, but also towards the existing city centre. Physically by offering attractive functions and visually by a significant expression.



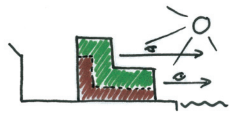


HEIGHT + ORIENTATION
The building height at the specific site should not follow the intention of the masterplan, but instead reflect the orientation by decreasing towards South. This increases the possibility for use of solar radiation as well as a view to the open water of the harbour.

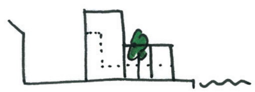


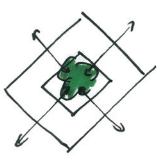


MIX OF FUNCTIONS
In order to obtain variety and diversity, which signifies a dense urban area, there should be a mix of functions within the specific site of this project. It is the intention in the masterplan, that the distribution between residential and commercial functions is 50/50 for the overall harbour area, but since other sites in the plan host more commercial than residential functions, the distribution is 60% residential and 40% commercial functions for the specific site. The commercial functions should be placed at ground floor and towards North, in order to relate to the existing city centre, and residential functions should be placed on top of these. In this way the two functions can benefit from each other regarding energy consumption.



SHELTERED GREEN HEART
In relation to the tough, industrial and open characteristic of the harbour area, the specific site of this project should host a sheltered green area for both residents of the site as well as visitors.





Ill. 73a: Conclusions of physical context analysis

PROGRAMME

DWELLERS

According to the project brief the main goal of the project is to develop an architectural design for sustainable dwellings in the urban area of Aarhus Harbour. More specific, sustainable dwellings which can act as an alternative to the detached single-family house. From a sustainable point of view, however, it is more beneficial to mix different functions and different user groups in order to obtain as much diversity and variety as possible. Also, it is more sustainable to stay in an area or even a specific dwelling thoughout one's life, since this minimizes need for transportation, as well as the affiliation with a certain area increases the consideration and care for the surroundings and results in less vandalism.

Moreover, this responds to the need of feeling rooted in relation to constituting a home-feeling (see chapter Home and dwelling on p. 29) [Thiis, 2011][Lauring, 2010][Pedersen, 2009]
Consequently, the focus is on designing dwellings for families with children, but the whole spectre of possible dwellers is taken into account. This is, however, generalized into two different user groups:
- singles or couples
- families with children, min. 3 persons

Following illustrations and quotations are not taken from the same reference and consequently not directly connected, but are merely a tool for giving an image of the possible dwellers:

Ill. 76a: Inspiration pictures of possible dwellers of the architectural solution of the project

"The only negative thing with this area is that there are no shops ... It is hurting my self-feeling or self-image of being a big-city-metropolitan who has to use these things and have access to these things."

"We would like a house and a garden...if we could get closer to town then we would like to live closer"

"... well you don't need to be more than 1 or 2 km from them otherwise you don't use them – you might as well live in Jutland."

"..We felt like living in a glass jar, not so cosy, could not walk down to the street and see a lot of people around us, and it is great fun that things are going on. You don't have that feeling here, because there is 3 km to where things are happening..."

"But now we have begun to talk to the neighbours.. and we became really happy with it. Now it is home..."

all quotations are from [Oldrup, 2008]

ROOM PROGRAMME

FUNCTIONS

The specific site is in the masterplan for Aarhus Harbour defined as an urban block. Below it is specified which functions are contained within the block for this project.

URBAN SCHEME	net area, %
offices	18%
daycare	7%
shops	11%
café/restaurant	4%
dwellings	60%

Ill. 78a: The abovelisted percentages are based on the masterplan for the area, where it is the intention to obtain a distribution of 50% commercial functions and 50% residential, with 9000 workers and 7000 inhabitants respectively. [debynærehavnearealer, 2011]

Dwelling units

The following lists the specific demands for the rooms within the single dwelling units concerning area, height and light, atmospheric and thermal climate [DS 474][CR1752]. Except for the light, atmospheric and thermal climate, the values are based on personal estimations.

The room programme is considered a tool in the design process, why the values for the rooms in the final architectural solution may differ from the areas listed below as a result of the integrated iterative design process, where the sketching e.g. may influence on the demands.

DWELLINGS	family unit, net area, m2	height, m	light climate		atmospheric climate, Air Change	thermal climate, comfort temperature, °C	
			DF, %	light type		summer	winter
technical installations	1	-	-	artificial	-	-	-
entrance	4-6	2,3	> 5	natural	10 l/s	24,5 +/- 1,5	22 +/- 2
kitchen	10-15	min. 2,3	> 5	natural	20 l/s	24,5 +/- 1,5	22 +/- 2
dining area	10-15	min. 2,3	> 5	natural	10 l/s	24,5 +/- 1,5	22 +/- 2
living area	15-25	min. 2,3	> 5	natural	10 l/s	24,5 +/- 1,5	22 +/- 2
bedroom	10-15	2,3	> 2	natural	10 l/s	24,5 +/- 1,5	22 +/- 2
bath/WC	4-8	2,3	> 2	(natural/) artificial	15 l/s	24,5 +/- 1,5	22 +/- 2
storage/washing machine	3-5	-	> 2	(natural/) artificial	10 l/s	-	-
front"garden"	8-12	3	(100)	natural/ artificial	-	-	-
back"garden"	20-30	6	(100)	natural	-	-	-

indoor areas
outdoor areas

Ill. 79a: Room programme for the dwelling units of the design

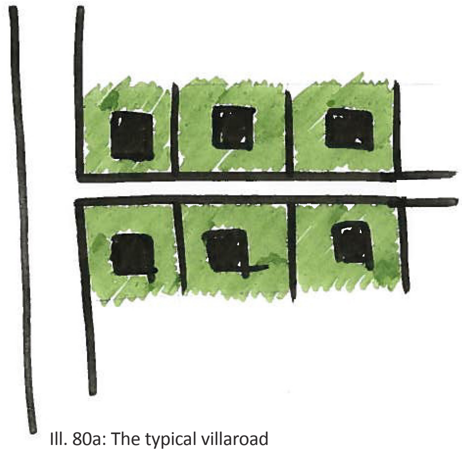
CONNECTIONS

Following shows how the different rooms and functions relate to each other, both on urban scale and on the scale of the individual dwellings.

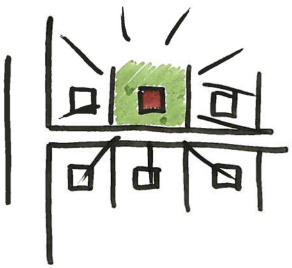
The villaroad

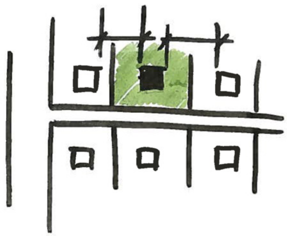
A main characteristic of the detached single-family house is the spatial principles of the villaroad. All the important aspects in the constitution of a "home-feeling" (safety and shelter, movements, autonomy and freedom, privacy, neighbours and neighbourhood, to be rooted, should embrace symbols, rituals and emotions of the dweller(s), see p. 35) relate to the organisation of the single dwellings around the villaroad.

The main principles of the villaroad are interrelated and connect in different ways to the important aspects in constituting a "home-feeling".



Ill. 80a: The typical villaroad





Ill. 80b: Spatial principles of the villaroad

Visual connection

The visual connection between the single dwelling and the villaroad makes it possible for the dwellers to obtain an image of the dwelling and to see the movements of people to and from their dwellings. Also, the feeling of shelter and safety is enhanced by being able to look out from the single dwelling to the villaroad.

Sense of territory

The sense of territory relates to the feeling of autonomy, freedom and privacy and of having one´s own space in the community of the villaroad.

Distance

The visual connection to the single dwelling is closely related to having a distance to the dwelling. If there is not a sufficient distance, it will be impossible to obtain a view of the dwelling. The distance also relates to the sense of territory, in the way that privacy, autonomy and freedom is obtained by feeling distanced to the neighbours and the villaroad, but at the same time connected and thereby obtaining a feeling of being rooted in a neighbourhood.

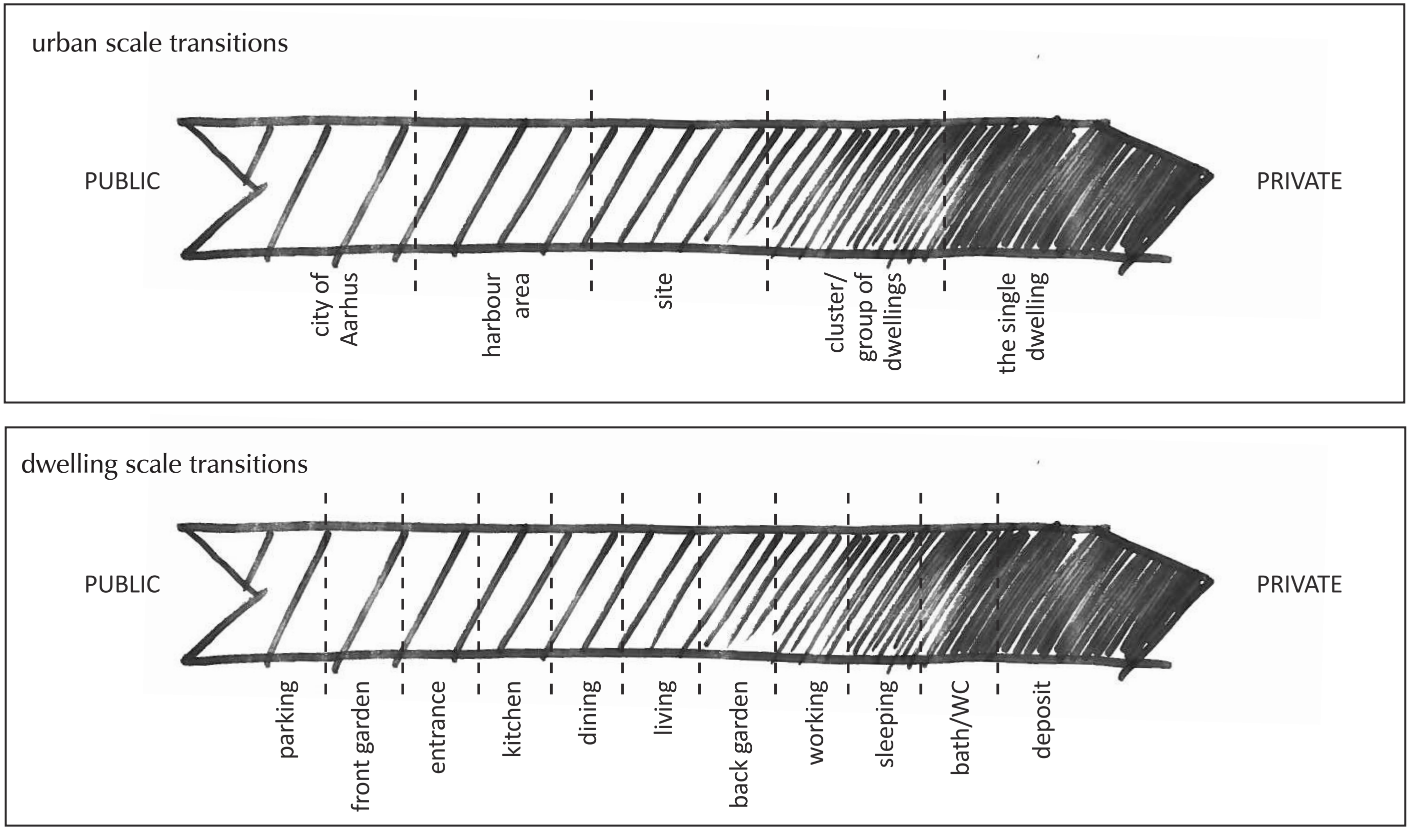
Gradual transitions

However, the main spatial principle of the villaroad is that of gradual transitions from public to private, where the individual dwellings connect to the villaroad like a fractal. This differs fundamentally from the principle of the city-apartment, where the transition from public to private is a lot more direct and does not allow for visual connection, sense of territory or distance in the same way as the villaroad.

Consequently, the connection of spaces for this project should take place by use of gradual transitions from public to private, both on urban scale and on the scale of the individual dwellings.

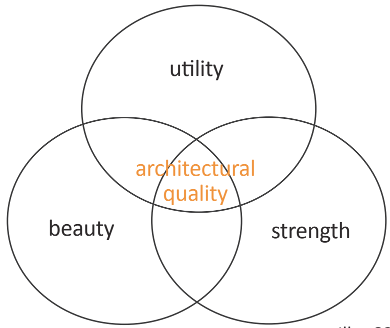
"However, a space must have intrinsically had rich gradations between 0 and 1" [Fujimoto, 2010, p. 37]

Ill. 81a: Gradual transitions from public to private for the functions at urban and building scale

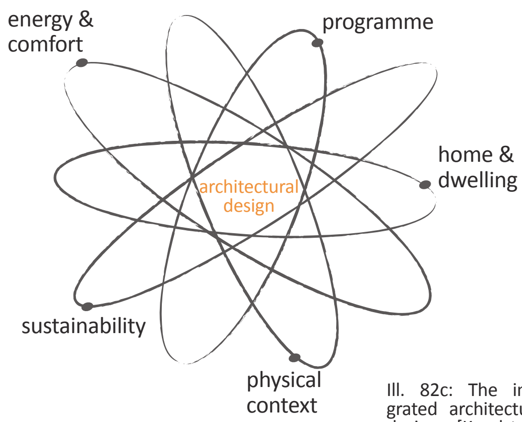


ARCHITECTURAL QUALITY

The following will explain the approach towards architectural quality in this project. As mentioned in the chapter on methods (see p. 20.) there focus is on the integrated design process, where the architectural design solution is the result of an iterative process taking several aspects into account. These are considered in relation to utility, strength and beauty, as defined by Vitruvius. The aspects dealed with in this project all cover several sub-aspects, which is listed to the right.



Ill. 82b: Vitruvius' definition of architectural quality



Ill. 82c: The integrated architectural design [Knudstrup, 2005]

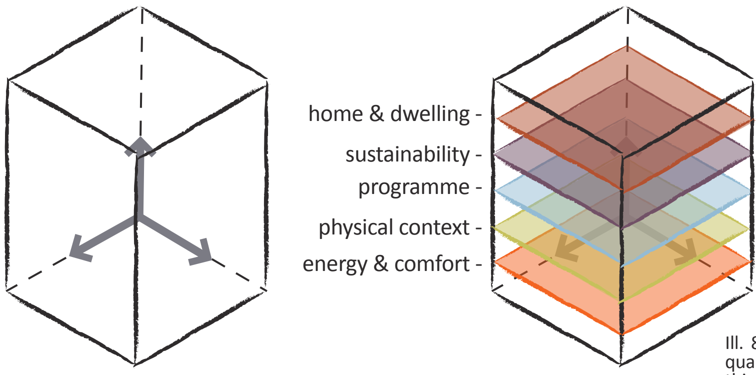
Home & dwelling
- physical level:
  the house
- psychological/phenomenological level:
  the home
- the detached single-family house
- contemporary lifestyle

Sustainability
- economical, environmental and social level
- Life-Cycle Assesment

Energy and comfort
- energy consumption
- physical level:
  indoor climate (thermal, atmospheric, acoustic and light)
- psychological/phenomenological level:
  comfort level

Physical context
- place and history
- topography and typologies
- functions
- paths and connections
- climate
- characteristics and materiality

Programme
- dwellers
- rooms and functions
- connections
- architectural quality
- vision



Ill. 83a: The space of the high quality architectural solution of this project

It is the goal of this project to obtain an overall architectural concept, which contains all the beforementioned aspects in a holistic design, which will be perceived as a unity, a whole. In this way, Vitruvius' definition of architectural quality can be interpreted into three axises defining a space, which is the architectural design of the project - the project space. The five aspects are then layers of the architectural design.

VISION

The aim of this project is to design

dwellings with high architectural quality at Aarhus Harbour,

combining

a sustainable life in a dense urban context

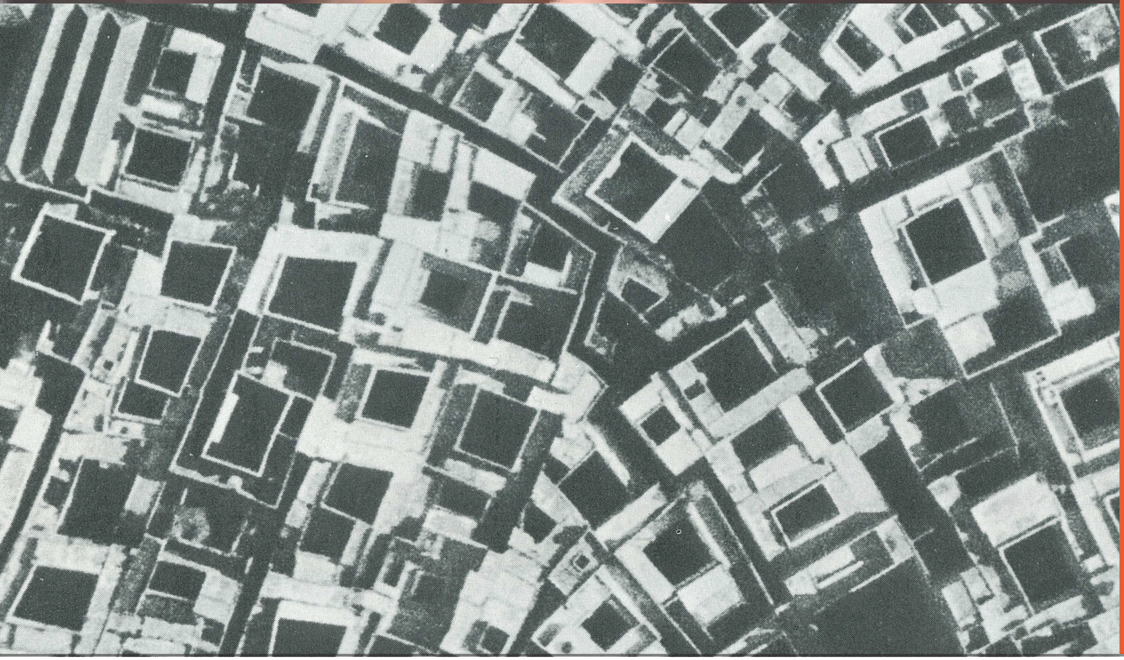
and

the values found in the detached single-family house.

Ill. 85a

The aim of the project is to show that dense living in an urban context does not necessarily have to compromise with the achievement of dwellings with high architectural quality and high quality of life for the residents - as enhanced by the detached single-family house.

"To be part does not equate to being a unit. If the whole is gone, so will the parts. If a part is gone, so will the whole. Network of an emergent field." [Fujimoto, 2010, p.63]



Ill. 85b

CATALOGUE

The catalogue forms the basis for the design process in the form of a collection of spatial principles, inspiration and ideas. These are extracted from the various investigations which are done according to the themes of dwelling and sustainability.

CASES

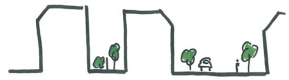
Several other projects and different architectural solutions to the problem posed in the vision has worked as inspiration in the design process. These include projects related to:
- urban housing
- sustainability
- dense living in general

In the following the projects studied will be presented.

Urban housing

As inspiration in the design process different housing projects have been visited. Through the study of these projects, experience is gained as to how housing can be designed in a dense urban context, but which still maintains some of the qualities enhanced in the detached single-family house. The projects are all situated in a Northern context - Denmark, United Kingdom and The Netherlands - why they are all comparable to the specific project site in Århus concerning climatic conditions.
Concludingly, the different projects are ranked according to their performance in relation to the Code for Sustainable Homes and the seven parametres in relation to home-making (see p. xx.)

Kartoffelrækkerne



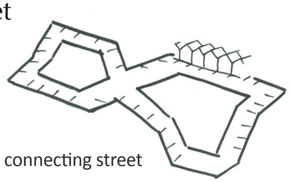
street-section
- private/communal transitions

<u>site</u>
Copenhagen, Denmark
<u>design</u>
Frederik Bøttger
<u>year of completion</u>
1889
<u>number of dwellings</u>
480 (today)
<u>density</u>
Approx. 60 dwellings/ha
<u>typology</u>
2½ storied row houses
<u>functions</u>
mainly residential

Originally built to house workers in Copenhagen with the social aim of providing good daylight and fresh air for the occupants in the, at the time, somewhat polluted city environment. Upon completion each house was intended for two families, however many were reorganized to fit 3 families due to difficult economic conditions. Today this renowned housing area with its small, intimate scale, situated in the centre of Copenhagen, is a desired area for prosperous families and is mainly single-family houses [kartoffelraekkerne.dk].

Ill. 88a: Kartoffelrækkerne is visited in February, 2011

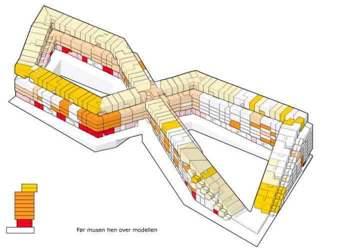
8-tallet



twisting, connecting street

<u>site</u>
Ørestaden, Copenhagen, Denmark
<u>design</u>
Bjarke Ingels Group
<u>year of completion</u>
2010
<u>number of dwellings</u>
476 (owner-occupied)
<u>density</u>
-
<u>typology</u>
city apartments, city “houses” and penthouse apartments (46-171m2)
<u>functions</u>
residential, café, daycare, real-estate office, “bootcamp”, common room/facilities, parking

A one kilometer long pedestrian walkway, is sloping upwards in the shape of an 8-figure and connecting all dwellings. The residential block is close to nature and green areas. Besides the dwellings the block contains common rooms, a daycare, a cafe and office space.
It is situated at the outermost edge of Ørestaden, but is connected to the city centre of Copenhagen by the metro. [8tallet.dk]



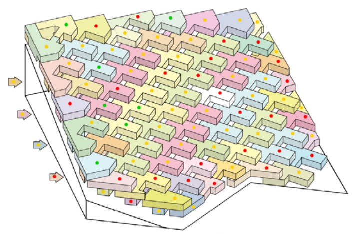
Ill. 89a: The 8-figure is visited in February and March, 2011

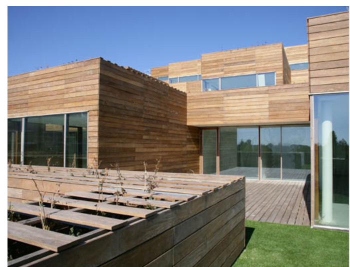
VM-mountain

privacy + sun for everyone

<u>site</u>
Ørestaden, Copenhagen, Denmark
<u>design</u>
Bjarke Ingels Group
<u>year of completion</u>
2008
<u>number of dwellings</u>
80 (mixed tenancy)
<u>density</u>
(dwellings:33.000m2/site:8000m2)
<u>typology</u>
apartments
<u>functions</u>
residential, parking (480 P-spaces)

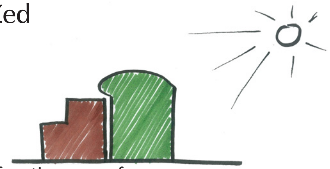
In the VM-mountain the dwellings are distributed over a big surface placed above a man-made sloping topography, consisting of parking spaces. Consequently, all the dwellings are placed optimally for the sun and consequently obtain good light conditions and access to private outdoor terraces. The entrance to the dwellings is from within the parking space and is separated from a public path, which runs all the way to the top corner on 10th floor and down again. The terraces obtain privacy from the neighbouring terraces by a approx. 0,5m wide plantbox along the edge. [vmbjerget.dk]





Ill. 89b: The VM-mountain is visited in February and March, 2011

BedZed



mix of functions - sun for everyone

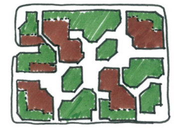
site
London, UK
design
ZEDfactory by Bill Dunster
year of completion
2002
number of dwellings
82 (mixed tenancy)
density
ca. 50 dwellings/ha
typology
flats, maisonettes and town houses
functions
offices, residential, common facilities, parking

BedZED is the UK's largest mixed use, carbon-neutral development. It is built on a brownfield site, and shows how it is possible to combine workspace with housing in a high-density residential area. This is done by matching south-facing rows of housing, which all have a roof garden or terrace, with north-facing workspaces. Passive measures are combined with proven cost effective technologies, e.g. a biomass combined heat and power plant, onsite sewage treatment, a rainwater recycling system and natural wind-driven ventilation. The result is an integrated, sustainable development with high quality of life for the residents as well as the workers. [zedfactory.com] [sustainablecities.dk]

Ill. 90a: BedZed is visited in March, 2010

Odhams Walk

kasbah



site
London, UK
design
Greater London Council Architects Department
year of completion
1982
number of dwellings
102 (61 affordable)
density
154 dwellings/ha
typology
flats and maisonettes
functions
residential, retail, common facilities, parking

Odhams Walk is an urban block consisting of housing rising on a podium of shops towards the street and underground parking. The block is turned inside-out since all dwellings have their entrance and private outdoor space towards the inner yard. All roofs are flat, which enables the use of the roofs for private outdoor terraces, and all openings are as far as possible turned towards these private outdoor spaces. In the allocation of tenants local people have first priority, which makes sure that the tenants feel a connection to the place and a sort of urban village is created. This reflects in social security and prevention of vandalism. [Levitt, 2010] [showcase.hcaacademy.co.uk]

Ill. 90b: Odhams Walk is visited in March, 2010

Borneo-Sporenburg

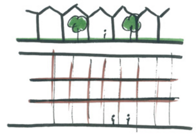
part/totality - individuality/community

site
Amsterdam, The Netherlands
design
West 8
year of completion
1996
number of dwellings
2500
density
100 dwellings/ha
typology
canal houses and apartments
functions
residential

The project is situated at *"...two peninsulas in the eastern part of the Amsterdam docks. For a new interpretation of the traditional Dutch canal house, West 8 suggested new types of three-storey, ground-accessed houses deviating from the usual terraced house in being strongly oriented to the private realm by incorporating patios and roof gardens. By repeating this type in a great variety of dwelling modes and with maximum architectural variation, an animated street elevation emerges with a focus on the individual. At a larger scale, a delicately balanced relationship exists between the repetition of the individual dwellings, the roofscape and the great scale of the docks. Three immense sculptural blocks take their place as landmarks in the vast expanse of houses."* [west8.nl]

Ill. 91a: Borneo-Sporenburg is visited in April, 2007

De Citadel



mix of functions - privacy and density

site
Almere, The Netherlands
design
Christian de Portzamparc (architect), OMA (masterplan)
year of completion
2006
number of dwellings
10.000m2
density
-
typology
row-housing
functions
residential, retail, parking

De Citadel is an urban area within the town of Almere, where a block is cut into four by two pedestrian streets rising above parking and the public car network beneath. The blocks make up a small commercial centre, where housing is placed on the top, distributed around a convex meadow, thereby preserving the intimacy of the inhabitants. [Dbook][chdeportzamparc.com]

Ill. 91b: De Citadel is visited in April, 2011

Sustainability - architectural expression

In relation to architecture, there are various ways to approach sustainability and various terms are used for defining sustainable architecture. In general, the design strategies associated with the different terms are what defines the different approaches to sustainable architecture. This is one of the conclusions in the PhD thesis by Hanne Tine Ring Hansen "*SENSITIVITY ANALYSIS as a Methodical Approach to the Development of Design Strategies for Environmentally Sustainable Buildings".* In order to get an overview of the different approaches found in architecture towards environmentally sustainable buildings, point of departure is taken in this thesis. Here, there is listed six general approaches to environmentally sustainable architecture are categorised, according to their concern with nature as well as climate.

<u>Approaches that are more concerned with nature:</u>

- ecological architecture
- bioclimatic architecture
- green architecture

<u>main focus:</u>
biodiversity, life-cycle, reduce transportation
<u>secondary focus:</u>
energy consumption

<u>Approaches that are more concerned with climate:</u>

- self-sufficient architecture
- solar architecture
- environmental architecture

<u>main focus:</u>
energy consumption
<u>secondary focus:</u>
biodiversity, life-cycle, reduce transportation

Ecological architecture
Is often associated with the hippie culture of the 1960's - 70's and with self-builders, often in contradiction to architects. Focus on the relationship between people and surroundings, materials, renewable energy, self-reliance, low-tech solutions and the impact on environment by considering life-cycle assessment. Is mostly site specific. Examples are Friland, Andelssamfundet Hjortshøj (see ill.), but also the Eco-houses by Vandkunsten.

Bioclimatic Architecture
Originates from the 1930's in the writings of Olgyay and was treated again from the 1990's with the architecture of Ken Yeang. Both have an urban outset, both deal with the relation between climate and human environment and both are working with and not against nature.
Bioclimatic architecture is concerned with energy reduction by utilisation of the site specific climatic conditions, and the resulting interactive relationship between the inside and outside of a building. Examples are all Ken Yeang's projects, e.g. Elephant & Castle in London and Editt Tower in Singapore (see ill.).

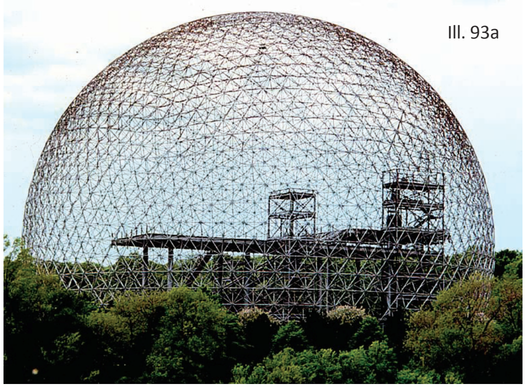
Green Architecture
Closely related to political organizations of the 1970's and -80's and often associated with environmental conservation and protection and a visual relationship with nature. Can be viewed as the architects' interpretation of ecological architecture, with focus on the relationship between energy, ecology, environment and life-cycle assesment. Examples are Fondation Cartier in Paris, and Truss Wall House in Japan (see ill.).

Ill. 92a



Ill. 92b

Ill. 92c

Ill. 93a

Self-sufficient architecture
Represented by e.g. Buckminster Fuller's Geodesic domes from 1950's - 80's (see ill.) and the Dymaxion House from 1946, and the projects of Paolo Soleri. Nowadays the approach is seen in ecological communities of self-builders. As the word indicates, this approach deals with independence and self-reliance, it is self-contained and build in response to the environment. This implies that buildings build are zero-energy.

Ill. 93b

Solar architecture
Originates from 1960's and became very popular in the 1980's and 90's. The term covers both low-energy, zero-energy and passive housing, where the common denominator is the passive and active use of solar energy. The development of the term is related to the development in the building regulations (in DK), which focuses primarily on energy consumption and secondarily on embodied energy. Examples are a residential passive house by Walter Unterrainer (see ill.) and Hauptschule in Klaus-Weiler-Fraxern by Dietrich Untertrifaller Architekten.

Ill. 93c

Environmental architecture
Initiated in the late 70's by the electricity council in UK and later redefined by Ove Arup and partners.
The selective approach focuses on the relationship between building and climate, and the way the building enables the internal environment to respond to the external environment in order to minimize energy consumption. Consequently it is always site specific. Examples are Arup Campus, UK, (see ill.) and the Helicon building in London.

All six approaches deal with the same aspects of sustainability, but with different foci and different design strategies. In the thesis, the six approaches are evaluated in relation to sustainability for their relation to nature, climate, culture, technology and economy (see table below). The architectural approach which has considerations for most elements of sustainability is Ecological architecture, which covers all aspects. The design strategy of this project will be similar to that of Ecological architecture, but according to Claus Bech-Danielsen, who has done research on the subject, it is important to obtain a synergy between the self-builder approach and the visually oriented approach of the architect, as seen in Green Architecture. According to James Steele, important aspects of ecological architecture are tradition, technology and urbanism. These aspects will be implemented respectively by the consideration for the history and evolvement of the Danish single-family house, a selective approach regarding climate as seen in Environmental architecture and the location of the site in the physical context of a dense, urban area. [Hansen, 2007][Hansen, 2010]

much consideration

little consideration

no consideration

	nature	climate	culture	technology	economy
ecological architecture	much	little	much	little	little
bioclimatic architecture	much	much	much	much	no
green architecture	little	no	little	little	no
self-sufficient architecture	no	much	much	little	no
solar architecture	no	much	no	much	little
environmental architecture	no	much	much	little	no

Ill. 93d

DENSE LIVING

In relation to the assignment of designing dwellings at the harbourfront in Aarhus, it has been important to take a closer look into dense living in relation to sustainability.
As previously mentioned in the chapter "Sustainability", urbanization takes place on a global scale and will not decrease in the years to come. The sustainable cities of the future will be relatively dense, as compactness supports sustainability, both on societal, social, energy-related and economical level. The city's compact, dense character and the mix of functions results in maximum usage of space, minimum use of resources, e.g. for transport and heating, and generates more life, variety and a higher degree of social contact and security, since there is life 24 hours a day, seven days a week. In an economical perspective, it is also much more efficient and rational to live compact. Consequently the compact city with its variety and diversity is the goal seen from a sustainable point of view.

But the compactness and dense living has to be discussed in conjunction with requirements for architectural quality, as the city also has its downsides. Dense housing does not necessarily imply a low energy consumption, as many of the housing blocks in the city are relatively old and poorly insulated. Also, there is usually more traffic, noise and pollution in the cities, and just because one has neighbours and people all around, this does not necessarily imply a lot of social contact. The staircase of a typical city apartment block does not exactly encourage informal meetings on the stairs. Moreover, sustainability also depends on the lifestyle and general behaviour of the occupants, and there is a tendency towards segregation in society, as mostly wealthy and socially strong people can afford living in the city centre, whereas the lower classes have to live in social housing in the suburbs of the city.

Consequently, it is important to take both a quantitative and qualitative approach when designing compact housing in a city context. Sustainability should be integrated on more levels together with a concern for architectural quality and quality of life. [botaet.dk][Pedersen, 2009] [Lauring, 2010][Thiis, 2011]

Ill. 94a: The kasbah-typology is seen as a good example of how the single dwellings can form and give identity to an urban composition without loosing its individuality - like building stones, every dwelling has a unique placement and role to play in the overall configuration.

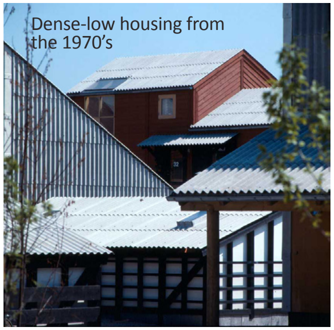
Ill. 94b: Through time, there has been a lot of examples and projects on how to live dense. Following are examples representing general approaches and aspects from different periods and different cultures.


The traditional Danish market town house


The traditional Danish city apartment building


A 20th century Danish apartment building


A modern kasbah-typology; Odhams Walk in London


Dense-low housing from the 1970's

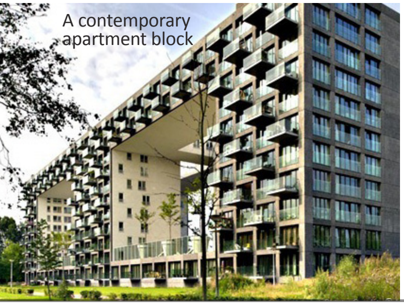

Row-housing from the 1980's (and my childhood-home)


Traditional Dutch canal-houses

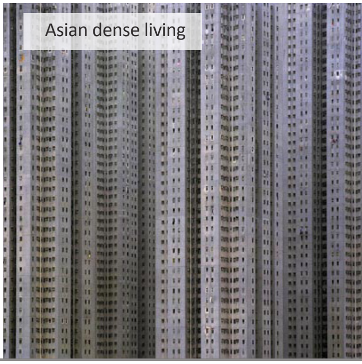

A vertical village


A Moroccan kasbah


Asian dense living


A contemporary apartment block

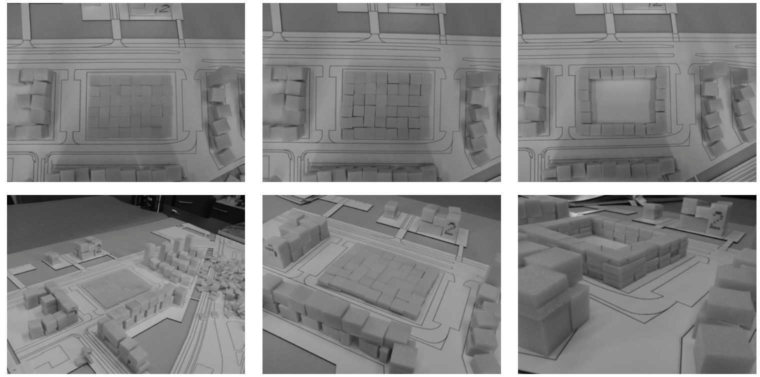

The modern dwelling machine - the apartment block


Asian dense living

Expected density at site

As a starting point for the design process, there is made investigations of different densities at the site. These are further evaluated against the aim of 60% residential and 40% commercial functions. From this, it seems that a density of ca. 200% is attainable. However, these investigations are not evaluated against the resulting light conditions at the site, why the expected density may be lowered.

Ill. 96a: The investigations of the expected density at the site are done in a 1:500-model of the clise surroundings



building percent: 100%

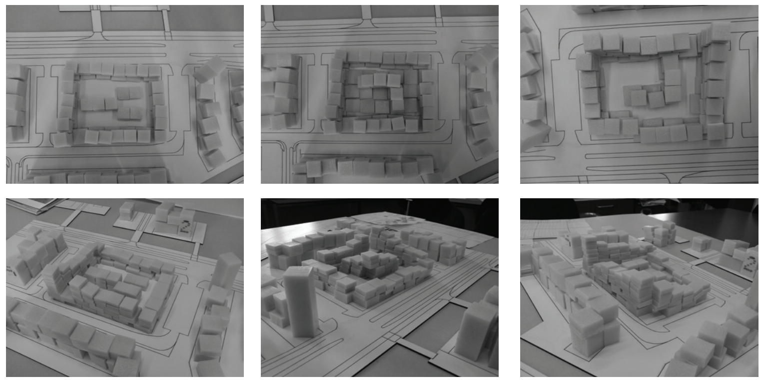
The whole site is covered with one layer of residential functions.

building percent: 200%

The whole site is covered with two layers of residential functions.

building percent: 200%

The edges of the site are covered with four layers of residential functions.



Building percent: 340%

The previous floor area for a building percent of 200% is considered to be residential only, and there is consequently added 40% commercial floor area.

Building percent: 400%

With point of departure in the previous investigations, the building percent is increased.

Building percent: 400%

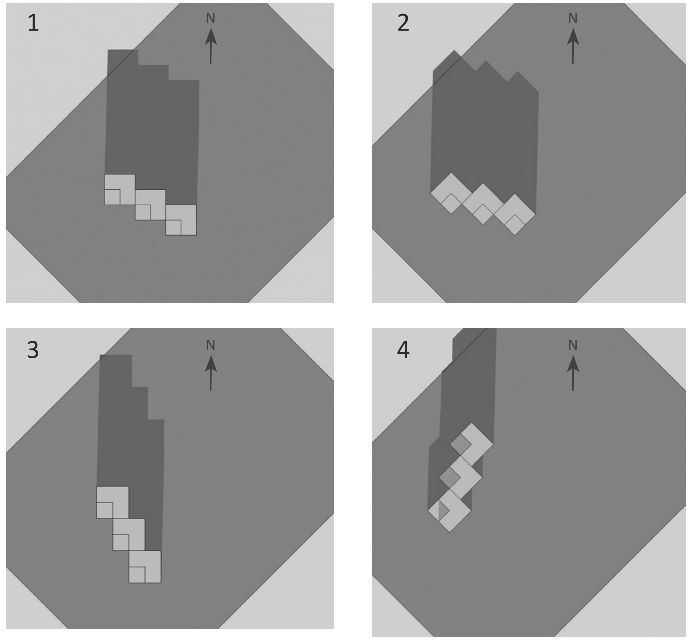
With point of departure in the previous investigations, the building percent is increased.

Light - orientation of dwellings

Different configurations have been tried out in SketchUp and evaluated against the resulting light and shadow conditions for each individual dwelling (see ill. to the right). This is done to get an idea of the optimal orientation of the dwellings in relation to the possibility of exploiting passive solar gain.

The aim has been to ensure each dwelling as much light as possible and light from as many different directions as possible. Further, it has been the aim that each dwelling will obtain the possibility of an outdoor area with evening sun, especially during summer where the residents can better benefit from their outdoor space.

All solutions shown can function, depending on the detailing of the final solution. The displacing of the dwellings allow for sun from several directions, and there is possibility of evening sun at the private outdoor area for each solution. However, the dwellings in solution 4 has the best possibility of getting evening sun, while the dwellings of solution 3 have the best possibility of exploiting solar gain from a Southern direction. Consequently the orientation of the single dwellings has to be weighed against the density and thereby the connection of the dwellings into the overall urban configuration of the design. In this way these investigations are merely seen as guiding principles to form basis for the sketching process.



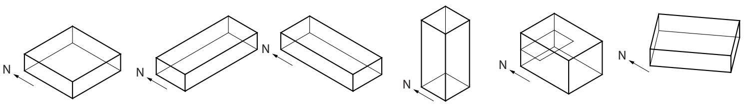
Ill. 97a: Shadow investigations of three dwellings connected in different ways and with different orientations. The investigations are done for December 21st at noon.

ENERGY AND COMFORT

Connections

In order to optimise the dwellings in relation to energy consumption, it is investigated how different types of volumes with different placements and orientations of openings will perform energy-wise.

The investigations are done by the use of Monthly Average-spreadsheets, where six different types of volumes have been investigated for six different placements of openings. All volumes have a gross floor area of 100 m², but slightly different volumes, as one of them includes a double-high space. The ventilation rate, internal heat loads, U-values and window properties are kept constant. The types of volumes investigated are:



a compact quadratic volume | a longitudinal volume with the biggest facades towards North and South | a longitudinal volume with the biggest facades towards West and East | a vertical volume | a compact volume with double-height | a compact, diagonally placed volume

The openings are defined as 20% of the respective facade areas, and the different oritentations of openings investigated are:

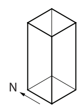
openings in all facades | only openings in North and South facades | only openings in West and East facades | only openings in West and South facades | only openings in East and South facades | only openings in South facade (40% of facade area)

Ill. 98a: Diagrams of the different solutions investigated

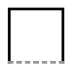
In terms of openings, it can be concluded that the highest energy consumption in general is with openings in all facades or with openings towards West and East only (almost same result). The same result is obtained with openings towards West and South as with openings towards East and South. However, the best result in all cases is obtained with large openings towards South.

Concerning the different types of volumes it can be concluded that the volume layouts which do worst by comparison are the longitudinal with the biggest facades towards West and East, and the compact volume with double-height. There is little difference between the results; except for the vertical volume which performs best out of all.

This might be due to the fact that it is easier to heat this slim volume by passive solar energy and easier to cool by natural ventilation. Also, it is easier to obtain good daylighting conditions in all rooms because of the big facade towards South. However, it has got a big surface-to-volume ratio, why it is a little surprising that it does so good in comparison with the other volume types.



a vertical volume



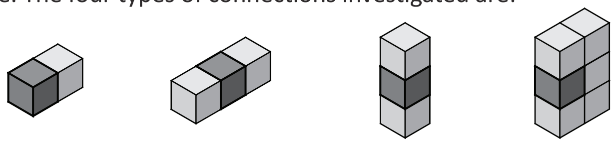
only openings in South facade (40% of facade area)

total energy consumption:
30,7 kWh/m2 pr year

energy consumption for heating:
30,3 kWh/m2 pr year

Ill. 98b: The solution which performs best energy-wise

As a next step, it is investigated how different ways of connecting the volumes will affect the energy consumption of the single volume. The four types of connections investigated are:



placement of one volume to the East of the one investigated

placement of one volume both to the East and West of the one investigated

placement of one volume above and below the one investigated

placement of one volume above, below and to the east of the one investigated

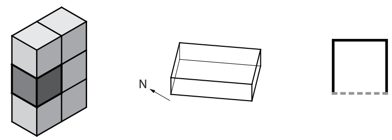
Ill. 99a: Diagrams of the different solutions investigated

The investigations are only carried out for the volumes with the best performance energy-wise in the previous investigations, and only for openings in maximum two facades.

It can be concluded that a small improvement is obtained by placing the volumes next to each other in comparison with placing them on top of each other. This is because heat mainly transfers upwards, as hot air is lighter than cold air.
Concerning the volumes, it shows that the vertical volume is now the one with the worst performance of the ones investigated. Consequently, energy-wise there is a limit to how slim a volume can be. The volumes with the best performance are the compact ones, however, there is not a very big difference between the energy consumption of the three other volumes investigated.
In terms of the openings, it still proves that the lowest energy-consumption is obtained by having big openings only towards South, and that there is not a big difference between combining openings towards South with openings towards North or West.

The overall conclusion of the investigations is that the energy-consumption of the single dwellings can be improved by connecting them. It seems that a vertical volume, or the placement of several dwellings on top of each other, will affect the energy-consumption the most. Also, it seems that it has a big effect to place big openings towards South in order to optimise the passive solar gain.

However, the placement of openings of course has to be balanced with the resulting indoor climate concerning the risk of overtemperatures and the light conditions of the interior. This will be taken into consideration in the following investigations of the orientation of the dwellings, and more detailed in the development of the architectural concept of the single dwellings.



placement of one volume above, below and to the east of the one investigated

a compact, diagonally placed volume

only openings in South facade (40% of facade area)

total energy consumption:
18,1 kWh/m2 pr year

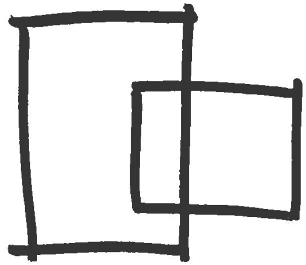
energy consumption for heating:
16,8 kWh/m2 pr year

Ill. 99b: The solution which perfomrs best energy-wise

SPATIAL PRINCIPLES

As a basis for the development of the architectural concept, initial investigations of different spatially related aspects has been made. These have resulted in different principles to be applied in the further process.

First of all it has been investigatede how gradual transitions can take place and what characteristics they have. In order to optimise the density Monthly Average-spreadsheets have been used to test the energy consumption in relation to different ways of connecting the dwellings. In relation to orientation of the dwellings, different solutions have been tried out and evaluated against the resulting light and shadow conditions for the dwellings.

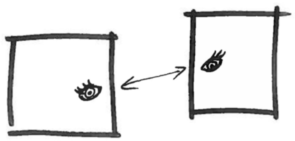


Ill. 100d: The gradual transition implies an overlapping of spaces

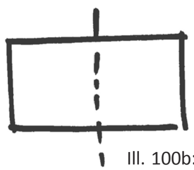
Gradual transitions

As previously explained, there will mainly be worked with gradual transitions in the development of the architectural design of this project.

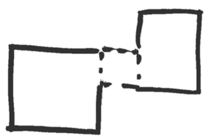
In general, gradual transitions imply an overlapping of spaces, where the one space gradually melts into the other, instead of direct transitions, where there is a clear distinction between one space and the other. This overlapping of spaces leads to an “in-between” space, or a buffer-zone, between the connected spaces, and a gradual transition between two spaces implies either a visual connection or a weak physical connection between them.



Ill. 100a: Visual connection

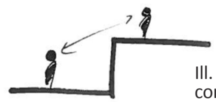


Ill. 100b: Weak physical barrier

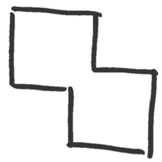


Ill. 100c: In-between buffer space

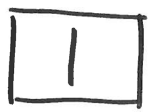
This loose and rather imprecise definition gives rise to almost infinitely many possibilities of this type of transition. The different variations shown below are used as guiding principles in the development of the architectural design of this project.



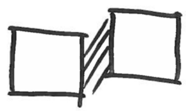
Ill. 100e: Visual connection and height difference



Ill. 100f: Narrowing of space



Ill. 100g: Open physical barrier



Ill. 100h: In-between buffer space

INSPIRATION

Ill. 101a: Various inspirational pictures of gradual transitions

Layering of space

Vertical connectors

Visual connections

Entrance zone

Vertical connectors

Ill. 102a: Various inspirational pictures of gradual transitions

Conclusions

The investigations carried out in the catalogue has formed a link between the analysis, the programme and the sketching process. However, the spatial principles that have been extracted still have to be combined and shaped into a new consistent design for this project.

Consequently, the results of the investigations may not be reflected directly in the further process or the final solution of the project, but they have nevertheless formed an important step towards the final architectural design of the project.

CONCEPT

CONCEPT

The development of the overall architectural design is a process resulting of the integration of aspects from the analysis, the programme and the catalogue. However, during the process there has also been incorporated elements from further inspirational research.

During the sketching process the design parameters have continuously been integrated in different architectural solutions. It has been attempted to integrate as many aspects and parameters at a time as possible.

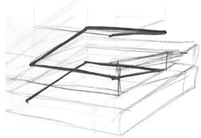
The different architectural solutions have then been evaluated against the parameters from the analysis, the programme and the catalogue, and in this way one design proposal has led to the other in a continuously looping process, where the architectural design constantly has been refined. Sometimes the process has taken some steps back in order to integrate some aspects and then further advance.

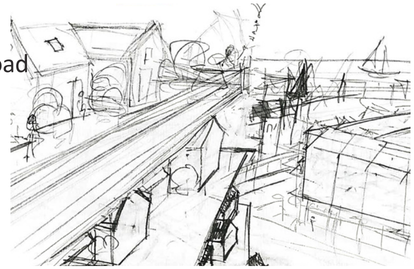
There has been worked simultaneously on the urban scale (primarily in models scaled 1:500 and 1:200) and the individual dwellings (primarily in models scaled 1:50 and drawings scaled 1:200). For the comprehension of the design process the urban and building scale are, however, presented in different chapters, as they concern different themes and aspects.

Firstly, the development of the overall architectural concept and the final solution is presented for both scales. Then the detailing of different aspects related to the two scales is presented in the following chapter.

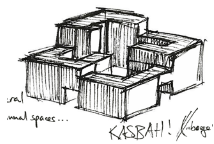
Some themes have been consistent throughout the entire process, both for the urban scale and the building scale, and consequently the presentation of the design process is organised around these themes. These are:

one connecting path
as expressed by the villaroad

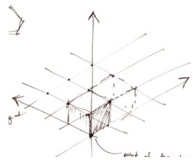


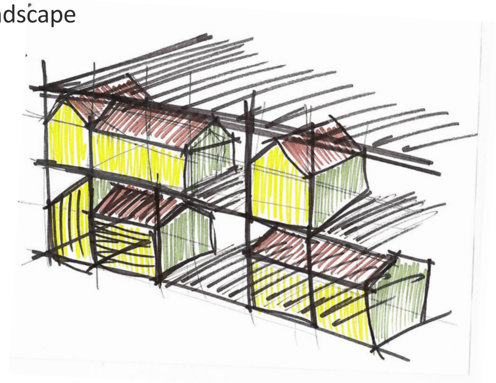


part vs. totality
as expressed by the kasbah



organic growth and an overall structure
as expressed by the landscape





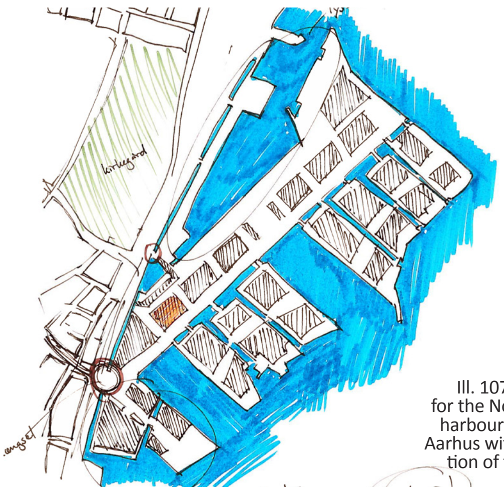
Ill. 106a: Main themes worked with during the sketching process

URBAN SCALE

The architectural design takes its starting point on urban scale with the overall configuration of the site.

First it has been investigated how the parameters from the context analysis can be interpreted into an architectural design solution in order to get an overall understanding of the site. This has acted as basis for the further sketching process, where the villaroad has been a main theme. Another main theme has been the kasbah-idea, where it has been exploited, how the single dwellings should relate to the overall urban design, and how they could benefit from each other. Finally, it has been investigated how the connecting path and the kasbah can be combined in a overall “dwelling-landscape”, and how the context of the harbour can be connected with the more intimate urban scale and with the most private scale of the dwellings.

The goal throughout the sketching has been to obtain an urban design with an overall strong identity, without compromising the quality of the individual dwellings. This has resulted in an urban configuration formed by the dwellings, thus emphasising the importance of the single dwelling, but with a clear and distinct identity of the overall urban design.

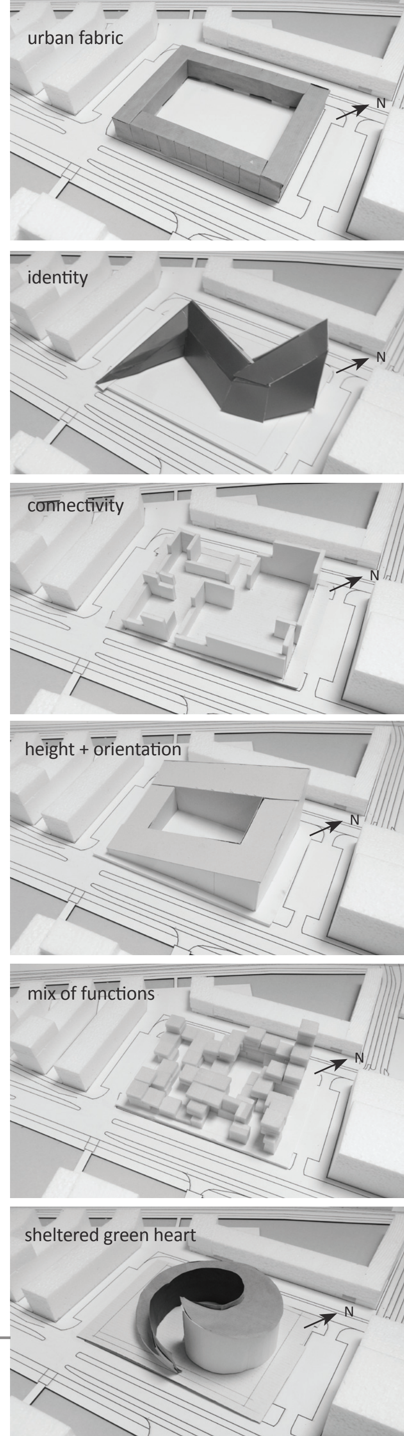


Ill. 107a: Plan for the Northern harbour area in Aarhus with location of the site

Physical context

First different sketch models in 1:500 are made according to the different parameters from the physical context analysis. The models reflect different approaches to the area and give an idea of how these approaches affect the architectural design and the expression of this.

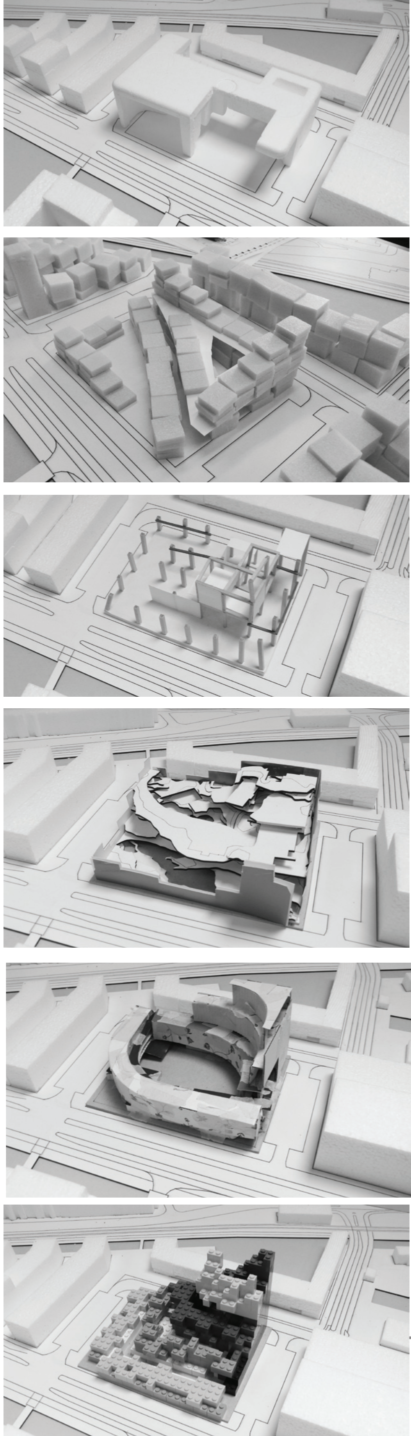
None of the models work on their own as they focus on only one parameter, why new models are made which combine several parameters and consequently have a more holistic approach.



Ill. 107b: Initial model investigations on context model in 1:500 according to parameters from physical context analysis

It is found that the height difference and sloping character of the urban configuration can both help to bring a strong identity to the design, as well as allow for good light conditions and views for the single dwellings. The height difference can be obtained by placing the commercial functions underneath the dwellings.

Furthermore, it is found that emphasising the edges of the site helps defining how the urban configuration can relate to the scale of the harbour area. This allows for creating a sheltered green heart internally at the site, while turning the back towards the context of the big scale harbour area.



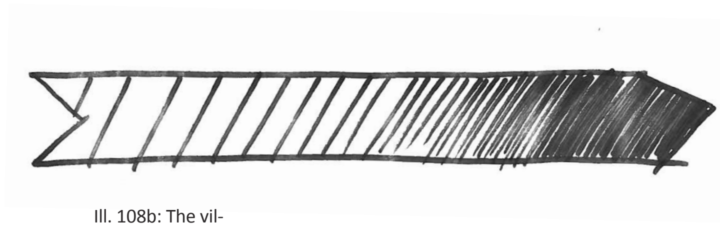
Ill. 108a: The next model investigations combine ideas and paramters from the first ones

The villaroad

A consistent theme during the development of the urban concept has been the villaroad, and how to implement the idea of one connecting path into the design.

Important aspects in relation to the villaroad are the visual connection, the sense of territory and the distance around or to the dwelling from the entrance. As mentioned earlier this is all related to gradual transitions.

In the design this is expressed by a continuous connection of the single dwellings along one path which slopes upwards. In the beginning of the sketching process it is considered important, that one can drive all the way up to the single dwelling and there is consequently mainly worked with a literal translation of the villaroad into the design.

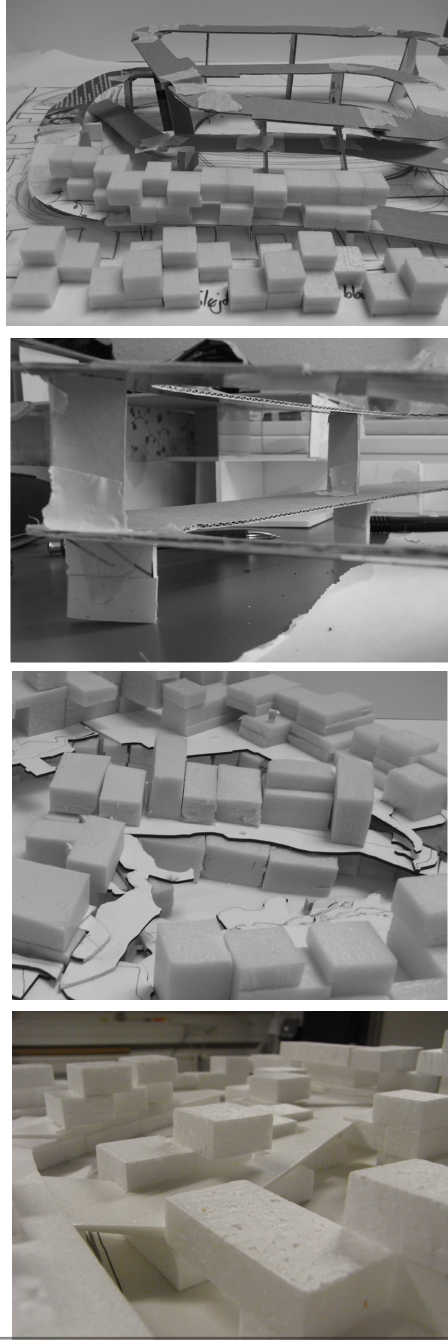


Ill. 108b: The villaroad is mainly characterised by gradual transitions

The literal translation of the villaroad into the design poses several difficulties during the sketching process. First of all the BR10 states a maximum value for the slope of an accessway of 1m pr 20m. this will make it quite difficult to obtain the desired height difference at the site and to layer the dwellings.

Furthermore, it is found relatively problematic to combine the sloping road with the dwellings in relation to light conditions of the dwellings. Furthermore, the slope of the road makes it difficult to achieve qualitative outdoor spaces adjacent to the road.

Nevertheless, there is made several models and investigations for the sloping villaroad, since the idea is found fascinating and to correspond well with the aspects related to the home-making of the single occupant.

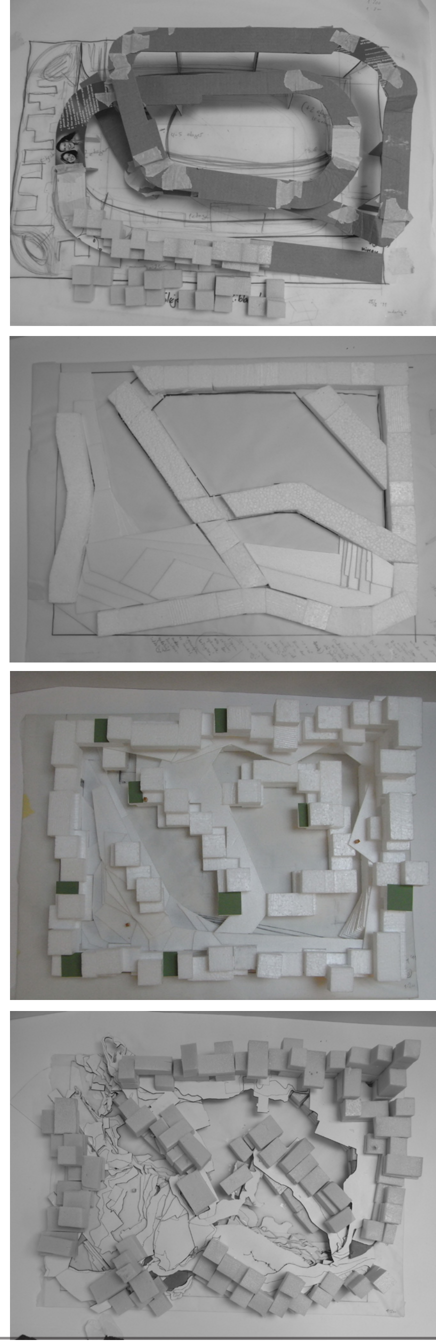


Ill. 109a: There is primarily worked with the sloping villaroad in models scaled 1:200

Another difficulty about the sloping villaroad is the detailing of the middle of the site. The road seems to want to "edge" the site, and consequently leaves the middle unused and un-defined.

The character of one sloping movement further makes it difficult to implement smaller clusters with different characteristics into the design.

This relates to the idea of dividing the overall urban configuration into smaller clusters or communities with different characteristics. The creation of smaller neighbourhoods in the overall scheme gives way for informal meetings and social contact with the closest neighbours, which again creates an attachment and sense of rootedness to the area.



Ill. 109b: There is primarily worked with the sloping villaroad in models scaled 1:200

The kasbah-idea - part/totality

Another consistent theme during the design process has been the kasbah-idea. The kasbah is characterised by its labyrinthic appearance, where a multiple of almost identical dwelling units form the overall urban configuration thereby giving it its distinctive character. This implies that the single dwellings and the urban fabric almost melt together, the one being unseparable from the other.

A significant characteristic about the kasbah, is that it is developed in accordance with the light conditions, where the main goal is the avoidance of light - and heat - into the interior of the buildings. Consequently, the streets are very narrow and do not run in straight axises and there are almost no outdoor open spaces or squares. Instead the urban flow is led by continuous series of spaces floating into each other. This also means that private outdoor areas, or gardens, are placed inside the outer walls of the single dwelling. As a consequence, the transition between public and private is very direct, with no intermediate zones between the private and the public space.

Consequently, it has been investigated how the concept of the kasbah can be applied in a Danish context, where the aim is inclusion of light into the dwellings for passive use of the solar energy and the daylight.

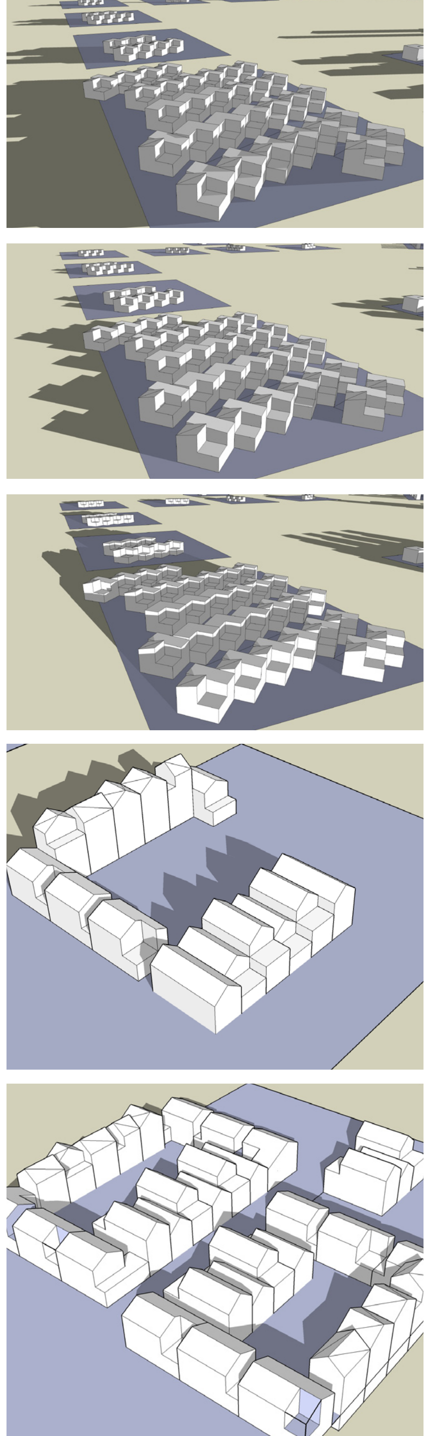
During the design process this is expressed in the puzzle-like organisation of the urban configuration shaped by displacements, vertical connections and openings in the building mass.

Light

The main difficulty by applying a kasbah-typology in a Northern temperate climate like Denmark is to obtain sufficient light conditions. The very purpose of the kasbah is to exclude light, while the main goal in a Danish context is to let in as much light as possible. Consequently, there has been focused on how to turn the concept of the kasbah around, to make it include light instead of exclude it.

This relates very much to the distances between the single dwellings and the heights of those.Consequently the dwellings have been puzzled together into urban configurations in SketchUp with the shadow-settings set at the darkest day of the year, in order to ensure a sufficient light level.

Furthermore, there is worked with relatively slender dwellings and with a fragmentation of the roof line in order to let light pass in between the sloping of the roofs.

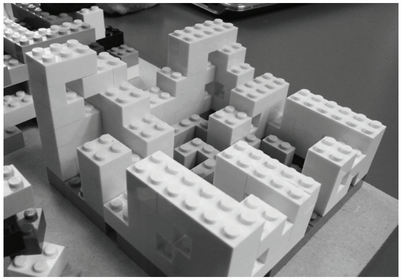


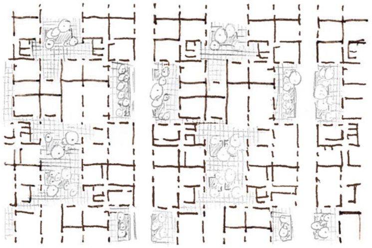
Ill. 110a: SketchUp has been used to puzzle the urban configuration into place in accordance with light/shadow-conditions

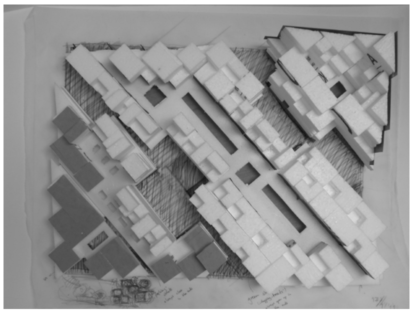
Logic and strucure

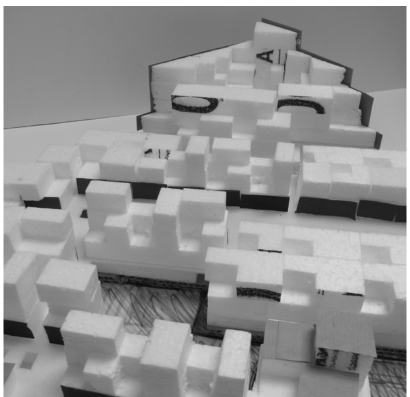
However, it proves to be quite difficult to puzzle the kasbah in to place. One of the main ideas of the kasbah is that of a landscape and of organic growthas a result of it actually having grown organically through time into its present state. Also a landscape has been shaped by some superior forces, why it has some overall characteristics, an overall order and logic, which can be recognised and brings identity to the different specific places.

In order to make the kasbah-typology work in the context of this project it has to have an overall logic and order, and there has to be some main organisational principles or guidelines for the organising of the dwellings. This should happen without losing the quality of the continous floating of spaces into each other and the gradual transitions, which characterises the kasbah.







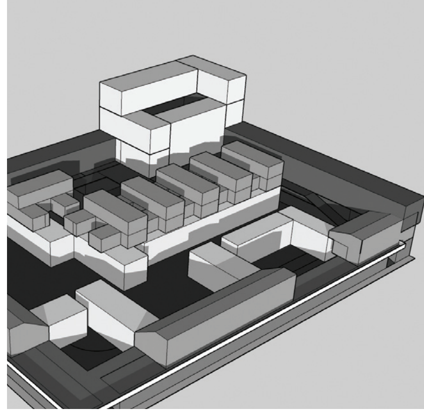


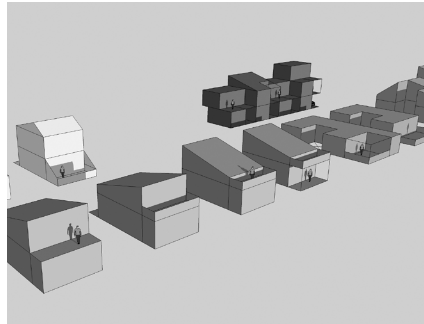
Ill. 111a: There has been worked with the idea of the kasbah from the beginning of the project in several ways

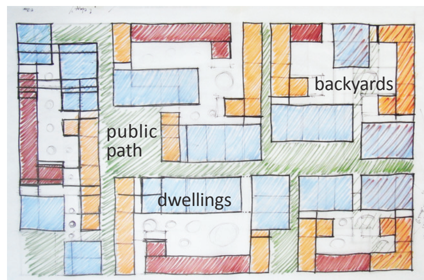
Individuality

One of the main qualities of the villaroad is that of the possibility of obtaining autonomy and freedom in the way that each house has its own territory independently of the others. This is, however, difficult to obtain for the kasbah-typology, where all the single dwellings easily become secondary on behalf of the overall structure. On the other hand, each dwelling is important for the creation of the overall picture and plays a special role in the totality

This problematic has resulted in working with different types of dwellings and for the single dweller to be able to adjust the dwelling to his or her individual preferences.







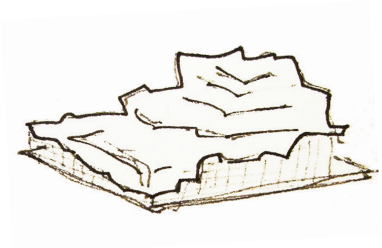
Ill. 111b: There has been worked with the implementation of different housing typologies in order to accomodate a certain degree of individuality and identity

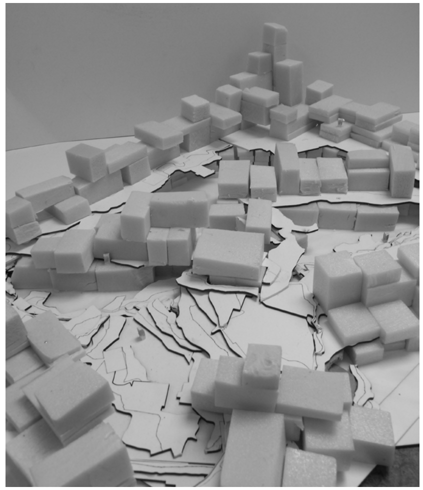
Landscaping

The landscape - in this project denotes an overall organising principle, a kind of structure. It is used for combining the different scales of the design and the concept of the villaroad with the concept of the kasbah.

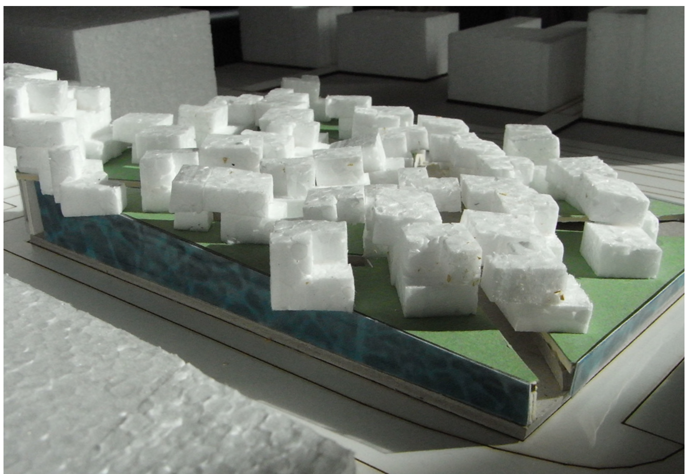
One of the main difficulties during the sketching process has been to combine the qualities of the villaroad with the urban characteristics and a more dense character of the urban layout, as seen in the kasbah-typology. This also relates to the problematic of how the architectural design should combine the physical context of the big-scale harbour area with the more intimate urban scale and the even more intimate and private scale of the dwellings - into an overall architectural design with a strong identity. How to create a sort of hierarchy without compromising the importance of all the different aspects.

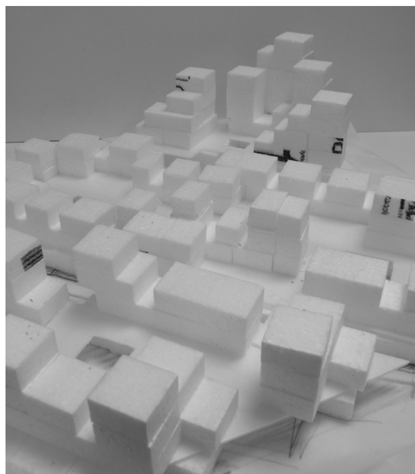
In the design the idea of one overall landscape has been implemented by working with levels, as an expression of landscape character.





Ill. 112a: There has been worked with the implementation of landscaping qualities and characteristics in the form of levelling of the configuration





Final urban concept

The final urban concept divides the design into three overall *scapes** with three different characteristics: a harbour-scape, an urban scape and a dwelling-scape.

The harbour-scape relates to the big scale and rough character of the harbour area. This is the back of the overall urban configuration, and the entry to the site happens from here. On the North of the site some functions, such as offices, may face towards the harbour-scape, but in general all functions face away from this and inwards into the site.

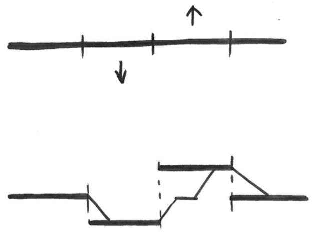
The urban scape represents an urban and more intimate scale, which is the interior of the site. This is situated at ground floor of the entire site and consists mainly of all the commercial functions such as offices, shops, daycare, private doctoral practices etc. However, some of the dwellings may cut all the way though to the urban scape and in this way enable a gradual transition.

The dwelling-scape cuts through all layers of the whole configuration and structures this. The dwellings are vertically orientated and constitute the build environment of the site. This is related to the kasbah-idea, where the connection of a multiple single units constitute the overall form and identity, like building-stones.

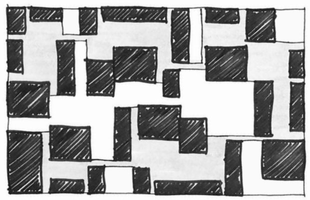
There should not be strict borders between the three scapes, instead they should be conencted by gradual transitions. This is among other things done by the layering of the villaroad, which connects all the scapes.

In order to make tension in the plan and to make it possible for the dwellers to identify and connect with the place, there is worked with hierarchy in the open spaces and with an increasing height towards North.

* *-scape*
a combining form extracted from landscape, denoting "an extensive view, scenery," or "a picture or representation" of such a view, as specified by the initial element: cityscape; moonscape; seascape. [dictionary.reference.com, c]



Instad of running in one linear course, the villaroad is split up and thereby connecting the different layers of the urban configuration. However, the connection between the single dwelling and the entrance to the dwelling with the parking of the car is maintained by placing the garage of each dwelling directly under the very dwelling, thereby obtaining a sense of territory.



The labyrinthic organisation of the urban layout/configuration relates to the kasbah-idea, where the dwellings constitute the overall urban composition. In this way the need for an intimate human scale and a sheltered green heart is respected.

The clear division of the urban layout into the three main spaces of the harbour scape, the urban scape and the dwelling-scape organises the site and gives hierarchy to the design. The composition turns its back against the harbour-scape and leads the flow of people into and through the site instead of around it.

Ill. 113a: Final concepts at the urban scale

BUILDING SCALE

The development of the concept at building scale is of course done in accordance with the concept at urban scale in the way, that the process at both scales have mainly evolved around the themes of the villaroad, the kasbah and the landscape.

The initial sketches show a preoccupance with the problematic of obtaining individuality and autonomy, a sense of territory and privacy when stacking dwellings on top of each other in an overall structure with a strong identity.

Alongside this, there has been worked with the idea of the kasbah and how to apply this in a Danish context at Aarhus harbour. In this connection there has been worked a lot with the light conditions for the individual dwellings, as this plays a crucial role for both the energy consumption, the indoor climate and the general quality of life within the dwellings. Also the problematic of obtaining a certain degree of autonomy and individuality for the single dwelling, without ruining the overall coherence of the urban scale design.

The principles of the villaroad and the connecting of the dwellings along one continuous path has has for this scale primarily shown/resulted in an occupance with access and the entrance to the dwellings and how they are connected.

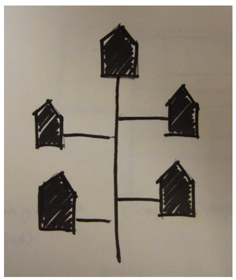
The design process has resulted in three different dwelling typologies with individual characteristics. They all interpret the villaroad-principle with its gradual transitions and continue this movement into the single dwelling, but in different ways.

Landscaping
- common individuality

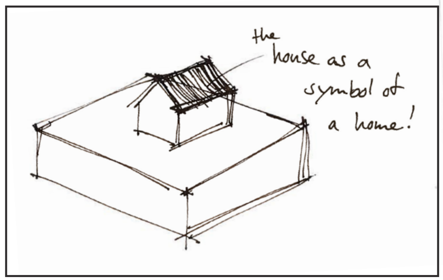
At first the main concern has been how to combine the dwellings into an overall structure or landscape, thereby establishing a strong identity of the site, without compromising with the possibility of expressing a certain degree of individuality in the single dwellings. The structure should allow for the residents to express their personality and to alter the dwelling to his/her personal taste. But only to some extent, as this should be weighed against the common ground of the overall urban configuration.

Consequently, there has been worked with the flexibility of the dwellings, in the sense of forming the frames for individual expression in the dwellings. However, this has more been in the sense of applying a sort of perfectibility to the dwellings, rather than literal flexibility with movable walls, multipurpose furniture etc.

The aim has been to form a general dwelling with basic features, such as materials, overall form and organisation, where the individual solution can be adjusted to the taste of the specific dweller. This can e.g. be done in the interior spatial organisation, exterior shading devices and detailing of the private outdoor areas. In this way there will be some sort of common identity of the urban configuration, but with a variety of individual dwellings.



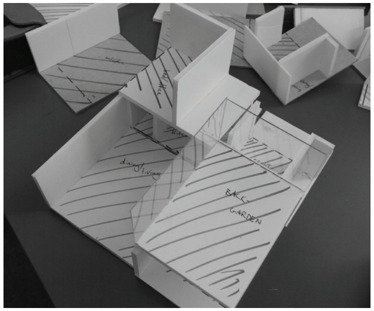
Ill. 114a: At building scale there has also been worked with the balancing of individuality with a sense of community

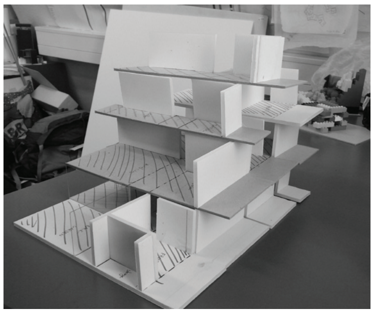


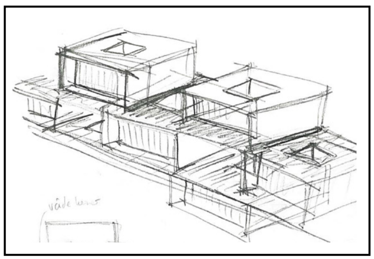
In relation to the theme of landscaping, one of the main difficulties has been how to obtain a sense of territory and autonomy, like it has been difficult to implement in the kasbah. There has been worked with an overall flexible structure, which allows for gradual adjustments to the single dwellers changing needs, but this queries the affiliation to a specific place within the structure.

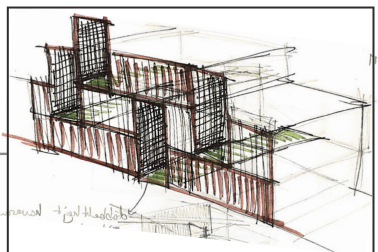
Moreover, the mroe flexible the structure has to be, the less possibilities there will be for affecting the exterior expression of the single dwellings.

Another topic in this discussion is the frontgarden and the role of this in the overall structure. This constitutes the main transition from public to private can be used for informal meetings and social contact with neighbours.



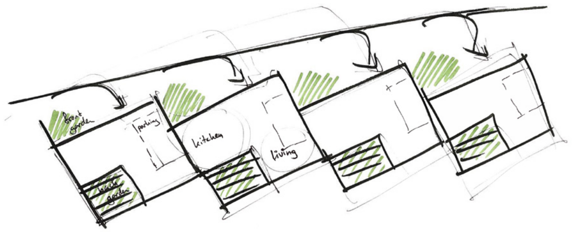


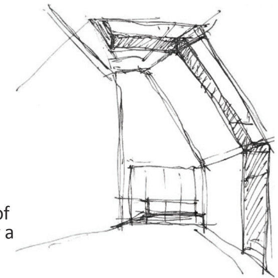




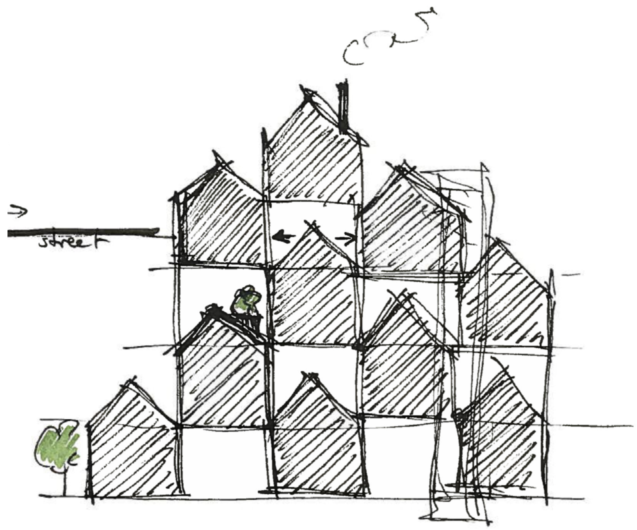
Ill. 115a: From the beginning of the process there has been worked with one overall flexible structure , which could expand almost infinitely in accordance with the need for new dwellings

Ill. 115b: In continuation of the considerations regarding the frontgarden there has to be taken spacial concern for providing a back garden as well. Especially it is important to ensure sufficient light conditions for this space.





Ill. 115c: One of the main problematics of the idea of one overall structure is how to apply a feeling of safety and shelter as symbolised by a sloping roof.

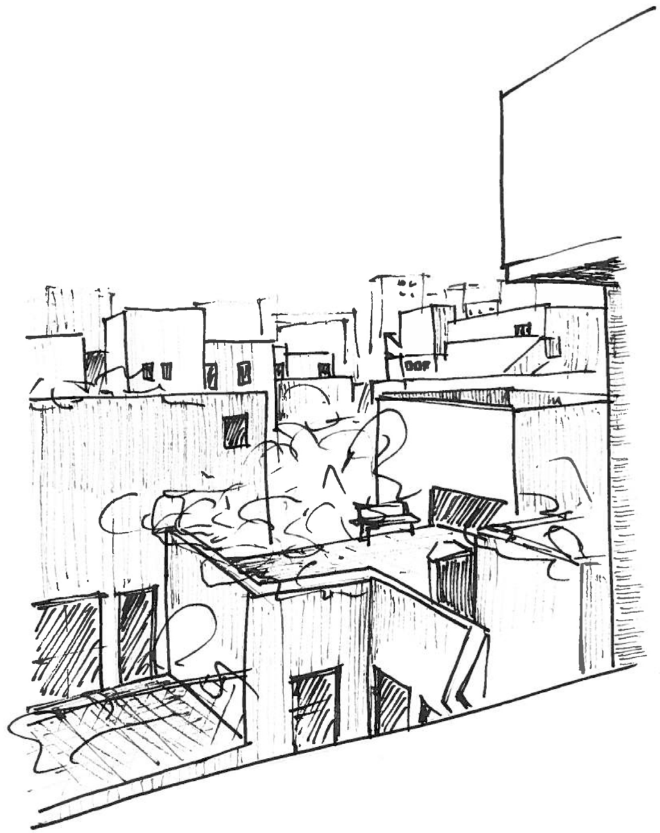


The kasbah-idea - light conditions

In continuation of the things worked with in relation to the landscape, the question has been how to maximise the density of the urban configuration by forming of a kasbah-like structure.

However, this structure should take the Danish climate into regard by considering light conditions in relation to energy and indoor climate. Also, it should integrate the principles of the villaroad by the use of gradual transitions in relation to the aspects of home-making of the single occupant.

In continuation of the investigations done in relation to the landscape, there has been worked with different typologies of dwellings, which constitutes the overall urban configuration when put together. The main concern at building scale in doing this has been the light conditions for the single dwelling, both in relation to the indoor climate, but also in relation to the private outdoor spaces.



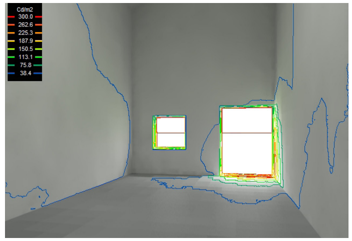
Ill. 116a: Odhams Walk in central London is a European example of the kasbah-typology which works well, but which also has some difficulties in obtaining sufficient light conditions

Indoor climate and energy

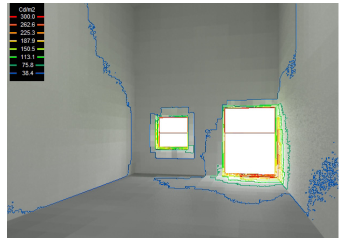
A significant characteristic about the kasbah, is that it is developed in accordance with the light conditions, where the main goal is avoidance of light - and heat - into the interior of the buildings.

In a Northern temperate climate like in Denmark, the aim is to let in as much light as possible into the dwellings, and sometimes also the heat from passive solar gain. This is mainly during winter and the heating season, while the goal during summer time is mostly to avoid heat into the dwellings.

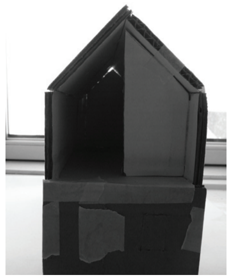
As an investigation of the possible light conditions for each dwelling, it has been examined how different placements and sizes of openings in only two walls and the roof can disperse daylight into deep, narrow spaces. This is done in a physical model scaled 1:50 and by the use of a digital tool for exact analysis of indoor light conditions (Velux Daylight Visualizer, see appendix 3, p. 176)

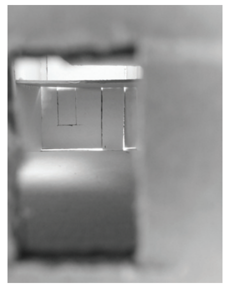


The effect of reflectance of surfaces is investigated by placing openings adjacent to a wall. The illustration above shows the resulting luminance level.

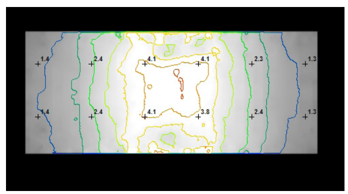


In order to optimise the effect of using the wall as a reflector, the glosiness of the wall's surface is increased, which results in a higher luminance level in the room.





By placing a skylight in the roof, the indoor light climate will be remarkably improved. The dispersion of daylight factors in the room shown to the right reflect the geometry of a model with no additional openings than a skylight.



Ill. 117a: Investigations of light conditions for a single dwelling

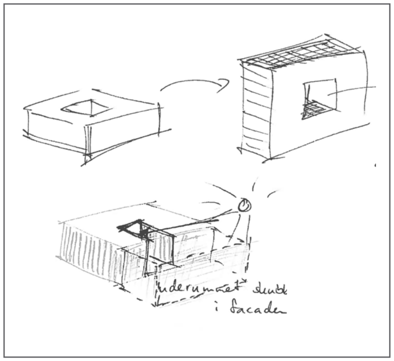
The conclusion is, that a skylight will offer a very good dispersion of light into the room, and openings placed high in general. Also, it has a great impact to place openings adjacent to a light surface, which will then act as a reflector of the light into the room.

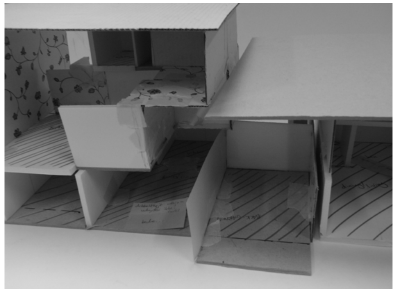
Big openings is not necessarily a good thing, as there is a risk of glare from a too big contrast between the opening and the wall. Consequently, it is better to have a moderate area of openings, placed where they are most needed and beneficial for the interior daylight level. [Lauring, 2010][Fich, 2010]

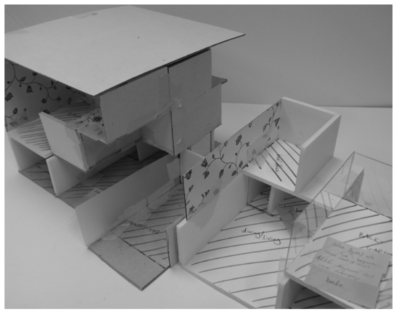
However, in order to minimise line losses from the openings, it can be beneficial to assemble the openings in bigger areas instead of many small openings.

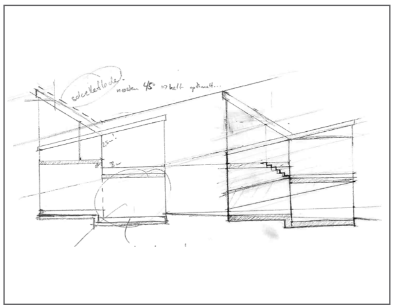
In relation to energy consumption and indoor climate, the area of openings have to be balanced with the occurrence of overtemperatures, why there has also been done initial investigations in a 24hour average-spreadsheet (see appendix 2-II, pp. xx) . It is found that the area of openings tested in the model and the Velux Daylight Visualizer does not necessarily cause overtemperatures, if they are sufficiently shaded.

These aspects will be taken into deeper consideration in the further process of detailing the dwellings.









Ill. 118a: Working with the structure of the dwelling to allow as much light into the outdoor areas as possible

Outdoor area

A quality of the Danish climate during summer is the long, light nights, where it is possible to have direct sun until 8 or 9pm in the evening. Consequently, it is highly valued that the private outdoor space is placed to get evening light and take advantage of the long nights. As a result outdoor space has been pushed towards the edge of the facade instead of being placed in the middle of the house as in the kasbah.

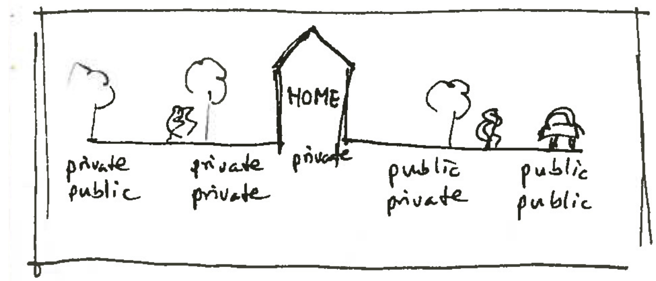
Furthermore, there has been worked with placing the private outdoor area above ground for all dwellings in order to obtain privacy.

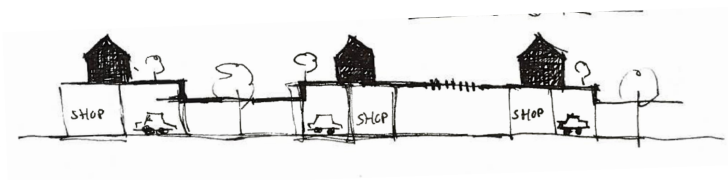
Another important aspect has been the fragmentation of the "roof-line" to let light into the common outdoor areas. This can e.g. be done by sloping the roof.

The villaroad

In relation to the building scale, it is investigated how the linear connection of the dwellings in one continuous path can be done and how this can be reflected into the interior of the dwellings. This also implies a focus on the entrance of the dwelling and the transition from the public path to the private space of the dwelling.
Furthermore, this has to be combined with the concept of the kasbah in an overall structure with a strong identity, why there has been worked with the design of a basic dwelling, a general typology, that can be altered to specific needs and demands of the single occupants.

Ill. 119a: The Kingo-houses by Jørn Utzon is seen as a good example of what can be obtained by connecting the dwellings to a continuous path





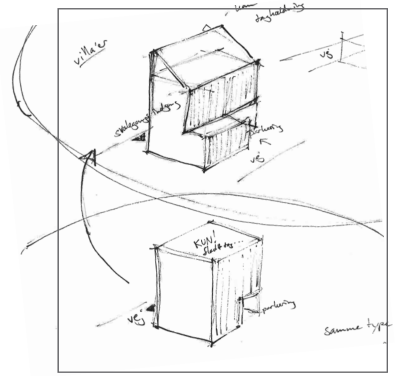
Ill. 119b: The villaroad has been implemented in the working with sections and gradual transitions from public to private

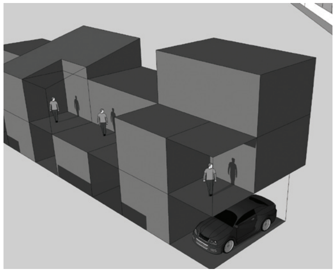
An important aspect in relation to the villaroad is that of a direct connection between the access path and the entrance of the single dwelling. This is considered important for the creation of social relations with neighbours and for the visual contact with the coming and going of people.

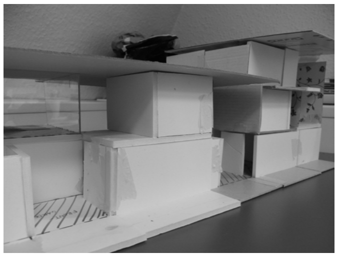
At first, the parking of the car is placed directly adjacent to or in the single dwelling, thereby being emphasised as an important part of the the dwelling. This further relates to the sense of territory and to the autonomy and privacy of the single dwelling. Another aspect is convenience, which, however, has not been a deciding factor for this project.

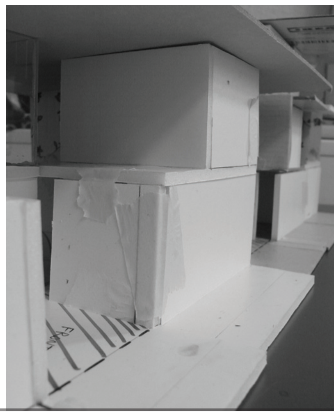
The previously mentioned problematic s with the sloping of the villaroad relates to the building scale in the sense that each dwelling would need a specific entrance level in order to connect to the road.

In the end the car gets to play a too deciding role in this solution, and in the final solution the garage and the entrance to the single dwelling are placed farther from each other.

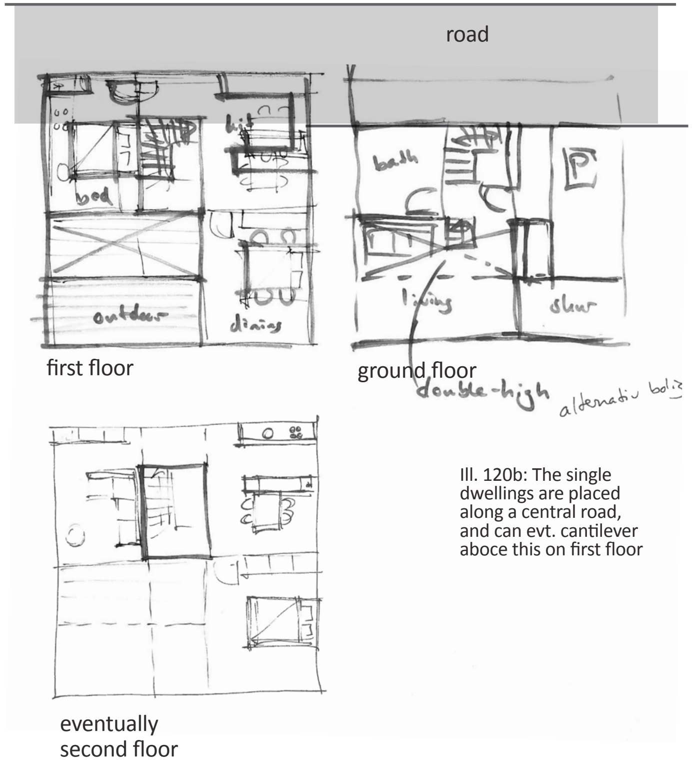








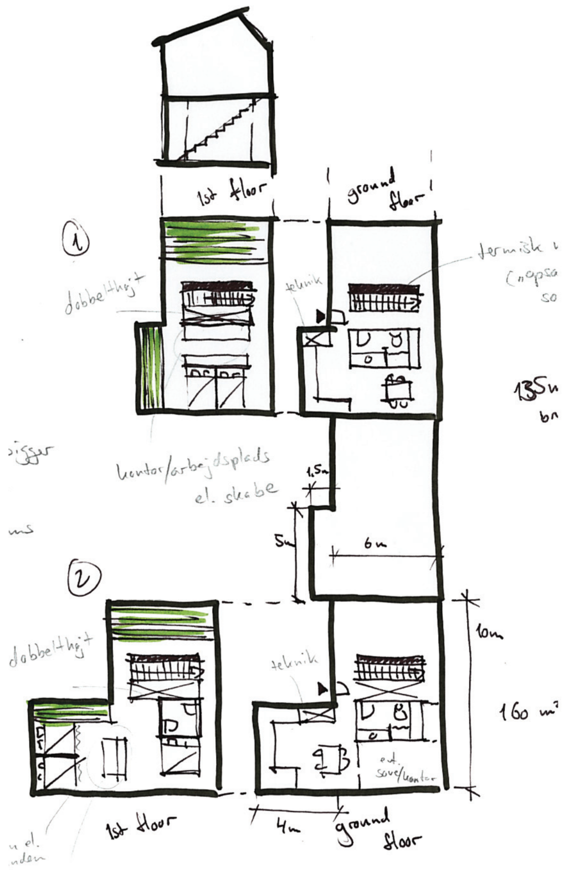
Ill. 120a: For a long time, there is worked with a direct conenction between the entrance to the dwelling and the access road

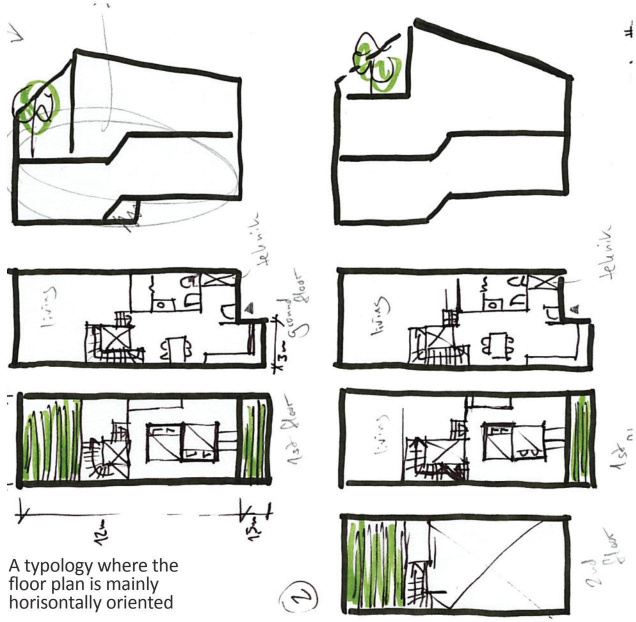


Ill. 120b: The single dwellings are placed along a central road, and can evt. cantilever aboce this on first floor

Ill. 121a: The placement of the parking garage elsewhere frees the shaping of the single dwelling in order to make a bigger variety of dwelling layouts. There is worked with different types of spatial organisation of the dwellings, in order to give each a specific character and identity.

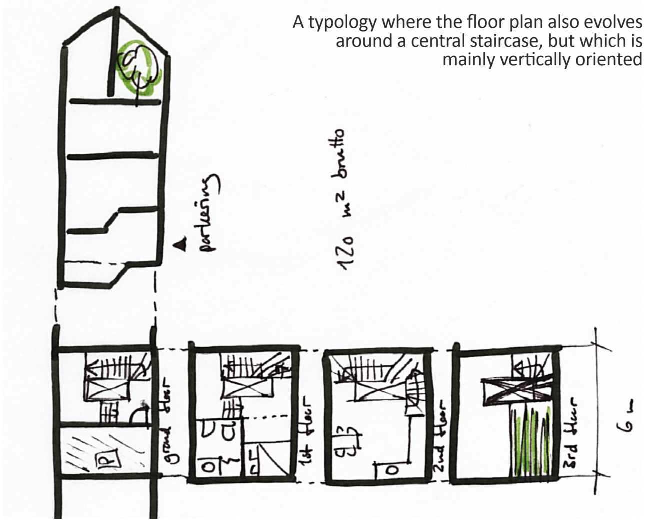
A typology where the floor plan evolves around a central stair





A typology where the floor plan is mainly horisontally oriented

A typology where the floor plan also evolves around a central staircase, but which is mainly vertically oriented



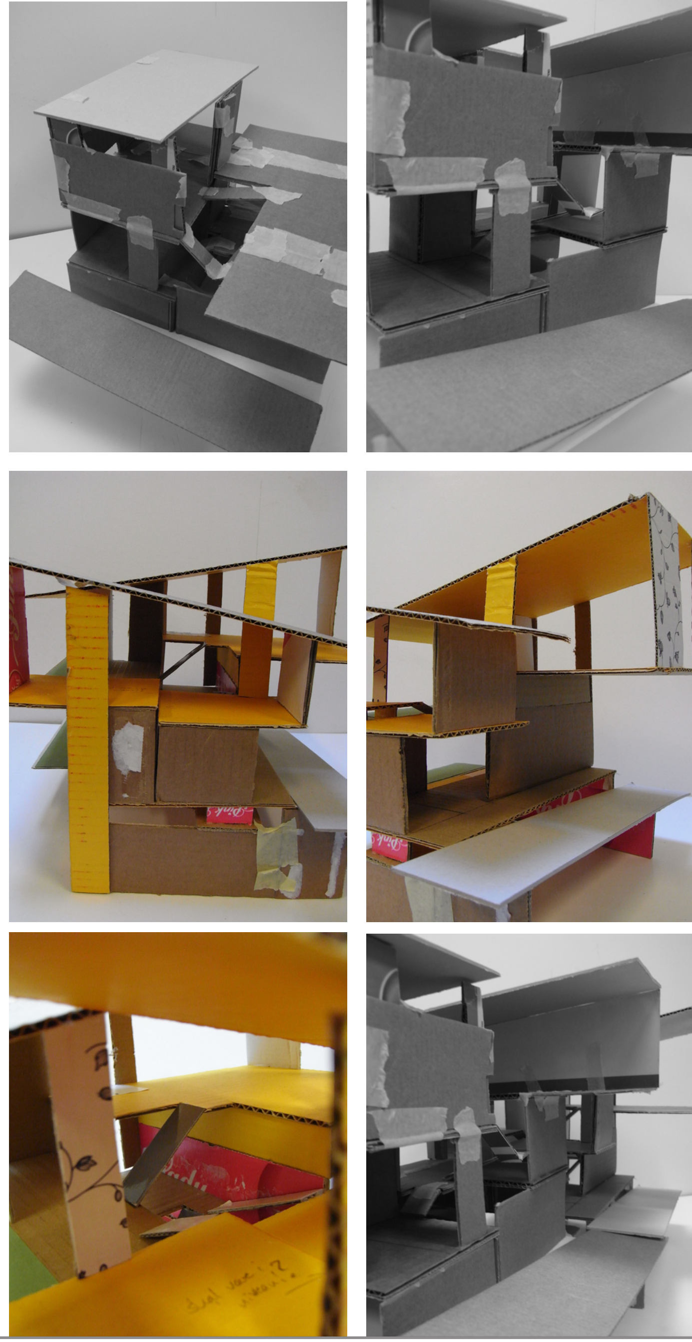
In relation to applying the principles of the villaroad at urban scale, there has been worked with a continuation of the gradual transitions into the single dwellings. This is expressed by organising the rooms along one continous path, at first, spiralling up through the dwelling by a multiple of levels organised around a main staircase.

A main idea is to avoid waste of space in the dwellings in the sense of space, which is rendered un-used during most of the day. Instead of making a big individual space for each dweller, the private spaces are held on a minimum, only allowing space for a place to rest and to sleep. The rest of the time is spent in more or less public spaces of the dwelling. In this way, there are almost no sharp divisions between the different spaces and rooms of the dwelling.

A main difficulty of this concept is the resulting high level of complexity which are not very flexible for multiple use. Moreover the stair gets to play a too deciding role, and it seems difficult to make one clear identity of the dwelling. There are too many concepts going on, and the spatial principle of the dwelling does not stand clear.

Moreover, it is difficult to make variations of this dwelling typology, which does not correspond very well with the possibilities for individual home-making of the single occupant.

As it proves rather problematic to detail the sloping of the connecting path and the levels of the dwellings, this idea is discarded in the final concept. Also, the sloping road is difficult to combine with the concept of the kasbah and the idea of one overall structure, giving identity to the urban configuration.



Ill. 122a: At building scale, there is worked in models scaled 1:50

Final concepts - the three dwelling typologies

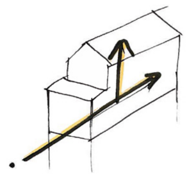
The final concept at building scale has resulted in three different dwellings typologies, defined according to three different spatial principles. Each dwelling typology is based on a single principle, and in this way the multiple spatial principles worked with during the sketching process have been split up and implemented in the concept for each different dwelling typology. This makes the concept more clear and comprehensible and simplifies the detailing of the spatial organisation of the different dwellings. The concepts are based on the translation of the principles of the villaroad - the gradual transitions - into the dwellings. The illustrations to the right show how the path of the gradual transitions is continued into each dwelling typology.

Through the sketching process it proved rather challenging to combine the idea of one connecting path with the kasbah and one overall structure. Instead the villaroad is split up into multiple levels, with the parking of the car in a garage below ground level. However, the single dwelling still maintains a sense of territory and a connection with the garage by placing this directly below the dwelling itself. By placing a deposit space for each dwelling in direct connection with their garage, this level becomes like a basement of the single dwellings, a place for storage.

At ground floor, between the very dwelling and the garage, there is placed commercial functions, which relates to the urban scape and the public path through the site. In this way the urban scape and dwelling-scape overlap and benefit from each other - the commercial functions are placed for optimal interaction with the flow of people through the site, while the dwellings get more privacy by being lifted from the ground. Energy-wise the two functions also benefit from each other, as the commercial functions constitute a heat buffer between the ground and the dwelling.

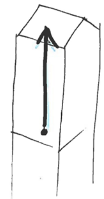
The types of the nuclear and the tower house have good possibility of achieving sufficient daylight condtions, while the holland-house will be more challenging to detail. Consequently, there is focused on detailing this type rather than the two others.

the holland-house



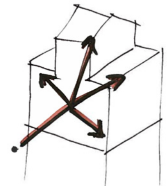
The concept of the holland-house is based on the combination of a horisontal movement with a vertical movement.

the tower-house

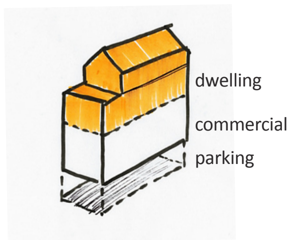


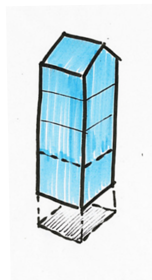
The concept of the tower-house is based on one vertical movement going all the way from base to top.

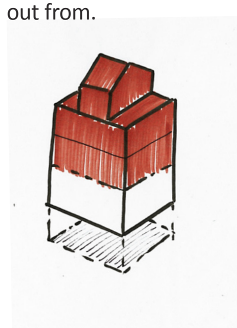
the nuclear-house

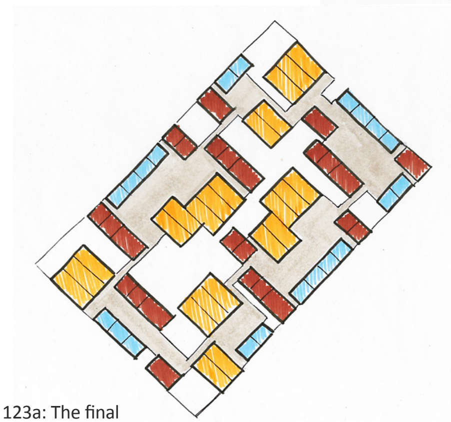


The concept of the nuclear-house is based on a centralised entrance which the rooms and functions are spread out from.









The concept for the individual dwellings connect to the concept at urban scale in the way, that the single dwellings structure the overall urban configuration, like buildings stones. The three different typologies of dwellings are placed in rows of two to four together, and these then form smaller clusters, which in combination shape the public streets and the urban scape.

Ill. 123a: The final concepts for the building scale

DETAILING

DETAILING

The further detailing of the concepts is also split up into urban and building scale respectively in order to make the explanation more comprehensible. However, they have been carried out in close connection and are of course inseparable.

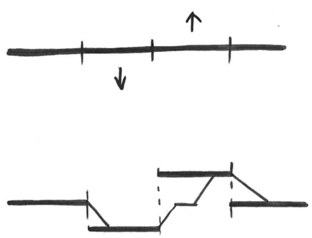
For the urban scale there is zoomed out in order to put the overall urban organisation of the site into perspective and to take a closer look at the linking of the site with the close physical surroundings. This relates to the detailing of the harbour-scape, where the detailing of the urban scape concerns the spatial configuration of the dwellings, the detailing of the layered villaroad and the materials and tactile characteristics at the site itself.

For the building scale, there is primarily focused on balancing the energy consumption with the indoor climate and the overall architectural design of the single dwellings. This is mainly expressed in the detailing of the facades. However, due to the time frame of the project this is only done for the typology of the holland-house, where the principles and conclusions derived from the detailing investigations are applied to the other two typologies.

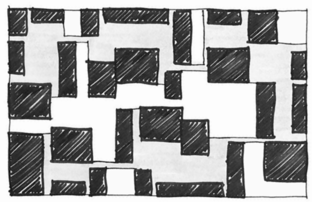
The final solution is shown in the presentation report.

URBAN SCALE

The detailing of the urban scale takes its point of departure in the concept for the urban scale, which defines the landscaping of the site and how this relates to the idea of the kasbah and the principles of the villaroad.



Instad of running in one linear course, the villaroad is split up and thereby connecting the different layers of the urban configuration. However, the connection between the single dwelling and the entrance to the dwelling with the parking of the car is maintained by placing the garage of each dwelling directly under the very dwelling, thereby obtaining a sense of territory.



The labyrinthic organisation of the urban layout/configuration relates to the kasbah-idea, where the dwellings constitute the overall urban composition. In this way the need for an intimate human scale and a sheltered green heart is respected.

The clear division of the urban layout into the three main spaces of the harbour scape, the urban scape and the dwelling-scape organises the site and gives hierarchy to the design. The composition turns its back against the harbour-scape and leads the flow of people into and through the site instead of around it.

Ill. 126a: The concept at urban scale divides the design into the three overall spaces of the harbour-scape, the urban scape and the dwelling-scape

Spatial organisation

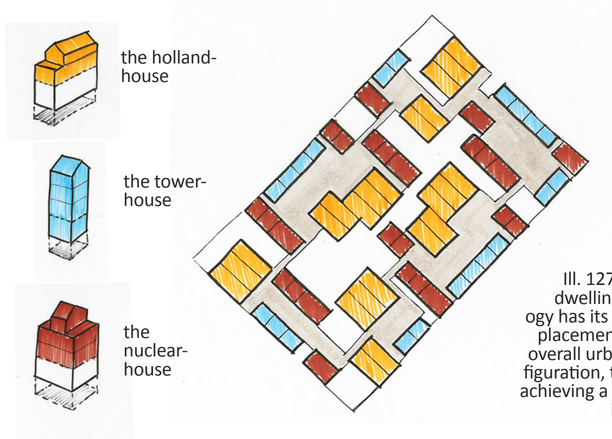
Clusters

The spatial composition of the design on urban scale results from the arraying of the different dwelling typologies two to four together, and combining these groups into clusters. The different typologies are placed in the same way in all clusters and obtain a certain kind of identity in this way.

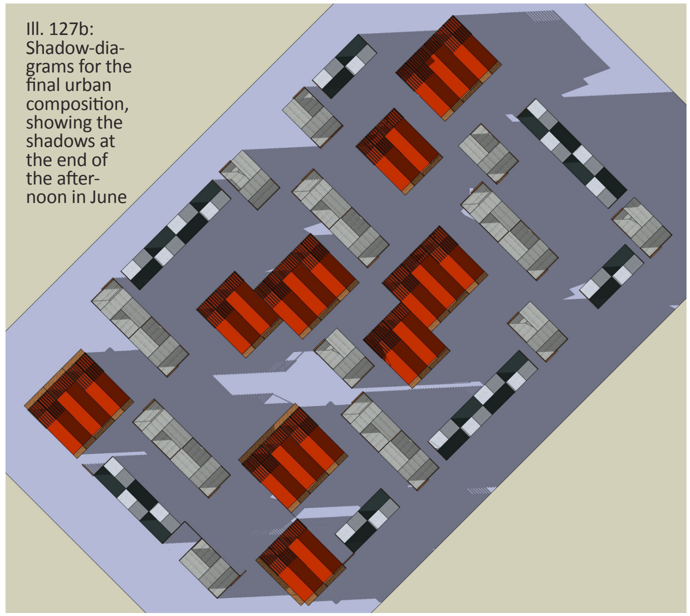
The holland-house forms a sort of spine of the configuration by mainly being placed towards the inner of the the site, however, reaching out to the edges at a few places. The tower-house edges the site towards the harbour-scape and the nuclear-house connects the holland-house and tower-house thereby completing the clusters. In order to emphasise the identity of the different dwelling typologies the single typology is not physically connected with dwellings of a different typology. In this way, there is established a distancing in-between space, which enables a gradual transition between the dwelling typologies.

The configuration of the dwellings into clusters shape the whole composition of the site, thereby establishing a close connection between the urban scape and the dwelling-scape. The main inspiration through the design process has been the kasbah, and consequently the intended experience of the spatial composition is that of a somehow unpredictable continuous flow of spaces in three dimensions. Sometimes a space is opening up, sometimes it is narrowing down, with visual connections and unexpected views linking the different spaces to each other. This is very much related to the principle of gradual transitions, which is a key factor in directioning the flow through the site, and in organising the urban scape in accordance with the dwelling-scape and the harbour scape.

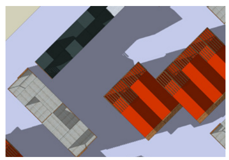
Another design intention with the kasbah is to make a more intimate space, related more to human scale than that of the surrounding harbour area. The in-between spaces are intended to make people stay and experience the place, rather than just passing through.



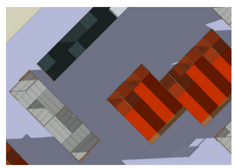
Ill. 127a: Each dwelling typology has its specific placement in the overall urban configuration, thereby achieving a specific identity



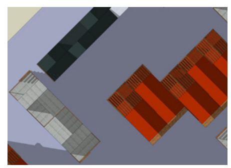
Ill. 127b: Shadow-diagrams for the final urban composition, showing the shadows at the end of the afternoon in June



Shadows at 4pm



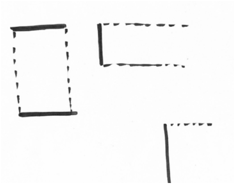
Shadows at 5pm



Shadows at 6pm

Directioning

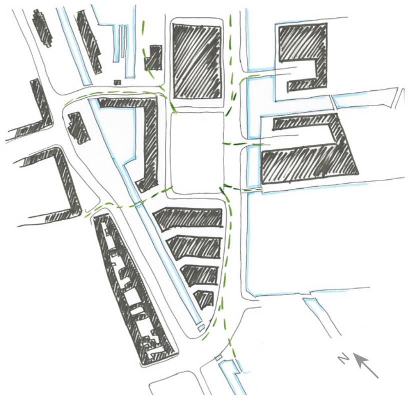
The in-between space is further related to the orientation of the dwellings, where the facades mainly address two directions only, leaving the remaining facades relatively closed. This enables the physical arraying of the dwellings and privacy for the the single dwelling by either turning its front facades towards a relatively open space or to the the closed facade of a neighbouring dwelling.



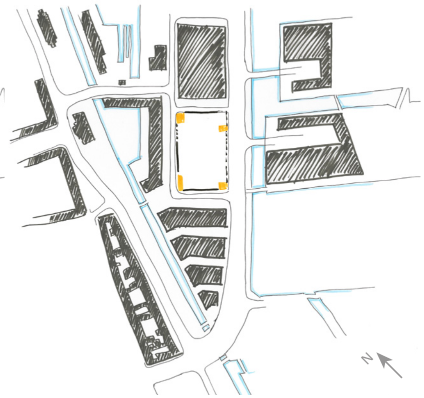
Ill. 128a: The directioning of the dwellings and their facades is done with consideration for the privacy of the single dwellings

On overall scale, there is likewise worked with the addressing of the urban spaces. This is done by the use of gradual transitions in the modelling of open and closed spaces, or rather semi-open and semi-closed.

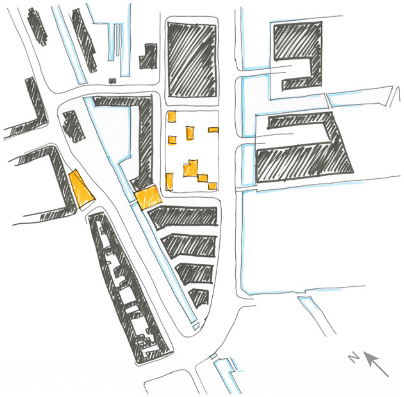
Like the kasbah, the urban configuration is turned inside-out, where the site turns its back against the big scale of the harbour area and the hard traffic of the adjacent roads bordering the site. Instead, there is established a more intimate scale inwardly at the site with public streets passing through, thereby leading the flow of soft traffic this way instead of along the edges. However, the edges of the site are softened in order to enable gradual transitions between the physical surroundings and the site. Consequently the site is linked with the surrounding paths and flow of people by opening up the corners in small plazas. The plazas thereby constitute a link in a continuous flow of open spaces from the existing urban fabric of Aarhus into the site.



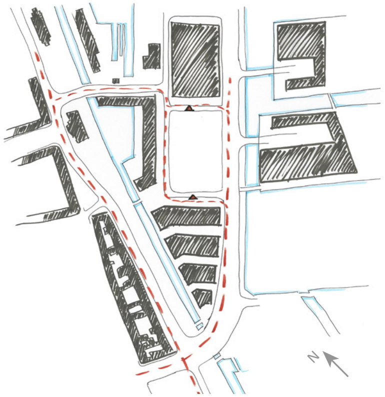
Ill. 128b: The flow of cyclists and pedestrians in the area will mainly come to the site in the corners



Ill. 128c: The urban configuration consequently opens up in the corners in order to connect to the flow of cyclists and pedestrians



Ill. 128d: The open spaces of the urban configuration connects to and continues an existing flow of open squares and spaces in the surrounding urban fabric



Ill. 128e: The flow of cars surround the site, and the placement of the entrance and exit to the parking garage below ground are placed at the short edges of the site

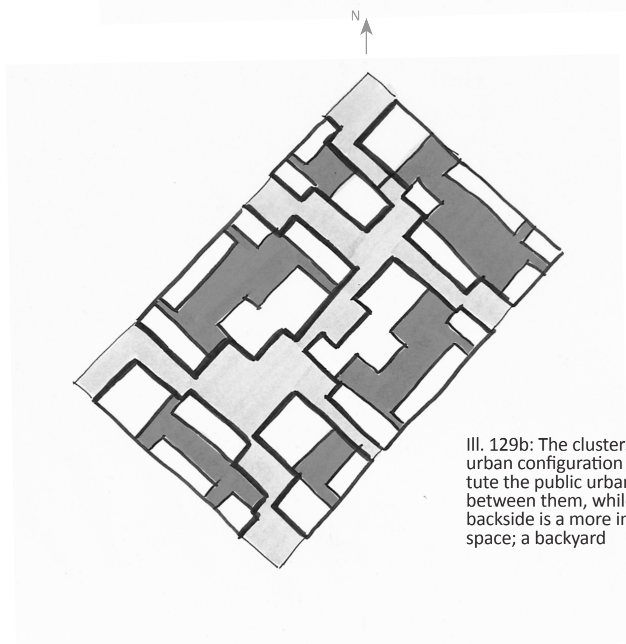
The flow of open spaces serves as the main public space of the composition, and is situated in-between the different clusters of dwellings, or at the “outside” of the clusters. All commercial functions are placed at ground floor addressing this space. Internally of the clusters there is both the staff entrance of the commercial functions at ground floor, bike-parking and waste deposal as well as the access, the villaroad, of the dwellings, which are placed above the commercial functions. Thereby this “inside” space of the clusters is both a backside for the commercial functions and a frontside for the dwellings respectively.

This enables a gradual transition between the urban scape and the dwelling-scape and results in an exchange of flow and functions. The bike-parking and waste deposal are e.g. common functions, where social interaction between people can happen.

However, the access to the dwellings should not be experienced as a backside while, on the other hand, the commercial functions should not be restrained in their functioning.

In order to solve this problematic and to make it possible to distinct the two functions from each other there is worked with a layering of this space. This is done in close connection with the detailing of the villaroad and the layering of the urban composition in general, which will be explained further in the following.

Ill. 129a: The public path of the urban configuration is alternating opening up and narrowing down in a continuous flow of spaces



Ill. 129b: The clusters of the urban configuration constitute the public urban path between them, while the backside is a more intimate space; a backyard

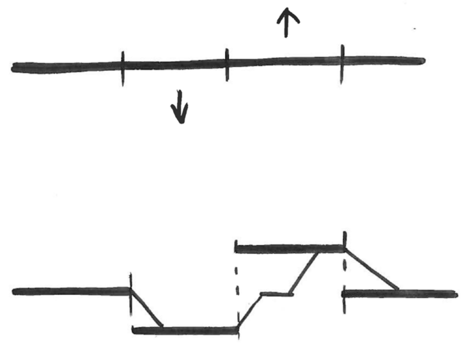
Infrastructure - the villaroad

In the concept at urban scale of the overall composition the villaroad is cut into layers rather than treating it as one continous path connecting all the dwellings. This complicates gradual transitions to a bigger extent, as the layering of the villaroad necessitates a vertical movement between the spaces of the different layers, which is usually a more direct transition than gradual.

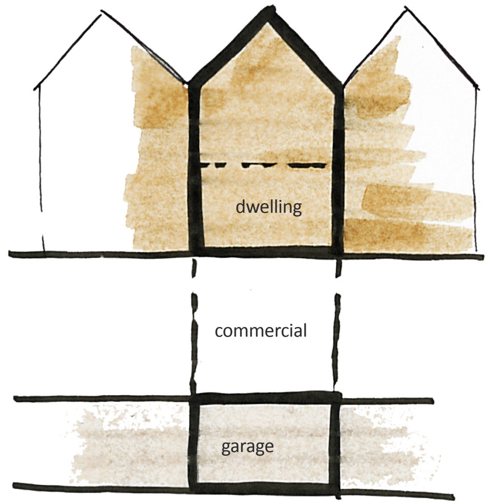
However, it also enables a more complex and interesting spatial translation of the villaroad, where the single ingredients and spatial principles are broken apart and puzzled together in new ways. Making people move vertically between the different layers of the villaroad can further increase the awarenes of these movements among the people, and can thus play a role in the home-making of the single occupants. Moreover, the layering relates to the inspiration from the kasbah and the attempt to combine the two guiding principles of the kasbah and the villaroad in the architectural solution.

The layering of the villaroad is done in concordance with a layering of the single dwellings themselves. Part of the concept at urban scale is the single dwelling going all the way from parking garage to roof top, thus preserving a sense of territory and as close a connection as possible between the access to the site, the parking of the car and the entrance to the single dwelling.

As the ground floor is defined as the space of the urban scape, there is put commercial functions into the building fabric at ground floor with benefits related to the energy consumption for both the dwellings and the commercial functions. However, this does only apply for typologies of the holland-house and the nuclear-house, as the tower-house is always placed at the edges of the site. And since the edges area related to the big scale of the harbour area, there are not placed any commercial functions here.

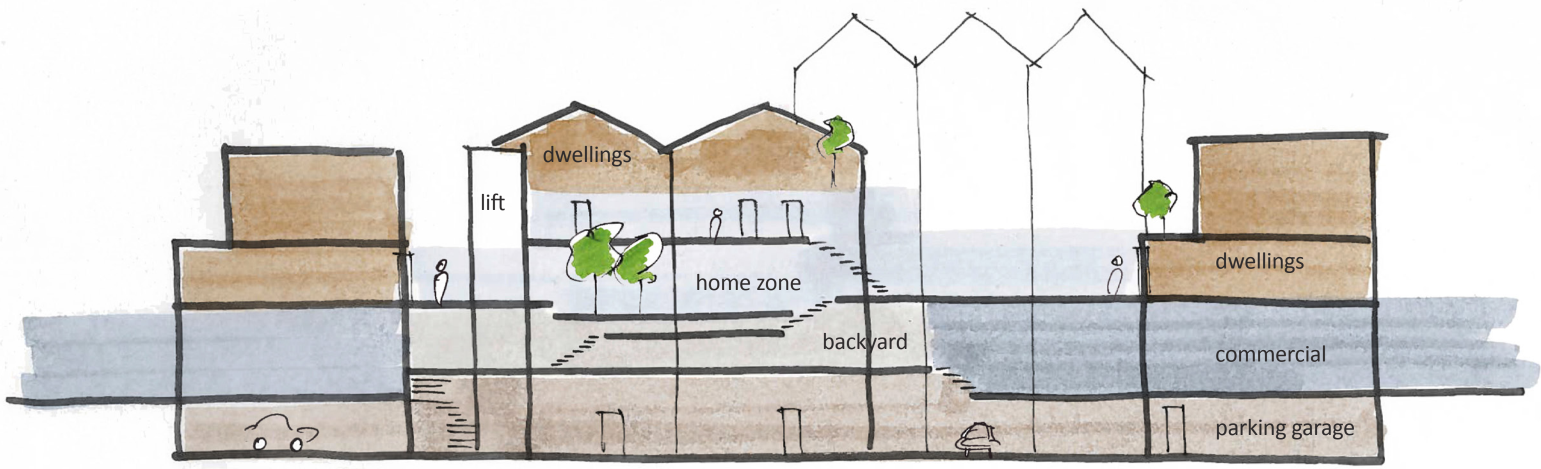


Ill. 130a: The villaroad is split up and layered in order to facilitate the gradual transitions from public to private



Ill. 130b: The single dwelling goes all the way from the garage to the roof top, with the commercial functions placed in the middle at ground level

The section through the site shows the character of the different layers and how they relate to each other. There is worked with a multiple of layers in orde to be able to mark a gradual transition between the different spaces, by bringing some layers closer to each other. Furthermore, the different levels at ground floor defines the different spaces of the “front” and “back” of the clusters, with a height difference of 1,5m. In addition, this raising of the staff entrance area to the commercial functions enables light and visual connections to the parking garages underneath.



The parking garage is connected to the physical surroundings by two ramps at the two ends of the composition. The layout of the parking area follows the layout of the urban fabric, since the individual parking spaces and deposit spaces are placed directly under the dwelling to which they belong. In this way the retaining walls of the parking garage also constitute the foundation of the single dwellings.

Ill. 131a: The section above reflects the layering of the villaroad into different zones, which enables a gradual transition from the public harbour-scape to the more private dwelling-scape

From the parking garage there is access to the inside of the culsters by stair cases placed at the edges of the site. In this way there is a visual connection between the surroundings and the flow of people in/at the site. This layer can also be accessed directly from the adjacent streets that borders the site as well as from the public path through the site at the front of the clusters.

The stair cases from the parking garage leads all the way to the entrance area of the dwellings. In the middle of these areas there is a common green outdoor area, which is lowered in order to allow light and visual connections to the layer underneath. The entrance area to the dwellings is split up into two layers, as the entrance to the nuclear-houses is situated in the middle of the houses, in accordance with the concept of this typology.

From the entrance area to the dwellings the layers become more private, as they move inside the dwellings. Here the layering principle and the gradual transitions is continued, and the detailing of the single dwellings will be explained further in the following chapter.

In order to break up the flow and allow for gradual transitions between the difference layers, there is implemented secondary connections from the parking garage to the public path and from this to the entrance area of the dwellings. Furthermore, there is of course placed lifts, which connect all the layers of the urban composition.

Materiality

The materials play an important role for the expression of the architectural solution. The work with the materials has been carried out in close connection to the development of the facades of the individual dwellings, and the construction of these. However, for comprehension of the process the overall choices related to the expression of the design concerning materials and construction are presented here.

In relation to the kasbah - one overall identity, connection between the different spaces, the gradual transitions. The urban composition is build up from the single dwellings, like building bricks. Each dwelling has its unique place in the totality, gain its identity in this way.

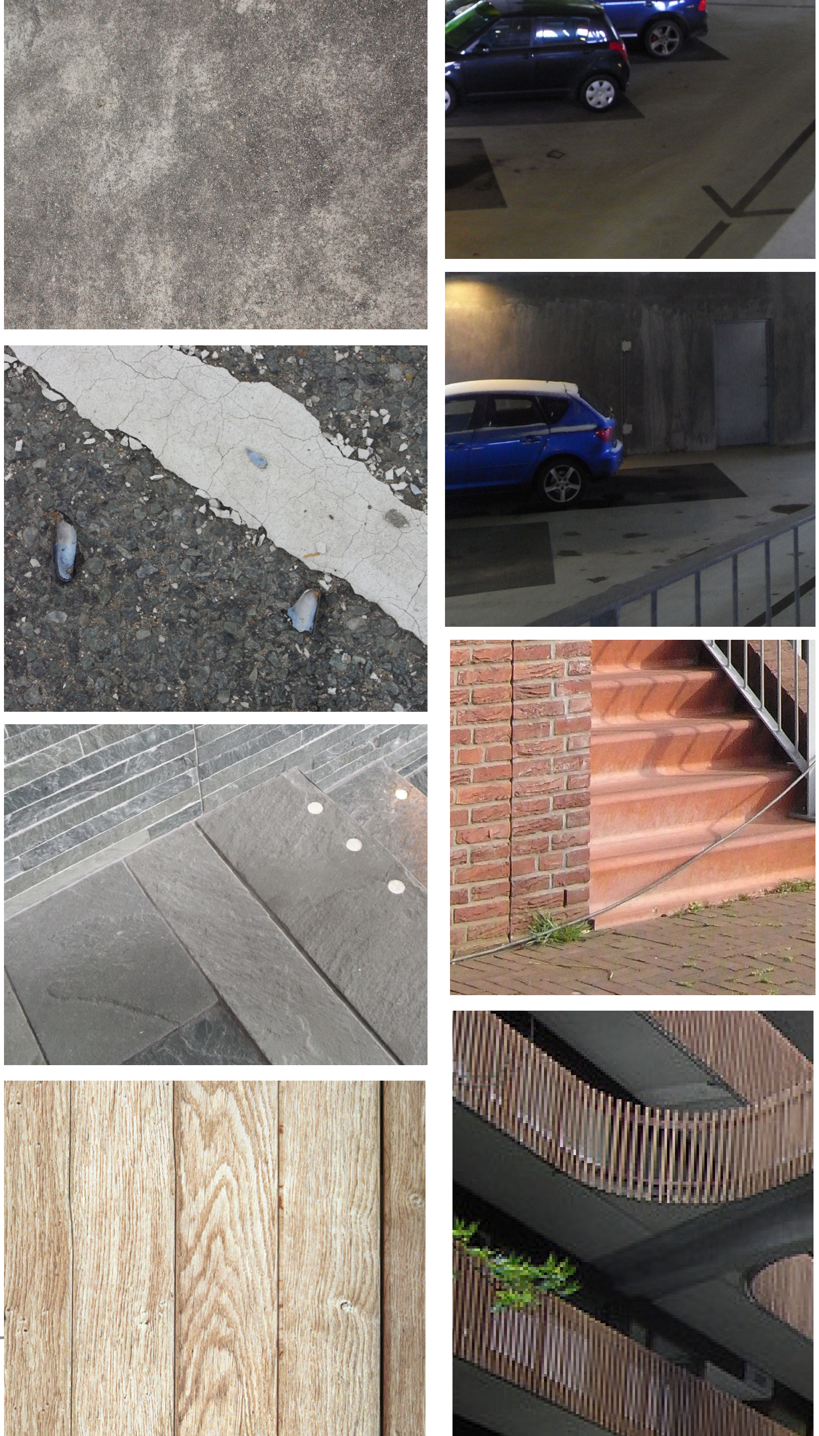
Consequently, the choice of materials should reflect this duality between the individual and the common. Furthermore, the materials should of course take the Danish climate as well as the rough climate and characteristic of the harbour area into perspective (see physical context analysis on p. 62).

As a common feature, the overall materiality of the site should be of different variations of stone. Stone gives connotations to safety and durability, also in relation to the climate. Moreover, stone weathers nicely and requires a minimum of maintenance and in relation to energy consumption, it shows that it is beneficial for the dwellings with a high heat capacity. In relation to sustainability, it is quite expensive to exploit and transport heavy materials energy-wise, but since there is tradition for the use of stone in a Danish context, this is considered a local material which results in a minimum of transport. Also, the little maintenance and durability of the material is considered to account for the high energy-costs of the production.

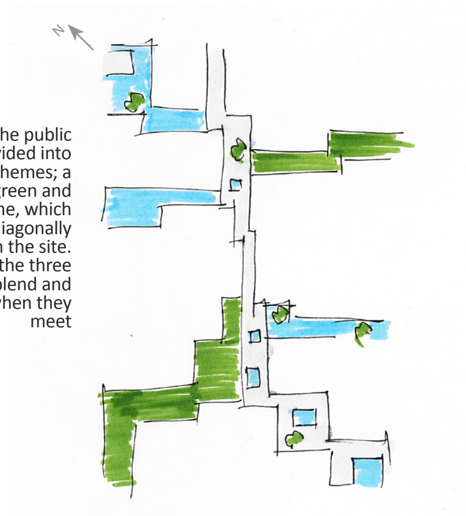
The different varieties of stone are applied according to the character of the spaces, where they are used. When used for cladding the material relates to the identity of the dwelling-typology it is used for.

As stone is a hard and cold material it is complimented with the warmer and softer material of wood. This is used for places where there is physical contact with people like benches and handrails. Further it is used to mark the front-garden of the single dwellings, and in the design of the common outdoor areas between the dwellings. Another quality of wood is its appealing and decorative character, why it is used as transparent partition faces/sections between the different layers and spaces of the composition, thereby allowing for gradual transitions.

In order to bring life and intimacy into the urban design, there is placed trees and plants in the spaces between the dwellings, where the previuously mentioned partition sections can be used for climbing plants. The plants used in the design should have a shallow root net, as there is no real ground to plant in, but instead containers with earth. Further, as part of the concept there is attempted to avoid direct sunlight into the public streets at ground floor in order to avoid overheating of the commercial functions, why the trees planted here should be able to survive without a lot of direct sunlight.



Ill. 133a: The materials used for the urban scape are primarily stone and hard materials. However, wood is used for paving of the home zones and other exterior finishings like e.g. railings and benches



Ill. 133b: The public path is divided into three themes; a stone, green and water theme, which run diagonally through the site. However, the three themes blend and mix when they meet

BUILDING SCALE

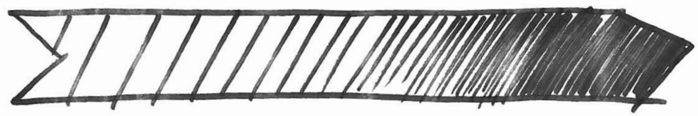
The detailing of the dwellings has mainly focused on the typology of the holland-house, since this seems the most demanding to solve in relation to balancing the indoor climate with the energy consumption. The relatively deep and narrow character of the house makes it challenging to obtain sufficient light conditions inside the house - while the placement of large openings towards Southwest may cause the occurrence of overtemperatures. Furthermore the worst-case scenario has a relatively large surface-to-volume ratio, as only one of the facades is connected to an adjacent house, which causes a big transmission loss from the facades. Consequently, this is the example considered in the following investigations.

The spatial organisation have been done in accordance with the concept of the typology, which is based on the translation and-continuation of the villaroad into the single dwelling. The detailing of the facades reflect considerations concerning construction, materials and expression of the dwellings as well as the balancing of the energy consumption with the indoor climate. This is consequently explained more elaborately both in relation to energy consumption and indoor climate.

The final solution is shown in the presentation report, but the solution related to each theme is shown together with the explanations.

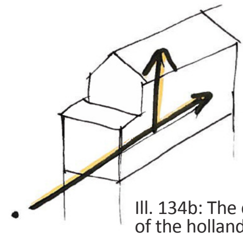
Spatial organisation

The overall idea of the spatial organisation of the single dwellings is the translation of the villaroad with gradual transitions from public to private. This movement continues into the single dwelling and organises the rooms along a path with the most private rooms towards the end of the path, in accordance with the concept for the different dwelling typologies.

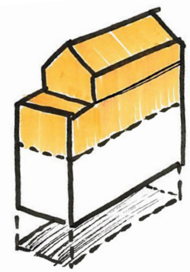


Ill. 134a: The gradual transitions are continued into the single dwellings

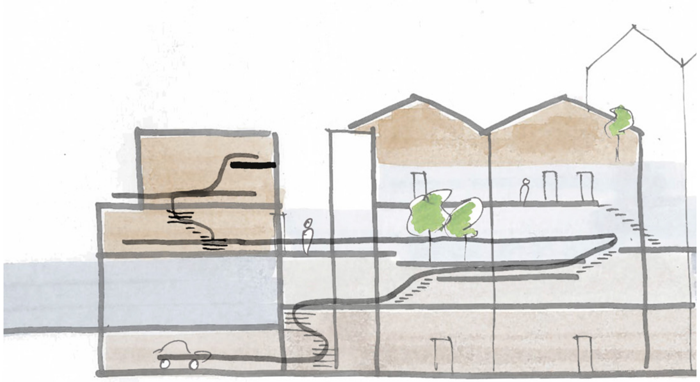
However, for all dwelling typologies the movement actually begins in the parking garage, which is the most public function of the single dwelling (see definition of the dwelling-path on pp. xx). The parking space of each dwelling is situated right under the actual dwelling, only separated by commercial functions in between. Consequently there is obtained a close connection between the parking, which is part of the access and entrance to the single dwelling, and the very dwelling.



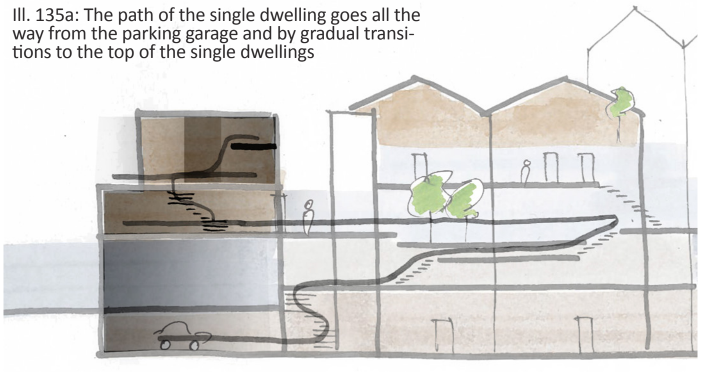
Ill. 134b: The concept of the holland-house



The most private space of the single dwelling, the deposit space, is nevertheless also placed in the garage, adjacent to the parking space of the single dwelling. This is due to the closed character of the deposit space, and to its connection with emotions, rituals and symbols of the home, where the deposit is related to the basement and the unconsciousness. [Pallasmaa, 1995]



Ill. 135a: The path of the single dwelling goes all the way from the parking garage and by gradual transitions to the top of the single dwellings



As the section shows, the most public functions of the dwelling, the kitchen and the dining area, are placed in close connection to the entry of the single dwelling. The placement of openings enable visual connections with the outside area of the dwelling, the front garden, the entrance and the kitchen area. There is made a small overhang over the front door as a shelter and a buffer-zone between the inside and outside of the single dwelling. The very entrance is placed slightly off-axis thereby allowing for a good overview of the space of the ground floor upon entry.

The preoccupation with gradual transitions and the investigation of spatial principles of doing so has resulted in very few partition walls in the single dwellings. This goes hand-in-hand with the idea of avoiding unused spaces during the day, thereby minimising the private spaces which are mainly used for sleeping. Consequently, there are no big bedrooms in the dwellings, resulting in more common space and less individual space. This also enables a minimisation of the floor area of the single dwelling.

Despite the few partition walls, the relatively slender dimensions of all the dwelling typologies and the distribution of the functions over several stories allow for a gradual division of the spaces and functions. For the holland-house typology all the most private functions are placed on first floor opposite the private outdoor space. The dwellers do not have to pass these private functions in order to reach another function, and the path of the dwelling consequently ends here. In this way, here is obtaines privacy for these functions.

The most private space inside the dwellings, the bathroom, is, however, separated with a partition wall, thereby making a direct transition. On the other hand, this organises the other functions around the bathroom, thereby reducing the need for additional partitions.

The relatively open spaces and little use of partition walls further results in a relatively large flexibility of the interior organisation. This enables to single dweller to adjust the placement of the different functions according to his or her individual preferences. Also, there is the possibility of putting up partition walls, if a greater distinction between the different spaces is wanted. Furthermore, it is possible to make use of the pitched roof for bed lofts, allowing for additional sleeping space, and a bigger flexibility of use of the remaining floor space.

Facades - materials and construction

The detailing of the facades is done in accordance with considerations for the indoor climate, the energy consumption as well as the overall expression of the concept of the single dwellings.

The materials used for the different dwelling typologies should emphasise the character of the single typology, thereby differentiating them from each other. The main idea of working with three typologies is the possibility of the single dweller to be able to identify with one of the types, and consequently the three typologies should be distinctive and different from each other. However, as an overall characteristic of the urban composition, the general choice of material is stone complemented by plants and wooden elements. These wooden elements are used for shading and as a decorative element, which binds the urban configuration together, and there is freedom for the single dweller to shape these to individual preferences.

Another common characteristic is to enhance the volumes of the different typologies, since the volume also expresses the translation of the villaroad-movement into the single dwelling. Consequently there is worked with openings, which are either experienced as cut-outs of the volume, or which are more or less leveled with the facade, thereby not breaking up the surface.

The choice of materials of the single dwellings is of course also applied for the commercial functions placed underneath the dwellings. In this way the connection between the parking garage and the single dwelling will be maintained, leaving the impression of the dwelling going all the way from the parking garage to the roof top.

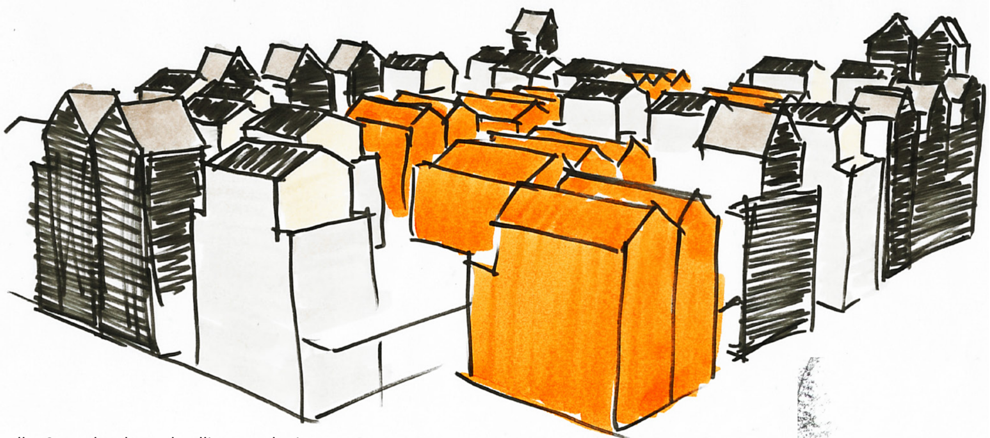
Ill. 136a: The different materials used for the facades of the different dwelling typologies.

The nuclear-house
This typology should be affordable dwellings, thereby avoiding the use of exclusive materials, but instead there is used concrete or panes with a concrete finish in light grey. For the roof there is used a dark cladding. The openings are cut out in horisontal strips going around the corners to emphasise the concept of the nuclear movement.

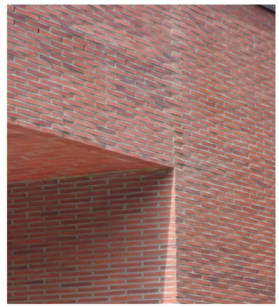
The tower-house
This typology is for the more individual occupant, thereby using the more exclusive materials of slate and zink. The verticality is be expressed by a long vertical strip of openings.

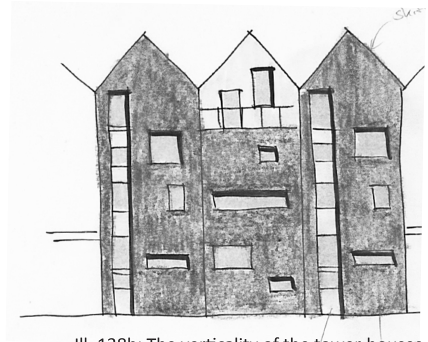
The holland-house
This typology should look more like a traditional house and consequently there is used red bricks for the facades and red roof tiles for the roof. The openings should be relatively big and emphasise the “house-shape” with the pitched roof, and should mainly be placed in the two gables - even for the ones that are not connected to both sides, in order to emphasise the directioning of the typology.

For all dwelling typologies there is used wood as exterior finishing for shading devices etc.

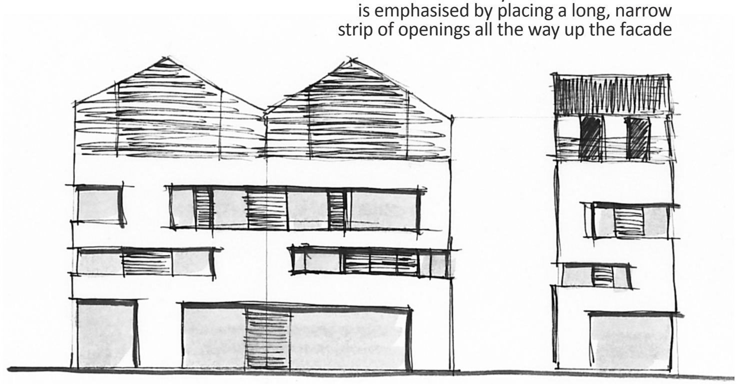


Ill. 137a: The three dwelling typologies should each have a distinct character. This is among other things done by emphasising their different types of volumes. The materials chosen for the facades complement each other, while still preserving its own individual character

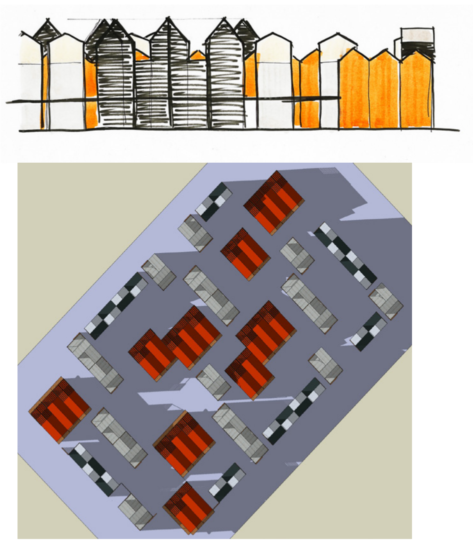




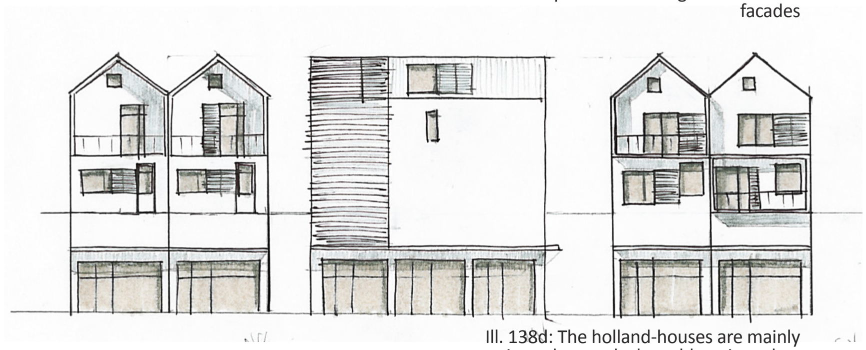
Ill. 138b: The verticality of the tower-houses is emphasised by placing a long, narrow strip of openings all the way up the facade



Ill. 138c: The openings of the nuclear-houses go around the corners in order to break up the relative big surface of the facades



Ill. 138a: The three dwelling typologies should have three different expressions

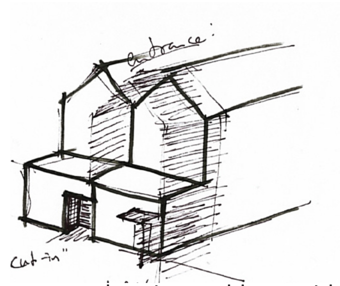


Ill. 138d: The holland-houses are mainly oriented towards the gables, since they should be able to be connected to an adjacent house

At first, evaluations concerning indoor climate and energy consumption is made for an initial design solution. As a starting point the light climate is evaluated in a digital model (Velux Daylight Visualizer) until this fulfills the requirements (see room programme p. 79). This design solution is then further evaluated concerning the energy consumption and the thermal and atmospheric indoor climate respectively. These investigations has again affected the design solution in continous loops.

For the evaluation of the energy consumption during the process and the final specification of this there is used Be10, which is required to do for all new building projects in Denmark. As previsouly mentioned, there is aimed for a 2015-standard. The program calculates the predicted primary energy consumption on the basis of monthly average values and general values for e.g. internal gains as defined in the Danish Building Regulations (BR10). This is to be able to compare the calculations for different projects and apply an energy-standard. Consequently this value is a predicted primary energy consumption, which does not necessarily reflect the actual energy consumption of the single dwelling in use. (See the final Be10-calculation in appendix 4 on p. 178.)

For the evaluation of the thermal and atmospheric indoor climate there is used Bsim, which is a shell for multiple programs for the simulation of different aspects related to the indoor climate and energy consumption of buildings. It calculates on the basis of hourly average values and takes moist- and heat capacity of the construction parts into consideration. Consequently the results from bsim are considered to better reflect the actual use of the dwelling. The calculations in Bsim are primarily used for the evaluation of the thermal and atmospheric climate of the dwelling as well as a concluding comparison of the actual energy consumption of the dwelling in use with the predicted calculated energy consumption in Be10. (See the final Bsim-simulation in appendix 2 on p. 170.)



Ill. 139a: The first solution investigated included a small "cut-in" at the entrance. However, this would cause a big transmission loss and reduce the net floor area, why it is not included in the final solution

In general it seems that there are not any alarming problems with the indoor climate and the energy consumption of the dwellings, which probably results from the continuous integration of considerations in relation to energy and indoor climate from the beginning of the design process.

These considerations are e.g. expressed in the orientation of the dwellings diagonally on a North-South direction on the site, thereby allowing for the use of passive solar gain. Also the general layout of the building volumes is relatively compact, spreading vertically rather than horisontal and thereby exploiting that heat transfer mainly takes place upwards. However, the connection of the dwellings is done horisontally to respect the aspect of autonomy and sense of territory. This is on the other hand balanced by placing the dwelings on top of commercial functions, which eliminates transmission loss downwards to the ground for the dwellings, and upwards for the commercial functions. Moreover, the two functions can benefit from each other since the commercial functions usually have an excess of heat whereas the dwellings need heating. And the placement and distances between the dwellings brings shadow to the commercial functions, which, as mentioned, do not need heat from passive solar gain.

However, there are some problematics regarding the balancing of the energy consumption with the indoor climate, which will be explained further in the following.

Facades - energy consumption

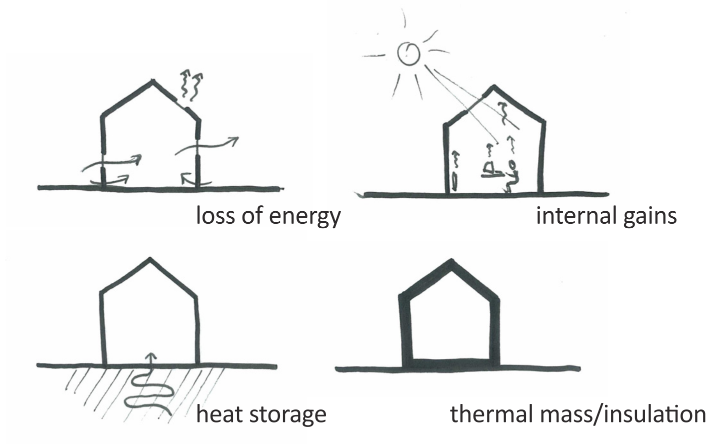
Transmission losses - construction

In relation to the construction of the buildings the deciding parameter has been to apply the same construction method all over, as this is the most efficient both in terms of time and economy. Another consideration has been to use more or less local and reusable materials in accordance with sustainability.

According to calculations in Be10 as well as initial calculations in monthly- and 24hour average spreadsheets, it shows beneficial to have a semi-heavy building. The heaviness of the building has got to do with its heat capacity which is related to the evening out of temperature differences. This results in a more stable indoor climate and hence a more stable and energy-efficient operation of the building systems.

The guiding transmission coefficient for the exterior walls according to Be10 is 0,14 (see appendix 4 on p. 178). A cladding of brick causes walls of a considerable thickness (0,495m), whereas the thickness if it is constructed with steel-beams and posts can be reduced to 0,4172m (found by the use of Build-Desk U, see appendix 1 on p. 167) with a resulting increase of the net floor area of approximately 2,5% (2,5m²).

Since a relatively big amount of the holland-houses are placed two and two together, the use of a steel construction would be quite extensive, and conseuqnetly it is chosen to make the load-bearing structure (slabs and walls) in concrete with an external cladding (see appendix 1 on p. 167). This construction method is cheaper, both in terms of the construction method itself, but also in relation to the application of the same construction method throughout the entire building mass, and it results in a higher heat capacity of the single dwellings.

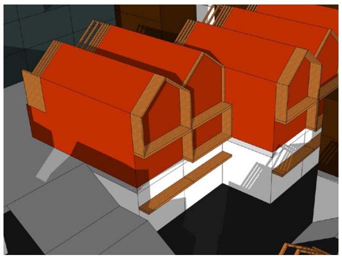


Ill. 140a: Principles related to the energy consumption of the dwellings

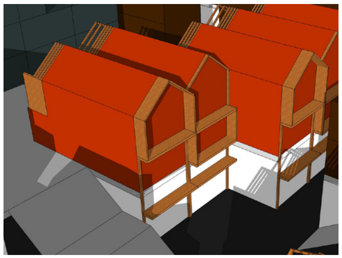
Transmission losses - installations and line losses

There has been put emphasis on avoidance of heat losses from cold bridges and other linear lossed, including losses from installations. Consequently, there has been considered different solutions for the construction of sun screening and balconies.

One solution could be to construct as an external structure outside the dwellings, carrying itself, and thereby completely avoiding cold bridges. On the other hand, this would not fit well with the expression of the dwellings as one volume going all the way form the parking garage to the roof top. Also, the idea of the urban composition as one overall structure would be confused by an additional structure. Moreover, this does not have a big effect on the energy consumption, as the resulting line losses are relatively small due to well insulated joints (see appendix 1 on pp. 167 for construction details).



Ill. 141a: The exterior balconies and shading devices are cantilevered from the load bearing contruction of the very dwellings



Ill. 141b: The exterior balconies and shading devices are carried by an additional construction outside the construction of the dwellings

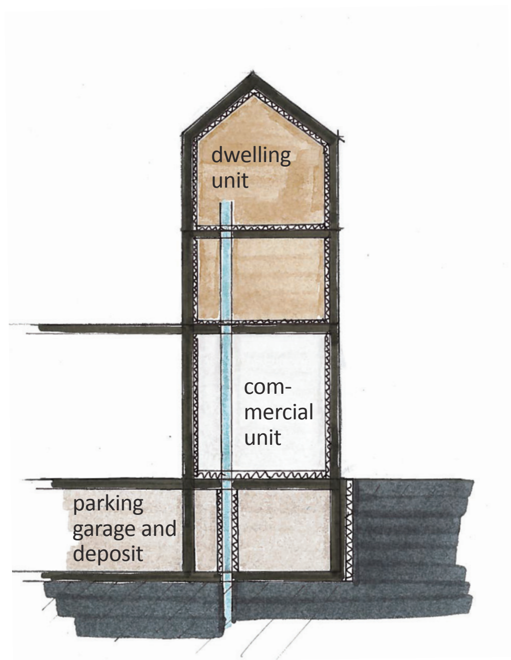
As the installations are placed inside the thermal screen the heat losses from these are minimised. However, since part of the villaroad is placed below ground in the parking garage, the installations cannot be led directly to the individual dwellings, but have to be led through the parking garage. This causes a heat loss from the pipes but in order to minimise this, the installations are led through an insulated space in the deposit space of the single dwellings.

Heat recovery

In order to further minimise the heat losses from the installations, there is used a heat recovery unit, which enables outdoor temperature compensation by adjusting the supply temperature of the water delivered from the district net to the outdoor temperature, and thereby lowering excess heat in the net in total and for the supply to the individual dwelling. [Hemdrup, 2011]

Furthermore, there is used mechanical ventilation with heat recovery during the heating season (November - April), in order to avoid heat losses due to natural ventilation with cold outdoor air.

See further specifications of the systems used in the dwellings in appendix 2 on pp. 170.



Ill. 141c: The installations to the dwellings have to go through the garage and the commercial functions.

Facades - indoor climate

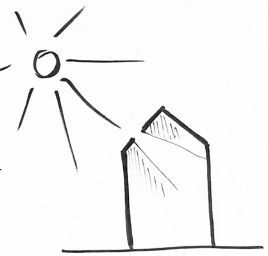
Concerning the indoor climate, the main problematics have been the placement and area of the openings. As previsouly mentioned, the openings play a crucial role for the several aspects concerning the indoor climate as well as for the energy consumption. Especially the skylight has been problematic due to its placement towards Southwest in order to let in as much light as possible, which on the other hand results in overtemperatures during summer.

Another aspect of the heat losses of the openings is the line losses, why a reduction of the opening areas will decrease the energy consumption of the dwellings. Consequently, there is worked with the facades and the placement of openings, in order to try to reduce the window areas. The placement of openings has also been done in accordance with the expression of the spatial concept of the dwellings and how the translation of the gradual transitions has been done.

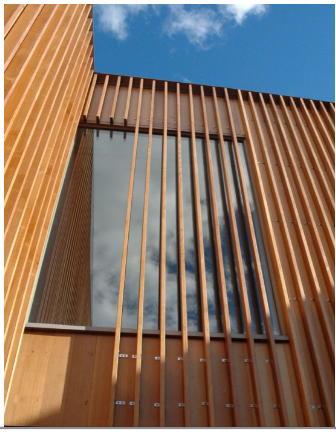
There has been taken inspiration from traditional Dutch houses by working with shutters, big openings placed high in combination with relatively high ceilings. The use of exterior shading devices hinders heat to reach the interior of the dwellings and is consequently more efficient than interior shading devices. Furthermore shutters can add character and life to the facades.

The area of the skylight has been reduced by the use of simulations in Bsim in order to avoid overtemperatures during summer and. This has been done in accordance with calculations of the energy consumption in Be10 and by simulations of the light conditions in Velux Daylight Visualizer to ensure a good light indoor climate. It has showed that the use of external shading can elimit a lot of passive solar gain during the summer months where the altitude of the sky is high.

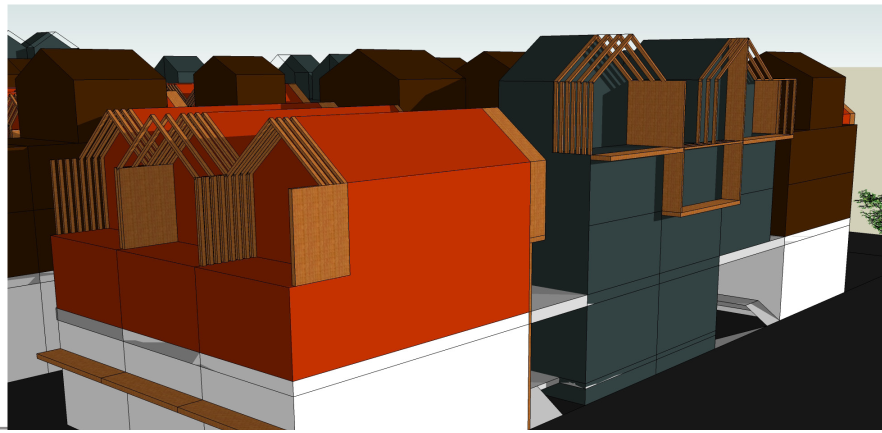
However, the minimisation of the openings can only be done to a certain extent, as the openings have to be relatively big in comparison to the overall facade area, in order to light up the quite deep and narrow space of the holland-house (see appendix 3 on pp. 176 for the final documentation of the light indoor climate).



Ill. 142d: There is a risk of overheating from skylights, when the sun is high on the sky



Ill. 142a and 142b: the use of exterior shading devices in wood can both eliminate solar gain to the interior spaces as well as add extra character to the facades.

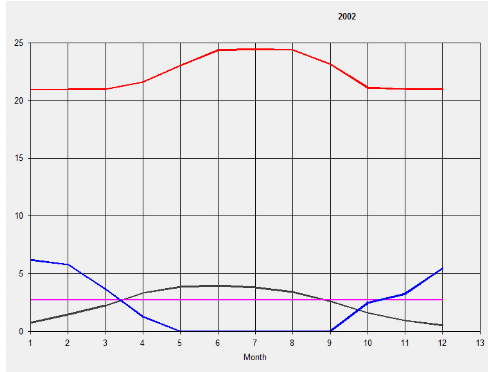


Ill. 142c: There has been worked with the expression of exterior shading devices on the facades

Bsim

From the simulations of the indoor climate in Bsim, it is found that the main factors influencing the thermal climate are the internal gains from people, equipment and solar gain through the openings. This is due to the tightness of the dwellings and the resulting resistance to transmission losses and infiltration, which decreases the heating requirement of the dwellings. Consequently, the otherwise relatively small contribution of heat from internal gains in dwellings have a high impact for low-energy dwellings. However, with sensible shading of the openings, the requirement according to DS 474, p. 15 concerning overtemperatures is fulfilled.

The thermal climate is of course not only related to overtemperatures why undertemperatures should also be considered. This can e.g. occur during cold summer days and nights, where the heating may be turned off. For this reason, the heating system is split up into radiator-heating and floor-heating, where the radiators are activated throughout the whole year in order to avoid undertemperatures at all times.

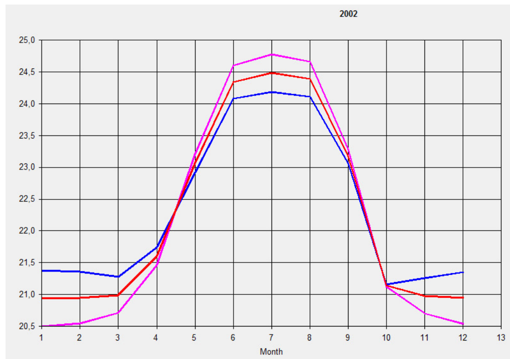


Ill. 143a

10*TopMean(°C)

10*qHeating(kW)
10*qPeople(kW)
10*qSunRad(kW)

The temperatures are higher during summer where the solar radiation is higher - during these months the heating system is not active. The peopleload is constant throughout the year.

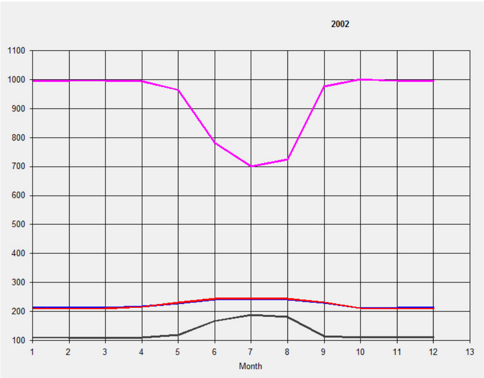


Ill. 143b

10*TiMean(°C)
10*TopMean(°C)
10*Tmrt(°C)

During summer, higher indoor temperatures can be accepted due to higher outdoor temperatures. Consequently, the temperature difference between outdoor and indoor is decreased.

Internal gains and the thermal indoor climate is closely related to the atmospheric indoor climate by being the main reasons for pollution of the air. Furthermore, the importance of provision of fresh air increases with the increase in the air tightness of the dwelling. Further, the minimum required ventilation rate of 0,3 h-1 should be fulfilled (BR10, see requirements regarding the indoor climate in the room programme on p. 79).

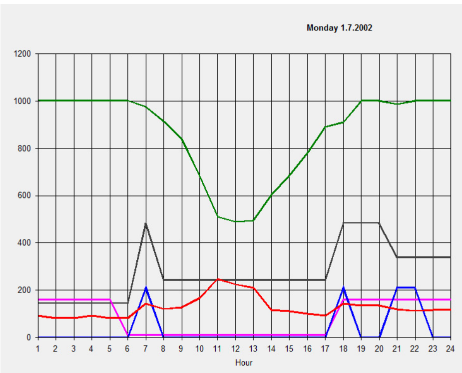


Ill. 144a

Co2 (ppm)

10*TopMean(°C)
10*TiMean(°C)
100*AirChange(/h)

The table show how the air change rate increases as the indoor temperature increases. At the same time the amount of CO2 in the air decreases, as it is ventilated away.

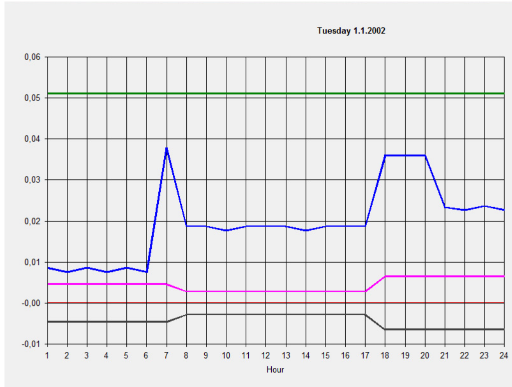


Ill. 144b

Co2 (ppm)

1000*qPeople(kW)
1000*qLighting(kW)
100*AirChange(/h)
1000*qEquipment(kW)

The same pattern is seen when looking at the air change rate over a single (summer) day together with the internal gains from people, equipment and lighting. The ventilation rate increases together with an increase of the internal gains, and the amount of CO2 in the air decreases accordingly.

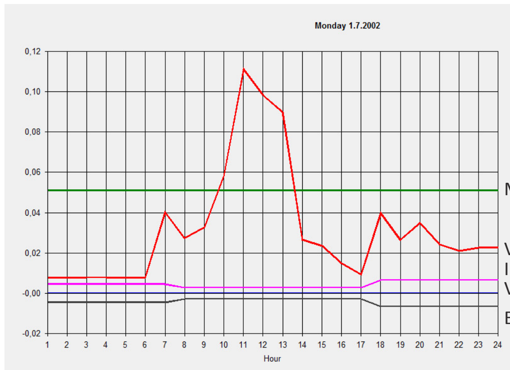


Ill. 144c

MixIn (m3/s)

VentilIn (m3/s)

Infilt (m3/s)
VentIn (m3/s)
Exfilt (m3/s)



Ill. 144d

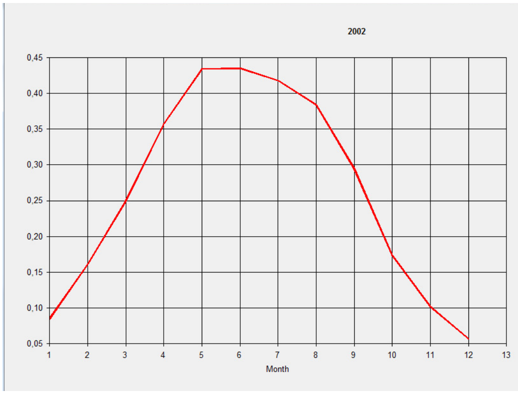
MixIn (m3/s)

VentIn (m3/s)
Infilt (m3/s)
VentilIn (m3/s)
Exfilt (m3/s)

The two tables above show the air change rate together with the ventilation, venting, infiltration, exfiltration and mixing. It shows that the main reason for variations in the resulting air change rate is the ventilation. Furtermore, there is greater variations during summer when the low temperature difference between outdoor and indoor enables use of natural ventilation.

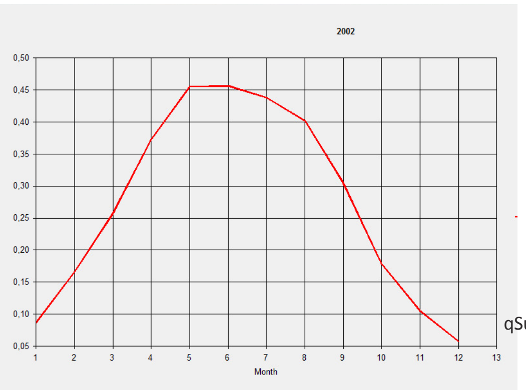
Concludingly, as a step in the detailing of the facades and placement of openings, the effect of removing all exterior shading is tried out in Bsim. The surprising result is, that even the removal of the shading of the skylight does not result in too many hours with overtemperatures (see appendix 2 on p. 170) or has a very big impact on the indoor climate in general. This also implies that the resulting energy consumption does also not change a lot.

Ill. 145a



qSunRad (kW)

Ill. 145b



qSunRad (kW)

The heat gain from solar radiation for the final Bsim model (top) and for the same model where all exterior shading devices are removed (bottom). The difference during summer at the peak of the graph is ca. 0,25 kW (out of ca. 0,45).

A reason for this surprising result might be due to the fact that the geometry of the Bsim-model has been altered during the process, where the first simulations were carried out for the two stories separately. Later the two stories have been simulated in the same model but placed in two different thermal zones. The system Mixing has been used, but has not worked correctly until the end of the process. Consequently, the effect of the shading might have been evaluated for simulations of the top storey only, where the skylight will of course have had a big impact. However, this shows that the organisation of the dwelling over two stories with a relatively high ceiling will affect the indoor climate positively. In reality, there will probably be a little warmer at first floor than at the bottom floor, due to the skylight.

The final placement of openings and eventual placement of shutters in relation to the openings is done more freely according to the exterior expression of the dwellings as well as the interior organisation. Internal shading will be applied for easier regulation of the indoor climate by the occupants of the dwellings, rather than external, automatically controlled shading, like e.g. shutters. However, it is still considered important to use external shading in order to avoid overtemperatures.

Furthermore, big openings might cause over- as well as undertemperatures locally and thereby big temperature variations within the dwellings, which should of course also be avoided. In this connection, shutters can both be used for leaving out passive solar gain as well as for decreasing the transmission coefficient of openings, thereby minimising heat loss during cold days when the sun is not shining.

As a final evaluation of the performance of the holland-house in relation to energy and indoor climate, the primary energy consumption is calculated on basis of the simulations in Bsim, as an expression of the actual energy consumption of the house in use. This is then compared to the predicted primary energy consumption as calculated in Be10 to see whether the two correspond.

The Be10-calculation give a value of 37,1 kWh/m² year for the 2015 energy frame, whereas the calculated value from the heat balance of the Bsim-simulation is 44,74 kWh/m² year. This value does not fulfill the 2015 requirements, but does fulfill the current 2010 requirement (68,1kWh/m² year). (see appendix 3-III on pp. xx).

This result shows that the actual energy consumption of the building in use is relatively higher than the predicted one, but not a lot higher. The difference is probably due to the different claculation methods used, where the Be10-calculation is done on the basis of a monthly steady-state, whereas the Bsim-simulation is a dynamic calculation done on the basis of hourly variations. Consequently Bsim takes account of changes over the month, which may result in an uneven service of the systems in order to fulfill the changing needs of the occupants, and with an increase of the energy consumption as a result. Moreover, the Be10-calculation is done according to the requirements of the BR10 which puts up general values, whereas the Bsim-simulation is done on basis of the actual values of e.g. internal gains, and consequently take occupant behaviour into regard.

However, even though the Bsim-simulation aims to give an exact evaluation of the indoor climate, this is still a predicted calculation done beforehand on the basis of some pre-defined occupants of the dwellings. And just like there should be room for adjusting the expression and interior organisation of the single dwelling to the needs of the single occupant, this indoor climate should and will vary accordingly. People are different and have different definitions of comfort. Consequently the resulting indoor climate will be different for the different dwellings depending on the occupants, and the resulting energy consumption will vary accordingly.

This is nevertheless an even bigger motivation factor in aiming for an architectural design which allows for as big a flexibility of the single dwelling as possible. This is obtained by the relatively open floor plans, where the occupant has a great deal of influence of the spatial organisation, but where the indoor climate will not vary a lot as a result of a different placement of the functions. Furthermore there is aimed for as low an energy consumption as possible, since the previous investigation showed that the actual energy consumption will probably be higher.

There is also the possibility for lowering the energy consumption by placement of solar cells on the roofs, which are orientated and sloped almost optimally for actively exploiting solar gain.

The detailing at building scale has been done for the holland-house which seemed to be the most demanding in relation to the balancing of the indoor climate with the energy consumption. Moreover, the results of the investigations done here are applied to the two other dwelling typologies, and it is assumed that these two types will prove to be able to perform likewise in relation to energy and indoor climate. They both have relatively shallow floor plans with good possibility for exploiting passive solar gain as well as for applying cross ventilation. [Baker and Steemers, 2000]

A further detailing of the dwellings would imply investigations of the acoustic indoor climate, which is an equal important aspect to consider in obtaining a high comfort level of the dwellings. This is very much related to the surfaces of the dwellings and the dimensions of the rooms. Since the holland-house has quite big rooms with few partition walls, the reverberation time might be quite high causing an unpleasant sound climate for speech and residential activities. However, the choice of materials can balance this - e.g. the wooden floors - as well as acoustic treatment of the ceilings and walls, why detailed investigations should be carried out.

Due to a limited time frame for detailing the project this aspect has not been prioritised, but there is the possibility of obtaining a good acoustic climate.

OUTRO

CONCLUSIONS

The conclusion sums up on the entire project and discuss how the final design solution reflects the parameters from the analysis, the programme, the catalogue and the design process itself.

DESIGN PROCESS

The design process has mainly been evolving around the themes of the villaroad and gradual transitions, the kasbah and the landscaping of an overall structure organising the composition of the design solution and giving it identity. The resulting compromise of the three lends its main features from the kasbah typology, which also makes account for the overall structuring landscape of the design. The principles of the villaroad is implemented into this by cutting it up and layering it. This results in a more holistic expression, which at a first glance may seem to contain more urban aspects than that of the villaroad and the detached single-family house. However, the aspects and spatial principles of the detached single-family house and the villaroad have been extracted and applied during the design process, while they are still contained within the overall architectural solution.

CATALOGUE

The design process has been an elaboration of the initial investigations done in the catalogue. These have resulted in a preliminary awareness of aspects related to the themes of urban housing, sustainability, dense living, gradual transitions, energy and comfort, orientation of the dwellings and general architectural inspiration, which is reflected in the final design solution. In this way the catalogue has constituted an important link between the more theoretic analysis, the programme and the design process.

PROGRAMME

The programme has defined the basis of the project in terms of user group, room programme, connections of rooms and functions, architectural quality for this project and the vision for the project. This clear formulation of the guiding parameters of the design has resulted in the focusing of the design process on the main themes of the villaroad, the kasbah and the landscape - as an answer to how dwellings can be designed at Aarhus harbour, which combines the aspects of the detached single-family house and the aspects of a sustainable life in a dense, urban context by using the principles of the villaroad. In continuation of this, the formulation of the main aspects related to architectural quality for this project has resulted in a constant awareness of integrating these aspects throughout the design process in order to obtain a holistic design solution.

The room programme and connections of the rooms and functions by the use of the principles of the villaroad is of course directly reflected in the final design solution. The definition of users/dwellers may not be directly reflected in the final solution, however, it has been assisting in the development of the architectural concept in the sense that it has given images on the possible future dwellers, thereby making it easier to put the decisions and solutions of the process into perspective.

ANALYSIS

The analysis consists of a physical and a theoretic context analysis, where the physical context analysis is reflected in the very concept of the final design solution, while the theoretic context analysis has been the point of departure of the whole project, defining the main themes of it.

Physical context

It is found that the scale proposed in the plan for the Northern harbour area at Aarhus Havn is quite big and not well fitted for more intimate and human scale urban functions nor for the scale of dwellings. Consequently, the composition turns its back against the harbour area and establishes a more intimate and human scale inwardly at the site, where the urban scape and dwellingscape meet. However, there is an exchange of flows between the three scales, and of course the final design solution is connected to the surrounding physical environment of the harbour area.

Furthermore, the composition of the site is seen as an attempt to continue the existing urban fabric of the surrounding city of Aarhus but with a new expression and identity. However, the expression of this identity is not that of a new icon-building of the area, as there are already several existing landmarks as well as new projects planned and being constructed at the site.

The orientation and placement of the dwellings is done in accordance with the climatical conditions at the site, consequently being lowest towards South and the main road of the harbour area.

Theoretic context

The theoretic context deals with the different themes of energy and comfort, sustainability, contemporary lifestyle, the detached single-family house and finally; home and dwelling.

Energy and comfort

The two aspects of energy and comfort are very closely related, and has continuously been integrated throughout the design process. This is reflected in the final design solution on urban scale by the orientation of the dwellings, the connection of them in rows and the distancing between them, which allows for sufficient light for each single dwelling. Further, the overall composition of connecting the commercial and residential functions is beneficial energy-wise for both functions.

On building scale the aim for a low energy-consumption of the dwellings is balanced by providing a good indoor climate for the occupants, thereby increasing the quality of life in the dwellings. Since occupant behaviour is considered a key factor in the resulting indoor climate of the dwellings and thereby the energy consumption, there is focused on providing a general good indoor climate, which can easily be adjusted by the occupants, rather than on minimising the energy consumption to the lowest value possible. The idea is that if the indoor climate is good and there are good possibilities for influencing and easily adjusting this without complex electronical equipment, this will also reflect in a low energy consumption.

If, however, the occupants wish to lower their energy consumption further, there is good possibility for exploiting solar energy actively by placing solar cells or collectors on the roof or facades of the dwellings, which are oriented in a Southern direction. In this way, there is taken account for the autonomy and freedom of the single occupants.

Sustainability
Concerning sustainability, this has been one of the main departure points and motivation factors of the project. In this sense sustainability is more understood as an overall holistic design approach, which considers aspects related to social, environmental and economical sustainability, and conseuqnetly the aspect of sustainability is reflected in the final design solution, both on a social, environmental and economical level.

Socially by implementing the principles of the villaroad and the gradual transitions, which results in social relations and affiliation to the place as well as exchange between different user groups of the place. Environmentally by the preoccupation with energy and comfort and considerations for minimising use of resources in general. This, moreover, forms part of the fundamental basis of the project and the aim of investigating how the qualitites of the detached single-family house can be combined with a more dense and urban physical context; since the dense and urban lifestyle is considered to be more beneficial for minimising the use of resources than that of the detached single-family house. Economically the final design solution considers sustainability in the mix of functions which can benefit from each other, the minimising of resources and in the mix of dwelling typologies which increases the possibility of different types of ownership.

Contemporary lifestyle
Concerning contemporary lifestyle, this is taken into account in the final design solution by considering people's need and search for safety and fixed reference points because of the breaking up of traditions in society. This need is seen expressed in the popularity of the detached single-family house, why the final design solution has implemented aspects taken from this. Furthermore, the provision of a traditional image of a house and the respect for the individual dweller's possibility to express his or her personal identity with the single dwelling is taken into account. However, this is balanced with an overall expression and identity of the total composition, as the individual dwelling should also be expressed as a part of a totality, a commmunity, thereby establishing a relationship with the surroundings instead of an expression of the dwelling as being lost and lonely.

The detached single-family house
As mentioned above there is taken account of aspects related to the detached single-family house in the final design solution. Like the implementation of aspects related to sustainability, this is likewise one of the main departure points and motivation factors of the project. The investigations of the detached single-family are derived from the interest in the theme of home and dwelling, as an expression of the most preferred housing typology in Denmark.

However, the aim has not been to design a detached single-family house, but on the contrary to show that the qualities enhanced in this housing typology is not necessarily related to the actual typology, but can be applied in a more dense and sustainable context. Consequently the characteristics are broken down into spatial principles which have formed part of the basis for the design process. These are related to the aspects of home-making as derived from the investigations of home and dwelling, and evolve around the feeling of autonomy, freedom, privacy and sense of territory as well as the possibility for displaying one's identity and differ from the rest, while maintaining a sense of community and neighbourhood and of sharing the same values as the neighbours. In this way the resulting design solution maintains the qualitites of the detached single-family house, but applied in a more dense and urban context which reflects in the developed dwelling typologies. The question whether or not it is succeeded will be discussed further in the reflections on pp. xx.

Home and dwelling
Finally the aspect of home and dwelling has been the overall main starting point and motivation factor of the project. The investigations of the dialectic between the home and the house has resulted in the formulation of seven aspects, which try to encapsulate the essence of developing a home-feeling. This has formed the main basis for the design process, why the continuous integration of theses aspects into the design has resulted in a final design solution with optimal conditions for the home-making of the single occupant, having taken all aspects related to this into consideration.

The need of safety and shelter is reflected in the pitched roof used for all three dwelling typologies and in the organisation of the dwellings in smaller clusters, thereby establishing the opportunity for closer social relations in a smaller community within the big community.

Movements are implemented in the sense of the villaroad and the gradual transitions from public to private, which emphasises the movements towards the occupants.

As previously mentioned the aspect of autonomy and freedom has also been implemented in relation to the detached single-family house and contemporary lifestyle, and has resulted in the dwellings going all the way from parking garage to roof top instead of being placed on top of each other.

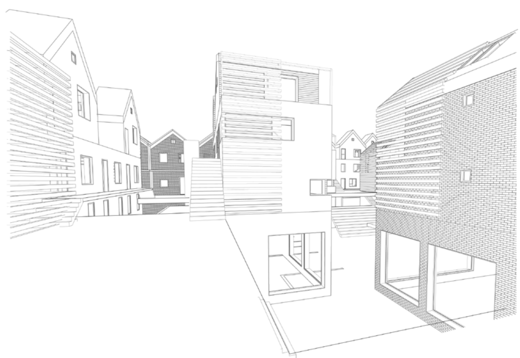
Privacy is obtained in the raising of the more private areas from ground floor. Both the communal outdoor area related to the single cluster, but also the private outdoor space related to each single dwelling.

The concern for neighbours and neighbourhood is also reflected in the clustering of the dwellings, as well as the arraying of the single dwelling typologies into small rows.

Rootedness is more difficult to obtain directly, but is considered implemented in the feeling of affiliation to the place. This is made possible in the general layout of the dwellings, thereby giving the opportunity to alter these to changing needs over a lifetime. Furthermore, there is the possibility of changing to a different dwelling more suitable for changing needs within the frame of the overall urban scheme, and even within the single cluster, thereby preserving the affiliation to the place.

Finally the aspect of embracing images, symbols and emotions of the dwellers is partly obtained through the design of the single dwelling as an image of a traditional house with a pitched roof. Likwise, the provision of a basement and an attic is considered a main point in relation to this as well as the affiliation to the place.

Concludingly, the aspect of time and the gradual adaption to the house is a key element in the home-making of the single occupants. Consequently a home can literally not be designed, why the dwellings of this project allow for the occupants to influence on the interior organisation as well as the exterior expression of the dwellings - to a certain degree - as part of the process of dwelling.



REFLECTIONS

In continuation of the conclusions drawn in the previous chapter, there is reflected upon the main themes and problematics of this project.

The motivation for the project has been to investigate architectural solutions for dwellings which combine the positive values and aspects from the most preferred housing typology in Denmark - the detached single-family house - with a more contemporary and sustainable way of life in a dense urban area – to re-invent the detached single-family house in a sustainable, urban context. This has been due to the conception of life in a detached single-family house as being a non-sustainable way of living, both in terms of social, environmental and economical sustainability.

The house as the frame for individual home-making

First of all, it is not necessarily sustainable to live densely in the city. There is a limit to density, especially in a Danish context, where the heat gain from passive solar energy is crucial for lowering the energy consumption, and thereby minimising use of resources. Second of all, in terms of social sustainability, this seems to be very much related to the aspects found important in relation to home-making (see analysis, pp. xx). As mentioned in the analysis, these aspects are all found in the detached single-family house, but can be difficult to achieve in a dense urban context.

In this way, my personal conception of the detached single-family house has changed during the course of this project. The things people value in this housing typology are actually related to the aspects of home-making and of feeling home, and seen in this perspective, the preference for a detached single-family house as the symbol of a "real" house and a safe and happy family life is fully understandable.

Common individuality

This further relates to late-modern lifestyle and the search for safety in a world where everything is for discussion and at choice and there are no longer any fixed values to navigate after. However, this hints at a major contradiction of the detached single-family house; on one hand there is a wish for displaying individual preferences, of marking one's territory and to differ from the rest, in order to feel valued. But on the other hand, there is also a wish to be part of a neighbourhood with common values and shared opinions on good taste. This common individuality reflects in the villaroads of typical standard single-family houses of the 70's and 60's, which are relative alike in the overall layout, but where each of them try to differ from the rest by all kinds of spectacular features.

This aspect is probably one of the main reasons why these neighbourhoods are disliked by professionals, myself included. But for a person, who grew up in such a neighbourhood this characteristic is a symbol of something known and consequently of safety.

Consequently, the preference for a detached single-family house is also related to up-bringing, where many of those, who move to a detached single-family house when they start a family, grew up in a such house themselves. This is maybe also part of the reason why many of those who would prefer to live in a detached single-family house will actually never do so. Through tradition this housing typology is considered the arhcetype of a real house and of "a good life" with good private economy and a happy family life.

The detached single-family house and sustainability

However, the detached single-family house does not correspond very well to present-day requirements concerning use of resources, where the goal is that all new buildings should be zero-energy standard by 2020. Nor is the detached single-family house economical sustainable, since it gives very little possibility of economic mobility and of mixing functions and benefitting from e.g. commercial functions.

Moreover, many of those who never move into a detached single. family house despite their preference for this, would prefer to live in an urban context with the variety and diversity this brings. Late-modern lifestyle implies an almost total freedom of choice, everything has become possible and attainable and even though there is a lack of tradition and fixed values, people are reluctant to give up upon this freedom.

Urban dwelling-scape

The main aim of this project has consequently been to show that it is possible to obtain the things valued in the detached single-family house in a different housing typology. Through own upbringing in a row-house with common facilities this goal seems realistic and within reach.

The architectural solution posed in this project is reached by breaking up the spatial principles of the the detached single-family house and combining them with a more urban context. These are defined by the villaroad and gradual transitions, where the urban aspects are defined by density and mix of functions.

The result is a small city of single-family houses, which all consider the aspects related to home-making of the single dweller as well as relates to the urban context of the harbour area in Aarhus. The villaroad has been broken up into a multiple of layers, which enable the gradual transition from public to private and thereby interaction between the different dwellers of the neighbourhood, as well as exchange between the flow of people of the public spaces and those of the more private spaces of the dwellings. In this way the dwellings are socially sustainable and related to the aspects of home-making of the occupants at the same time.

Moreover, the architectural solution respects the common individuality in the sense of an overall identity, which embeds varieties and the possibility for displaying personal preferences. In this sense, the final design actually resembles a typical villaroad, but in a more controlled manner with a stronger overall identity, and at the same time it has a distinct urban character with a typical layering of the commercial and residential functions; an urban dwelling-scape.

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- Brunsgaard, Camilla, Ph.D.-student, Architecture & Design, Aalborg University
- Entwistle, Johanne Mose, Anthropologist, Alexandra Institute
- Hauge, Bettina, Anthropologist, Copenhagen University

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Fujimoto, Sou, May 13th 2011

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Ill. 12a: http://www.topnews.in/files/Home-Loan3.jpg

Ill. 13a-b: Own illustrations

Ill. 14a:
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Ill. 15a Own illustration

Ill. 16a: http://www.tretres.dk/images/outside.jpg

Ill. 16b:
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Ill.17 a:
http://yndlingsbolig.files.wordpress.com/2010/12/slut-115.jpg
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Ill. 18a-19a Own illustrations

Ill. 20a: [Knudstrup, 2005]

Ill. 20b: Own illustration

Ill. 20c: [Knudstrup, 2005]

Ill. 21a: [Topp, 2010]

Ill. 21b-29a: Own illustrations

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Ill. 31a: [Lawrence, 2001, p. 145]

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Ill. 37a:
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Ill. 38a: Own illustration based on
http://www.pacificalumni.org/s/749/images/editor/Benefits%20Photos/Career%20Image1.jpg

Ill. 39a: http://www.getentrepreneurial.com/images/career.jpg

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Ill. 44a-45b: Own illustrations

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Ill. 48a: http://bb-j.dk/wp-content/uploads/2011/01/komforthusene.jpg

Ill. 48b:
http://www.mnshi.umn.edu/images/case/KingspanLighthouse.jpg

Ill. 48c: http://www.bolius.dk/typo3temp/pics/42ad3d7e53.jpg

Ill. 49a:
http://farm3.static.flickr.com/2757/4068340423_b6ab1be53c.jpg

Ill. 50a-50c: Own illustrations

Ill. 51a: Own illustration based on [energiforumdanmark.dk]

Il. 51b: Own illustration based on [Jensen, 2006][Brunsgaard, 2010][rockwool.dk, b]

Ill. 51c-51d: Own illustration based on [rockwool.dk, b]

Ill. 52a: Own illustration

Ill. 53a: [DS474E, 1995, p.17]

Ill. 54a-56e: Own illustrations

Ill. 57a:
http://www.solarnavigator.net/images/sun_viewed_through_camera_lens.jpg

Ill.61 a:
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Ill. 66a-91b: Own illustrations

Ill. 85a: http://www.topnews.in/files/Home-Loan3.jpg

Ill. 85b: Rudolfsky, Bernard (1964) *Architecture without architects,* Academy Editions, London, p.54

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Own illustration
http://www.inhabitat.com/wp-content/uploads/editttower34.jpg
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Ill. 96a-131a: Own illustrations

Ill. 133a: Own illustrations and
http://farm3.static.flickr.com/2592/3690315018_3495c9c7b6_z.jpg?zz=1 (Boemerang-gebouw)

Ill. 133b-136a: Own illustrations

Ill. 137a: Own illustrations and
http://1.bp.blogspot.com/_7ufOi_DCJl4/TT3FyYCLt_I/AAAAAAAAABY/TjZS4prbb74/s1600/summerhouse2.jpg (Experimental summerhouse)

Ill. 138a-141c: Own illustrations

Ill. 142a:
http://cdn.archdaily.net/wp-content/uploads/2011/02/1297790724-spiral-house-exterior-664x1000.jpg

Ill. 142b:
http://cdn.archdaily.net/wp-content/uploads/2011/04/1302794847-3-200844pl456-667x1000.jpg

Ill. 142c-145b: Own illustrations

APPENDICES

APPENDICES

The appendices contain additional documentation of investigations, where the outcome have contributed to the process of developing the architectural design.

Appendix 1
Construction details

Appendix 2
Indoor climate and heat balance, Bsim

Appendix 3
Light indoor climate, Velux Daylight Visualizer

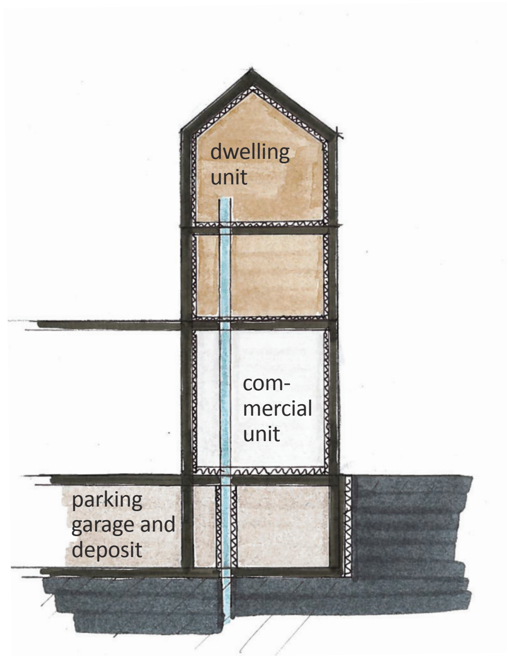
Appendix 3
Energy consumption, Be10

APPENDIX 1

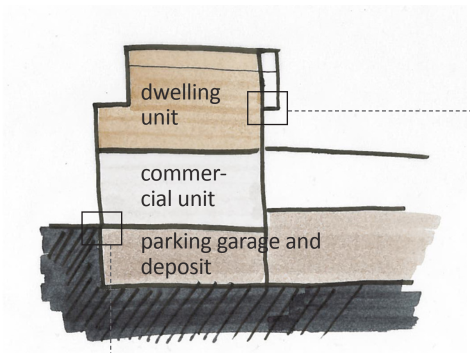
Construction details

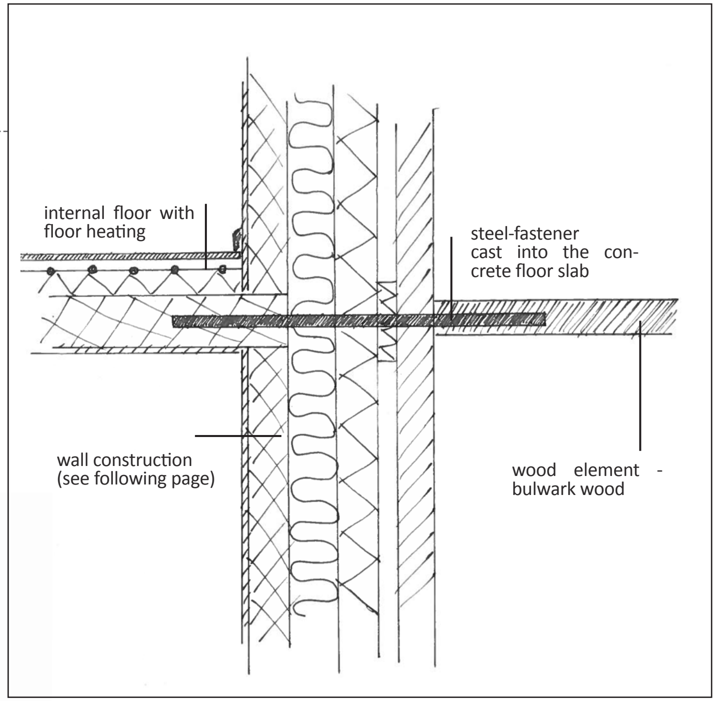
The specification of the construction parts used for the calculations in Bsim and Be10 is shown in the following. Further, there is shown construction details of the foundation where the parking garage meets the ground and the cantilevering of balconies from the holland-houses. Finally, there is shown how the installations are led to the single dwellings through the parking garage.

The structure of the construction parts is done by use of BuildDesk U, in order to make sure that the U-values required according to the energy calculations in Be10 are kept.

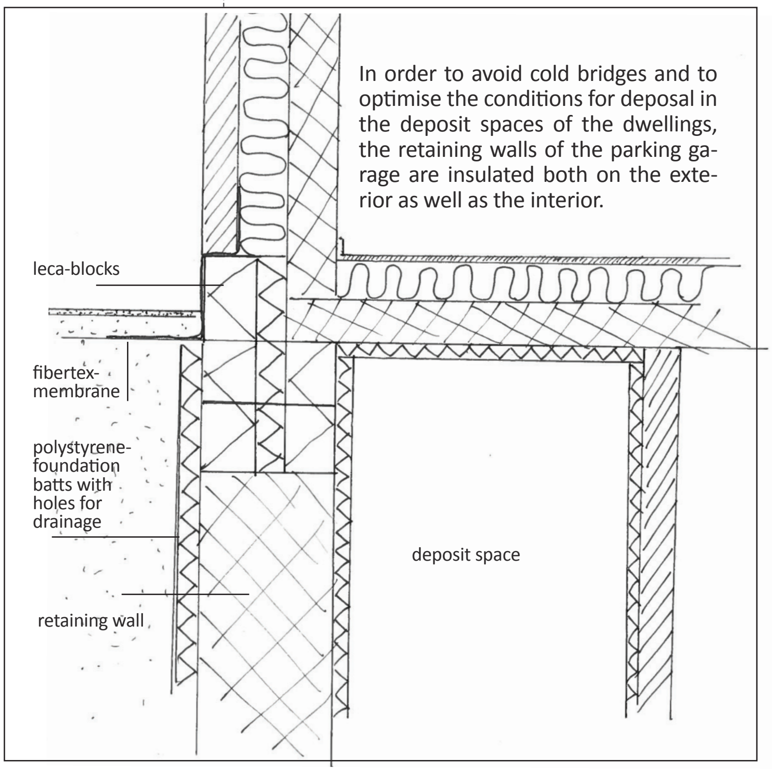


Since non of the dwellings are placed directly on the ground, all installations have to be led through the unheated parking garage, which will cause a heat loss from the installation pipes. In order to reduce this, the pipes are insulated. Also, the parking garage itself is insulated, since it is going to be used for deposit space as well as parking. Moreover, the installations are led through a layer of commercial functiones, before they reach the dwellings, which will further minimise the heat loss. Consequently, the resulting heat loss from leading the installations through the parking garage will be minimal.



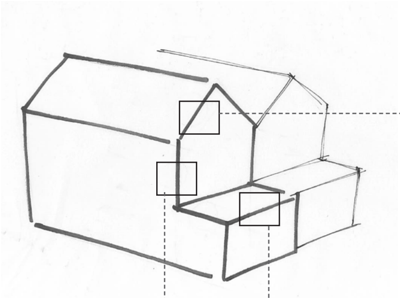


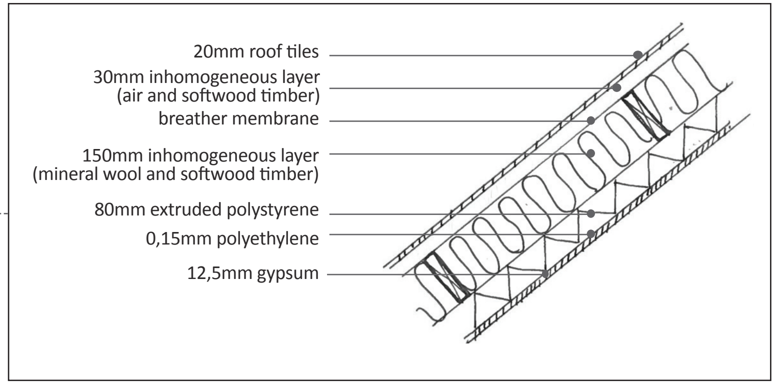
In order to avoid cold bridges and to optimise the conditions for deposal in the deposit spaces of the dwellings, the retaining walls of the parking garage are insulated both on the exterior as well as the interior.



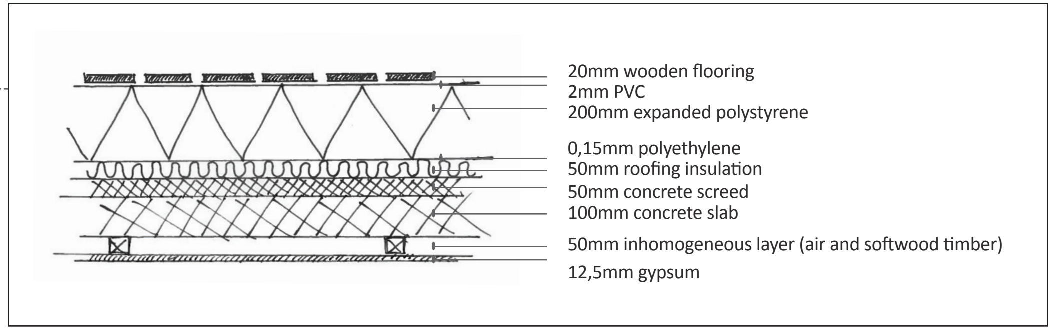
During the sketching process it is chosen to attach external balconies and shading elements directly to the load-bearing elements of the dwellings, instead of being carried by a secondary structure. In this way, the experience of the urban configuration as one overall structure, shaped by the dwellings, is enhanced.

The external balcony is made of wood from old bulwarks, which is well fitted for the rough environment at the harbourfront. Moreover, this will make it possible to construct the element in hardwood, which will simplify the construction, as well as minimise cold-bridges since the steel-element used for fastening of the balcony can be fastened directly into the wood, which has a very low transmission value.

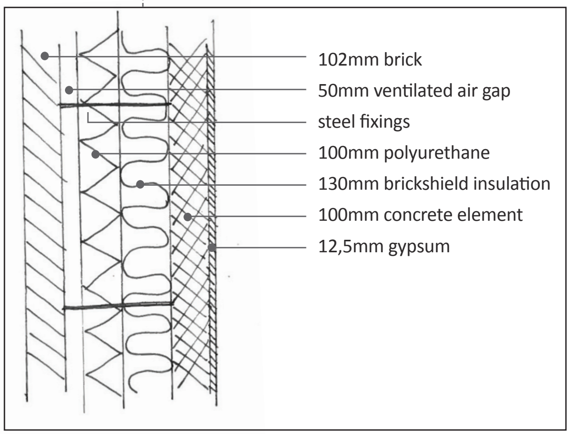




Pitched roof
(40°)
total thickness:
292,8mm
U-value: 0,15



Flat roof
total thickness: 464,7mm
U-value: 0,15



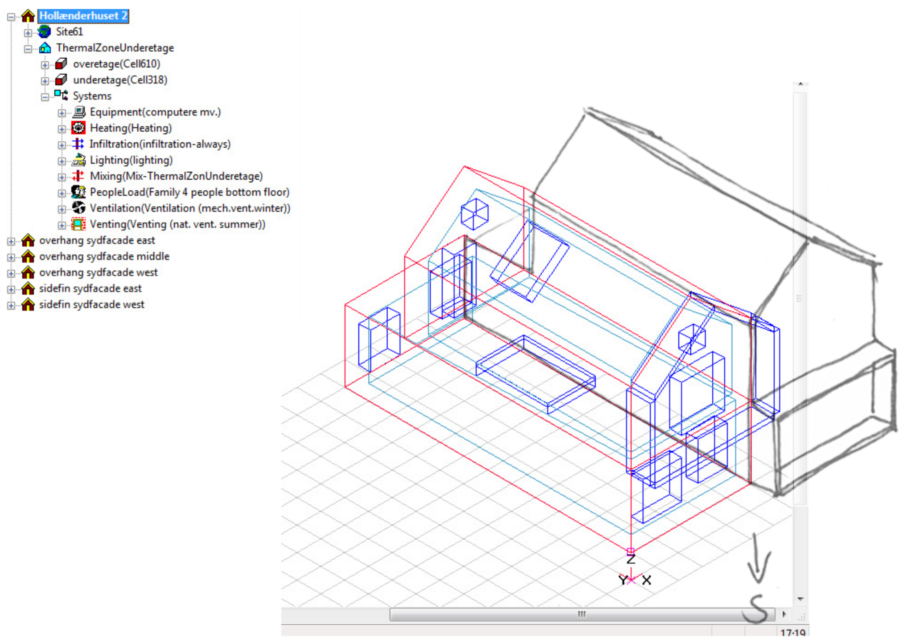
External walls
total thickness: 495mm
U-value: 0,14

APPENDIX 2

Indoor climate and heat balance, Bsim

There has been done simulations in Bsim in order to evaluate and document the thermal and atmospheric indoor climate as well as the heat balance of the holland-house typology. In the following the systems used are explained as well as the resulting heat balance of the geometry.

The simulations are done for a worst case scenario, meaning a dwelling which is only connected to an adjacent dwelling at one of the sides (towards NorthEast).



Schematic overview of systems used in Bsim-model

Systems	Description Heat losses		Schedules Regulation	Time
Ventilation (mech. vent., winter)	input: supply: 0,051m3/s pressure rise: 360Pa total eff.: 0,9 part to air: 1 output: return: 0,051m3/s pressure rise: 200Pa total eff.: 0,9 part to air: 0	recovery unit: max heat rec.: 0,65 min heat rec.: 0 max cool rec.: 0,65 max moist rec.: 0 heating coil: max power: 25kW cooling coil: max power: 0kW surf. temp.: 5 degrees air source: outdoor	return air control: min. supply ratio: 0,05 min return ratio: 0 max return ratio: 1 setpoint CO2: 1000ppm setpoint humid: 0 setpoint dehumid: 0 min. inlet temp.: 18° max inlet temp.: 20° setpoint temp.: 21°	winter (Oct.-Mar.): always
Venting (nat. vent., summer)	basic air change: 2h(-1) TmpFactor: 23,0473(/h/K) TmpPower: 0,5 WindFactor: 0,2(s/m/h) max air change: 3h(-1) (active for all wind speeds) sensor zone: current		setpoint: 24,5 degrees setpoint CO2: 1000ppm factor: 1	summer (Apr.-Sep.): always
Mixing (between upper and lower floor)	air flow: 0,051m3/s		factor: 1 temp.limit: 26° temp.diff.: 0° min. outdoor: -15° (should always be active)	always
Infiltration	basic air change: 0,1356 h(-1) temp.factor. 0 temp. power: 0 wind factor: 0		weekdays: 0-7am 50% 7am-6pm 30% 6-24pm 70% weekends: 0am-12pm 50%	weekdays: all day weekends: all day

<table>
<tr><th rowspan="2">Systems</th><th rowspan="2">Description
Heat gains</th><th colspan="2">Schedules</th></tr>
<tr><th>Regulation</th><th>Time</th></tr>
<tr><td>People</td><td>family with 4 people
heat generation: 0,121kW
moist generation: 0,123kg/h</td><td>0-7am 70%
7-8am 100%
8am-6pm 50%
6-9pm 100%
9-24pm 70%</td><td>always</td></tr>
<tr><td>Lighting</td><td>task lighting: 0,001 kW
(is not regulated)
general lighting: 0,15kW
general lighting level: 300lux
light type: fluorescent (LED-lights)
solar limit: 0,15kW
exhaust part: 0</td><td>light regulation:
factor: 1
lower limit: 0,1kW
max temp.: 24°
solar limit: 0kW

daylight regulation:
desired light level: 300lux
switch off: 0%
control form: continuous</td><td>always</td></tr>
<tr><td>Equipment</td><td>1 PC, 1 TV (flatscreen)
and kitchen appliances
heat load: 0,211 kW
part to air: 0,7</td><td>weekdays:
100% performance
6-7am, 5-6pm and 8-10pm
weekends:
100% performance
7-9am, 5-6pm and 8-11pm</td><td>weekdays:
6-7am, 5-12pm
weekends:
always</td></tr>
<tr><td>Heating</td><td>max power: 5 kW
fixed part: 0
part to air: 0,7</td><td>heat/cool control
(radiator heating):
factor: 1
set point: 21°
design temp.: -12°
min power: 5kW
min exterior temp.: 17°

floorheat control
(floor heating):
factor: 1
set point: 20°
max surface temp.: 25°
design temp.: -12°
min power: 1kW
min exterior temp.: 17°</td><td>always

winter
(Oct.-Apr.):
all days</td></tr>
</table>

Heat balance

The table on the following page show the resulting heat balance for the holland-house over the year. The first column shows the total sum for the whole year, where the rest of the columns show the values for each month. The values show that the requirements for the indoor climate are met. The table also shows how and when the different systems work. Also, several systems are not in use at all, as e.g. cooling.

Concerning over temperatures, these only occur during the three summer months, where the occupants are more tolerant because of the higher outdoor temperatures in general. In this period, the heating is not used (qHeating).

It is seen that ventilation is only used during Winter (defined as the period from November - April) whereas venting is only applied during Summer (May - October).

The infiltration and transmission losses are higher during Winter, as there is a bigger temperature and pressure difference between outdoor and indoor during this period. Also, there is a bigger sun radiation during Summer with a higher mean operative temperature as a consequence. On the contrary, there is an almost equal people and equipment load over the year.

Concerning the energy, there is only used heat recovery during Winter, since it is only applied in relation to the mechanical ventilation.

Important for the results is the automatic control of the external window shading, the ventilation, heating, lighting and venting. This means that the systems automatically turn on and off in order to constantly uphold a satisfying indoor climate.

In order to evaluate the predicted calculated energy consumption in Be10, the values of the heat balance of the Bsim-simulation are used for calculating the actual energy consumption of the building in use.

Heating

HtCoil	517,42 kWh
qHeating	1998,89 kWh

Total

2516,31 kWh

Total primary energy, heating

(2516,31 kWh x 0,8 =)

2013,048 kWh

Electricity

FanPow	68,05 kWh
qEquipment	351,95 kWh
Lighting	662,83 kWh

Total

1082,83 kWh

Total primary energy, electricity

(1082,83 kWh x 2,5 =)

2707,075 kWh

Total energy consumption

(2013,048 kWh + 2707,075 kWh =)

4720,123

Energy consumption per m2 per year

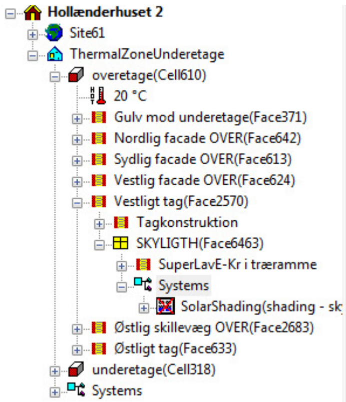
(4720,123 kWh/105,5m² =)

44,74 kWh/m² year

The final heat balance over the year of the holland-house.

		January	February	March	April	May	June	July	August	September	October	November	December
ThermalZon	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	1998,39	456,61	381,02	257,27	89,52	0,37	0,00	0,00	0,00	0,93	175,85	230,09	406,73
qCooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
qInfiltration	-693,98	-87,57	-81,09	-79,30	-63,33	-48,11	-35,94	-31,69	-32,45	-41,99	-49,15	-63,69	-79,68
qVenting	-1643,51	0,00	0,00	0,00	0,00	-236,86	-316,72	-355,61	-337,60	-191,70	-205,02	0,00	0,00
qSunRad	2305,33	63,43	108,42	185,56	257,26	322,85	313,03	310,98	285,91	212,32	129,56	73,62	42,39
qPeople	2402,58	204,05	184,31	204,05	197,47	204,05	197,47	204,05	204,05	197,47	204,05	197,47	204,05
qEquipment	351,95	29,54	27,01	30,38	28,70	29,54	29,54	29,54	29,96	29,12	29,54	29,12	29,96
qLighting	662,83	55,81	44,45	43,55	35,63	56,60	49,23	51,69	58,25	69,17	89,04	52,09	57,32
qTransmissic	-5169,68	-682,73	-628,15	-606,52	-507,73	-328,04	-236,55	-208,97	-208,10	-274,75	-372,62	-490,42	-625,11
qMixing	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
qVentilation	-210,60	-39,14	-35,74	-34,39	-37,43	0,00	0,00	0,00	0,00	0,00	0,00	-28,26	-35,64
Sum	3,30	0,01	0,23	0,61	0,08	0,41	0,06	-0,00	0,04	0,57	1,26	0,03	0,01
tOutdoor me	7,7	-0,5	-1,0	1,7	5,6	11,3	15,0	16,4	16,2	12,5	9,1	4,8	1,5
tOp mean	22,3	20,9	21,0	21,0	21,7	23,3	24,4	24,5	24,4	23,3	21,2	21,0	20,9
AirChange/h	1,3	1,1	1,1	1,1	1,1	1,3	1,7	2,0	1,9	1,2	1,1	1,1	1,1
Rel. Moistur	47,9	38,9	36,7	39,8	44,0	48,4	53,4	56,4	54,4	58,9	54,8	49,0	40,0
Co2(ppm)	917,6	994,9	994,9	994,8	994,8	935,4	760,0	684,7	706,5	955,3	1000,7	994,8	994,8
PAQ	0,2	0,4	0,5	0,4	0,3	0,2	0,0	-0,0	0,0	0,0	0,2	0,3	0,4
Hours > 21	4673	5	35	139	428	743	720	744	744	718	290	95	12
Hours > 26	64	0	0	0	0	0	21	24	19	0	0	0	0
Hours > 27	8	0	0	0	0	0	3	0	5	0	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	68,05	11,66	10,54	11,66	11,25	0,00	0,00	0,00	0,00	0,00	0,00	11,27	11,66
HtRec	1202,34	234,14	214,63	206,00	161,56	0,00	0,00	0,00	0,00	0,00	0,00	171,90	214,11
ClRec	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HtCoil	517,42	102,03	96,00	92,56	63,90	0,00	0,00	0,00	0,00	0,00	0,00	71,71	91,22
ClCoil	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Humidif	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
FloorHeat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
FloorCool	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HeatPump	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HeatPumpE	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

The heat balance over the year of the holland-house when removing all exterior shading. As the amount of hours with overtemperatures does not exceed the maximum allowed amount in the building regulations, this does not have a very big impact on the indoor climate. Consequently the final design of the facades does not include shutters. However, the single dwellers does still have the possibility to apply such, if wanted.



ThermalZon	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating	2065,71	472,90	391,35	266,70	94,99	0,05	0,00	0,00	0,00	0,43	169,51	245,90	423,88
qCooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
qInfiltration	-693,80	-87,53	-81,04	-79,20	-62,73	-48,55	-35,98	-31,67	-32,45	-42,24	-49,21	-63,56	-79,62
qVenting	-1714,94	0,00	0,00	0,00	0,00	-243,61	-337,81	-375,51	-354,67	-198,41	-204,93	0,00	0,00
qSunRad	2400,10	64,97	111,47	191,55	268,01	338,54	328,60	326,09	298,75	219,82	133,35	75,44	43,50
qPeople	2402,58	204,05	184,31	204,05	197,47	204,05	197,47	204,05	204,05	197,47	204,05	197,47	204,05
qEquipment	351,95	29,54	27,01	30,38	28,70	29,54	29,54	29,54	29,96	29,12	29,54	29,12	29,96
qLighting	658,28	55,40	44,26	43,07	35,55	55,89	49,01	51,25	58,09	68,69	88,06	51,86	57,16
qTransmissi	-5129,05	-681,47	-625,24	-602,69	-491,84	-335,51	-230,77	-203,71	-203,69	-274,38	-369,04	-487,54	-623,18
qMixing	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
qVentilation	-337,46	-57,87	-51,88	-53,24	-70,05	0,00	0,00	0,00	0,00	0,00	0,00	-48,65	-55,77
Sum	3,37	-0,00	0,23	0,63	0,09	0,40	0,06	0,04	0,05	0,50	1,33	0,04	0,00
tOutdoor me	7,7	-0,5	-1,0	1,7	5,6	11,3	15,0	16,4	16,2	12,5	9,1	4,8	1,5
tOp mean	22,3	20,9	20,9	21,0	21,6	23,4	24,4	24,5	24,4	23,4	21,2	21,0	20,9
AirChange/I	1,5	1,4	1,4	1,4	1,4	1,3	1,8	2,0	1,9	1,2	1,1	1,4	1,4
Rel. Moistur	44,0	31,4	29,4	32,4	36,9	47,8	53,0	56,1	54,1	58,5	54,8	41,5	32,6
Co2(ppm)	774,8	717,1	721,9	721,9	718,1	928,1	744,2	670,9	692,6	949,4	1003,9	715,7	714,0
PAQ	0,3	0,5	0,6	0,5	0,4	0,2	0,0	-0,0	0,0	0,0	0,2	0,4	0,5
Hours > 21	4646	5	32	128	410	744	720	744	744	720	334	61	4
Hours > 26	72	0	0	0	0	0	25	25	22	0	0	0	0
Hours > 27	13	0	0	0	0	0	7	0	6	0	0	0	0
Hours < 20	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	129,77	22,21	19,85	21,95	21,55	0,00	0,00	0,00	0,00	0,00	0,00	21,72	22,49
HtRec	2441,90	477,75	432,68	414,54	324,00	0,00	0,00	0,00	0,00	0,00	0,00	352,30	440,63
ClRec	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HtCoil	884,78	179,15	167,72	158,22	102,50	0,00	0,00	0,00	0,00	0,00	0,00	119,07	158,12
ClCoil	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Humidif	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
FloorHeat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
FloorCool	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HeatPump	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HeatPumpE	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

APPENDIX 3

Light indoor climate, Velux Daylight Visualizer

The final investigations with Velux Daylight Visualizer are used to verify the light indoor climate of the design solution verified by Bsim and Be10. However, as the placement, size and shading of the openings showed to not have a very big impact on the energy consumption or indoor climate in the final investigations with Bsim and Be10, the design of the facades as showed in the presentation material is an interpretation of this solution verified in Velux Daylight Visualizer.

The investigations are done on an overall basis for the whole volume of the holland house without a separating floor slab and furniture. Consequently, the actual daylight level will be reduced why there is aimed for a higher value than the minimum required daylight factor of 2% in the building regulations (BR10).

The final solution gives a daylight factor of ca. 3,7% in the middle of the room at 800mm above the floor. The dispersion of the daylight factor over the floor section shows, however, that the daylight factor gets up to 12% at the openings in the facade. In order to avoid the risk of glare from a too big contrast caused by very big openings, the openings are not made bigger and the daylight

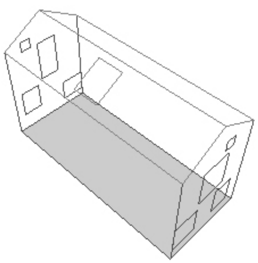
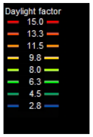
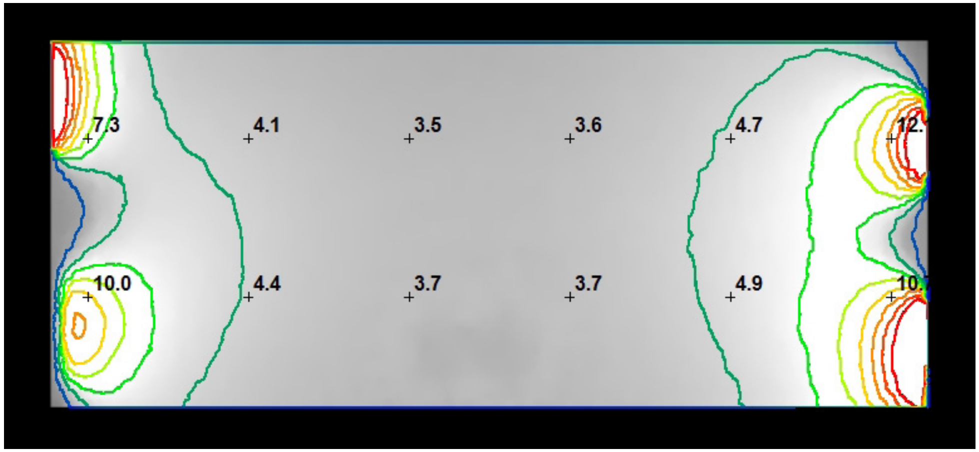
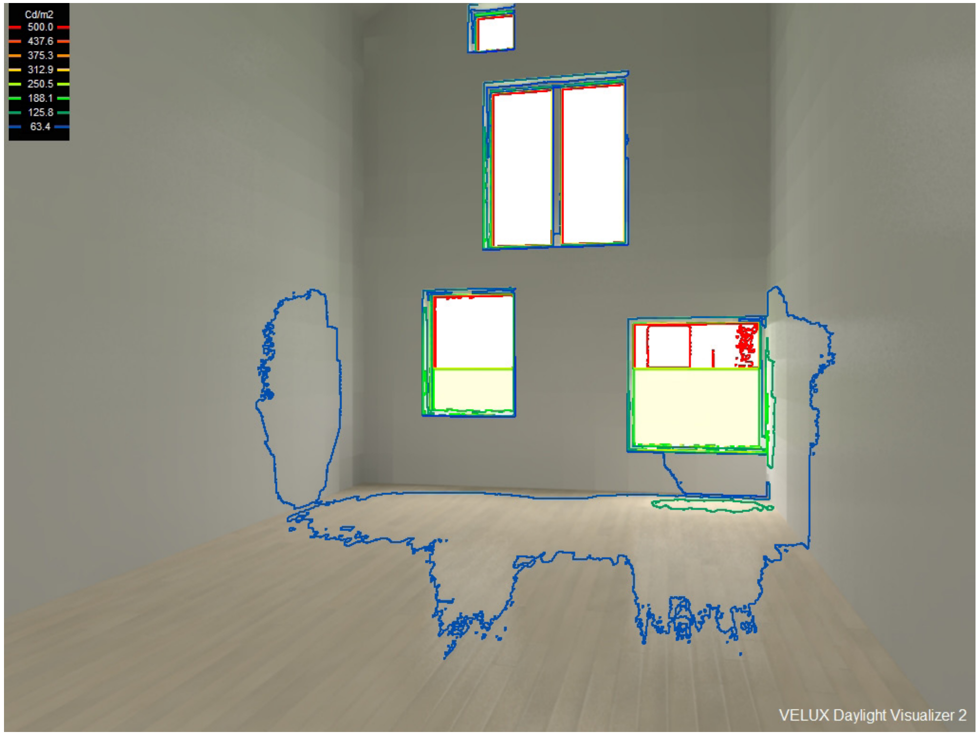


Illustration of the geometry analysed in the Velux Daylight Visualizer





Dispersion of the daylight factor at 800mm above floor level (ground floor). This shows a relatively even gradient of distribution of the daylight from the facades to the middle of the room.



The perspective image shows the luminance level in the room, which is an expression of the experienced light level. Inside the room, this is relatively even and well distributed, but there is a quite big difference between the luminance level inside and outside. Consequently, the openings are not made bigger in order to avoid the risk of glare from a too big contrast between outside and inside.

APPENDIX 4

Energy consumption, Be10

For the evaluation of the energy consumption during the process and the final specification of this there is used Be10, which is required to do for all new building projects in Denmark. As previsouly mentioned, there is aimed for a 2015-standard (see pp. xx.). The program calculates the predicted primary energy consumption on the basis of monthly average values and general values for e.g. internal gains as defined in the Danish Building Regulations (BR10). This is to be able to compare the calculations for different projects and apply an energy-standard. Consequently this value is a predicted primary energy consumption, which does not necessarily reflect the actual energy consumption of the single dwelling in use.

The Be10-calculation is done for a unit consisting of two holland-houses, which is considered the worst case scenario. The resulting predicted primary energy consumption is shown in the “Key numbers”-table in Be10 (see table to the right).

Key numbers, kWh/m² year

Energy frame in BR 2010

Without supplement	Supplement for special conditions	Total energy frame
68,1	0,0	68,1
Total energy requirement		39,4

Energy frame low energy buildings 2015

Without supplement	Supplement for special conditions	Total energy frame
39,5	0,0	39,5
Total energy requirement		33,0

Contribution to energy requirement		Net requirement	
Heat	31,9	Room heating	14,6
El. for operation of bulding	3,0 *2,5	Domestic hot water	15,0
Excessive in rooms	0,0	Cooling	0,0

Selected electricity requirements		Heat loss from installations	
Lighting	0,0	Room heating	1,9
Heating of rooms	0,0	Domestic hot water	2,9
Heating of DHW	0,0		
Heat pump	0,0	**Output from special sources**	
Ventilators	2,3	Solar heat	0,0
Pumps	0,5	Heat pump	0,0
Cooling	0,0	Solar cells	0,0
Total el. consumption	33,7	Wind mills	0,0

The 2015-requirement is 30 + (1000/gross area) kWh/m² annually, which is 39,5kWh/m² annually for this case. From 2015 electricity counts a factor 2,5, while district heating only counts a factor 0,8, why there is a difference in the value for the 2010- and 2015-requirements.

The “Key numbers”-table show, that one holland-house in a unit with two dwellings has a predicted primary energy consumption of 33kWh/m² annually and consequently meets the 2015-requirements. Moreover, there is no energy requirement for removal of excessive heat in rooms, which means that there are no overtemperatures.

If the specific dwellers wish to reach a zero-energy standard, this is attainable by actively exploiting solar energy by use of solar cells or solar panels. These can be placed on the roofs of the dwellings, which are orientated and sloped almost optimally for making use of solar gain.

2 holland-houses	
The building	
Building type	Nondetached house
Number of residential units for non-detached houses	2
Rotation	0,0 deg
Area of heated floor	211,0 m²
Heat capacity	100,0 Wh/K m²
Normal usage time	168 hours/week
Usage time, start at - end at, time	0 - 24
Calculation rules	
Calculation rules	Certification
Heat supply and cooling	
Basic heat supply	District heating
Electric panels	No
Wood stoves, gas radiators etc.	No
Solar heating plant	No
Heat pumps	No
Solar cells	No
Wind mills	No
Mechanical cooling	No

The 45° rotation of the dwellings is applied in the orientation of the openings.

Load-bearing walls and floor slabs in concrete.

With outdoor-temperature compensation.

Room temperatures, set points	
Heating	20,0 °C
Wanted	23,0 °C
Natural ventilation	24,0 °C
Mechanical cooling	25,0 °C
Heating store	15,0 °C

See detailing of construction parts on pp. xx.

Dimensioning temperatures	
Room temp.	20,0 °C
Outdoor temp.	-12,0 °C
Room temp. store	15,0 °C

External walls, roofs and floors

Building component	Area (m²)	U (W/m²K)	b	Dim.Inside (C)	Dim.Outside (C)
Loft: 220 mm isolering, lambda 0,15 W/m² K	153,6	0,15	1,000		
Terrændæk med gulvvarme (0,39 m fundament)	0,0	0,11	1,000	30	10
Ydervæg (155 m² brutto): 290 mm	284,0	0,14	1,000		
isol. 0,14 W/m² K					
loft ved balkon: 0,15W/m² K	25,0	0,15	1,000		
Ialt	462,6	-	-	-	-

Foundations etc.

Building component	l (m)	Loss (W/mK)	b	Dim.Inside (C)	Dim.Outside (C)
Ydervægsfundamenter	0,0	0,12	1,300	30	
Samling omkring vinduer og døre	128,8	0,02	1,000		
Ialt	128,8	-	-	-	-

Windows and outer doors												
Building component	Number	Orient	Inclination	Area (m²)	U (W/m²K)	b	Ff (-)	g (-)	Shading	Fc (-)	Dim.Inside (C)	Dim.Outside (C)
Vindue, lille øverst	2	nv	90,0	0,4	0,80	1,000	0,80	0,40	1. sal, nord (vindue)	- 0,70		
terrassedø, balkon	2	nv	90,0	3,0	0,80	1,000	0,80	0,40	1. sal, nord (terrassedør-parti)	- 0,70		
glasparti, stue	2	nv	90,0	2,0	0,80	1,000	0,80	0,40	stueetage, nord (vindue)	- 0,30		
vindue, stue	2	nv	90,0	1,9	0,80	1,000	0,80	0,40	stueetage, nord (vindue)	- 0,70		
vindue, lille øverst	2	sø	90,0	0,4	0,90	1,000	0,80	0,40	1. sal, syd	- 0,70		
glasparti stue	2	sø	90,0	2,6	0,90	1,000	0,80	0,40	stueetage, syd (terrassedør-parti)	- 0,30		
vindue, stue	2	sø	90,0	1,9	0,90	1,000	0,80	0,40	stueetage, syd (vindue)	- 0,70		
terrassedøre, øverst	4	sø	90,0	2,1	0,90	1,000	0,80	0,40	1. sal, syd	- 0,30		
SKYLIGHT 3,0x3,0	2	nø	30,0	3,0	0,80	1,000	0,80	0,40	afskærmning skylight	- 0,10		
vestlig facade	2	sv	90,0	0,4	0,80	1,000	0,80	0,40		0,70		
østlig facade	2	sø	90,0	0,4	0,80	1,000	0,80	0,40		0,70		
Ialt	24	-	-	39,9	-	-	-	-	-	-	-	-

Shading					
Description	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening (%)
1. sal, syd	15	22	22	22	10
stueetage, syd (terrassedør-parti)	15	53	13	18	10
stueetage, syd (vindue)	15	34	27	10	10
1. sal, nord (terrassedør-parti)	15	22	55	38	10
1. sal, nord (vindue)	15	22	32	68	10
stueetage, nord (fordør)	15	39	34	64	10
afskærmning skylight	15	85	6	6	10
stueetage, nord (vindue)	15	12	0	0	10

Ventilation													
Zone	Area (m²)	Fo, -	qm (l/s m²), Winter	n vgv (-)	ti (° C)	El-HC	qn (l/s m²), Winter	qi,n (l/s m²), Winter	SEL (kJ/m³)	qm,s (l/s m²), Summer	qn,s (l/s m²), Summer	qm,n (l/s m²), Night	qn,n (l/s m²), Night
Hele huset	211,0	1,00	0,48	0,90	18,0	No	0,00	0,00	0,7	0,00	0,90	0,00	0,00

Internal heat supply				
Zone	Area (m²)	Persons (W/m²)	App. (W/m²)	App,night (W/m²)
Hele huset	211	1,5	3,5	0,0

Lighting											
Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)
Hele huset	211,0	0,0	0,0	300	3,00	A	1,00	0,0	0,0	0,0	0,0

Heat distribution plant

Composition and temperature		
Supply pipe temperature	70,0 °C	
Return pipe temperature	30,0 °C	
Type of plant	2-string	Anlægstype

Pumps				
Pump type	Description	Number	Pnom	Fp
Constant service all year		1	0,0 W	0,00
Constant service during heating season	konstant i opvarmningssæson	1	50,0 W	0,50
Time-controlled service during heating season	tidskontrolleret pumpe i opvarmningssæson	0	60,0 W	0,60
Combi-pump (const. during heating season)	Behovsstyret pumpe	0	60,0 W	0,40

Heating pipes					
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b	Outdoor comp (J/N)	Unused summer (J/N)
heat loss from installations through parking garage	6,0	0,40	0,800	J	N

[Danfoss Redan, 2011]

Domestic hot water	
Description	Beholder med varmespiral
Hot-water consumption, average for the building	230,0 litre/year per m² of floor area
Domestic hot water temp.	55,0 °C

Hot-water tank	
Description	VBV Beholder
Number of hot-water containers	2,0
Tank volume	110,0 liter
Supply temperature from central heating	70,0 °C
El. heating of DHW	No
Solar heat tank with heating coil	No
Heat loss from hot-water tank	1,0 W/K
Temp. factor for setup room	0,0

Charging pump	
Effect	0,0 W
Controled	Yes
Charge effect	6,0 kW

Heat loss from connector pipe to DHW tank			
Length	Loss	b	Description
0,0 m	0,2 W/K	0,00	Varmerør 3/4"
0,0 m	0,0 W/K	0,00	

Cirkulating pump for DHW	
Description	PumpCirc
Number	0,0
Effect	0,0 W
Number	0,0
Effect	0,0 W
Reduction factor	1,00 W
El. tracing of discharge water pipe	No

Domestic hot water discharge pipes			
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b

District heat exchanger	
Description	Ny fjernvarmeveksler
Nominal effect	5,0 kW
Heat loss	1,0 W/K
DHW heating through exchanger	No
Exchanger temperature, min	0,0 °C
Temp. factor for setup room	0,00
Automatics, stand-by	4,0 W

Heat pumps		
Description		Ny varmepumpe
Type		Combined
Share of heating requirement		1,0
El. driven heat pump		
-	Room heating	DHW
Nominal effect	5,0 kW	0,8 kW
Nominal COP	3,20	2,20
Rel. COP at 50% load	0,80	0,00
Test temperatures		
-	Room heating	DHW
Cold side	7,0 °C	20,0 °C
Warm side	45,0 °C	50,0 °C
Type		
-	Room heating	DHW
Cold side	Outdoor air	Venting
Warm side	Heating plant	-
Additional		
-	Room heating	DHW
Special auxiliary tool	0,0 W	0,0 W
Automatics, stand-by	6,0 W	0,0 W
Heat pumps connected with ventilation		
-	Room heating	DHW
Temp. Efficiency for HRV before heat pump	0,00	0,00
Dim. air supply temperature	21,0 °C	-
Air flow requirement	0,00 m³/s	0,09 m³/s