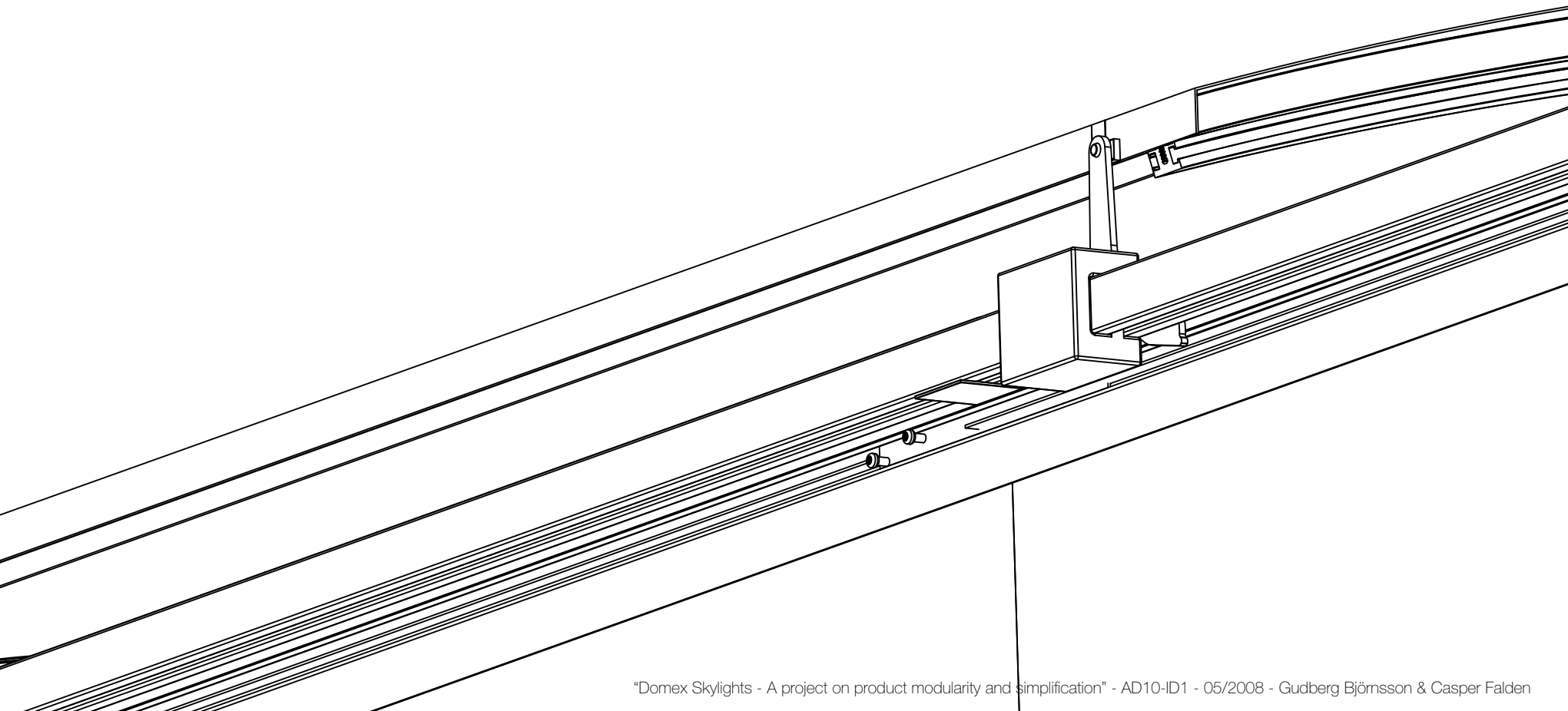
Domex Skylights

- A project on modularity and simplification



Aalborg University
Architecture & Design
Industrial Design
4th Semester MA

Theme

Product Design

Title

Domex Skylights - A project on product modularity and simplification

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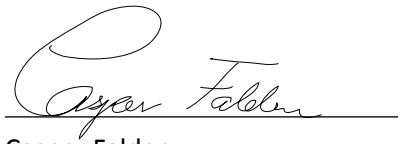

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Summary

This project concerns the development of a new skylight window with integrated fire ventilation devised in collaboration with Domex Skylights A/S.

The development of the new skylight takes its underlying basis in problem areas defined by the company management, the production personnel and mounting crews as well as issues experienced by the design team through analysis and observations.

Through the development of the skylight the focus is modularity and simplification with special attention on production, assembly and mounting along with a strategic and methodical approach to enhance or create identified market selling points in the design proposal.

The outcome is the vaulted fire ventilation skylight Contego – offering a modular and aesthetically clean design proposal for a next generation skylight solution that can be utilized both as fire ventilation skylight and fire ventilation light row.

Project Objective

In this thesis project the project group wants to demonstrate and strengthen a selection of competences obtained through earlier semesters. A high focus will be given to detail design and the design development regarding production, assembly and mounting will be applied to a higher degree than on earlier semesters.

The project thus focuses on bringing manufacturing, function and aesthetics together as a whole along with strategic decision making. The group feels that this is most optimally demonstrated, challenged and elaborated on in collaboration with a company - presenting a concrete and real design challenge where details, assembly and production are key areas in the design task.

The project is devised in collaboration with Domex Skylights A/S.

Reading Guidance

The project is presented as two main parts; a process report called “Domex Skylights - A project on product modularity and simplification” and a brochure called “Contego by Domex”. The brochure is meant as presentation material to Domex Skylights A/S. For a complete understanding of the underlying process of the project, the process report should be read before the brochure.

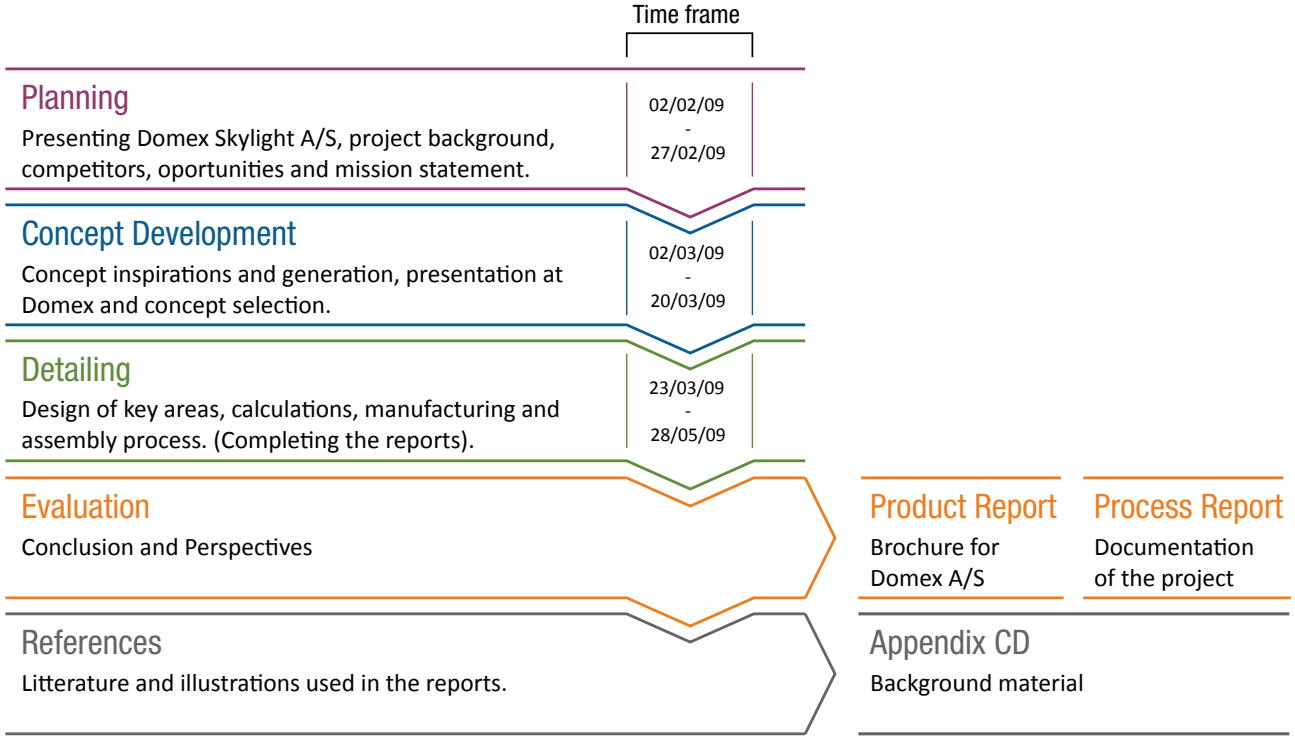
The process report is divided into five main parts where the three parts containing the design process will take inspiration in Karl T. Ulrich and Steven D. Eppinger product development process in “Product Design and Development” (Ulrich and Eppinger, 2003, p.9). Furthermore a separate CD is enclosed including Appendix with background material. (ill. 1.1.).

At the end of each of the three design phases in the process report, a chapter with reflections on process, methods and learning will sum up the learning of each phase.

In the reports the collaborator Domex Skylights A/S will be referred to as Domex, Domex A/S or Domex Skylights A/S. No names on employees at Domex will be mentioned in the reports on the request from the CEO at Domex.

Furthermore the Harvard method of reference will be used throughout the process report, and references from the campaign brochure will be listed in the process report.

On the opposite side a combined time schedule and phase diagram can be seen.



ill. 1.1 - An overview of the reports structure and segmentation into phases.

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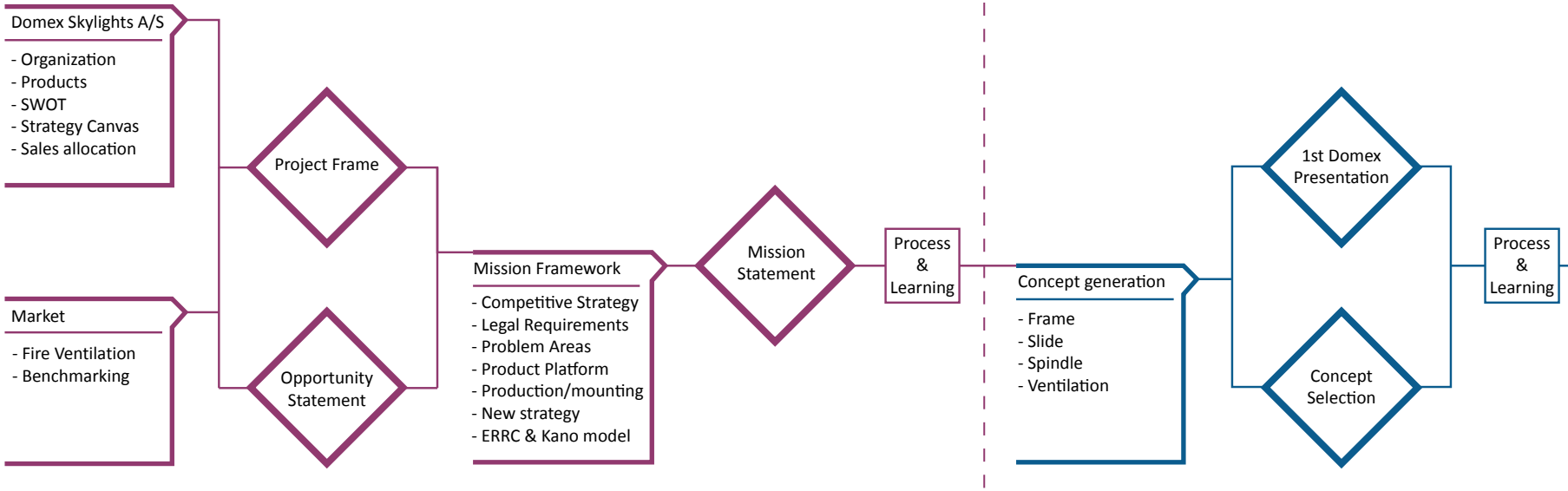
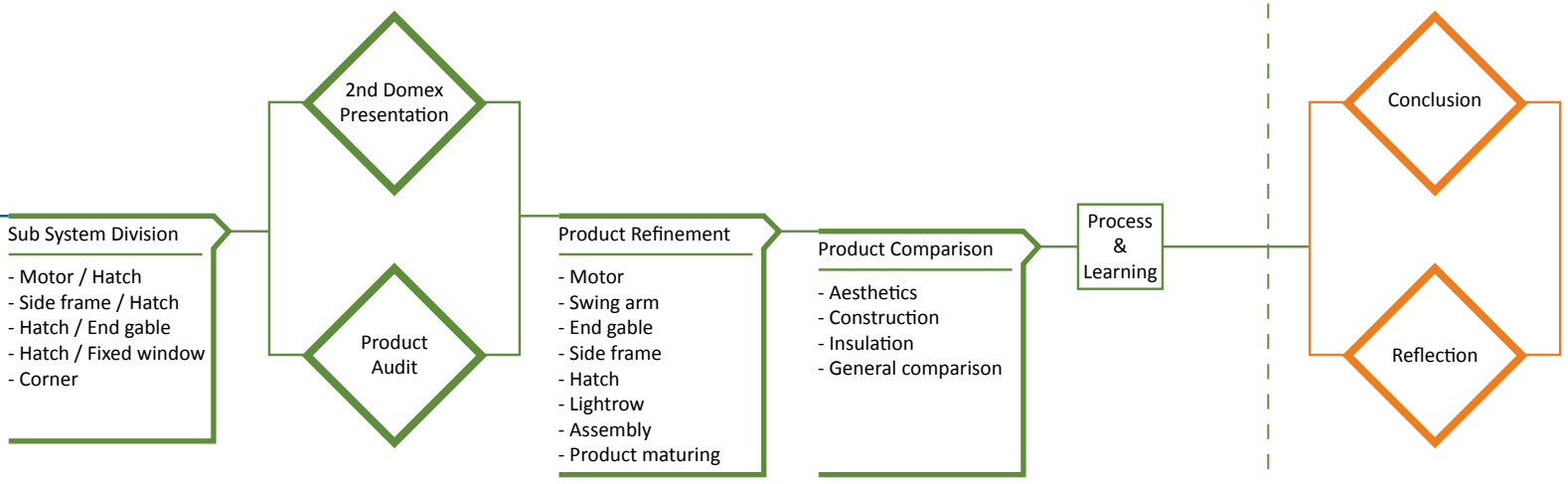
Planning

Concept Development



Detailing

Evaluation



Planning

In the Planning phase Domex Skylights A/S and their products are presented. Strategy, market objectives, competing market and product opportunities are investigated, resulting in a mission statement.

Methods

- Interviews
- Meetings
- Strategy canvas
- Benchmarking
- SWOT Analysis
- ERRC Grid
- Registration
- Competitive strategy
- Product platform
- Product/Process matrix
- Kano Model

Domex Skylights A/S

Project collaborator

Domex Skylights A/S – the selected collaborator for this thesis project - is a producer of skylights and fire ventilation skylights targeted at the industrial market in Denmark.

Domex is a part of an umbrella organization named Winther Holding A/S along with Green House A/S and Hydro-Nail A/S. (ill. 1.2.)

The companies operate in the construction industry with independent brands and are autonomous except regarding marketing and economy which is managed by Winther Holding A/S. Furthermore Hydronail A/S is a supplier of wood to both Green House A/S and Domex A/S.

In illustration 1.3. key information about Domex A/S is presented in short.

ill. 1.2. - Diagram of the umbrella organization Winther Holding A/S and the underlying companies.

DOMEX

OVENLYS A/S

Profile

Location

Kongerslev, North Jutland

History

Startup in 2003.
Producer of PC and acrylic skylights and fire ventilation skylights.

Currently market leader in fire ventilation skylights for industry buildings.

Market

Market

Denmark

Customers

Roof contractors

ICOPAL

Roof companies

Usage

Main usage

Storage buildings
Production facilities
Gyms
Large shops etc.

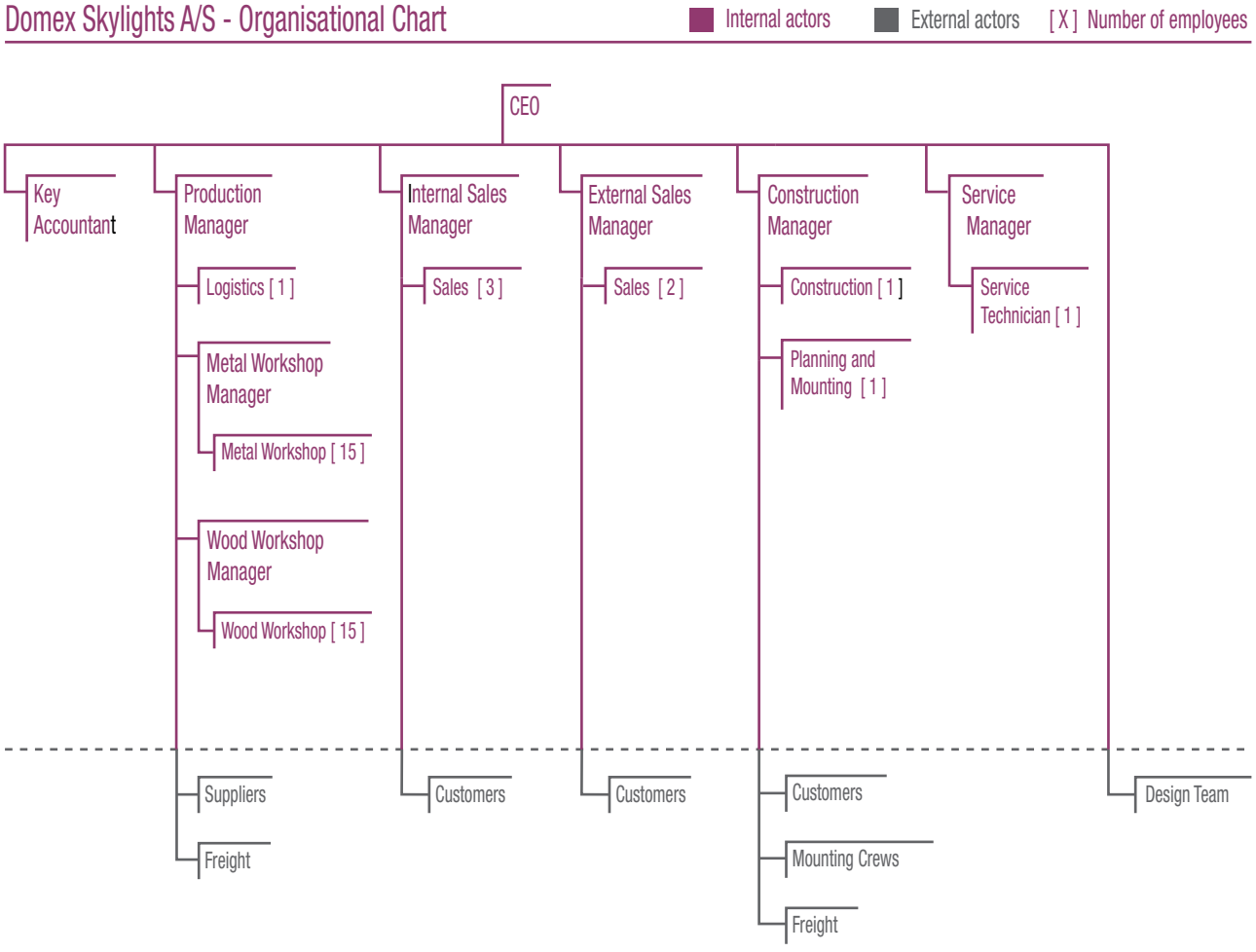
Company structure

Domex has 43 internal employees with roughly 2/3 in production and 1/3 in administration and sales. Other personnel are either external or positioned in the mother company Winther Holding A/S (ill. 1.4.).

Product portfolio

A selection of various skylight products from Domex can be seen in illustration 1.5. Later in the report a detailed presentation of selected products will be conducted.

ill. 1.3. - Key information about Domex Skylights A/S, their products, customer and market.



ill. 1.4 - The organisational chart of Domex and their connections to outside actors.

Note that the project team operates as external consultants on the same level as the managers of each sublevel within the company, with direct communication to each sub manager and the director of Domex – a set-up that that is possible because of the flat management structure used at Domex.

ill. 1.5 - A selection of various skylights in the current production at Domex.A/S.

Competitors

According to Domex their competitors are Lumex A/S, PrimaLux A/S, Optilite A/S and Unilite A/S. They are all Danish skylight producers operating in the professional market in Denmark, and they offer similar product solutions.

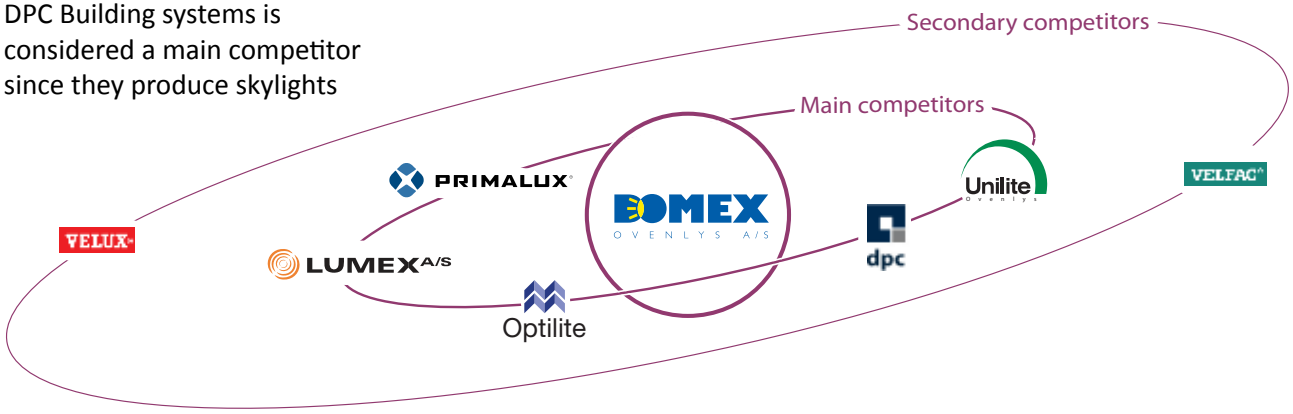
Beside the previous mentioned competitors, pointed out by Domex A/S, the project team considers DPC Building systems A/S, Velfac A/S and Velux A/S as possible competitors.

DPC Building systems is considered a main competitor since they produce skylights with fire ventilation and operate on the both the Danish and international market.

Velfac A/S and Velux are positioned as secondary competitors because they offer skylights on the Danish market – but not in the market for skylights with fire ventilation for industry buildings.

However the project group finds it appropriate to view these companies as secondary competitors because they offer skylight solutions on the Danish market - even though they are not in direct competition with Domex.

In illustration 1.6 an overview of the competitors is provided in relation to Domex as the market leader in fire ventilation skylights. Later in the report a comparison between a selected Domex product and the equivalent products from the main competitors will be conducted.

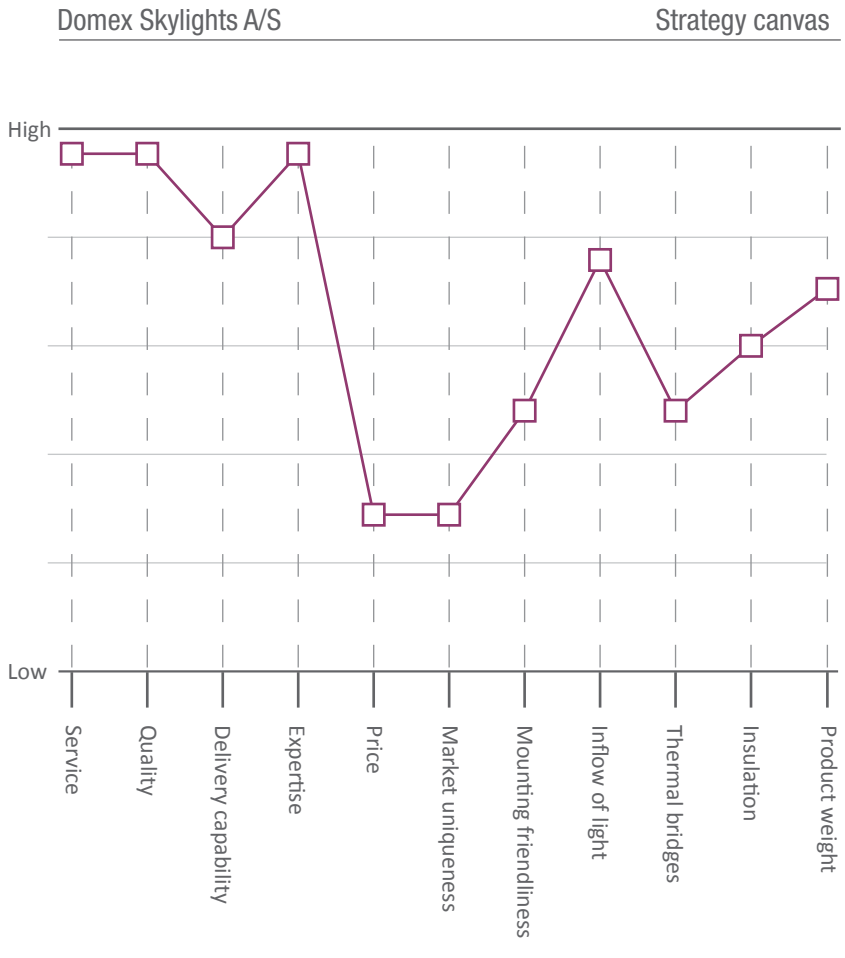


ill. 1.6. - Overview of Domex's competitors on the Danish market. The main competition is shown closest to te market leader - Domex A/S.

Current Strategy

At present time Domex Skylights A/S is primarily selling their products to entrepreneurs engaged in large scale constructions such as: Production/storage facilities, sports halls, shopping malls and other large shopping facilities.

To present the current strategy at Domex and their present approach to the market, a strategy canvas is created. The strategy canvas consists of certain factors that have been pointed out by the CEO of Domex as key selling points in the market.



ill. 1.7. - The current strategy at Domex A/S in relation to the key selling point within the market - defined by the CEO at Domex A/S.

The mapping in the strategy canvas represents how Domex is positioned in relation to these selling points and thereby also presents some of the parameters that can affect the development of a new product for Domex A/S.

The strategy canvas can be seen in ill. 1.7. The mapping of each value has been based on interviews with Domex and the external assessment of the project group.

Findings in strategy mapping

Based on the mapping of Domex, it is clear that Domex has a strong strategy in several areas – especially price, delivery time, service and quality.

However it also becomes clear that there are some areas where Domex can improve to offer even better products to their customers - this being in the areas of market uniqueness, thermal bridges, insulation and product weight.

These findings regarding the current strategy at Domex will operate as a background for a possible strategy change.

This possible change will be conducted upon the selection of which product from Domex' portfolio the project group will work with and a benchmarking of competing products to this product.

The strategy canvas will - along with a competitor benchmarking and a SWOT analysis - be used to pinpoint where Domex's strategy should change in relation to the current strategy canvas – both regarding themselves and their competitors.

Company Vision

Through the interviews with the employees and the CEO at Domex it is discovered that Domex has begun to formulate a vision for their skylight products based upon the fact that they have become market leader for fire ventilation skylights.

The vision is formulated in this way by the CEO at Domex – ill. 1.8.

Based on this information about the vision for Domex, the project group is interested in developing a product that can help open up for this vision to become reality.

In the following chapter the product portfolio of Domex is presented and the product that has the highest potential to help fulfill the vision will be selected as the starting point for the development of a new product.

ill. 1.8.

"The vision is to make Domex skylights the product of choice on the Danish market - regarding skylights and fire ventilation for roofs on industry buildings and private out-houses."

- CEO Domex Skylights A/S

Product Range

Domex' product portfolio consists of several different types of skylight with different possibilities for variation.

A scheme presenting the different skylights and their variations have been compiled (ill. 1.11.)

Special orders

Beside the standard skylights, Domex also does custom orders – either regarding special measurements on their standard windows or custom designed skylights for special projects.

This approach is taken for two reasons. For one, it is very common that some kind of adaptation of the standard windows must be performed to make the standard windows fit to a specific roof due to the construction of the building.

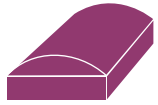
ill. 1.9. - An example of a custom order together with standard skylights.

Secondly Domex has the approach that they do not say no to a custom order (ill. 1.9. – 1.10.) – out of the philosophy that a custom order can generate business for their standard products, because the customer will feel inclined to choose Domex for the standard skylights as well.

Product details

Details regarding measurements, production and mounting will be presented later in the report, for the skylight type that will be selected as the offset for this project.

ill. 1.10. - A similar custum solution as the one seen in ill.

Variations / Skylight Type	 SINGLE (Pre assembled)	 LIGHTROW (On-site assembled)	 FIRE VENTILATION (Motor opening)	
 Vaulted	✓	✓	✓	
 Dome	✓		✓	
 Pyramid	✓		✓	
 Ridge	✓		✓	
 Plane	✓		✓	
 Northern	✓		✓	

ill. 1.11. - A n overview of the different types of skylights produced at Domex, and the possible variations of these.

	 Manual opening	 Fixed window	 Polycarbonate	 Acrylic	 Transparent	 Translucent	 Food industry
		✓	✓		✓	✓	
	✓	✓		✓	✓	✓	
	✓	✓		✓	✓	✓	
	✓	✓		✓	✓	✓	
		✓	✓		✓	✓	
		✓	✓		✓	✓	✓

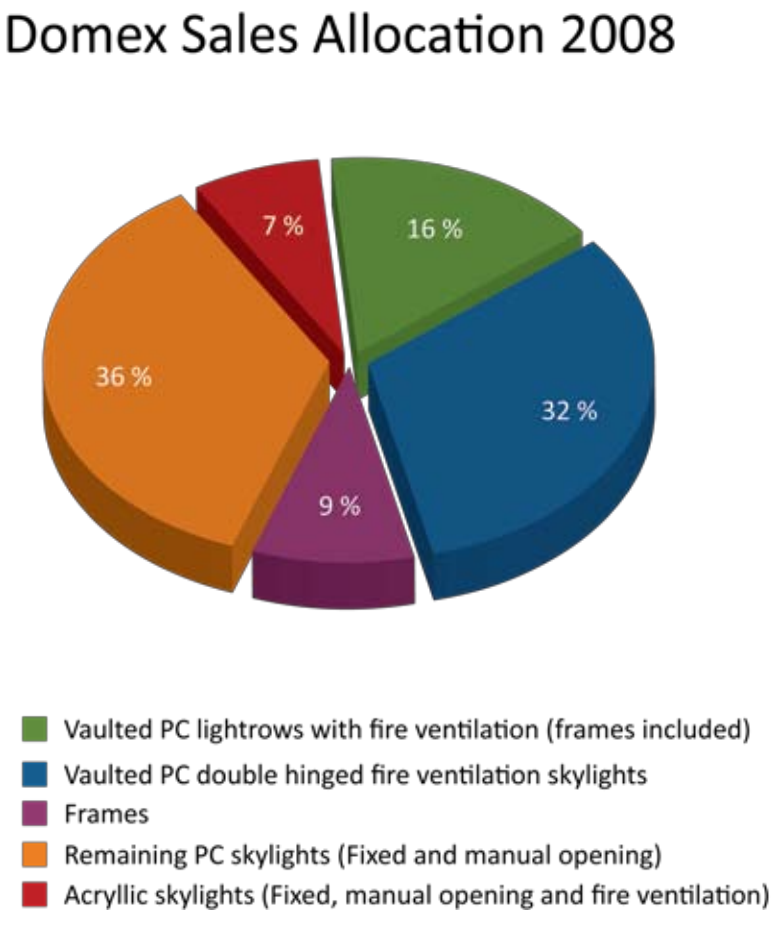
Sales allocation

As illustrated in the previous chapter, Domex offers a wide range of different skylights with a broad spectrum of possible variations.

To help determine where to focus the project between all the different products offered by Domex, the project group has investigated the current production at Domex in terms of sale. In illustration 1.12. the different skylight types are listed with a percentage of the total sales in 2008. (Appendix 0)

Main products

According to the CEO at Domex, it is the vaulted PC fire ventilation skylights and the vaulted PC light row with fire ventilation that have secured Domex' place as market leader in skylights for industry buildings. This is consistent



ill.1.12 - Domex sales allocation from 2008

with the percentage sales listed in ill. 1.12., showing that the combined sales of vaulted PC fire ventilation skylights makes up 55% of the total sales from Domex.

Project focus

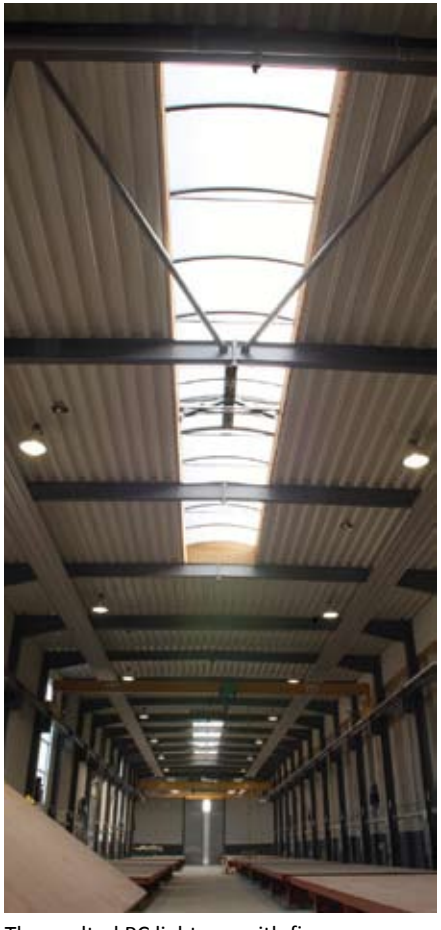
Based on the fact that it is the vaulted fire ventilation products that have secured Domex' position as market leader, and the fact that these skylights make up the majority of products being sold - these two products are selected as the point of origin for the project. The selected skylights can be seen in ill. 1.13 and 1.14.

In addition the arguments from the project group and Domex for selecting these skylights can be seen in illustration 1.15.

Vaulted PC skylight with fire ventilation - during opening sequence

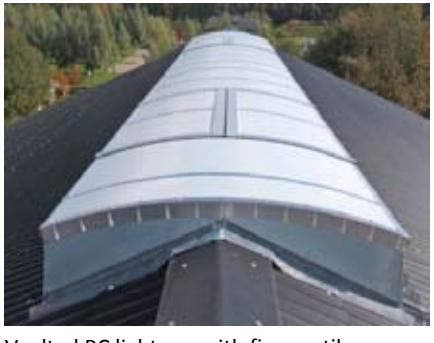
Vaulted PC skylight with fire ventilation

ill. 1.13. - The vaulted fire ventilation skylight - one of the Domex products selected as the starting point for the development of a new product for Domex.



The vaulted PC lightrow with fire ventilation seen from inside.

Vaulted PC lightrow with fire ventilation mounted on a flat felt roof.



Vaulted PC lightrow with fire ventilation mounted on a ridge tile roof.

A detail shot of the corner.

ill. 1.14. - The vaulted fire ventilation lightrow - the second Domex product selected as the starting point for the development of a new product for Domex.

Why work with the vaulted PC fire ventilation skylights?

Project group

- These leading products can be weak towards solutions by competitors if they are not improved continuously - a potential problem because these windows make of the majority of Domex' sales.
- These products have the highest potential to reach the vision within fire ventilation products
- The products within fire ventilation should continue to secure Domex' as market leader through even better products
- It is possible to address many of the weak areas in the current fire ventilation products by developing a new product from scratch. Thereby avoiding the running updates that have had a big impact on the design of the current skylight.

Domex

- Our primary part of sales and expertise are in fire ventilation skylights
- The best selling product in our product portfolio are the fire ventilation models - we would like to maintain that position through improvements
- There are many unsolved issues regarding weight, production, light passage, mounting, insulation, engine etc.. By solving some of the issues we can distance ourselves from the competition
- Insulation/thermal bridges must be improved because of upcoming legal requirements that demand better insulation/U-value. We would also like to offer a product that induces a better work environment regarding weight.

ill. 1.15. - The arguments for selecting to work with the vaulted fire ventilation skylights.

Fire ventilation

As the vaulted fire ventilation is the product in focus in this project it is following relevant to investigate the functionality of - and regulations for - fire ventilation skylights in Denmark.

In the following chapter the different regulations for fire ventilation skylights will be introduced along with a scenario for a fire in an industry building with fire ventilation skylights installed.

This is done to explain the different requirements of fire ventilation in industry buildings and the sequence regarding fire ventilation skylight when a fire starts in an industry building.

Fire Ventilation

To understand the reasons for installing fire ventilation in industry buildings and the legal requirements established for this, one must understand the benefits by installing fire ventilation (www3):

- The risk of built up heat and smoke igniting materials is reduced.
- Better visibility and thereby better work conditions for the fire fighters.
- The spreading of smoke is decreased.
- The temperature is lowered and thereby the spreading of the fire is decreased – diminishing the affect on the bearing structure.
- Dangerous smoke gasses are removed via the fire ventilation skylight.
- The risk of corrosion damage is reduced.

General legal requirements regarding opening modules of fire ventilation skylights
Reliability requirement to open/close cycles in opening module. 50 for fire ventilation only and 10.000 for fire/comfort ventilation. Plus annual function test.
Opening module must be fully functional with a load of 720 N/m^2
Opening module must be fully functional at a temperature of -5 °C
Opening module must in closed condition be able to withstand uplift of 1500 N/m^2
Opening module must be fully functional at a temperature of 300 °C for 30 minutes.
Materials used in the fire ventilation opening must at leat be Class E-d2 (www4)
Minimum opening area: 0,4m x 0,5-2,5m. Minimal frame height: 0,3m.
Max opening time 60 seconds (time from activation to window is fully open).

ill. 1.16. - Regulations for motors in fire ventilation skylights with Danish CE marking.

Requirements

Fire ventilation can be divided into two main categories – thermal ventilation and mechanical ventilation. Domex offers products in the category thermal ventilation.

Danish legal requirements specify that industry buildings above 200 m^2 must have CE certified fire ventilation installed.

A set of rules apply when fire ventilation skylights are to be CE certified. (ill. 1.16 and 1.17). Only certified test institutions can provide the CE certificate, which Domex receives from SP Technical Research Institute of Sweden (www1).

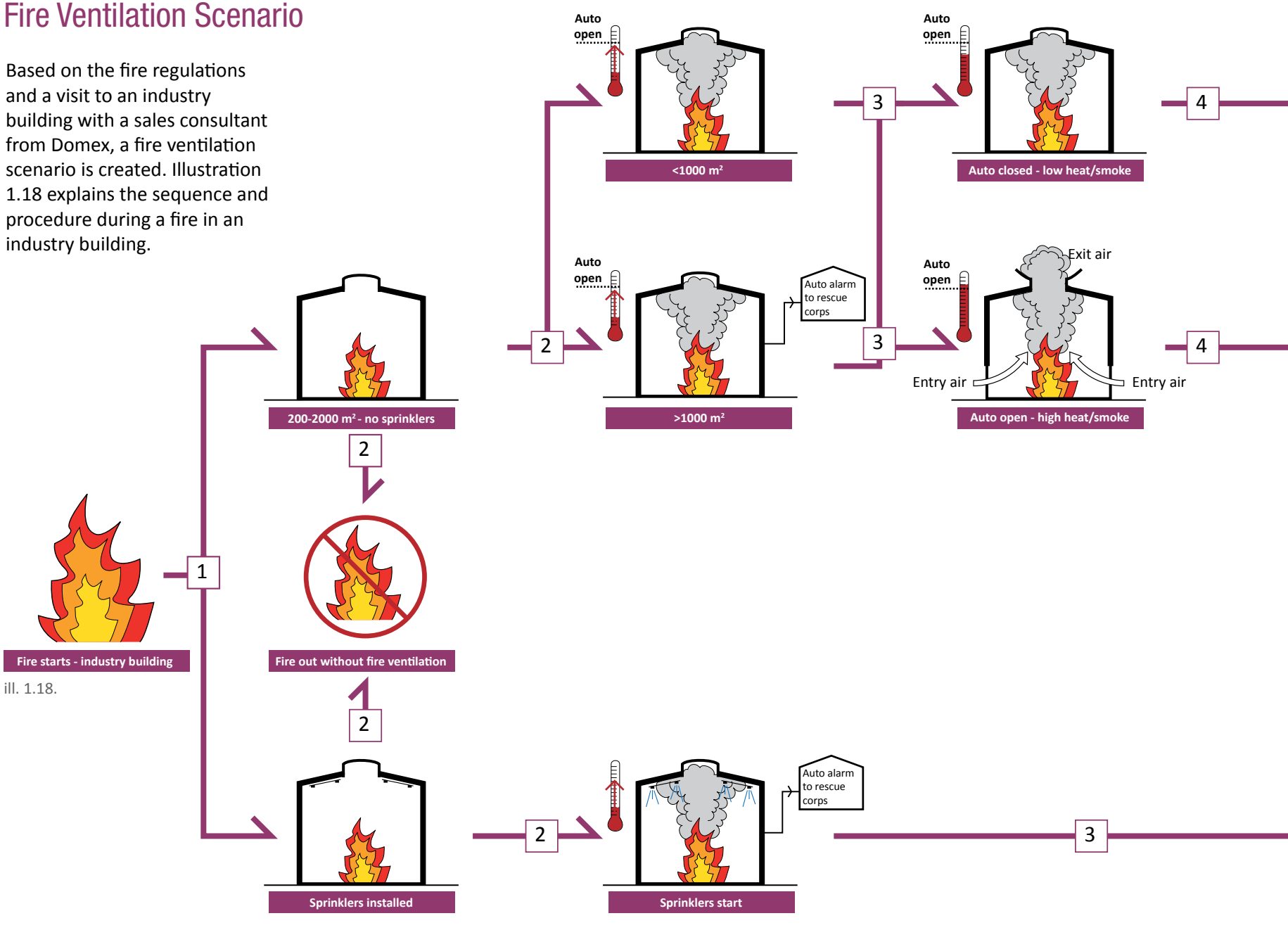
The detailed fire ventilation regulations in DK can be seen at www2 and www3.

	Fire section between 200 - 1000 m^2. Where fire ventialtion is installed to protect bearing construction	Fire section between 600 - 1000 m^2.	Fire section between 1000 - 2000 m^2.	Fire section with sprinklers.
Activation of the fire ventilation opening.	Automatic activation at smoke/heat detection. Possible to activate manually.	Automatic activation Possible to activate manually.	Automatic activation Possible to activate manually.	Only manual activation.
Alarm to the rescue corps.	No requirements for direct auto alarm to rescue corps.	No requirements for direct auto alarm to rescue corps.	Direct auto alarm to rescue corps required.	Direct auto alarm to rescue corps required.
Size of ventilation opening.	2% of floor area for up to 600 m^2. Otherwise 12 m^2 for production hall and 24 m^2 for warehouse and packaging.	12 m^2 for production hall only. 24 m^2 for warehouse and packaging hall.	12 m^2 for production hall only. 24 m^2 for warehouse and packaging hall. Also protection of bearing construction	0,5% of floor area.
Placement	Evenly distributed with a max space of 24m between openings. At 7° roof slope openings are to be placed as high as possible.	Evenly distributed with a max space of 24m between openings. At 7° roof slope openings are to be placed as high as possible.	Evenly distributed with a max space of 24m between openings. At 7° roof slope openings are to be placed as high as possible.	Evenly distributed with a max space of 40m between openings. At 7° roof slope openings are to be placed as high as possible.

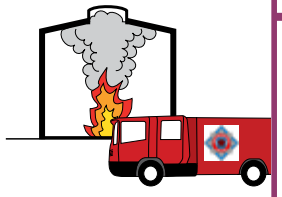
ill. 1.17. - General regulations for fire ventilation skylights installed in industry buildings in Denmark.

Fire Ventilation Scenario

Based on the fire regulations and a visit to an industry building with a sales consultant from Domex, a fire ventilation scenario is created. Illustration 1.18 explains the sequence and procedure during a fire in an industry building.



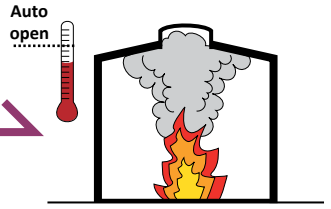
ill. 1.18.



The rescue corps arrives and analyzes the situation - amount of smoke, heat, sight and sprinkler effect.

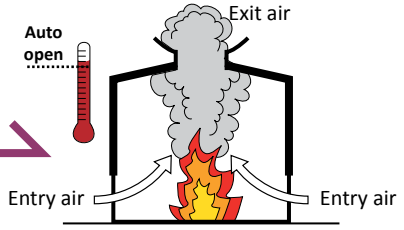
Fire fighters arrive at scene

5



Auto closed - low heat/smoke

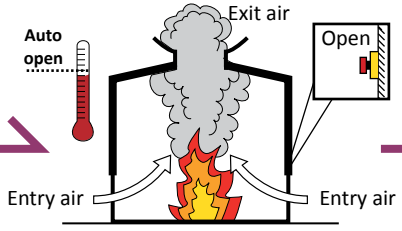
6



Auto open - high heat/smoke

7

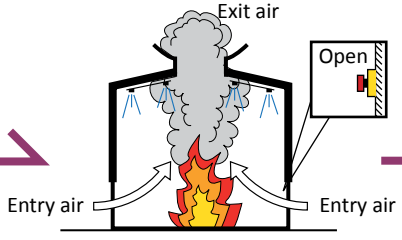
5



Manual open - fire fighters choice

Closed - fire fighters choice

5



Manual open - fire fighters choice

6

Fire under control

Benchmarking

Following the selection of starting point in terms of skylights and the investigations into fire regulations and fire scenarios, it is logical to investigate what the competitor's can provide of comparable products within fire ventilation.

The project group has contacted the main competitors, but they have not wished to participate with neither strategic information nor detailed information about their products – based on the collaboration between the project group and Domex A/S.

Due to this the project group has made the benchmarking based on what common information could be found on the fire ventilation skylights on the main competitors web pages – in particular fire ventilation products that are similar to the selected products from Domex.

Therefore the benchmarking consists of images of pre-assembled and on-site assembled fire ventilation skylights, possible sizes on the pre-assembled skylights and the U-value for the pre-assembled skylights.

The possible sizes for the on-site assembled will not be included due to the fact that the on-site assembled skylights come in all widths available in the pre-assembled skylight and with varying lengths.

The benchmarking can be found on the following pages with Domex as an introduction. Following the benchmarking is a recapitulation.

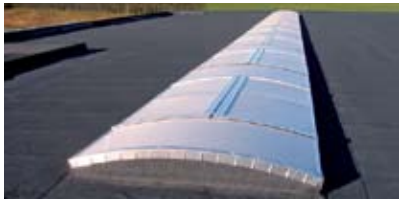
DOMEX
OVENLYS A/S

The pre-assembled skylight from Domex consists of three main parts; A flat wooden frame made of construction wood, a vaulted PC/aluminum window with an opening area and a motor placed crosswise in the middle of the window under the opening area.

The light row is based on the same principle but is built as a modular system due to the on-site assembly. (See more in “Production and Mounting”)

ill. 1.21 - Windows and frames for pre-assembled skylight ready for transport.

ill. 1.19 - Vaulted PC fire ventilation skylight from Domex.



ill. 1.20 - Vaulted PC light row with FV.

ill. 1.22 - Motor shown in light row.

Standard sizes (mm):

880 x 1930	1200 x 2400
1000 x 1000	1200 x 4800
1000 x 2000	2400 x 2400
1200 x 1200	2400 x 4800

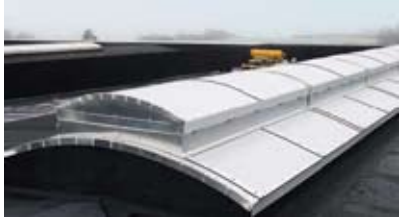
Special sizes made by order

U value: 1,8 W/m^{2}K

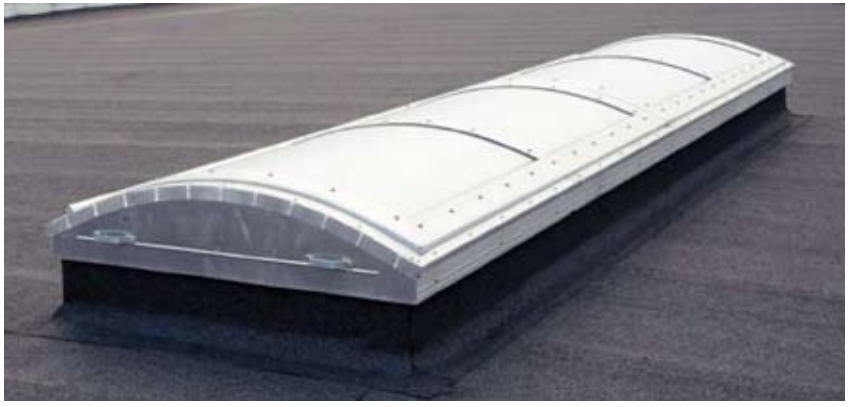
www.domexovenlys.dk

The comparable skylight from Unilite is very similar to Domex´s skylight as it has the same vaulted shape and a big motor visible from the inside. The main differentiator is that the skylight opens the entire window to one side instead of two part opening module.

The light row is based on the same opening principle but differs a lot in appearance from both the pre-assembled skylight from Unilite and the light row offered by Domex.



ill. 1.25 - Lightrow with fire ventilation from Unilite.



ill. 1.23 - Vaulted PC fire ventilation skylight from Unilite.

ill. 1.24 - Open, unmounted skylight.

ill. 1.26 - Light row shown from inside.

Standard sizes (mm):

880 x 1930	1200 x 2400
1000 x 1000	1200 x 4800
1000 x 2000	2400 x 2400
1200 x 1200	2400 x 4800

Special sizes made by order

U value 1,8 W/m^2K

www.unilite.dk

Optilite

Optilite offers a skylight that is very similar to Unilite in terms of construction and assembly. However Optilite installs the pre-assembled skylight in clusters of three with two fire ventilation skylights and one fixed skylight. This presents a different appearance in mounted condition – compared to Domex and Unilite.

The light row is based on the same opening principle and is practically identical to the light row offered by Unilite.

ill. 1.27 - Vaulted PC fire ventilation skylight from Optilite. Note the different measurements of the two types of windows in the cluster and the fact that the middle window has no motor.

ill. 1.28 - Open, unmounted skylight.

ill. 1.29 - Lightrow with fire ventilation from Optilite.

ill. 1.30 - Light row shown from inside.

Standard sizes (mm):

880 x 1930	1200 x 2400
1000 x 1000	2400 x 2400
1000 x 2000	
1200 x 1200	

Special sizes made by order

U value 1,8 W/m^2K

www.optilite.dk

PRIMALUX®

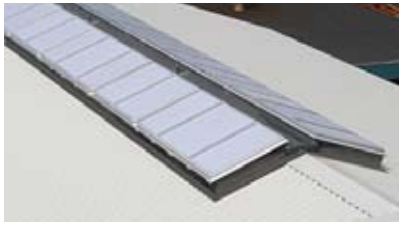
Primalux offers a plane skylight where two motors are placed at each end gable of the skylight – offering a cleaner look aesthetically. Apart from that the construction and assembly is very similar to the competitors products.

The light row is based on the same skylight simply placed up against each other in two separate rows. Primalux is however the only one of the competitors only offering light rows in pre-assembled modules.

ill. 1.31 - Plane PC skylight with fire ventilation from Primalux. On the right an open module from a light row is shown.

ill. 1.32 - A light row liftet into place.

ill. 1.33 - A light row close up from inside.



ill. 1.34 - Lightrow with fire ventilation from Primalux.

ill. 1.35 - Light row shown from inside.

Standard sizes (mm):

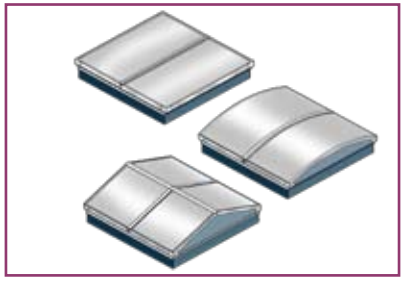
520-1800 x 520-2000
Special sizes made by order
U value 1,8 W/m^{2}K

www.primalux.dk

LUMEX A/S

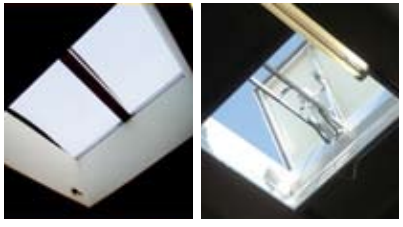
Lumex offers two types of fire ventilation skylights – a hinged type and a sliding type – where both types are offered in a flat, ridge and vaulted model. The sliding model offers a very clean aesthetical look from the inside compared to the hinged model.

The light row is based on the same skylights – again offering two types – a hinged type and a sliding type with the option of a flat, ridge and vaulted model.

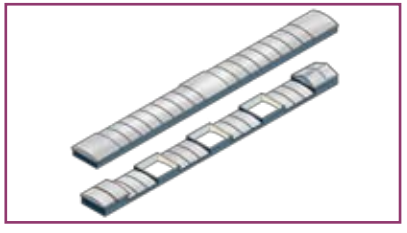


ill. 1.36 - The two types of pre-assembled skylights - A hinged model and a sliding model. The two types comes in Flat, Ridge and Vaulted.

ill. 1.37 - A open sliding light row.



ill. 1.38 - The two types of skylights shows from inside.



ill. 1.39 - The two types of light row. The upper: Hinged, and the lower: Sliding.

ill. 1.40 - Sliding light row from outside.

Standard sizes (mm):

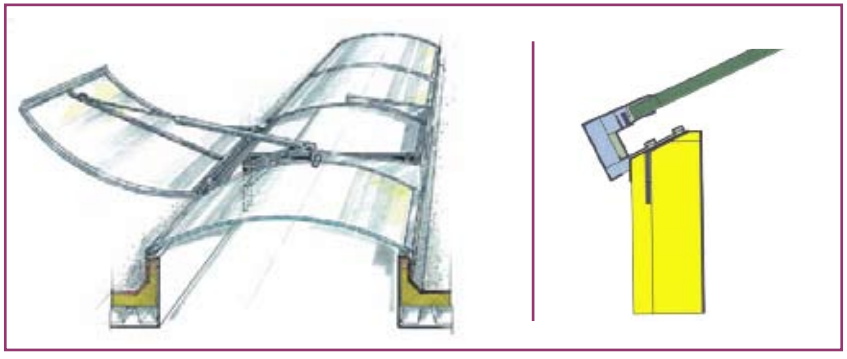
800-1500 x 1200-2500
Special sizes made by order
U value 1,8 W/m^{2}K

www.lumex.dk

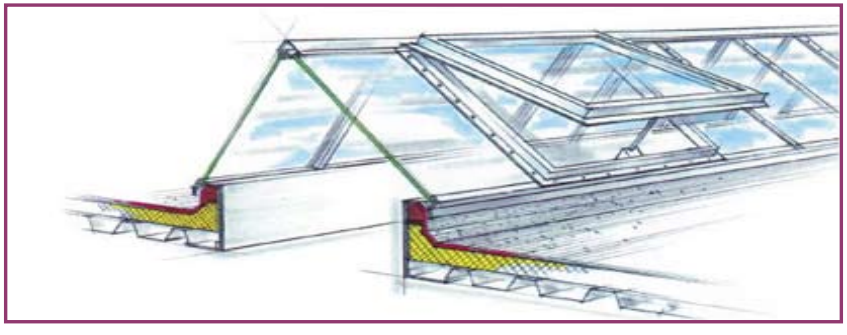
dpc

DPC does not distinguish their products into skylights and light rows but simply offer two solutions that can vary in size.

Skylights from DPC Building Systems (DPC) offer a more clean appearance although the shape is similar to some of the others as well as having a visible motor on the inside. Furthermore DPC has a simple approach to the construction.



ill. 1.41 - A hinged vaulted skylight. Note the simple construction in the section cut.



ill. 1.42 - A ridge skylight from DPC A/S.

Standard sizes (mm):

1000-7000 x By requirement

U value 1,8 W/m2K

www.dpc-byggesystemer.dk

Recapitulation

The benchmarking has helped the project group to get an overview of how well equipped Domex is to reach the company vision of “being the skylight company of choice for industry buildings” with the PC skylight chosen for this project – based on what the competitors offer in this category.

Through the product benchmarking and the strategy mapping of the competitors, it becomes clear that there are a lot of similar products and similar approaches to the market in the category of the selected windows.

To fulfill the ambition of remaining market leader and becoming the preferred skylight producer, Domex needs to show a difference and advantage compared to the competition – a difference that can be defined through a change in strategy for the selected products.

Through a SWOT analysis and a definition of the project frame, a future strategy for the new skylight and the opportunities for the new product will be defined.

SWOT analysis

Following the benchmarking of the selected products and the competing products, a SWOT analysis is applied to get a deeper understanding of Domex as a company and how they stand on the market with the selected skylights - thereby identifying Domex’s Strengths, Weaknesses, Oppertunities and Threats. (ill. 1.43)

The analysis is made with focus on the selected skylights making Domex market leader and performed on basis of interviews with employees at Domex, observation of production and mounting and the benchmarking.

Strengths

- Market leader
- Strong economy
- High service level
- Tailored solutions
- In-house production
- Short production time
- Production by order
- Short delivery time (2-4 weeks)
- Employees with high experience within the industry
- No stock of skylights

Weaknesses

- No innovative distance to competitors
- Low product uniqueness compared to competitors
- Ad-hoc product development
- Only incremental improvements to products
- No stock of skylights
- Complex construction of skylight

Opportunities

- Divert from a uniform market
- Expand outside Denmark
- Environmental friendly product and production tendencies
- Increased demand for highly insulating products
- Implement Domex Skylights in the sister company Green House A/S.

Threats

- Competitor introducing highly innovative product
- Foreign producer exporting to Denmark
- Increased demand for highly insulating products
- Competitors utilizing cheaper production abroad

ill. 1.43 - A SWOT analysis of Domex Skylights A/S with focus on the vaulted PC skylight.

Findings

The general finding in the SWOT analysis is the fact that Domex needs to shift to a product development that diverges from the current ad-hoc development.

The future product development should have a higher focus on coherence, assembly, construction and features.
By doing so Domex has the opportunity to present a better product to the market and thereby the possibility to create a further distance to the competitors.

This is – based on the benchmarking – clearly necessary to both maintain the position as market leader within fire ventilation skylight and to fulfill the vision of becoming the skylight of choice within this area.

Project Frame

In the previous chapters Domex has been presented in terms of company, strategy, products, competitors and a SWOT analysis.

Based on these investigations the project group is able to define the frame for the project – by setting the strategy for the new skylight and frame the scope of the product development through an Eliminate/Raise/Reduce/Create Grid (ERRC).

Findings

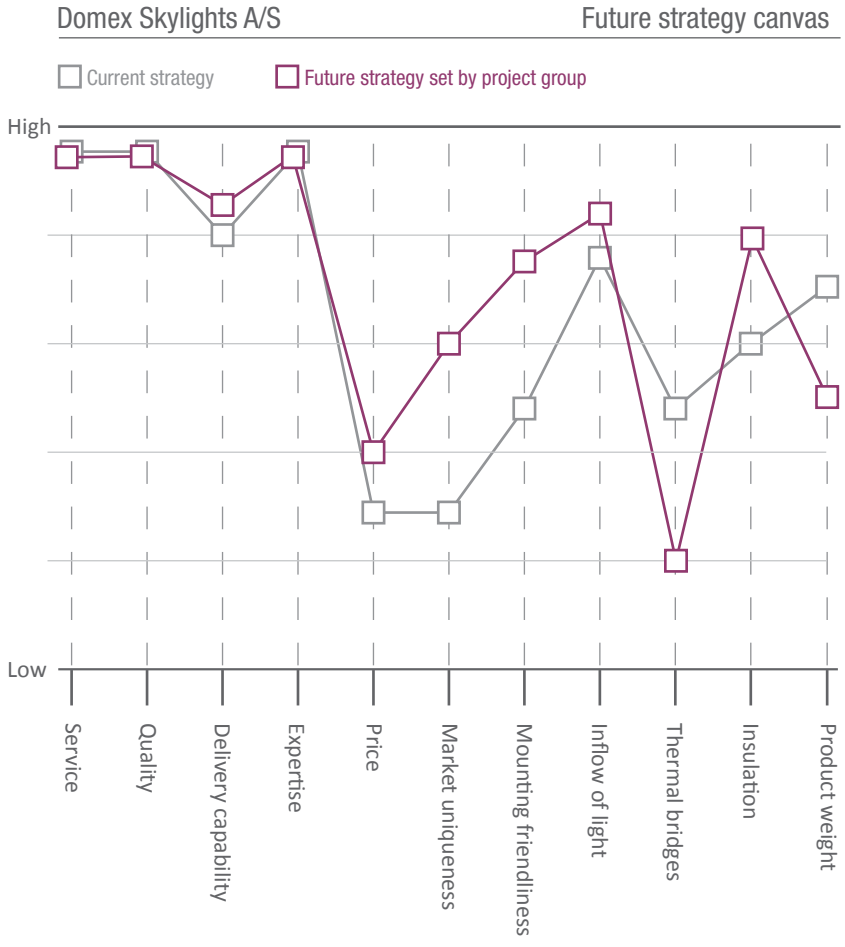
As mentioned by the CEO of Domex, Domex has the ambition of becoming the preferred skylight company on the Danish market for industrial buildings.

In the previous chapters "Benchmarking" and "SWOT Analysis" it is pointed out that Domex's product differ little from the competing products. In essence the market presents very uniform products to the consumers.

To fulfill the ambition of remaining market leader and becoming the preferred skylight producer, Domex needs to both differentiate their product from the competition and break out from the habit of using only ad-hoc development regarding production and design solutions.

New strategy

To meet the findings from the previous chapters a new strategy canvas is produced to identify a new direction for Domex. This direction will be followed by the project group when developing the new product for Domex – keeping focus on where the product in development should differ from the current strategy and where it should remain equal to Domex' current strategy (ill. 1.44).



ill. 1.44 - A new strategy for Domex set up as aim forthe new product development.

Development framework

In addition to the new strategy canvas a preliminary ERRC grid is produced to define areas to improve and encapsulate the direction for the development of the new motorized skylight as the project group sees it at present time (ill. 1.45).

The grid will be updated after a more thorough investigation of the chosen product and used as a governing tool for the development along with the Kano model that will be used to identify Basic, Performance and Excitement factors of the product development.

Eliminate / Raise / Reduce / Create - Grid

Eliminate

Raise

- Airflow (CW factor)
- Inflow of light
- Insulation
- Areas of application

Reduce

- Weight
- Workprocesses
- Thermal bridges
- Motor

Create

- Uniqueness
- Innovativeness
- Differentiation

ill. 1.45 - The argumentation for selecting to work with the motorized skylight.

Opportunity Statement

With the findings from the previous chapters as an underlying foundation, the following opportunity statement has been set as the basis for the product development for this project.

The opportunity statement frames the rough outlines of the project. Following a more detailed investigation of the chosen product is needed in order to establish how the defined opportunity can be carried out.

This will be investigated in the following chapters resulting in the formulation of a mission statement.

A new modular skylight with integrated fire ventilation is developed for Domex A/S - ensuring improved solutions to the pinpointed weak areas, offering an advantage to competing products - while still complying with current regulations for fire ventilation.

Glossary

Improved solutions to the pinpointed weak areas:

- The pinpointed areas: high weight, mounting friendliness, production friendliness, insulation and thermal bridges will be a key factor in the development process, aiming at improving the new product in these areas.

Advantage to competing products:

- Developing a product that presents a clear advantage and puts Domex in front of the competitors regarding, materials, solutions, production, insulation and mounting.

Current regulations for fire ventilation:

- Building Regulation BR08 (www5), Technical Regulations for Flammable Fluids (TF-BR) (www3), Technical Regulations for Wood Processing … (TF-VISSE) (www3) and Guide about Natural Thermal Fire Ventilation (www3).

Production & Mounting

In this chapter the production process of a pre-assembled vaulted fire ventilation skylight will be presented - followed by the mounting process of an on-site assembled vaulted fire ventilation light row.

Unfortunately it has not been possible to document the production of a fire ventilation light row and the mounting of a pre-assembled fire ventilation skylight, but many of the procedures and solutions are very similar or identical.

The experience gathered by observing these two processes will provide the project team with a great deal of knowledge about the assembly and mounting of both products.

Problem areas

A compilation of the different problem areas during production and mounting will follow the presentation of the processes be compiled in a chapter called “Problem areas”.

This information will be used to pinpoint how the project group could address the task of developing a new product and where to focus the design task.

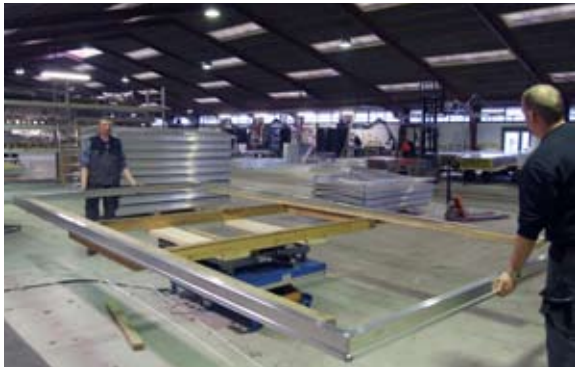
Production

The production of a pre-assembled vaulted fire ventilation skylight is described in sequence with pictures and words on the following pages.

Mounting

After the presentation of the production, it will be introduced how a PC light row with fire ventilation is installed on an industry building.

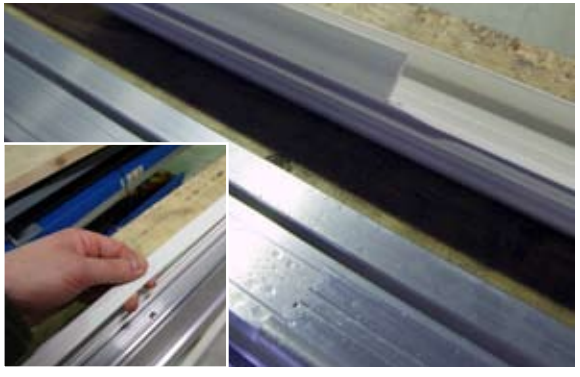
Production



[1] A welded alu-frame is placed on a workbench.

[2] An alu profile with a hinge for the opening windows is screwed onto the alu frame in the middle of each long side.

[3] Plastic profiles for collecting condensation and reducing thermal bridges are are clicked on in one end of each long side.



[4] The backside of the plastic profiles are cut away in the area where the opening part of the skylight will be placed.

[5] On each long side, an prior assembled opening module is slided onto the alu profile with the hinge.

[6] Alu profiles to fasten the fixed PC plates onto, are mounted to each long side on each side of the opening modules.

[7] The plastic profile is clicked on to the alu frame in the full length of the long sides.

[8] Plastic list are clicked onto the two short sides of the alu frame.

[9] Holes are drilled through the alu profile mounted in [6] and the plastic profiles for mounting braces between each long side. This is done on each side of both opening modules.

[10] Bolts are slided into the side of the transverse braces, and a transverse brace is mounted on each side of the opening modules.

[11] A plastic profile to collect condesation is mounted on an alu brace that is mounted between the bolts in the two transverse braces shown in [10].

[12] A wooden end gable is mounted onto each short end of the alu frame.

[13] Construction glue is filled into the gap between the plastic condensation profiles and destributed to make the corner water tight.

[14] Two PC plates are placed on top of each other on each side of the opening module. The PC plates are closed with tape that allows condensation to exit the ducts.

[15] Alu profiles with a weatherstrip are clicked onto the alu profile shown in [6]. This is done to fasten the two fixed PC plates to the frame.

[16] The gap between the fixed PC plates and the opening modules are checked for the required clearance. Potential surplus material is cut away.

[17] In the meeting between the opening PC plates and the fixed PC plates, an alu profile is mounted on top of the opening PC plates.This is done to secure these PC plates to the frame of the opening module.

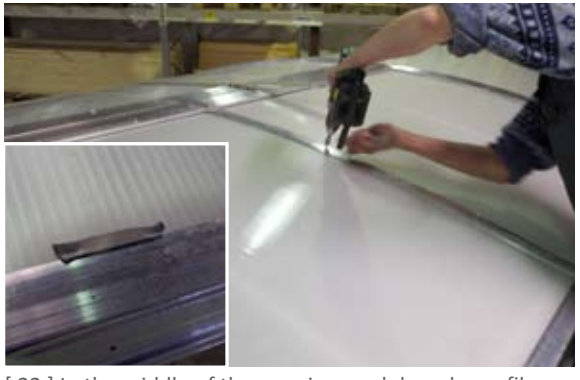
[18] Silicone filler is applied around the alu profile [17] in top and bottom to prevent water from getting in and moving inside through the holes for the screws.

Production

[19] Two welded alu profiles - to ensure the openings between the modules are tight when the window is closed - are equipped with self-adhesive rubber lists.

[20] The alu profiles from [19] is mounted onto the opening modules of the skylight.

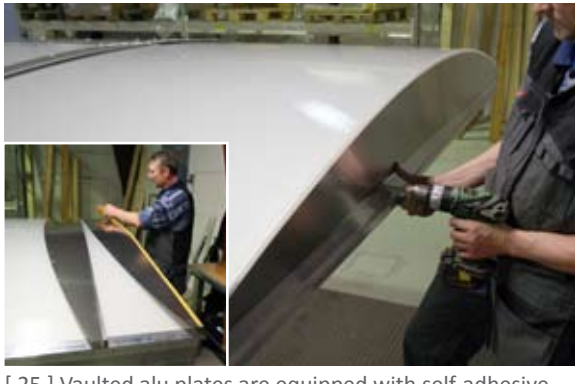
[21] An alu profile is mounted between the two opening modules to ensure the window can't open during transport. (Profile is removed during mounting)



[22] In the middle of the opening modules, alu profiles with underlying weather strips are mounted to an underlying brace. Extra weatherstrip in top and bottom.

[23] An alu profile with self-expanding weatherstrip is mounted where the opening and fixed modules meet and fixed to the opening module to weather seal this area.

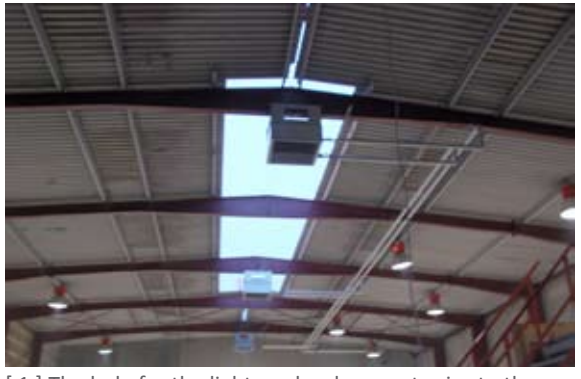
[24] The fixed PC plates are nailed to the wooden endgables.



[25] Vaulted alu plates are equipped with self-adhesive rubber lists and mounted to the wooden endgables.

[26] Self-adhesive rubber lists are applied on top of the fixed PC plates at each end of the skylight. Vaulted alu profiles are mounted on top of the rubber lists.

[27] The assembled PC light is lifted outside for storage until transport to the customer.



[1] The hole for the lightrow has been cut prior to the delivery of the assembly kit from Domex.

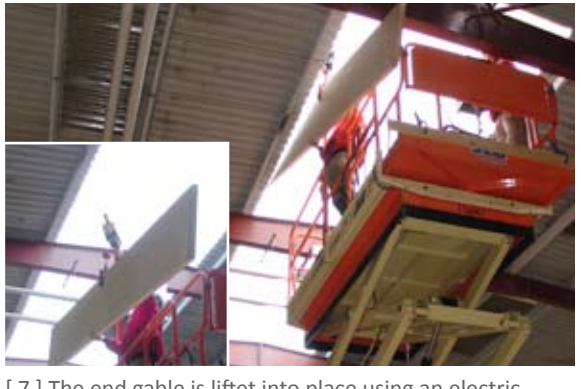
[2] The materials for the lightrow arrive by truck and are unloaded with a forklift.

[3] One of the two people from the mounting team measures the hole to identify if anything should be cut away for the wooden frame to fit into the hole.

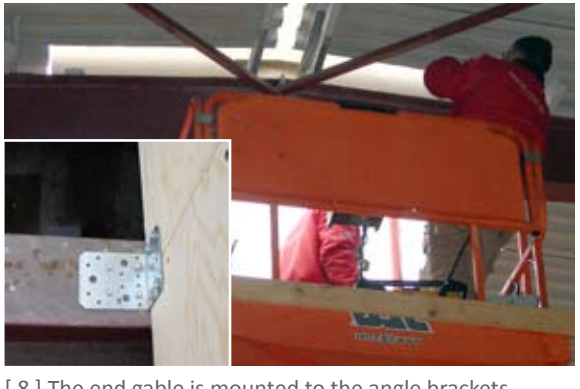
[4] The second person from the mounting crew performs the modifications to the frame if it is needed.

[5] The modules for the wooden frame are transported into the building below the hole for the lightrow on a wagon for easier handling.

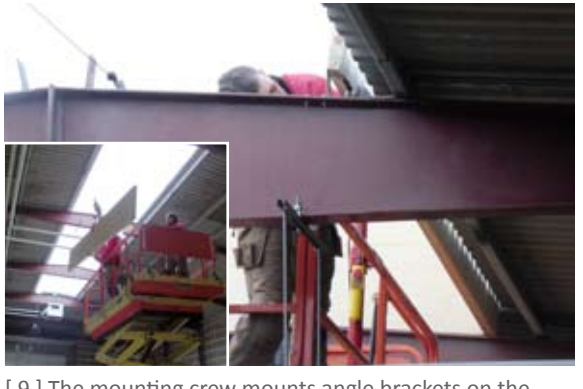
[6] Angle brackets to fix one end gable are mounted onto the bearing steel construction.



[7] The end gable is liftet into place using an electric winch mounted to the work lift.



[8] The end gable is mounted to the angle brackets.



[9] The mounting crew mounts angle brackets on the next bearing steel structure and mounts a side frame. This continues all the way to the end and the second end gable is mounted.

Mounting

[10] Alu profiles that lead water away from the top of the side frames are mounted. Felt roofing will be burned onto the side gables up under the alu profile.

[11] An opening module and a motor is hoisted into the lift. The opening module is placed loosely on the two side frames.

[12] The position of the motor is measured and the motor is loosely placed - resting on the side frames and secured with one or two screws.

[13] The opening module is lifted over the motor towards the end gable. Again the opening module is just placed loosely on the side frames.

[14] The opening module is placed in its correct position using alu profiles that ensures the correct distance to the end gable.

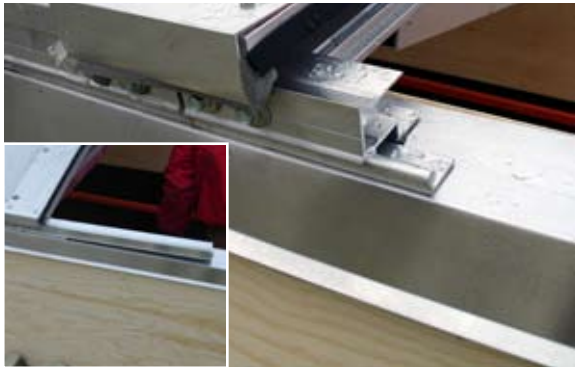
[15] The transport security is removed so the window can be opened.

[16] The motors electrical system is connected to a 24V portable battery case with controls for opening/closing.

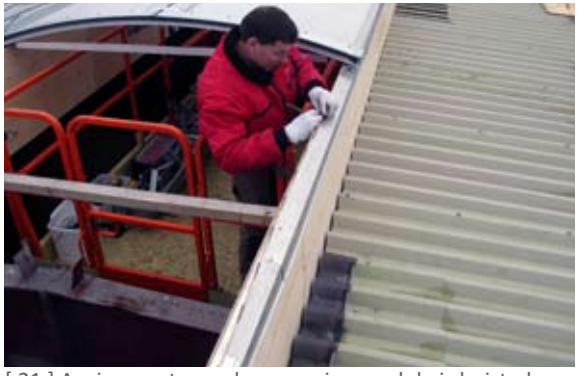
[17] The motor is activated slightly to ease the mounting of the motor brackets to the recieving brackets on the two opening module.

[18] The opening function is checked. Potential allignment inaccuracies in the mounting is corrected and all bolts/screws between the frame, motor and opening modules are securely fastened.

[19] The opening module is opened completely. Following this the alu profiles of the opening modules that rests on the side frames can be fastened to the side frame.



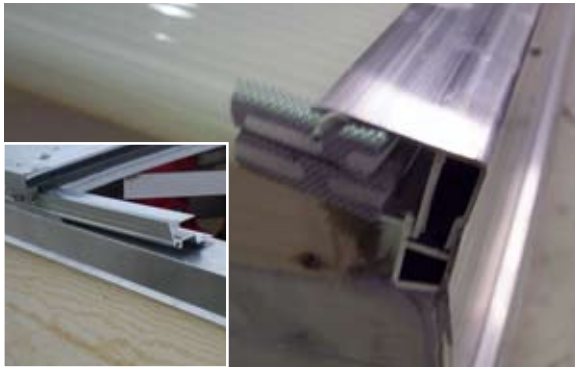
[20] An alu profile is slided onto the alu profile with the hinge for opening. This is done to ensure the correct distance to the next opening module - as seen in [14].



[21] Again a motor and an opening module is hoisted up in the lift like in [11] and [12]. The motor position in measured as the distance to the profile mounted in [20].

[22] When positioning this opening module like in [13], the opening module is slided into the alu profile mounted in [20].

[23] The procedure of mounting the motors and opening modules goes on down towards the last end gable untill the lightrow consists of mounted opening modules with spaces in between for fixed pc plates.



[24] Subsequently the fixed PC plates are mounted onto the distance alu profiles in the same way as in the assembly of the pre-assembled window. (Large picture taken from the pre-assembled window).

[25] Here the lightrow is completed with a new felt roof. (Reference photo)

Problem areas

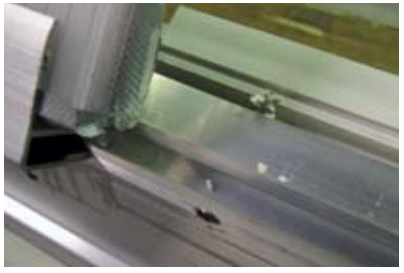
Based on the registrations of the assembly and mounting procedures it is possible to identify certain areas that should be in focus for the development of a new skylight for Domex A/S.

The identified weak areas are as follows:

- Thermal bridges
- Assembly
- Different frames
- Weight
- Inflow of light / Aesthetics

The different weak areas are pinpointed through pictures and text, followed by a paragraph that elaborates on the way the project group will address these areas in the development of a new product for Domex.

Thermal bridges

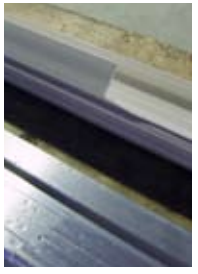


Drilling through the thermal bridge insulation to fasten transverse brace.

Outside alu profiles touches inside alu profiles with no change in material which produces a thermal bridge.

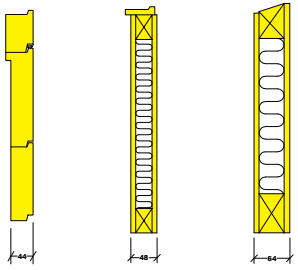
Assembly

Applying construction glue to make the corner betwen the condensation profiles tight.



Cutting away material and applying extra material when assembling the skylight.

Different frames



Three different types of wooden frames / gables are used at present time:

- One for pre-assembled skylights. (Left image)
- One for light rows spanning below 6 meters between bearing steel construction. (Middle image)
- One for light rows spanning 6 meters or above between bearing steel construction. (Right image)

Weight

Needing to use lifting equipment to handle elements due to weight and/ size.

Needing to lift heavy elements where or when lifting equipment cannot be applied or when it is unfavourable.

Inflow of light / Aesthetics

The motor in the skyligt / light row is placed across the window in the middle, which decreases the inflow of light into the building. Furhtermore this solution increases the perceived aesthetic complexity.

Recapitulation

In the light of the experiences regarding the problem areas in production and mounting, a list has been compiled – defining how the project group intends to address these problem areas:

- Thermal bridges
  - Minimize thermal bridges in the new product by ensuring change in material in the construction and eliminate mounting procedures that compromises insulation.
- Assembly
  - Minimize the number of parts needed for the skylights and develop parts that require a minimum of processing and measuring in the production/mounting-procedure.
- Inflow of light / Aesthetics
  - Create a skylight with increased inflow of light and a simple aesthetic look by seeking to remove the motor from sight - when observing the skylight from inside.
- Different frames
  - Minimize the number of used frames to one – making it easier to develop a solution for the skylight that can be applied to both pre-assembled skylights and on-site assembled skylights.
- Weight
  - Seeking to implement a modular system that can ensure that each module for both the pre-assembled and the on-site assembled skylights does not exceed 25 kg – the max weight one workman is allowed to lift according to the Danish work environment regulations.

Strategy and Platform

After defining how the project group will address the specific pinpointed weak areas in the selected products, the direction for product platform and competitive strategy have to be set.

This is done in order to set a level for the application of new technologies/processes and the use of existing solutions/ techniques in the development process.

Competitive Strategy

Based on earlier findings on competitors and Domex's product it is clear that Domex to a wide extend competes on price in an overall uniform market.

The project group wants to maintain and strengthen the price competitiveness strategy by improving the production efficiency and material use - aiming to ensure that the company vision can be obtained by both presenting the consumer with a product that can compete on price and product features.

Cost Leadership

Improvement of production efficiency through better management of production system and simplifacation of product construction.

Technology Leadership

Focus on basic research and development of new technologies.

Customer Focus

Close collaboration with new and existing customers to assess their changing needs and preferences.

Imitative

Following trends in the market allowing competitors to explore which new products are succesful and following launch a product imitating the competitor.

ill. 1.46 - Diagram showing the selected strategy regarding competitive strategy and a short description of the other strategies according to Prouct Design and Development.

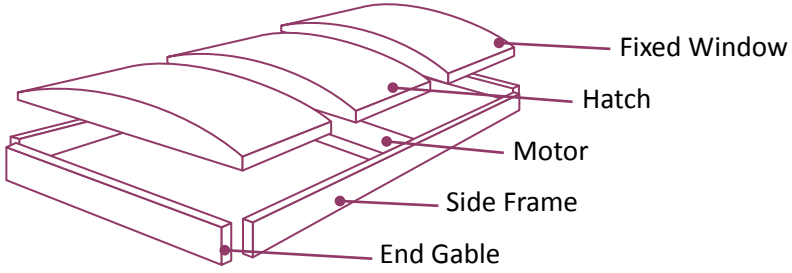
Consequently the project group has used Product Design and Development to investigate different competitive strategies, and has found the strategy most fitting to the intended approach to the development of the new skylight (ill. 1.46).

Product Platform

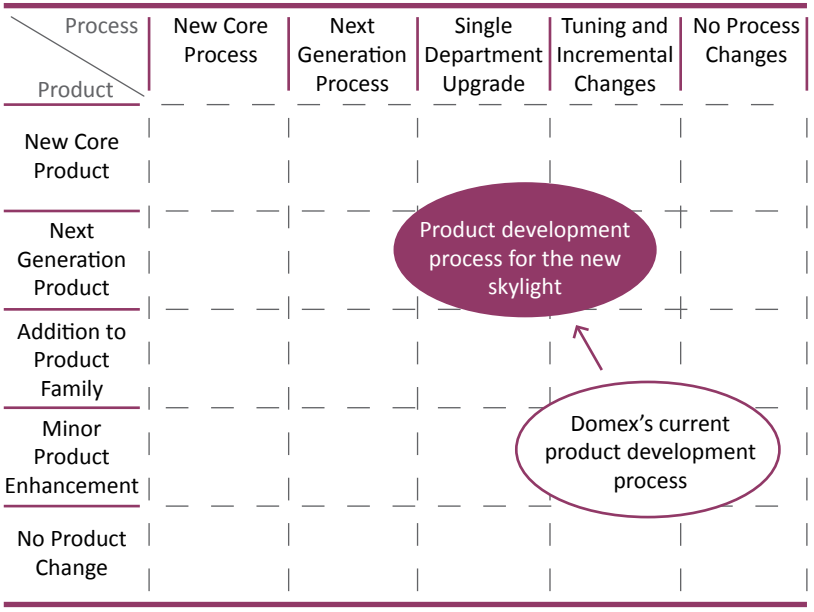
In order to maintain and strengthen Domex's cost leadership strategy it is important to define whether the existing architecture and sub systems in the current product can be used in the project.

In order to follow the competitive strategy set up for Domex, it is seen as beneficial by the project group to build on the existing product architecture within the skylights, but change the individual elements and the joining between elements due to product complexity in the existing product. The overall product architecture can be seen in ill. 1.47.

This induces a change in Domex's current product development process that moves away from the ad-hoc development approach (ill. 1.48)



ill. 1.47 - Current product architecture of functional elements.



ill. 1.48 - Product-process change matrix showing Domex's current position and the project groups position.

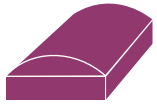
Basic shape

Based on the selected product architecture and product development process the project group has looked at basic shapes for the skylight.

The project group has decided to focus on a basic shape from Domex' current product portfolio. This is done to minimize costs for a reorganization of the production facilities – and thereby strengthening the selected cost leadership strategy.

In illustration 1.49. the different basic shapes available for the PC skylight can be seen along with pros and cons.

Based on the analysis of the basic shapes it is decided to work with the vaulted shape since this shape offer the highest advantages regarding set strategy, production and reuse of solutions.

Pros/Cons / Skylight Type	Pros	Cons
 Vaulted	▪ Fits visually both to a flat and ridge roof ▪ Few joinings ▪ Many current solutions can be used	▪ Visual similarity to competitors products
 Northern	▪ Many current solutions can be used	▪ Many joinings ▪ Many possible leak areas ▪ Poor visual fit to ridge roof due to angle
 Pyramid	▪ Many current solutions can be used	▪ Many joinings ▪ Many possible leak areas ▪ Poor visual fit to ridge roof due to angle
 Ridge	▪ Many current solutions can be used	▪ Many joinings ▪ Many possible leak areas ▪ Poor visual fit to ridge roof due to angle
 Plane	▪ Few joinings ▪ Many current solutions can be used	▪ Poor visual fit to ridges roof due to flat top ▪ Possible water flow problems

ill. 1.49 - A pros and cons analysis of the basic shapes available for PC skylights in Domex' current product portfolio.

ERRC Grid

With the deeper investigations into the selected products and the establishment of competitive strategy, product platform and product development process - a more precise EERC grid can be produced (ill. 1.50).

This encapsulates what and how the identified problem areas are intended to be handled in the development process of the new skylight.

Eliminate / Raise / Reduce / Create - Grid

Eliminate

- Workprocesses that compromise insulation or increases thermal bridges
- Two of the three frames currently used for pre-assembled and on-site assembled fire ventilation skylights.

Raise

- Airflow (CW factor)
- Inflow of light by moving motor and increase PC plate area
- Insulation by reducing thermal bridges

Reduce

- Weight
- Workprocesses through product simplification
- Thermal bridges by ensuring material shift in the construction
- Motor by moving it or alternative opening system
- Number of parts
- Production time

Create

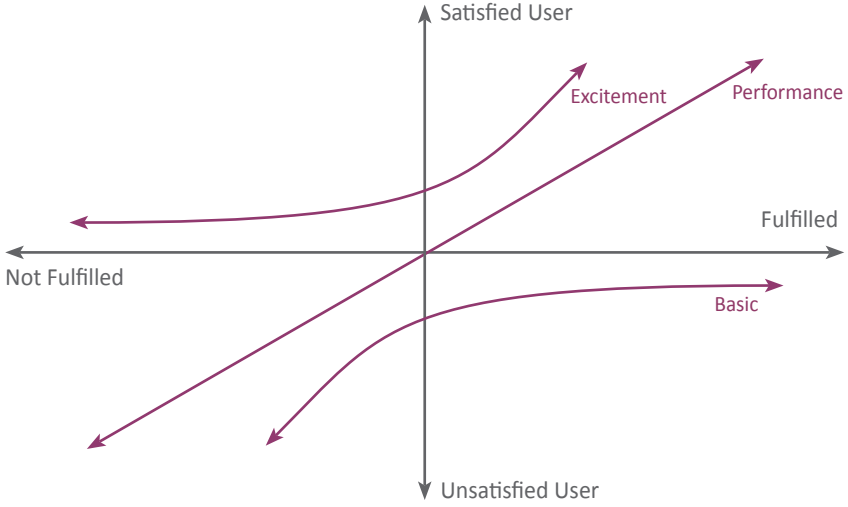
- A new frame for both pre-assembled and on-site assembled fire ventilation skylights
- A modular system for the assembly and mounting
- A cleaner aesthetic look
- An opening system that can support the relocation of the motor.

ill. 1.50 - The EERC grid created for the development of the new skylight.

Kano Model

Additionally to the EERC grid the Kano model can be used on the selected product to sort the desired features of the new skylight into Basic, Performance and Excitement factors (ill. 1.51).

- Basic demands (must be fulfilled)
- Performance demands (increase customer satisfaction)
- Excitement demands (unexpected features)



ill. 1.51 - Noriaki Kano's model for sorting product features into Basic, Performance and Exitement demands.

Basic Demands

- Fulfills regulations for insuation (U value of 1,8 W/ m^2K)
- Fulfills fire regulations
- Fulfills Danish work environment regulations regarding 25 kg max lift

Performance Demands

- Easy to mount/assemble onsite
- Minimal thermal bridges
- High durability
- No maintenance

Excitement Demands

- Increased inflow of light
- Aesthetically clean
- Surpass the regulations for insulation

Mission Statement

On basis of the previous investigations and analysis the project group can translate the opportunity statement into a mission statement for the project.

The chapters succeeding the opportunity statement have also enabled the project group to set up the demands, wishes and delimitations for the project.

The mission is to develop a new vaulted, modular fire ventilation skylight - offering a solution that can be used both for vaulted skylights and vaulted light rows.

The new skylight must strenghten the Cost Leadership strategy of Domex by optimizing and improving the following factors:

- Improve production efficiency and thereby the price competitiveness by simplifying the construction, reducing number of parts and simplifying assembly and mounting
- Differentiate the skylight from the competitors through improved aesthetics and altered opening mechanism.
- Increase inflow of light by minimizing blockage from profiles and motor.
- Improve U value from the required 1,8 W/m^2K to 1,5W/m^2K.
- Secure that a single module does not weigh more than 25kg.

Demands

- Fulfill work environment regulations
- Fulfill fire regulations
- Fulfill building regulations
- Only one frame for both skylight and light row
- Eliminate thermal bridges around the frame
- Reduce number of parts
- No modular parts must weigh over 25 kg

Wishes

- Increase inflow of light
- Improve aesthetics by a cleaner appearance on the outside and inside
- Same assembly procedure for PC light row and PC pre assembled skylight
- Improve U value to 1,5 W/ m2K for future building regulations

Delimitations

- The main effort will be on developing a vaulted pre-assembled skylight, but since the modular principle must operate on the same modular principle, the light row is considered as big a part of the development process as the pre-assembled skylight.
- Calculations will not be performed on all parts of the window, as the focus will remain on the most critical part – the bracket connecting the motor to the opening modules of the skylight. Furthermore the calculations will only be used as an estimation tool in the development process.
- The motor used for the project will not be specified in detail but only as a functionality principle. A reference motor from Linak (LA31 Techline), is used to drive the opening Appendix X).
- The project will only focus on the part of Domex' vision that targets the professional market for fire ventilations - not the professional market for fixed skylights and the area of private outhouses.
- Certain parts of the development process will be explained in the end of the detailing chapter as areas that will need to be developed/refined in a product maturing process. This is done due to time aspects.

Process and Learning

Process

After gathering general information on Domex's product portfolio and company through meetings and sales material the project team decides to work with the vaulted PC skylight and light row with fire ventilation and sets a general direction for the project.

An investigation of regulations, production procedure, mounting procedures and competitors products sheds a light on problem areas in the product and Domex's position on the market. The investigation shows that the market is uniform with very little differentiation between competitors.

Weak areas spotted are a product based on ad-hoc solutions resulting in a complex construction and assembly, thermal bridges in several places, lower inflow of light because of motor placement and cluttered aesthetics. Furthermore a change in the regulations regarding U-values is spotted.

On basis of the gathered information the project group formulates the projects mission that defines the starting point for the concept generation.

Methods

Interviews, meetings, telephone and e-mails are used to communicate and gather information from Domex.

Benchmarking has been used to compare the selected Domex products to what the competitor´s offer of comparable skylights

Production and mounting of the product is registered through observations of the processes and short onsite interviews.

To give an overview of Domex in relation to its competitors and status on the market the strategy canvas, SWOT analysis are used. This also helps understanding where Domex has the possibility for differentiation.

The selection of competitive strategy, product platform and Product/process development, has helped the project group define the direction, basis and development type to the development process of the new skylight.

ERRC and Kano model are used to define possible areas of improvement and to give an overview of what features of the product are must have and what are excitement factors.

Learning

The information gathering has been effective in providing the project team with valuable knowledge about Domex, their products and their position on the market when compared to their main competitors. Furthermore valuable knowledge about fire ventilation in industry building has been acquired.

Through the use of the strategy canvas the project group has been able to plot the different strategic areas in relation to each other. This has given a good overview of the relation between the different areas and thereby also an insight into what happens in one strategic area when one or more areas are changed.

Subsequently this knowledge has been a big part of the selection of where and how the strategy for the new skylight should focus - and how changes in all the areas of the strategy canvas could secure a coherent and plausible strategy change for Domex.

Via the benchmarking of competing products to the selected Domex products, the project group has gotten an idea of the conditions on the market for fire ventilation and the products offered on this market.

Unfortunately the project group has not been able to acquire very detailed information about the competitors. A fact the project group regrets – especially in relation to the product development, where more intimate knowledge about the competing products could have been very beneficial.

Through the selection of the cost leadership strategy for the new product, the group has created a point of reference for the concept development. Along with the product platform and product/process matrix, the cost leadership has provided the team with a frame of evaluation for all the concepts being proposed as a solution – where any proposals usability will rest on the compatibility with the selected scope in these three areas.

The Kano model and the ERRC grid has helped specify the three prior mentioned areas to a degree where the concept proposals can both be evaluation on a general level regarding strategy, platform and process but also on a more specific level with the ERRC grid and the Kano model – specifying the desired direction more accurately on a product level.

Concept Development

In the Concept Development phase inspiration, initial sketching and concept creation is presented, resulting in the selection of a single concept.

Methods

- Brainstorm
- Inspiration search
- Systematic sketching
- Meetings / Presentations

Introduction

From the beginning of the project the group has been sketching – and to sort the proposals the project team has divided them into three categories.

- Incremental changes
- Moderate changes
- Extensive changes

The sorting has been conducted according to the experienced change in production/processes needed at Domex for these concepts to be plausible.

The Incremental category has however quickly been deselected due to the fact the incremental changes is the current development process at Domex – and what the project group wishes to change.

Through the mission statement and preceding investigations the direction for the concept development has been set.

However some of the concepts that have been created in the planning phase do not correlate with the selected direction established at the end of the planning phase – only the concepts from Moderate changes correlate to selected direction.

Therefore sketches and brainstorm on Extensive changes can be seen in appendix 2. (ill. 2.1).

Concept initiation

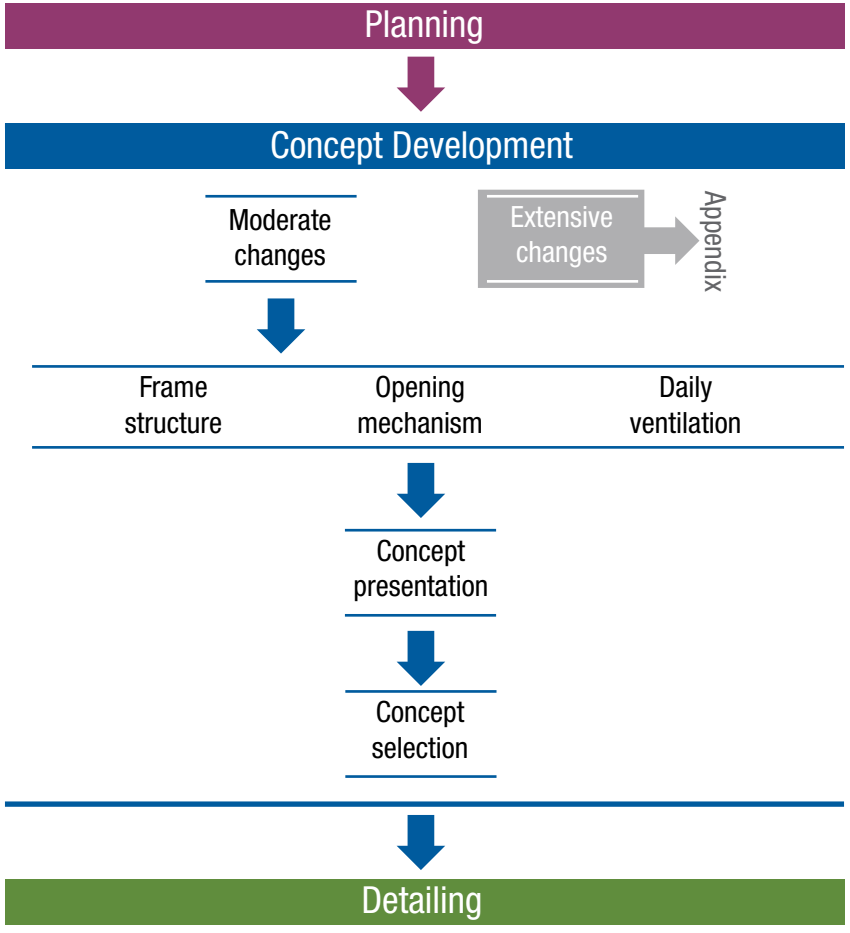
To kick-start the concept generation a preliminary brainstorm is performed to quickly generate ideas for the phase (ill. 2.2).

The highlighted areas define ideas the project group finds interesting and that can fulfill the mission statement. The areas roughly compose three areas on the skylight (ill. 2.3)

In order to elaborate on the brainstorm a search for inspirational images from international skylight producers and different product groups is performed. The imagery from the search has helped generate ideas for each of the three areas in Moderate changes is presented in ill. 2.3. The remaining images can be seen in appendix 4.

Phase structure

In order to structure the concept generation the phase is divided into three sections according to the area of the skylight that is in focus – frame, opening mechanism and ventilation. Each section is presented with investigations, opportunities and sketches concluded with a summary.



ill. 2.1 - An overview of the structure within the concept development phase.

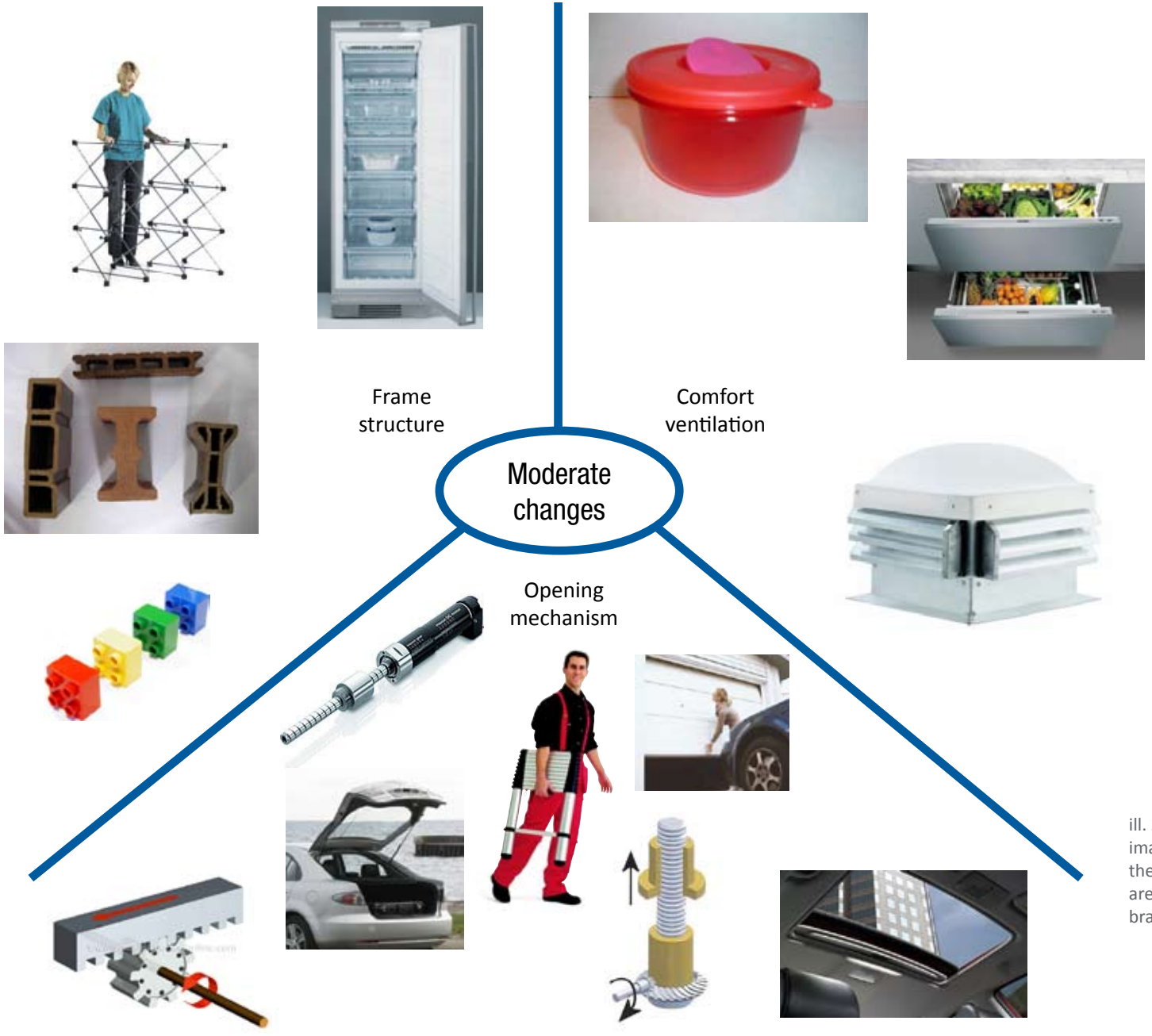
Only the most important sketches for each area are presented in the process report. The remaining sketches can be seen in appendix 3.

The three areas are presented in the following chapters where the chapters on frame structure and opening mechanism share the same structure.

Each of these areas starts with a selection of sketches where a few are highlighted. The highlighted sketches are presented in depth with a pros and cons list, inspirational image and description.

The ventilation concepts are presented in a slightly different way because the background for this area is different from the two others. The difference in background will be presented in the ventilation chapter.

ill. 2.2 - Brainstorm on moderate changes to Domex's current skylight.



ill. 2.3 - Inspirational images elaborating on the three composed areas from the brainstorm.

Frame

As mentioned in the recapitulation of the chapter “Problem Areas”, several areas have been identified as key areas when developing the new skylight window. The areas that affect the frame of the new skylight are translated into the following statements:

- Reduce thermal bridges, number of parts and joints
- Simplify production and assembly
- Make a single modular frame for both pre-assembled and on-site assembled skylights

Plastic wood

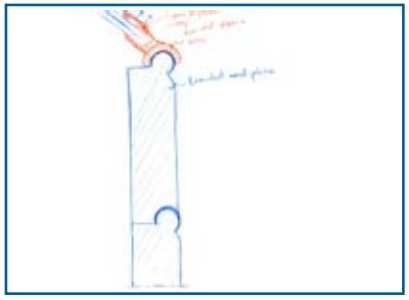
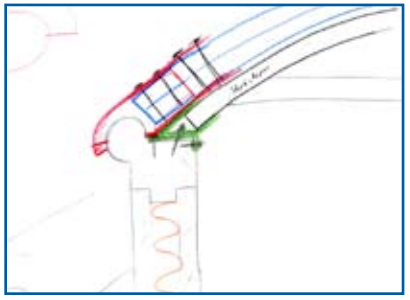
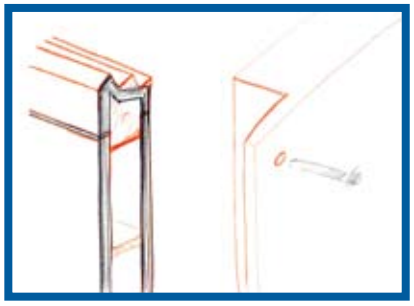
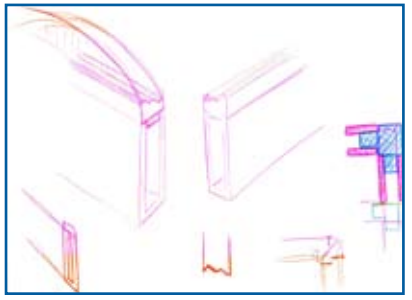
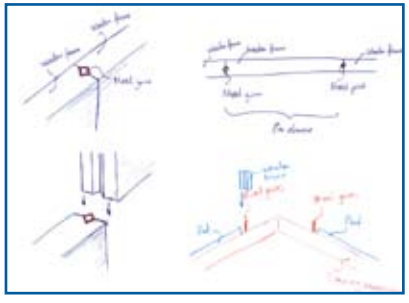
During the planning phase of the project, the project group has found a material that could offer some interesting possibilities for a new frame. The material “Plastic wood” has the following properties (www6):

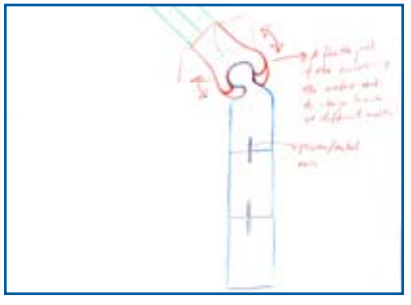
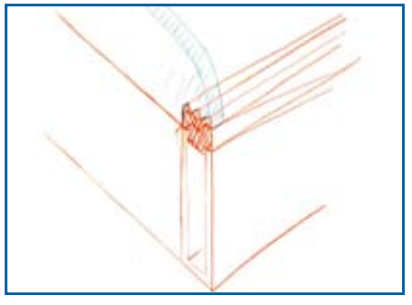
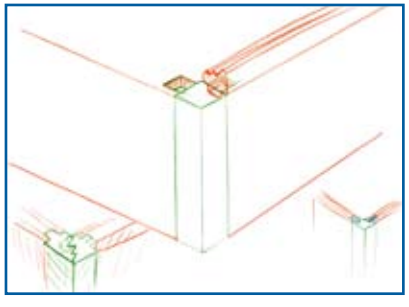
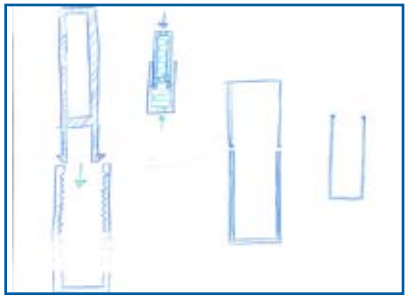
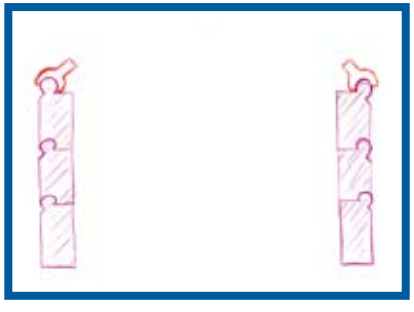
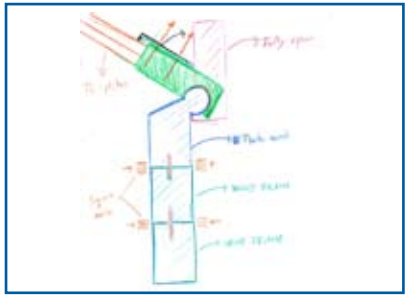
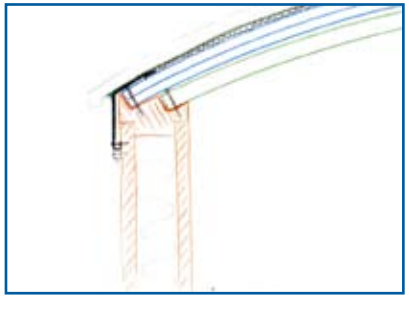
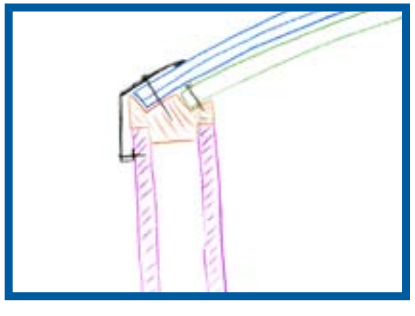
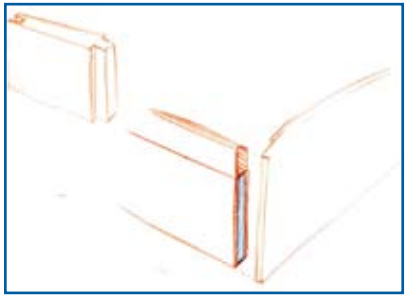
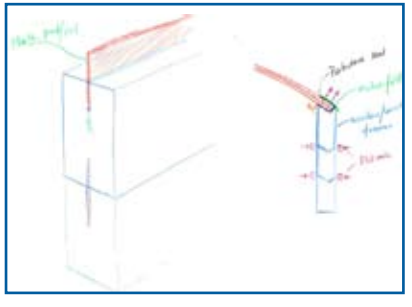
- Material: A combination of polymer resin and between 30 and 50% recycled wood flour
- Manufacturing: Profile extruding
- Can be cut, screwed, drilled, sawn and sanded like wood
- Can be dyed to any color
- Weather resistant- water absorption: 0,01 % (European spruce: 2-3 %) (www7)
- High UV-durability
- Fire retardant (varies between PW types)
- High durability

Material use

This material has been applied in the concept development for a new frame in order to accommodate the introductory statements. On the following pages the concept development for the frame can be seen.

Ill. 2.4. - Extruded plastic wood in different profiles and colors.

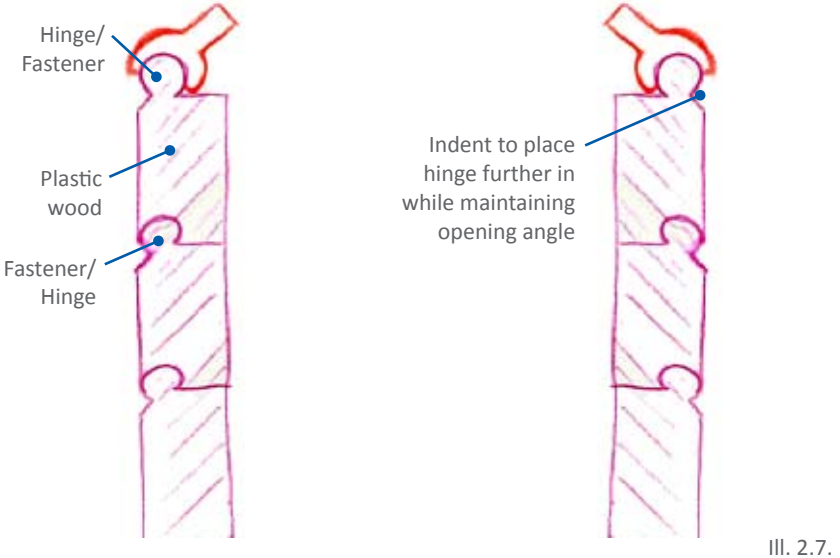











Ill. 2.5. A selection of the sketches made on the frame - the highlighted sketches are presented in detail on the following pages..

Hinge

The frame with incorporated hinge takes inspiration in Lego bricks (ill. 2.6).

The frame consists of extruded plastic wood blocks that slide into each other. The fastener also works as a hinge, which reduces the number of profiles between frame and polycarbonate plates.



Ill. 2.7.

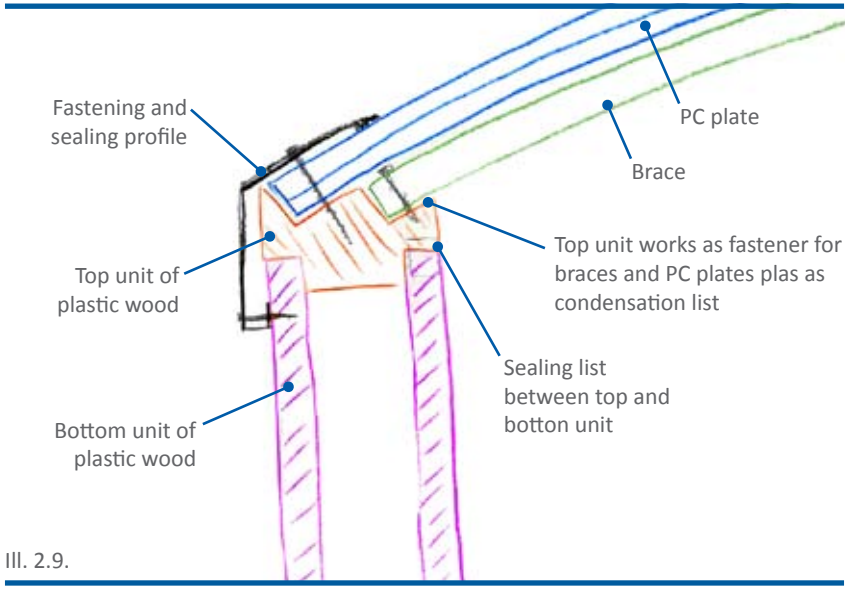
Ill. 2.6. The hinge principle for the frame takes inspiration from Lego bricks and the way they attach to each other because of their physical design.

Pros

- Frame modules are identical
- Reduced assembly time of frame
- Incorporated hinge
- Few profiles needed
- Extrusion = shape freedom
- Plastic wood warps very little
- Can be processed as wood

Cons

- Solid frame might be heavy
- Plastic wood is not fire resistant enough to resist heat from a gas burner used when mounting felt roofs
- Modules have to be very precise for this modular system to function.



Ill. 2.9.

Sandwich

The sandwich frame takes inspiration from ill. 2.8. A top unit in extruded plastic wood works as fastener for braces and PC plates, which can be mounted directly into the plastic wood as it possesses the woods processing properties. Separating top and bottom makes it possible to use some parts of the current frame. Furthermore many current profiles are incorporated into the top unit, which simplifies the assembly process.

Pros

- Light bottum unit
- Frame separated in top and bottom units
- Integrated condensation list and window fastening
- Possible to use different materials in top and bottom
- Reduces number of profiles
- Simplifies assembly process

Cons

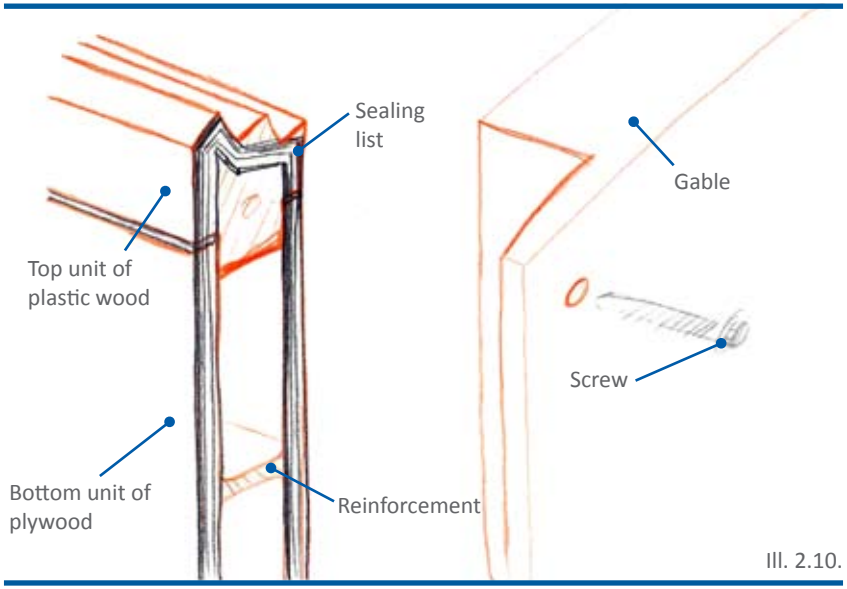
- Hollow frame can bend when fastening screws

Ill. 2.8. - Extruded plactic wood can be used in sandwich constructions - utilising the properties of the material where it is reguired in the construction.

Corner

The corner solution is a principle that builds in the sandwich principle. The idea for the corner assembly is inspired by Domex's current on-site assembly frame (ill. 2.11).

The solution is simple, functional and a solution Domex is familiar with. The hollow bottom unit has received reinforcement in the middle to prevent the frame to bend when used for fastening.



Ill. 2.10.

Ill. 2.11. - The outer spruce plate of the end gable in the current solution is used for sealing and fastening the side frame of the skylight.

Pros

- Familiar solution
- Can be used with the current assembly frame
- Light compared to a solid frame
- Principle can be used for both pre-assembled and on-site assembled skylights

Cons

- The top unit is fastened to the outer plywood plate of the end gable - resulting in reduced insulation capability, because the top unit has a different shape than the upper corner of the end gable.

Recapitulation

The concepts “Hinge” and “Sandwich” fulfill the criteria presented for the frame in the statements presented in the beginning of this chapter - and the concept “Corner” can be combined with either one of the other concepts.

However the “Sandwich” concept is a more plausible solution than the “Hinge” concept. “Sandwich” is lighter and doesn’t have to be as precise in assembly as “Hinge”. Furthermore the “Sandwich” concept can utilize some of Domex’s current frame for the on-site assembled skylights.

Additionally the modularity can be implemented – making it possible to convert the production to one frame for both the pre-assembled and on-site assembled skylights.

Based on these facts, the “Sandwich” principle appears to be the most suitable solution for a new frame that can fulfill the key points identified in “Problem areas”.

The final selection of one particular frame principle will take place after a meeting with Domex regarding the concepts. The final selection of concepts can be seen in the ending of the concept development phase.

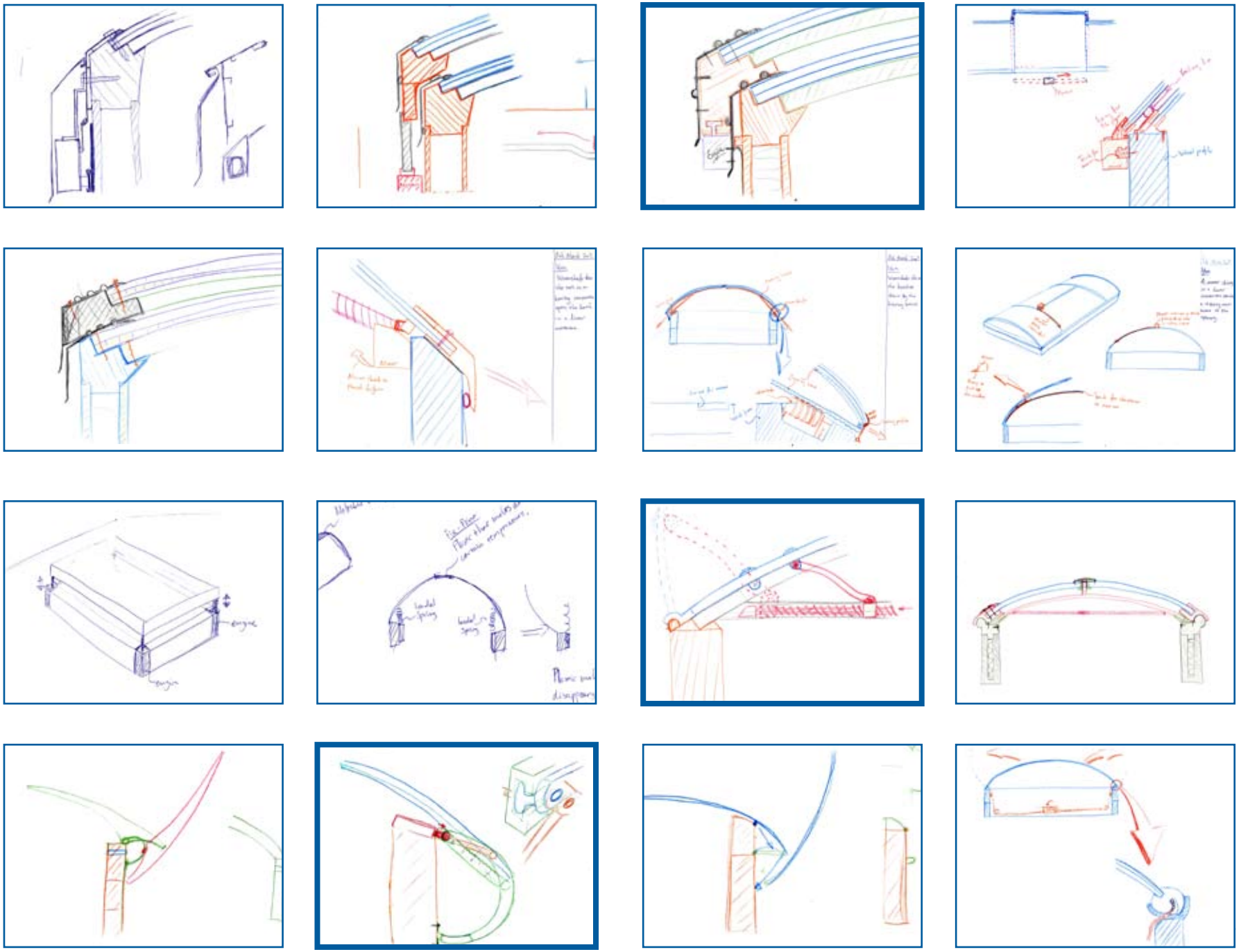
Opening Mechanism

The areas from the chapter “Problem areas” that affect the opening mechanism of the new skylight are translated into the following statements:

- Increase inflow of light by moving motor from the inside or changing the motor principle
- Improve aesthetics by making the motor less noticeable and make a cleaner appearance on the inside

The sketches presented on the opening mechanism build on similar frame principles as presented in the previous chapter “Frame”.

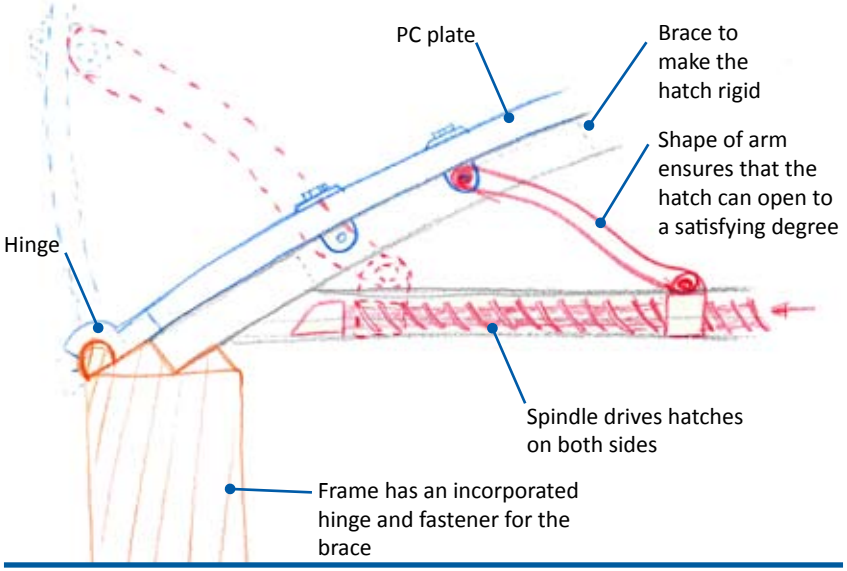
ill. 2.12. - The current motor is placed across the window, which decreases the inflow of light into the building. Furthermore this solution increases the perceived aesthetic complexity.



Ill. 2.13. A selection of the sketches made on the opening mechanism - the highlighted sketches are presented in detail on the following pages.

Spindle

The spindle solution is inspired by a discontinued motor from Domex where a small spindle motor opens the window (ill. 2.14.). In the sketch the spindle is placed horizontally instead of vertically. The spindle transforms a linear movement to a circular movement driving the hatch. The advantage of a spindle motor is that it needs little power to open the hatch depending on the threads denseness.



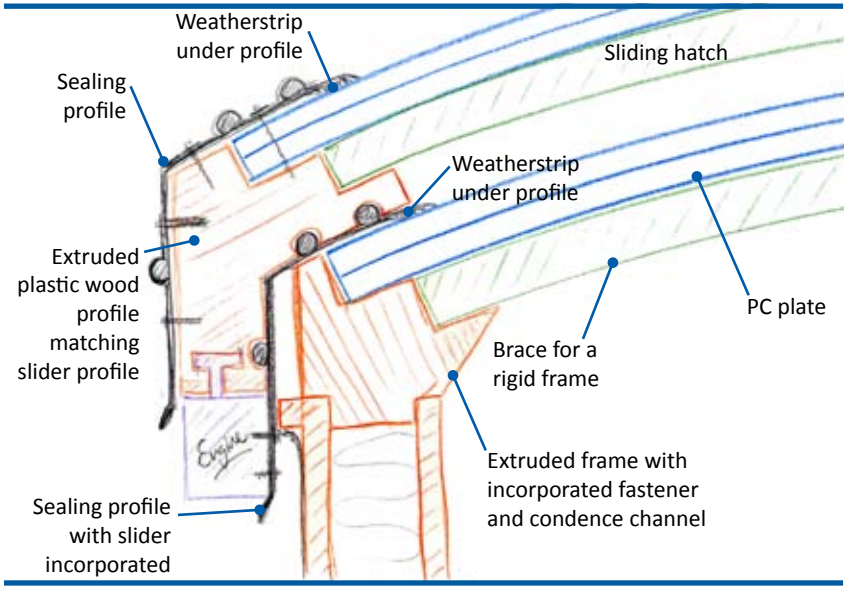
ill. 2.14. - The discontinued spindle engine increases the inflow of light into the building and can - through a design process - make the skylight appear simpler regarding aesthetics.

Pros

- Smaller than current motor
- Mostly a standard solution
- One motor can drive hatches on opposite sides
- Increases inflow of light beacuse it can be smaller
- Can blend in by brace appearance

Cons

- The motor is visible on the inside
- The motor might open slowly depending on the threads denseness
- Poor possibility to support spindle in the 2400mm transverse span



Slide

A cars sunroof inspires the slide concept for the opening mechanism (ill. 2.15). A slide solution requires a smaller motor. The moving window rests on the fixed window, sliding on an aluminum profile. PC plates and braces are fastened directly in the extruded profiles. Moving the motor outside increases inflow of light and gives a clean inside appearance.

Pros

- Clean linear movement needs less energy
- Smaller motor than current pneumatic actuators
- Motor not visible from the inside
- More inflow of light
- Clean inside appearance

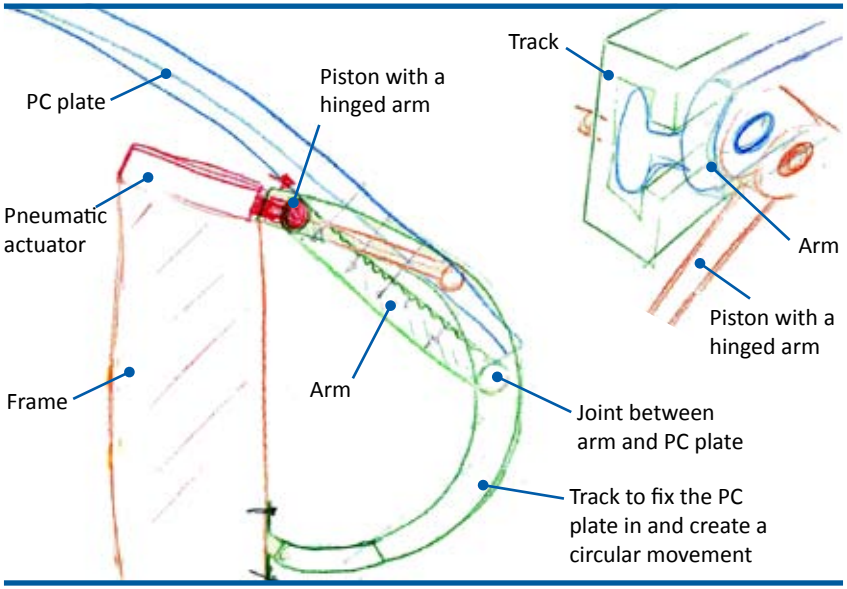
Cons

- Can be problematic to seal the ends of the sliding hatch
- Many extruded parts
- Possible friction problems between plastic wood alu sliding profile
- Thermal bridge in alu profile for sliding

ill. 2.15. - Car sunroof that can slide away on tracks in the roof.

Tailgate

The tailgate function is inspired by the tailgate on a car where the hatch is sealed all the way round (ill. 2.16). A pneumatic actuator fixed on the frame creates a circular movement by moving the hatch on a track mounted on the frame. This way the hatch can be sealed as on a cars tailgate.



ill. 2.16. - Tailgate on a car with pneumatic actuators and a weather strip round the border on the hatch.

Pros

- Motor not visible on the inside
- Standard motors
- Increased inflow of light
- PC plate can be sealed the whole way round

Cons

- The motor becomes very visible from the outside
- PC plates continue beyond the frame and is not supported there
- PC plates beyond the frame create lift when it is windy

Recapitulation

All the concepts fulfill the criteria presented for the opening mechanism in the beginning of the chapter.

However the “Tailgate” solution needs a lot of space for the motor on the outside, which requires a higher frame a fact that possibly causes increased weight higher material cost.

The concepts “Slide” and “Spindle” however are more plausible as they build on the frame solutions from the chapter “Frame” and have some cons that more easily can be solved.

Therefore the principles “Slide” and “Spindle” are most suited for new opening mechanism.

The final selection of an opening mechanism takes place after a meeting with Domex regarding the concepts. The selection can be seen at the end of the concept development phase.

Ventilation

ill. 2.17 - Upper left: A fire ventilation skylight shown as it is commonly opened during comfort ventilation.

Righ: The raid and wind sensor.

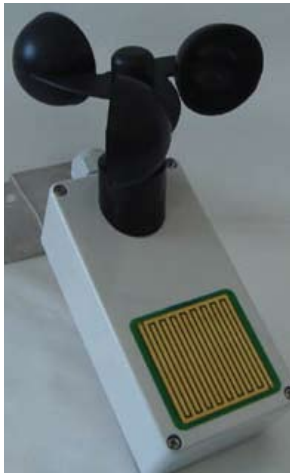
Lower left: The emergency button that is activated during a fire.

Middle down: The controls installed for comfort ventilation.

During the concept development the project group becomes aware that customers to the fire ventilation skylight commonly use the skylights for comfort ventilation.

Due to requests from customers Domex has therefore made rain/wind sensors and an open/close button that bypasses the emergency button available in their accessory program. (ill. 2.17.)

In that way it is possible for the workers inside to open the fire ventilation as little or much as they like on for instance on a hot day – and if it starts to rain or if the wind picks up, a rain/wind sensor can be connected that will close the window automatically upon certain wind and/or rain conditions.

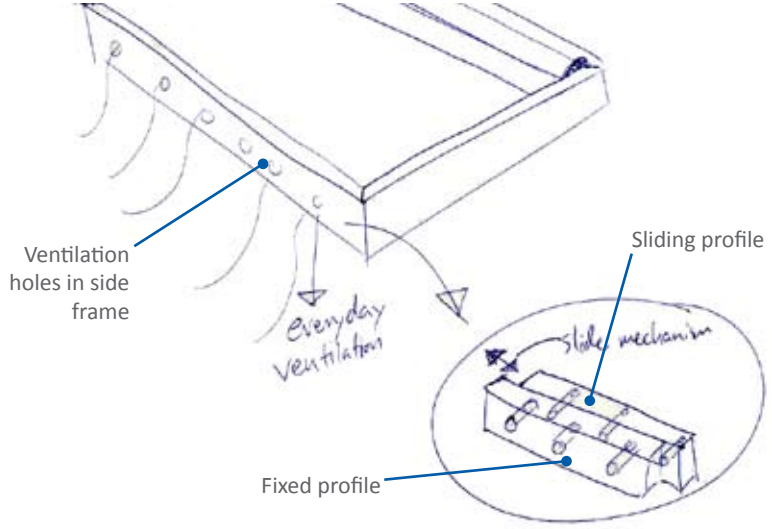


Additional sketching

Based on this knowledge, the project group has found it interesting to present Domex with an additional concept proposal – in addition to the proposals set to accommodate the key points identified in “Problem areas”. The approach to the comfort/fire ventilation is defined with the following statement:

- “Can the comfort ventilation with benefit be separated from the fire ventilation – avoiding the use for sensors and controls separate from the emergency button?”

In the following pages three concept proposals that address this statement can be seen. The selection/de-selection of these proposals will take place after the presentation of the concepts at Domex A/S.



Hole

This concept is inspired by the Tupperware container in ill. 2.18.

A small motor within the side frames controls a sliding mechanism between two profiles with holes. When the motor is activated it will position the holes in the two profiles opposite each other by sliding one profile to the side - and outside air for comfort ventilation can enter building. When closing the comfort ventilation the process is reversed.

Pros

- Comfort ventilation can be on in rain and when the wind is rising
- No rain/wind sensor required

Cons

- The side frames becomes more complex
- Ventilation holes interferes with felt roofing
- Additional cabling required

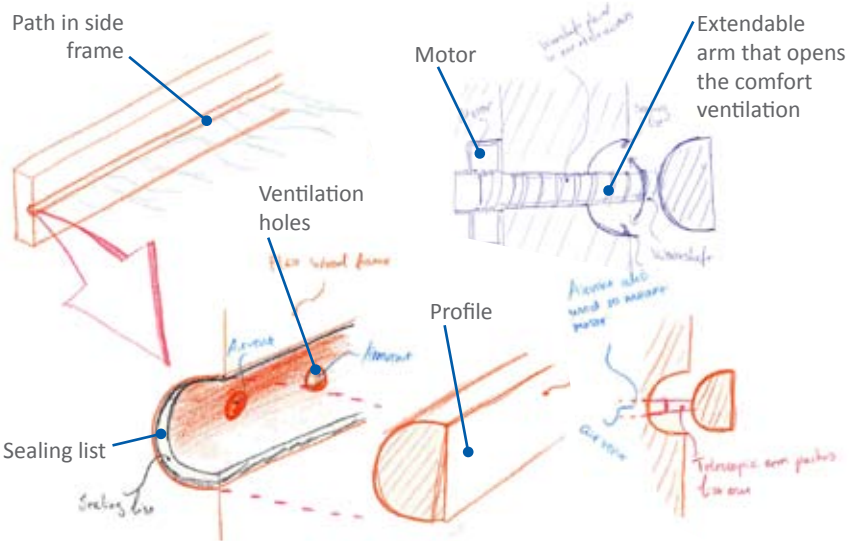
ill. 2.18 - A Tupperware container where a small opening makes it possible to ventilate the container without opening the entire container.

Profile

The profile concept is inspired by the drawers that can be seen in ill. 2.19.

A semi-circular path is cut in the side frame and holes are drilled within the path. A semi-circular profiles that fits the path is fastened to the path via a number of small telescopic motors. When opening the comfort ventilation these small telescopic motors will push the list outwards an outside air can enter the building.

ill. 2.19 - These drawers are designed to be very tight and operates like a chiller- thereby enabling the inside to have a controlled environment while still maintaining the functionality of a regular drawer.

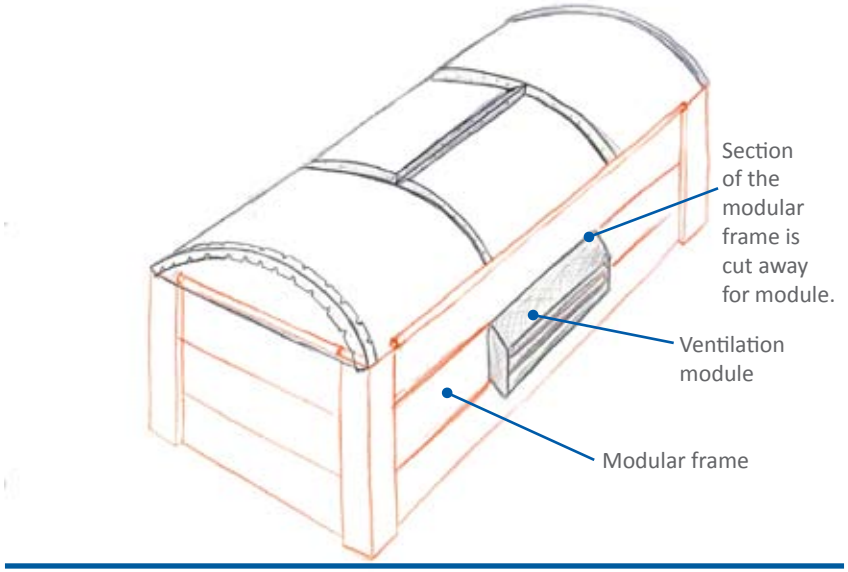


Pros

- Comfort ventilation can be on in rain and when the wind is rising
- No rain/wind sensor required

Cons

- Many small motors required
- The side frames becomes more complex
- Ventilation holes interferes with felt roofing
- Additional cabling required



Module

The module concept is inspired by a skylight window from Bristolite Skylights. (ill. 2.20.)

The idea is to mount a complete comfort ventilation module in each side frame that does not require anything to be built into the frame itself – rather a portion of the frame is simply cut away to make room for the ventilation module. After the mounting of the module into the frame – simply connect it to the power grid.

Pros

- Adds limited complexity to frame
- All needed for ventilation is placed within the module
- Comfort ventilation can be on in rain and when the wind is rising
- No rain/wind sensor required

Cons

- Additional cabling reguired
- Module interferes with felt roofing
- The module could become a thermal bridge

ill. 2.20. - The american company Bristolite Skylights have made a skylight with inbuilt comfort ventilation - an idea that could be adapted to fit the new Domex skylight.

Recapitulation

The “Hole” and “Profile” concepts ads a lot of complexity to the frames of the skylights – a fact that goes against the criteria presented for the frame in “Problem areas”.

The “Module” concept demands an extra effort in the work process when assembling the skylight, but since the module contains everything needed to operate and only needs to be connected to the power grid – it is seen as an acceptable trade-off.

Based on these facts it is chosen to present the “Module” concept to Domex.

The final selection/ de-selection regarding if this additional proposal should be a part of the development of the new window will take place after the concept presentation at Domex.

Domex Presentation 1

After sketching on the three areas of the skylight - frame, opening mechanism and ventilation – the four selected concept are presented for Domex (ill. 2.21).

Employees attending the meeting are the CEO, production manager, sales manager, construction manager and key accountant.

The key accountant is within the company regarded as the expert on skylights as he has a good understanding of all aspects concerning the skylight – also more detailed knowledge such as CW factor, U-values and motor design.

The four concepts have been redrawn for presentation purposes and easier communication of the concepts (ill. 2.23).

The presentation starts with an introduction to investigations performed in the project, followed by the four concepts.

With each concept the benefits compared to the current skylight are presented along with the background information containing the arguments for the specific concept proposal.

The presentation as a whole can be seen in appendix 5.

ill. 2.21. - Presentation at Domex with CEO, key accountant, production-, sales- and construction manager.

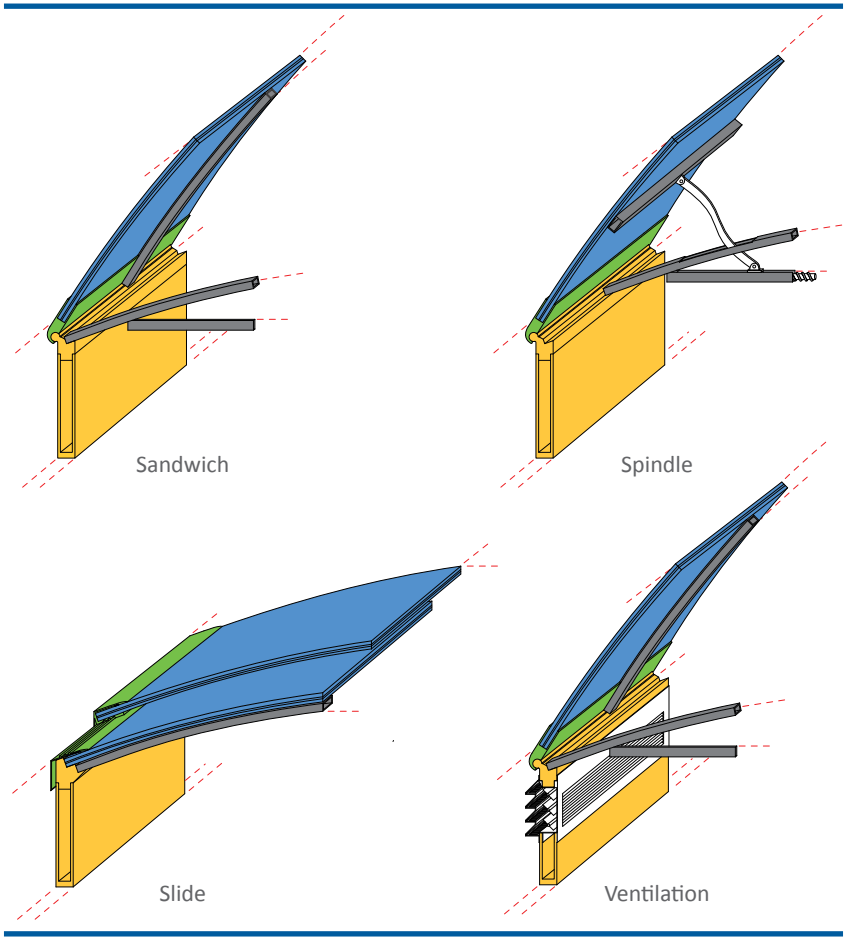
Feedback

Based on the presentation the project receives feedback on the four concepts.

The dialogue regarding the pros and cons of the different concepts has provided the project group with information which gives the project group an overview of the most plausible concepts for the further development.

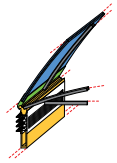
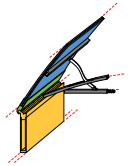
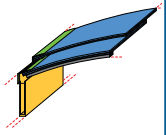
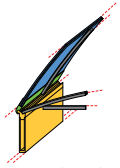
The feedback from Domex and the project group's reflections can be seen in ill. 2.24 – 2.25.

ill. 2.22 - Domex´s current skylight.

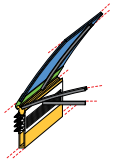
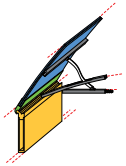
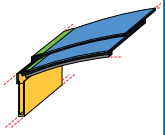
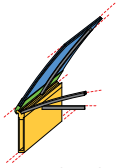


ill. 2.23 - The four re-drawn concepts presented at Domex.

Concept Evaluation

Concept	Domex feedback
 Ventilation	Domex does not consider the separate comfort ventilation as one offering strong selling points. This is because with growing demand to install mechanical ventilation in industry buildings it has become less common for customers to buy the comfort ventilation accessories– since this more often is handled by the mechanical ventilation. Furthermore separate ventilation in the frame could mean extra costs, thermal bridges, snow problems, and the need for a higher frame because of felt roofing.
 Spindle	Domex does not consider the spindle principle as one differentiating enough from their current solution - although some improvements are made in the concept proposal. Domex also sees the great span the spindle has to operate in as a problem due to the poor possibility to support the spindle in the transverse span.
 Slide	Domex is interested in the slide concept due to the fact that the motor could be removed from the inside and thereby offer an aesthetically simpler product. It is proposed that the slide principle is converted to a lift and slide principle for two reasons. Firstly a lift function could ease the slide function if there is snow lying on the skylight and secondly the lift function could offer the possibility to seal the closed window very tightly like for instance a fridge.
 Sandwich	The frame concept can offer some clear advantages regarding construction, assembly and insulation because the solution can eliminate a number of profiles and resolve some of the insulation problems. However Domex is interested in knowing more about the price of the plastic wood and the heat resistance of the material.

ill. 2.24 - The feedback from Domex for the different concepts.

Concept	Project group reflections
 Ventilation	The ventilation concept adds some complexity to the frame, which is not returned with a greater profit or better selling points. This is against the competitive strategy set up for the new Domex product and therefore it does not comply well with the company vision. Furthermore the frame ventilation concept presents a solution to an area of declining profit for Domex and it contains different issues regarding snow/sleet and the mounting of felt roofing.
 Spindle	Based on the fact that the spindle concept does not offer a solution that differs very much from the current solution the possibility to present a different product onto a very uniform market is reduced significantly. Furthermore only small steps are taken towards solving some problem areas – increase inflow of light, clean appearance on the inside. On top of that there is a challenge in the great free span the spindle has to cover.
 Slide	The slide concept offers a solution that is very different from the current product and with some of the modification suggested at the meeting this concept also holds the possibility of presenting a new product to the Danish skylight market. These facts comply well to the company vision and also offers a new range of possible selling points such as, improved aesthetics and improved inflow of light.
 Sandwich	The frame principle has been applied to all the presented concepts. Based on the fact that Domex considers this a very beneficial plausible solution regarding construction, assembly, insulation problems etc., clarifies to the project group that this concept has potential. Especially if price and material properties can fulfill the demands for the product.

ill. 2.25 - The reflection from the project group on each of the four concepts - based on the feedback from Domex.

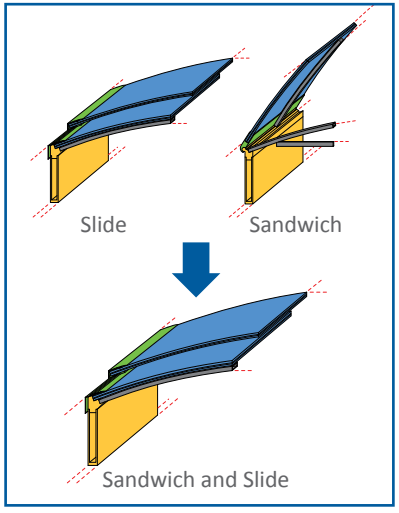
Concept Selection

In illustration 2.26 a diagram has been set up for how well the different concepts fulfill the mission statement.

Based on the evaluation and the concept comparison to the mission statement it becomes clear that the “Sandwich” and “Slide” concepts are the ones fulfilling the intension of the project group in the best way.

As the “Sandwich” concept receives very good feedback and based on the fact that it also is a part of the “Slide” concept it is decided that the further development should continue as a combination of these two concepts.

Now that two concepts are selected and combined into one, the detailing on this solution can begin. This concludes the concept generation.



ill. 2.27 - The two selected concepts merged into one concept for further development.

Criteria / Concept	Reduce thermal bridges	Increase inflow of light	Cleaner appearance on the inside	Simplify construction	Simplify assembly	Reduce number of parts	Differentiate skylight
Sandwich	+ + +	-	-	+ + +	+ + +	+ + +	+
Spindle	+	+ +	+ +	+	+	+	+
Slide	+	+ + +	+ + +	+	÷	+	+ +
Ventilation	÷	-	÷	÷	÷	÷	+ +

ill. 2.26 - Diagram of how well the concepts fulfill the mission statement.

Process and Learning

Process

With the pinpointed problem areas as a background, a brainstorm is performed to identify possible concepts to satisfy the defined weak areas. Furthermore a search is performed on international skylight producers and on principles from other product categories.

This is done to seek inspiration in the international market for skylights and to identify if products from other product categories can inspire the project group to solve the problematic areas by borrowing principles from entirely different products.

Following the introductory exercises it is defined that the concept development should focus on moderate concept proposals– giving the balance between small incremental ad-hoc improvements Domex currently are performing, and the radical solutions that would require drastic changes in Domex' production facilities.

An initial – and very general – concept sketching is performed and concepts that have the potential to meet the key point from the problem areas are selected for two areas – Frame and Opening mechanism.

These two concept areas are elaborated to a level where the concepts can be presented to Domex – along with a third area Ventilation that the project group chooses to present as well based on the use of the skylights for comfort ventilation.

Four concepts from the three concept areas are presented for Domex, and based on the discussions with Domex - two areas are selected as the main principles for the new skylight – the Frame principle and the Sliding principle.

Methods

Brainstorms and inspiration search have been used as tools for initiating the concept development and to expand the horizon after defining the problem areas of the current skylight.

The process of selecting product platform has been used to define the scope of the intended changes at Domex regarding the new skylight – and thus the selection of plausible concepts has been guided by this platform selection.

In the sketching process systematic sketching has been applied to combine part solutions for the skylight into combined solutions, and systematic sketching has also been applied to cover as many details about part solutions as possible.

Via presentation and discussion at Domex the project group has aimed at presenting the concepts in both a general and easy understandable fashion but also in a way that meet the technical and detailing aspects – caused by the intimate knowledge about fire ventilation skylights at Domex.

Learning

Through the concept development the project group has been able to generate concepts that from an early stage has been very detailed.

This detailed sketching have been possible due to two things – the detailed investigations into production and mounting and the definition on the product platform to work on.

The investigations into production and mounting has given the project group a detailed knowledge about the current skylight that has enabled the detailed sketching – because of the ability to implement the desired existing solutions, build further on these solutions and make sound evalutions on the sketches.

The selection of the moderate platform has also been a valuable tool in the sketching process and evaluation of the proposals. This definition of platform boundaries have made it possible to evaluate each proposal down to very small detailes by always measuring the concepts up against the facilities/processes it would require at Domex – and if this was a possibillity within the selected platform.

Finally the presentation at Domex has given the project group an insight into how a production company that has no prior experience with external designers reacts towards designers - How they react to presentations, respond to critical questions, view solutions that differ from their current production line etc.

This has been very educative – especially because the project group is in a collaboration where the company is involved to such a degree and with so many professional competences from within the company.

Detailing

In the detailing phase the sub systems of the product are developed and refined to finish the skylight proposal. Furthermore materials and production methods are chosen for the skylight.

Methods

- Sub system division
- Systematic Sketching
- Hand calculations
- Finite Element
- Therm
- Meetings / Presentation

Introduction

In the previous chapter the two concepts with the highest potential to fulfill the mission statement have been selected and combined – defining the base for the further development of the new skylight.

Subsequently the definition and development of sub systems can begin in order to finalize the design proposal.

Product sub systems

For the development in the detailing phase the skylight has been divided into five main sub systems (ill. 3.1.):

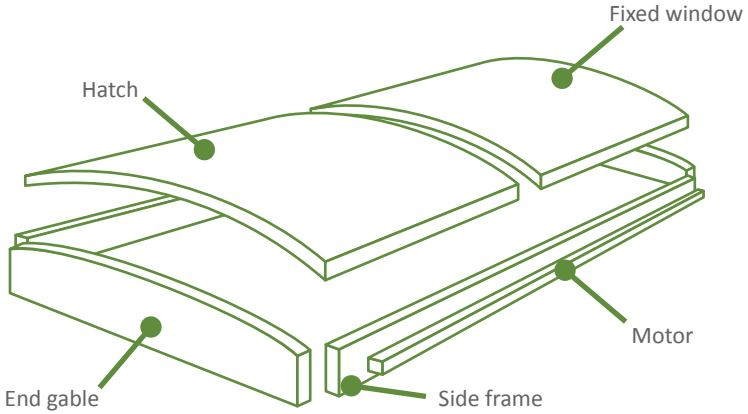
- Side frame
- End gable
- Motor
- Hatch
- Fixed window

This division into sub systems provides the project group with a better overview of the development progress as well as an overview of critical areas.

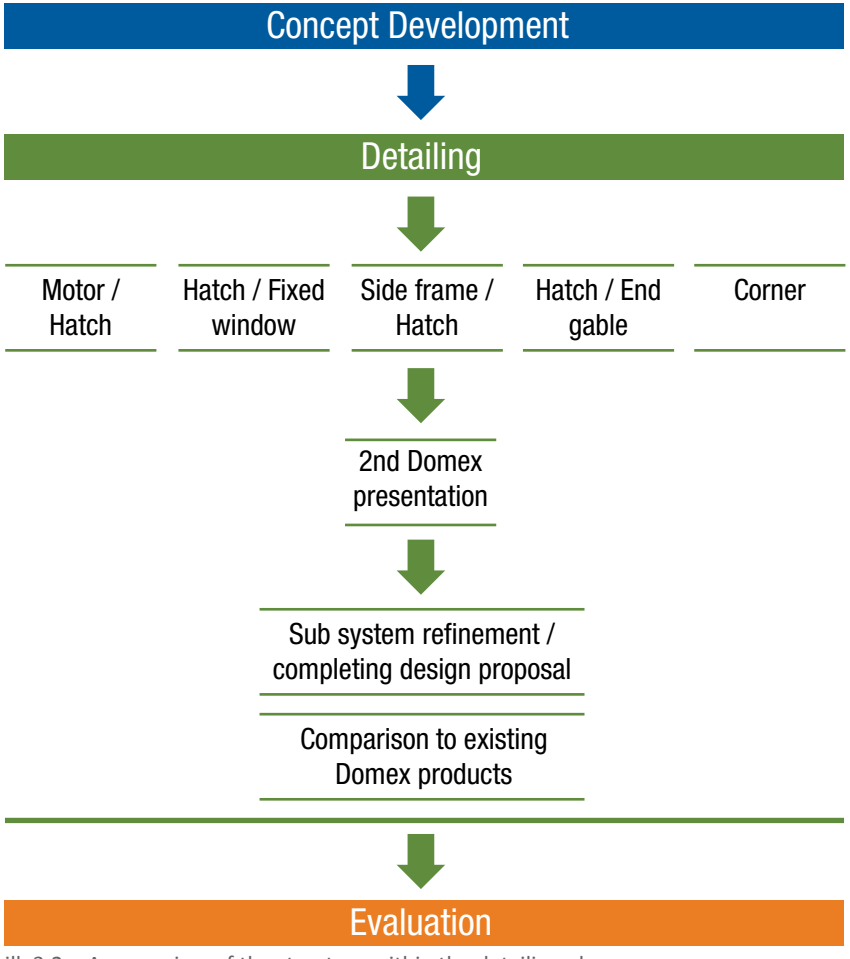
Development focus

In the detailing phase the development of the five sub systems are in focus - but a particular attention will be given to how the individual sub systems interact with other sub systems – how sub systems meet each other and how changes in one sub system affects other sub systems through the joining points between sub systems.

The development of the five sub systems and their sub system relations will be presented as a development process spanning from the selected concept in concept selection to the 2nd meeting at Domex.



ill. 3.1. - The main sub systems of the skylight selected in the concept development.



ill. 3.2. - An overview of the structure within the detailing phase.

The process shown in the detailing phase is a presentation of the key steps in the detailing process.

Phase structure

The structure of the detailing phase is built around the development of the meetings between sub systems – ending in a product proposal that will be presented for Domex A/S.

Subsequently follows a description of the development process after the meeting with Domex.

The detailing phase concludes with a status on the final result of the project development process and a comparison between the product proposal for the new skylight and the existing products from Domex (ill. 3.2).

Sub system relations

The project group has identified five important sub system relations based on the established sub systems (ill. 3.3.):

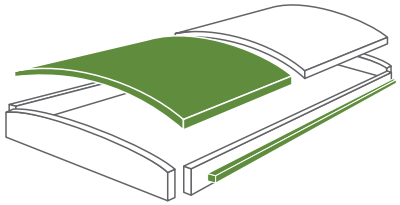
- Motor / Hatch
- Hatch / Fixed window
- Side frame / Hatch
- Hatch / End gable
- Corner

To illustrate the importance of understanding the relation between sub systems the group has set up an example with important sub system relations to consider in the development process of the skylight (ill. 3.4.).

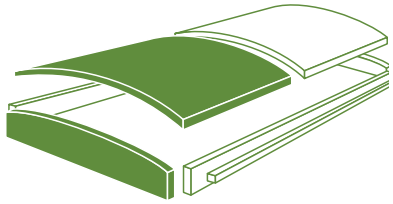
Through this example it is clear that even minor changes in one element can have implications in many other elements – elements that are not even directly linked to the modified element.

The project group intends to apply this knowledge in terms of developing and evaluating solutions in the following detailing on sub systems and sub system relations.

"Side frame / Hatch"
Sub system relation

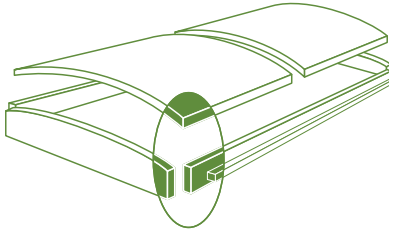


"Motor / Hatch"
Sub system relation



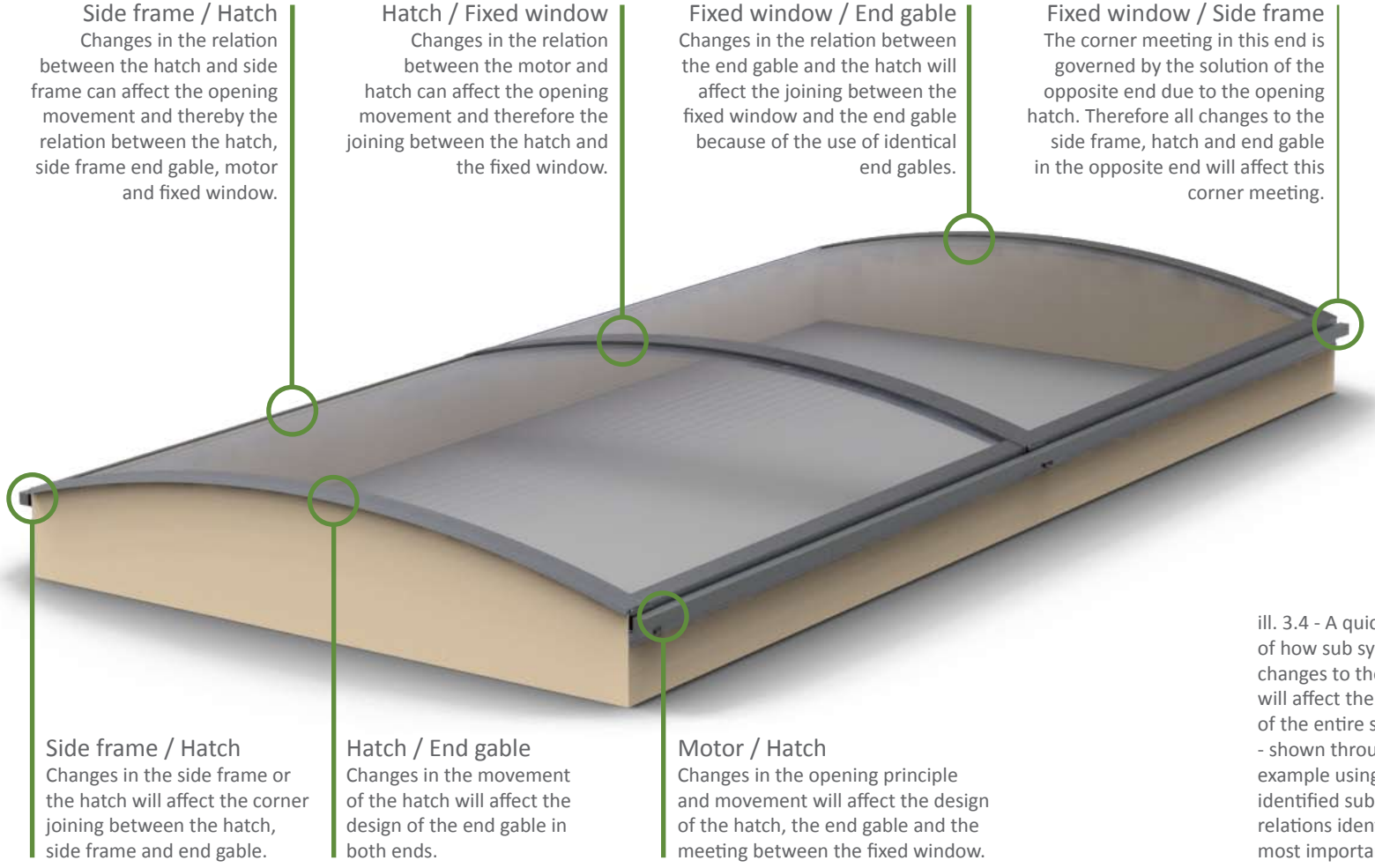
"Hatch / End gable"
Sub system relation

"Hatch / Fixed window"
Sub system relation



"Corner"
Sub system relation

ill. 3.3 - Diagram showing the five different sub system relations.



ill. 3.4 - A quick overview of how sub system changes to the skylight will affect the design of the entire skylight - shown through an example using the identified sub system relations identified as the most important.

Motor / Hatch

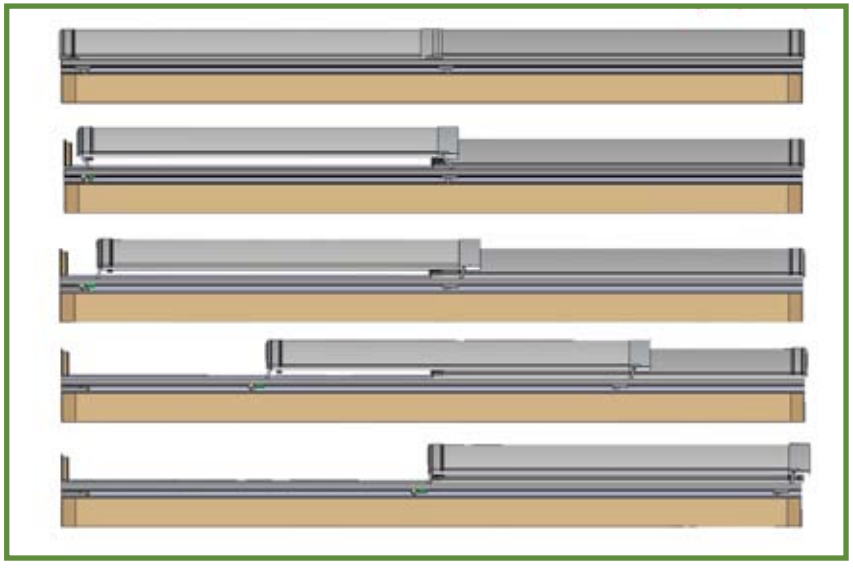
The design of the hatch and the motor and the relation between these sub systems are very important in the design of the skylight because they are essential for the further development of other sub systems.

This is due to the fact that the Motor / Hatch sub system relation has an impact on all other sub systems through the opening movement - as can be seen from the example in ill. 3.4.

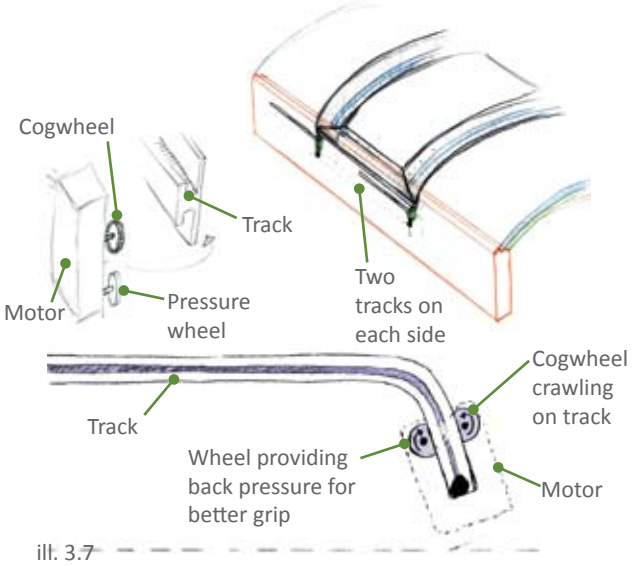
The proposal presented at the 2nd meeting regarding the Motor / Hatch sub system relation can be seen in overview and detail in ill. 3.5 - 3.6.

On the following pages a selection of sketches will explain the development in sequence from the 1st meeting at Domex towards the stage presented at the 2nd meeting.

ill. 3.5 - An overview of the area in focus in Motor / Hatch detailing.



ill. 3.6 - A step sequence of the opening hatch as shown to the 2nd meeting.



ill. 3.7

Curved track

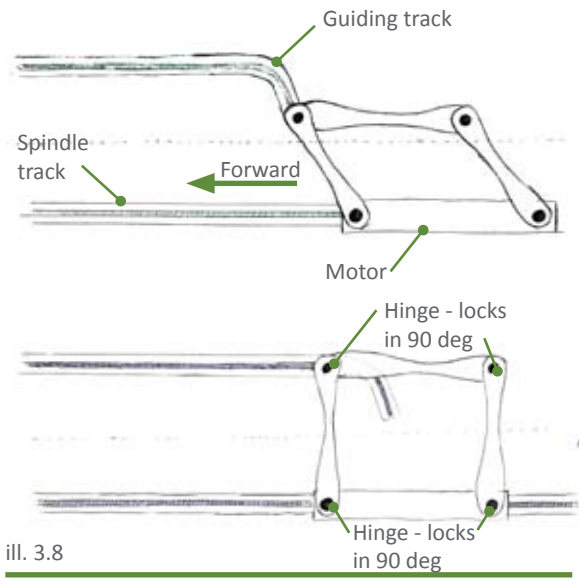
PRINCIPLE (ill. 3.7): Following the feedback from the 1st meeting with Domex the opening movement is changed from being a slide movement to being a combined lift and slide movement. This is done by placing a track with a motor on each side frame. The movement of the motor on the track thus performs both a lift and slide function.

Pros:

- Motor moved away from the inside
- Lift and slide in one movement

Cons:

- Strong motor needed due to lifting movement
- Large pressure power needed on the track for the motor not to skid



ill. 3.8

Linear track

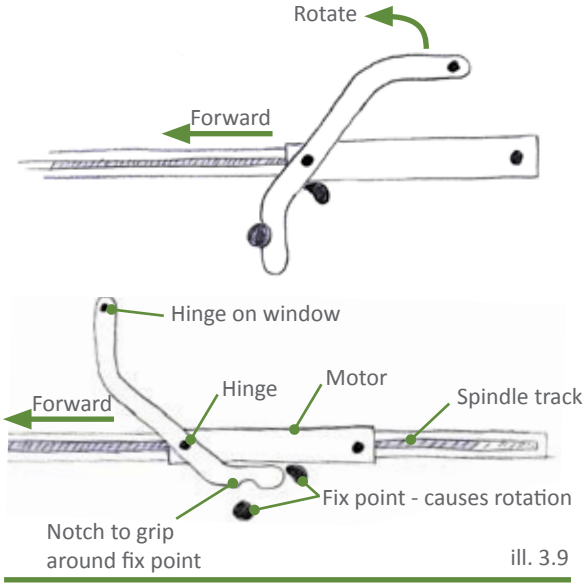
PRINCIPLE (ill. 3.8): In order to ensure a strong grip for the movement, it is decided to return to a linear driving track. To enable the linear track to perform a lifting movement a parallelogram driving on two tracks is created. The lower is the driving spindle and the top track guides the parallelogram in an upright position lifting the window.

Pros:

- Driving track remains linear
- Strong translation into lifting power

Cons:

- Takes a lot of space on the side frame
- Tension in the upper joints during forward movement
- Complex solution with many parts



ill. 3.9

Swing arm

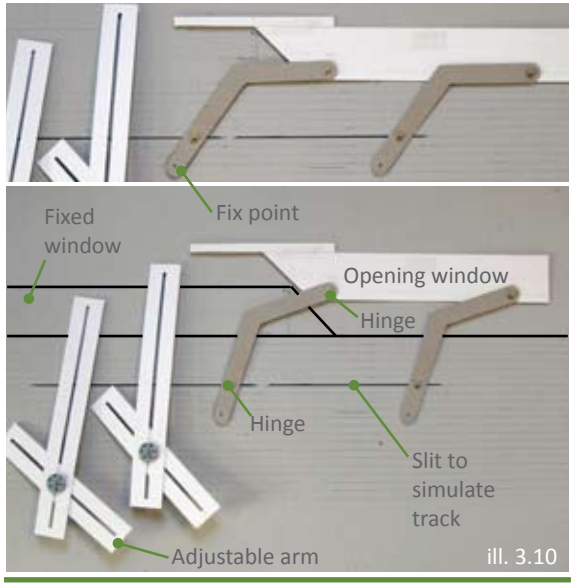
PRINCIPLE (ill. 3.9): To simplify the opening mechanism the parallelogram is replaced by a swing arm. The swing arm is attached to a motor on a spindle. When the motor moves forward it causes a rotating movement when the swing arm hits a fix point. When returning to closed position a fix point forces the swing arm to rotate the opposite way.

Pros:

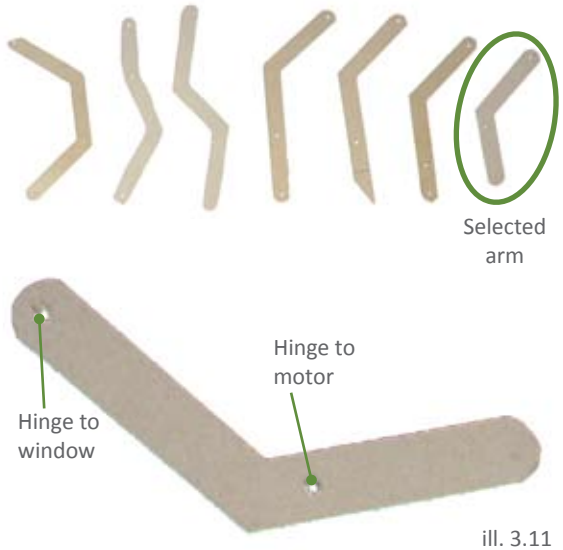
- Compact mechanism with few parts
- Linear and circular movement in one solution
- Simple appearance

Cons:

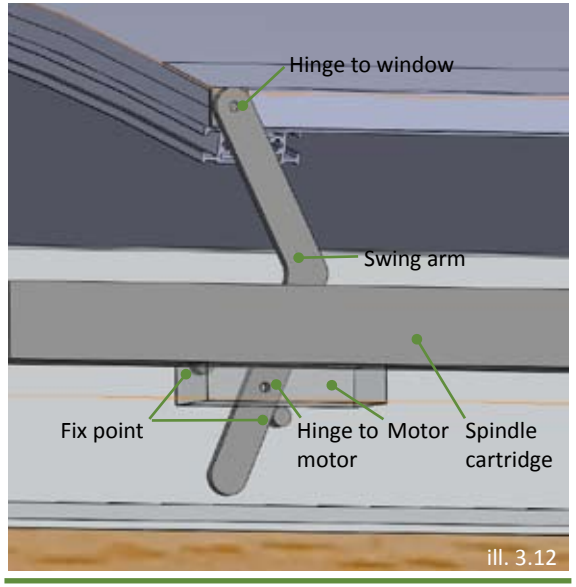
- Arm pressing on motor in open position
- The circular movement when closing is not a controlled movement



ill. 3.10



ill. 3.11



ill. 3.12

Selected principle

Using a single track to drive the motor and a swing arm to create the rotation movement is a plausible and simple solution – with the possibility to use largely standardized parts which correlates to the Cost Leadership strategy.

In order to investigate the movement thoroughly a 1:1 functional model is created. The rough shape of the arm shape is tested through two adjustable arms and then cut in cardboard (ill. 3.10).

The frame is marked up in vertical intervals to determine the optimal placement for the track and thereby the starting point of the rotational movement. A section cut is made in the fixed light and the hatch above the side frame since this is the area where the hatch must be lifted highest due to curvature. Two cm are set as the minimum clearance between the hatch and fixed window.

Arm design

The shape of the arm is very important in order to get as much rise on as short arm as possible. This is necessary to minimize the momentum on the arm and to get the spindle placed as high on the frame as possible (ill. 3.11).

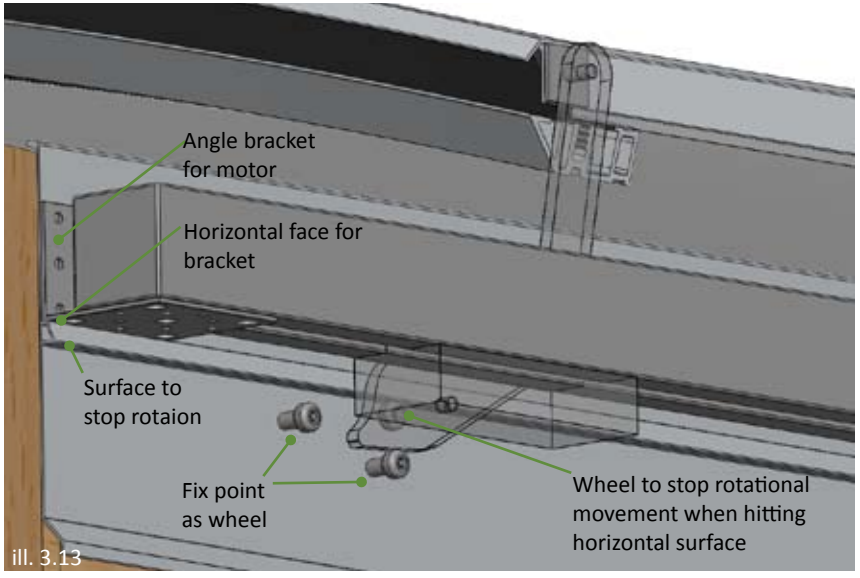
The enlarged arm in the picture above creates the right movement for the window so a calculation of strength can be performed. Calculations show that the arm can perform the movement with a safety factor of 204 regarding bend with a 5mm steel plate. The whole calculation can be seen in appendix 6. The arm can now be moved into Solid Works for a more detailed test of the movement and the shape.

CAD Modeling

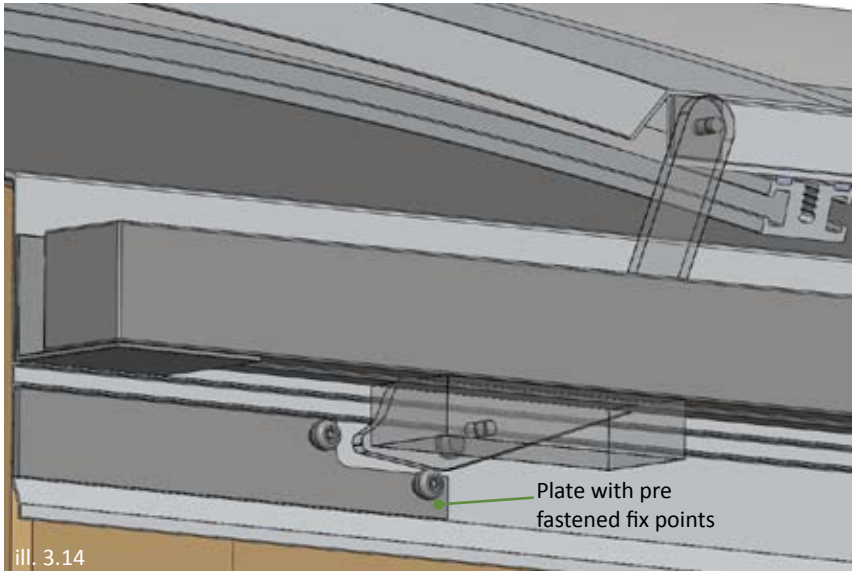
Moving into 3d gives a better understanding of the movement of the entire hatch and the fix points causing the rotational movement can be placed accurately. However adaptations are made since the movement cannot be translated directly from the cardboard model to 3d since it is too inaccurate compared to the rest of the 3d model (ill. 3.12).

It becomes clear that the motor should not be used as a stop bracket for the rotational movement as intended. This is based in the fact that it will be undesirable to expose the motor for external forces that could affect the linear movement.

Furthermore the assembly/mounting of the motor onto the frame and hatch needs to be solved in order to minimize mistakes and work processes.



ill. 3.13



ill. 3.14

CAD Modifications

The shape of the swing arm is changed in order to give the right movement and compensate for changes in the translation from cardboard to 3d model (ill. 3.13).

The fix points causing the rotational movement are changed to wheels to minimize friction and to make the movement smoother.

The part of the arm touching the fix points is modified to a shape that correlates better to the circular movement in the beginning of the opening function. A change that - combined with the placement of the wheels - ensures that the arm cannot fall back or forth when the window is opened or closed.

An element is added to the alu profile resting on the frame – securing that the angle bracket used to mount the motor is placed in the correct height.

Furthermore a wheel is put on the back of the swing arm to stop the rotational movement. The wheel stops on the same horizontal surface that secures the correct mounting height for the angle bracket.

2nd Meeting

As a final modification before the 2nd meeting at Domex, the fix points are placed on a metal plate that fits in between the area of the alu profile that stops the arm movement and the drip edge of the alu profile (ill. 3.14).

This secures a more accurate assembly process of the fix points since the plate only needs to align with the end of the alu profile.

An area of the plate is cut away to enable the stop wheel from moving freely when the skylight is moved into a closed position.

The project group also decides that the motor should be a pre-assembled module from a sub contractor as the current motor used by Domex. This is done to minimize potential errors in mounting/ assembly either at Domex or on a building site.

Manufacturer Feedback

Following the last changes regarding the motor Actulux - the supplier of the motors currently used by Domex - is contacted for feedback on the design of the opening principle.

Via contact through email and telephone the principle is explained and drawings are sent to a contact person at Actulux. The contact person finds the principle and design interesting and states that the technical aspects can be solved. In addition he discloses that Actulux is currently working on a comparable solution.

Actulux points out areas that require attention in a further development (Full feedback can be seen in appendix 7.):

- The cabling will be in the way of the motor if the motor runs on the spindle and not turning the spindle
- The stiffness of the spindle must be considered due to the span of the spindle.
- The spindle must be weather resistant, kept clean and have a minimum of friction
- A tandem steering between the two motors is needed
- The mounting/assembly needs to be precise

Recapitulation

The motor construction has become rather simple in relation to the first ideas and less space consuming.

A single linear track gives the opportunity to use a spindle, which has the ability to provide powerful thrust which is important as the opening movement both lifts and slides.

The project team has aimed at making an assembly process with a minimum of measuring to make the procedures as precise as possible.

Furthermore the motor is intended to be delivered as one unit from Actulux which also will minimize the possibility for inaccuracies in the mounting process. The areas mentioned by Actulux will be a part of the later development.

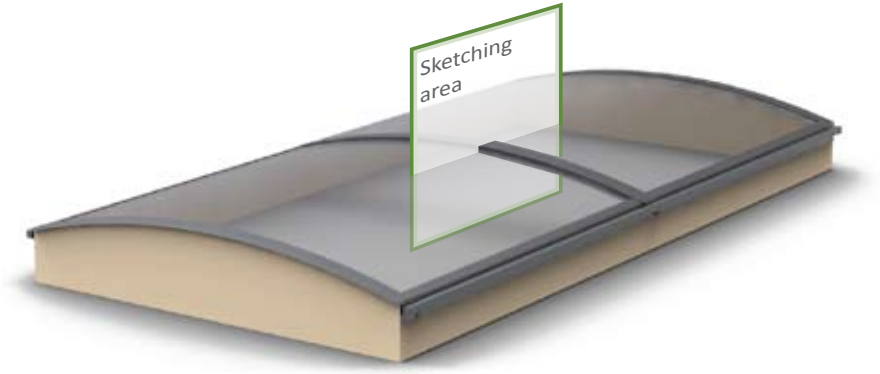
Since the design of the motor has been established and the sub system relation between the hatch and motor is developed, the design of the remaining sub systems and sub system relations can commence.

Hatch / Fixed Window

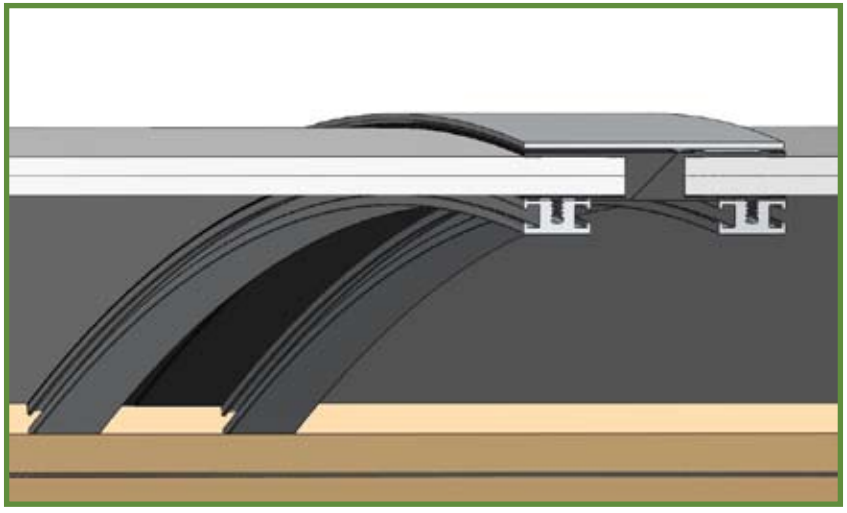
The design process of the meeting between the opening window and the fixed window shows the development of profiles that can accommodate the opening movement generated in the prior chapter. Furthermore thermal bridges and sealing of the joining area is in focus.

The proposal presented at the 2nd meeting with Domex regarding the Hatch / Fixed Window sub system relation can be seen in overview and detail in ill. 3.15 – 3.16.

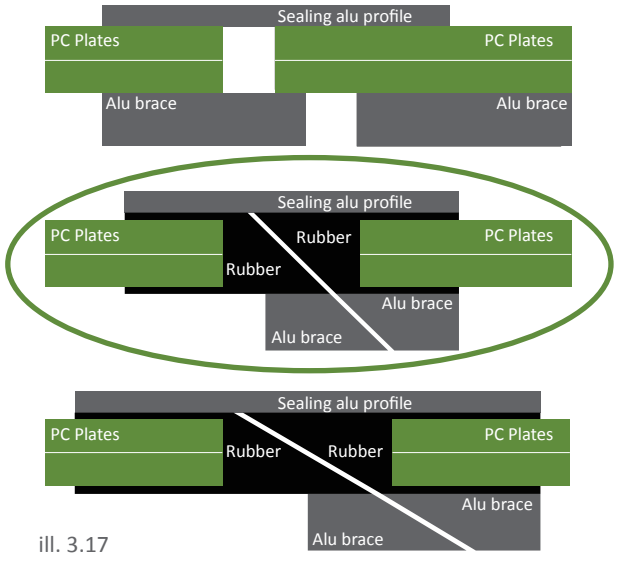
On the following pages a selection of sketches and screen dumps from Solid Works will explain the development of the Hatch / Fixed window sub system relation in sequence from the 1st meeting at Domex towards the stage presented at the 2nd meeting.



ill. 3.15 - An overview of the area in focus in Hatch / Fixed window detailing.



ill. 3.16 - A close up of the proposal for how the hatch and fixed window meets as shown to the 2nd meeting.



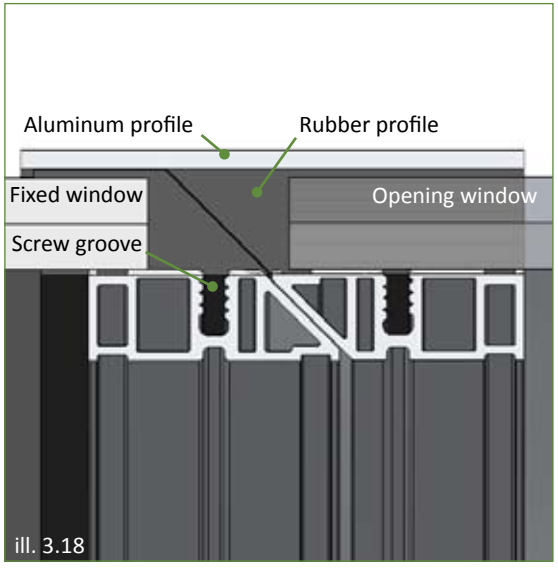
ill. 3.17

Cardboard Models

The meeting between the opening- and fixed window has partly been developed through cardboard models illustrated in ill. 3.10 in the previous chapter. The cardboard model has been used due to the direct link between the hatch/ fixed window joining to the movement of the opening window.

Three variations of the meeting between the two sub systems are developed. One with gaps between vertically cut elements and two where the sub systems meet in an angle (ill. 3.17)

The step solution has the inconvenience that there has to be space between the two sub systems in order for the two not to

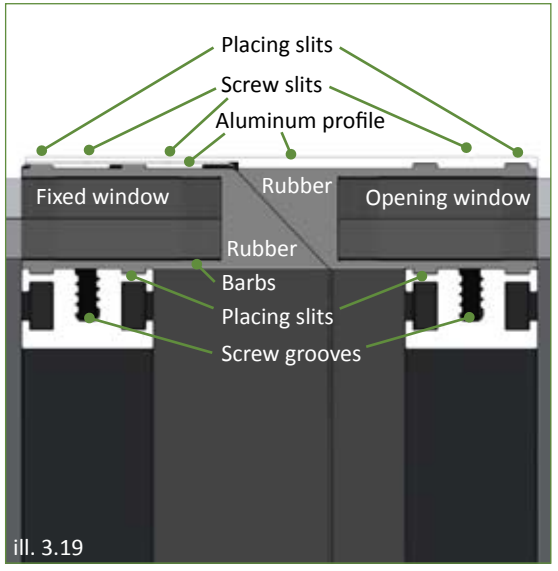


ill. 3.18

interfere with each other during the opening movement. The gap means a thermal bridge or bad insulation at best.

A meeting with a low angle induces the need for a sealing alu profile to cover the span between the braces. This will reduce the inflow of light and increase the price for the sealing alu profile.

It is discovered that an angle of 45 degrees is the most suitable regarding the clearance during the opening movement and for how the two rubber profiles meet during a closing movement. Therefore the 45-degree angle is selected as the solution as it is the most plausible solution.



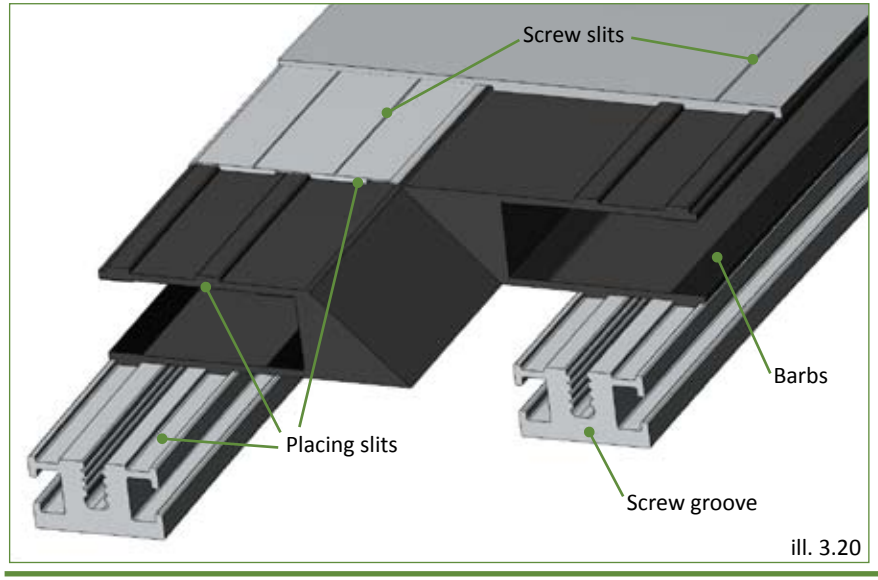
ill. 3.19

CAD Modeling

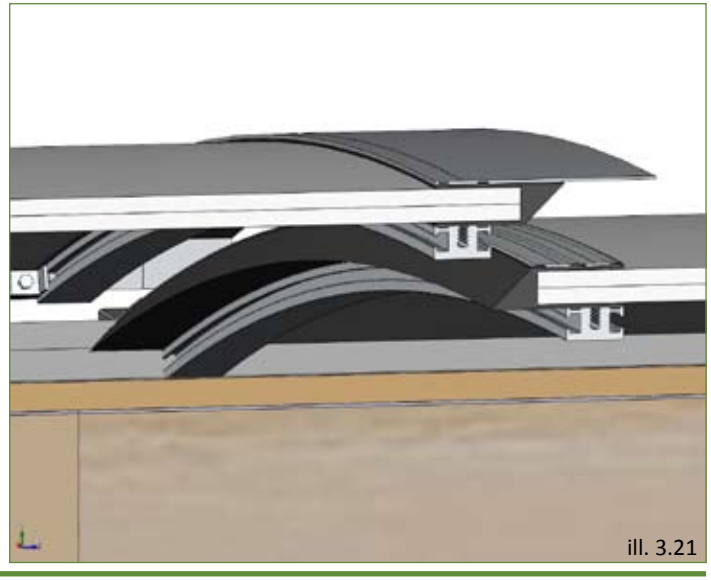
Translating the cardboard model into 3d gives a better overview of the solution (ill. 3.18). PC plates are covered with a rubber profile to seal the joint and prevent a thermal bridge. On top of the rubber profile on the opening window an aluminum profile is mounted to protect the rubber from the sun and seal the joint from water.

Bearing braces are placed beneath the rubber with incorporated screw grooves to fasten outside profiles to the braces and clam the PC plates.

The brace under the fixed window is badly placed, as the fastener cannot be used to clam the PC plates. Furthermore an additional profile is needed to clam the rubber and PC plates with the brace on the fixed window.



ill. 3.20


ill. 3.21

Far left: A reprenstation of the carboard models used to establish the joining between the hatch and the fixed window.

2nd from left: The first CAD model of the selected principle.

3rd from left: The solution presented at the 2nd Domex meeting show in section cut.

2nd from right: The solution presented at the 2nd Domex meeting shown in a view where the elemts are slided away from each other.

Right: The hatch shown early in the opening movement. Here the hatch is being liftet via the rotational movement before sliding above the fixed window.

CAD Modifications

Instead of cutting the braces in 45-degrees a smaller version of the current brace is used (ill. 3.19). In this way the same brace can be used in both places and the braces can be placed correctly according to the placing slits in the rubber and the screw slits in the upper alu profile.

The rubber profiles have incorporated placing strips for aluminum profiles and braces. This ensures that all profiles are placed correctly during the assembly of the skylight. Furthermore an aluminum profile is added on the fixed window – with incorporated screw slit and placing slits.

The inside of the rubber profiles are barbed to prevent the PC plates to slide out during the assembly procedure (ill. 3.20 – 3.21).

This solution represents the solution presented at the 2nd meeting with Domex. The solution can be seen in a large – where the different elements are slided away from each other to help illustrate the composition.

Recapitulation

The development process of the Hatch / Fixed window sub system relation has been short, as a plausible solution has been generated quickly.

The solution has no thermal bridges because a change in material has been ensured from the outside to the inside and the rubber is a poor heat conductor.

The assembly process is made simple as the rubber profiles are used to place the remaining profiles and braces due to the placing edges in the rubber profile. This also ensures that screwing slits are placed over each other.

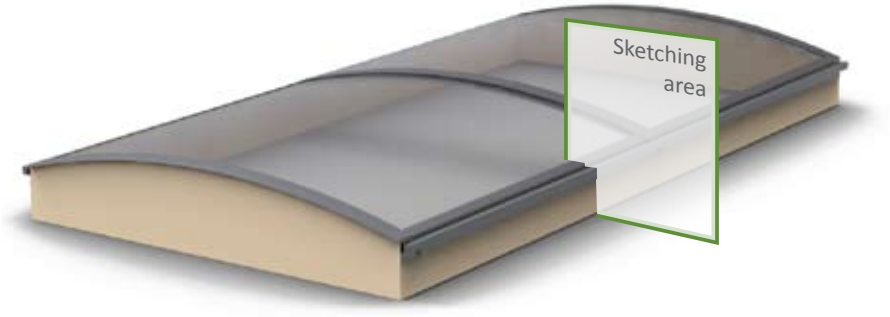
With the establishment of the Hatch / Fixed window sub system relation the design of the remaining sub systems and sub systems can be initiated.

Side Frame / Hatch

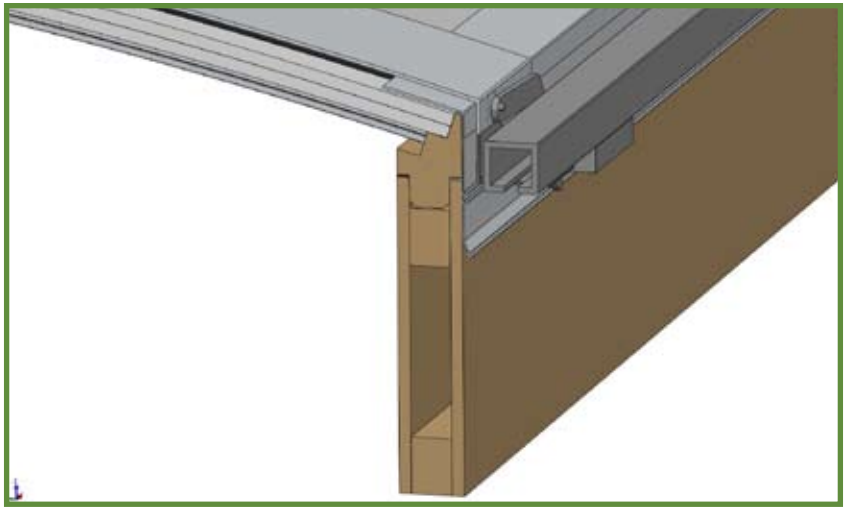
The design process of the sub system relation between the side frame and the hatch shows the development of the top side frame, profiles and sealing between the top frame and the hatch and fixed window.

The proposal presented at the 2nd regarding the Side frame / Hatch sub system relation can be seen in overview and detail in ill. 3.22 – 3.23.

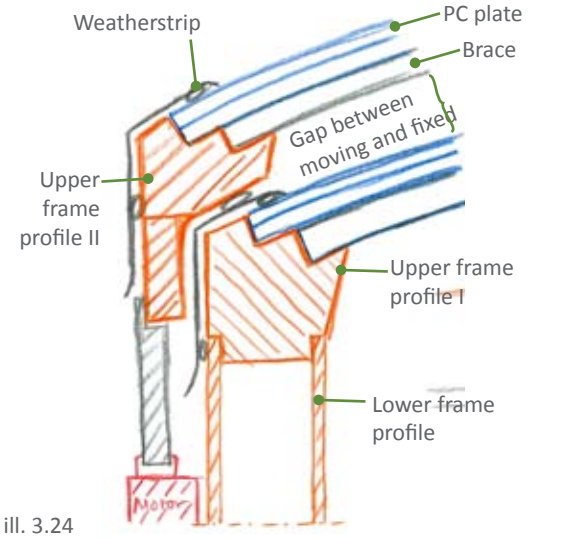
On the following pages a selection of sketches will explain the development in sequence from the 1st meeting at Domex towards the stage presented at the 2nd meeting.



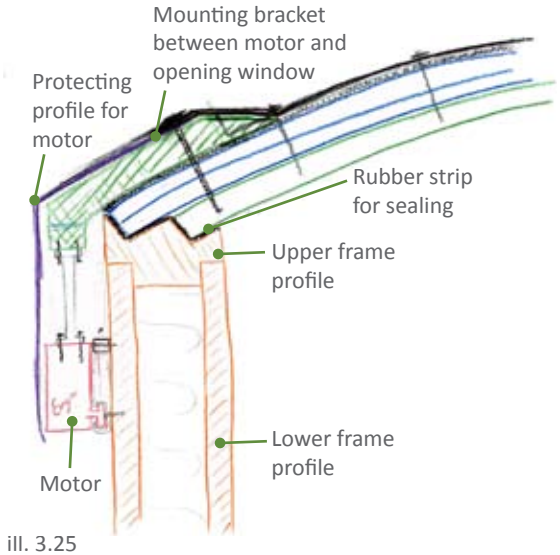
ill. 3.22 - An overview of the area in focus in Side Frame / Hatch detailing.



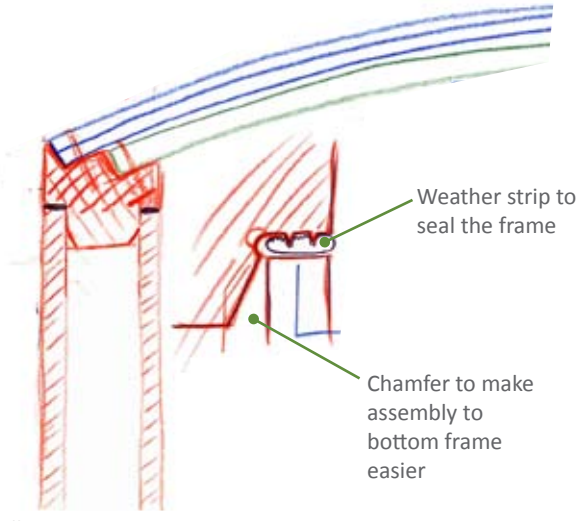
ill. 3.23 - A section cut of the proposal for the meeting between the hatch and side frame shown to the 2nd meeting.



ill. 3.24



ill. 3.25



ill. 3.26

Lift and slide

PRINCIPLE: With the decision to change the opening movement from slide to lift and slide, and the establishment of the movement - the top of the side frame and the area of the hatch meeting the side frame must be designed to follow these decisions.

Therefore the sliding solution is changed to a proposal where the hatch has a separate upper frame and rests on the fixed window in closed position. By doing so the hatch could close as a fridge by having a rubber profile in between the bottom of the hatch and the outside of the end gable and the fixed window (ill. 3.24).

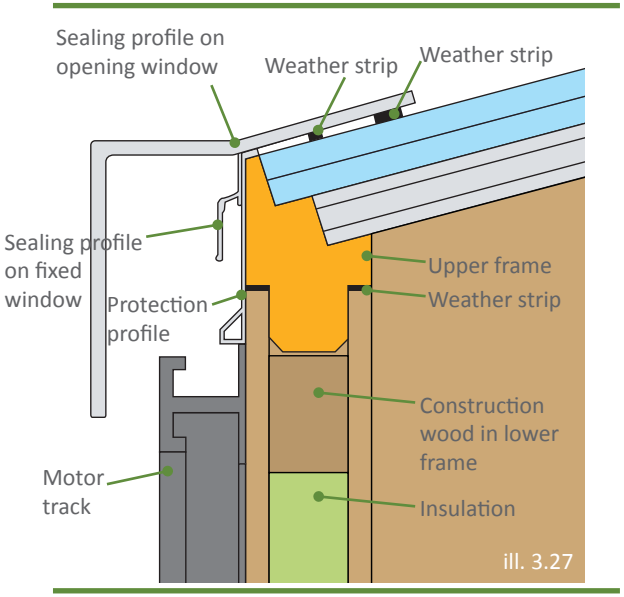
The section cut shows no thermal bridges but there lies a challenge in sealing the gap between the hatch, end gable and fixed window. Furthermore there will be problems with reduced insulation due to areas with little material thickness.

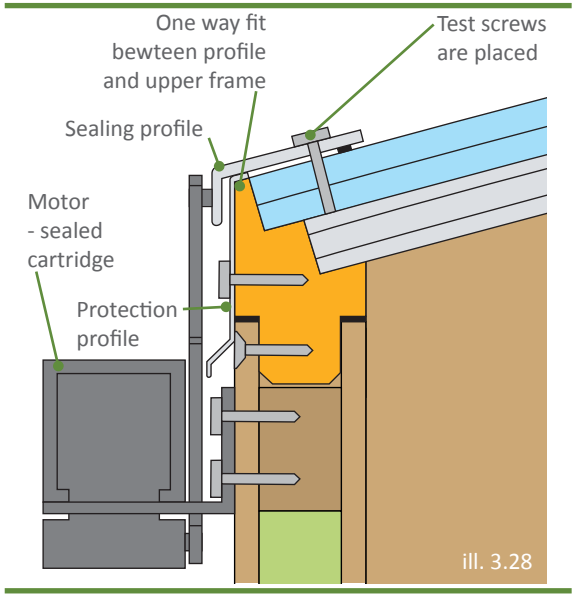
Simplifying principle

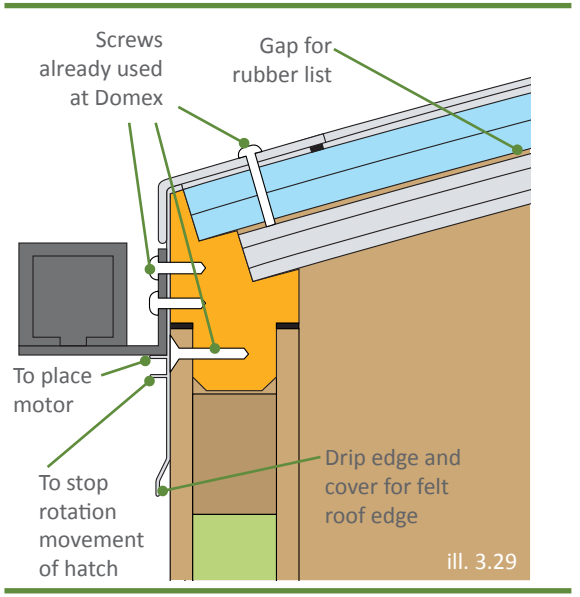
PRINCIPLE: Instead of moving a hatch on a separate top frame profile a solution where only the PC plates are moved is devised. The upper frame part is not a part of the moving hatch and can therefore be firmly fixed to the lower frame in the entire length of the window (ill. 3.25).

The fixed window is placed on the upper frame in the same way as the hatch – but simply fixed to the upper frame. In that way the hatch is on the same level as the fixed light when the skylight is closed – reducing poor insulation due to varying material thickness. By doing so the skylight also gets a simpler aesthetic look. The frame is sealed with a rubber strip under the PC plates and braces.

In order to ease the assembly process of the frame, bottom edges on the upper frame are chamfered. Furthermore a weather strip is put between the upper and lower frame in order to prevent air and water from entering the frame inside (ill. 3.26).







CAD Modeling

Switching to 3d modeling as well as making considerations on roof felting induce changes to the construction (ill. 2.27).

The upper frame part is made to have a larger area going into the lower frame in order for the fastening screws to get better grip in the lower frame. A gap between the upper frame and the construction wood in the lower frame is ensured to allow for slight deviations.

A profile is added to protect the weather strip between the upper and lower frame. The profile is also used to indicate the height where the felt roof should stop.

Additional profiles are put on to seal the fixed and opening windows. The sealing profile for the opening window also works as a bracket for the motor.

CAD Modifications

An investigation of profile extrusion induces an open protection profile, as a closed shape is more expensive than an open shape. This also creates a better drip edge. The profile can easily be placed as it fits only one way on the upper frame (ill. 3.28).

The sealing profile is made smaller since there is no need to protect the motor in a sealed cartridge. This also saves material and enables the list to be used on both the fixed and opening window.

Pre mounted motor

In order to make the mounting of the motor as precise as possible it will be a benefit if the motor is mounted onto the upper side frame at Domex. To be able to mount the motor directly from Domex the profile protecting the weather strip between the upper and lower frame needs to go beneath the motor brackets (ill. 3.29).

The protecting profile is made longer to cover the edge of the felt roof better – and also to accommodate the need to mount the wheels that induces the rotational movement.

The two horizontal arms sticking out are used to place the motor and to stop the rotational movement of the motor. A space between the PC plates and braces is created to make room for the rubber lists introduced in the previous chapter.

This solution for the Side frame / Hatch sub system relation represents the solution presented at the 2nd meeting with Domex.

Recapitulation

The meeting between the side frame and the hatch has evolved from a rather complex structure to a more simple structure.

Profiles are merged into fewer profiles and made simpler. The assembly procedure is also made simpler as profiles can only be placed in one way and they have incorporated edges for aligning. Fewer profiles also mean less cost and less weight.

There is no risk for thermal bridges in the joints between the frame and motor or frame and hatch due to a consistent approach in the development to change material.

Furthermore no thermal bridge barriers have to be perforated for anything to be fastened – as seen in the current solution from Domex. The only thermal bridge remains in screws fastened to the brace.

In relation to Domex's current skylight the construction has been simplified significantly. The risk for thermal bridges has been reduced considerably.

Furthermore the assembly process has been made simpler – reducing the need for measuring/adaptation and reducing number of parts.

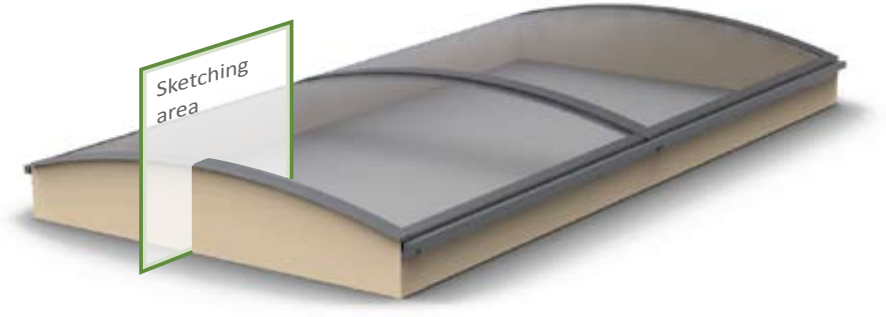
Opening / Gable

The design process of the sub system relation between the hatch and end gable includes development of profiles, reducing thermal bridges and sealing of the window.

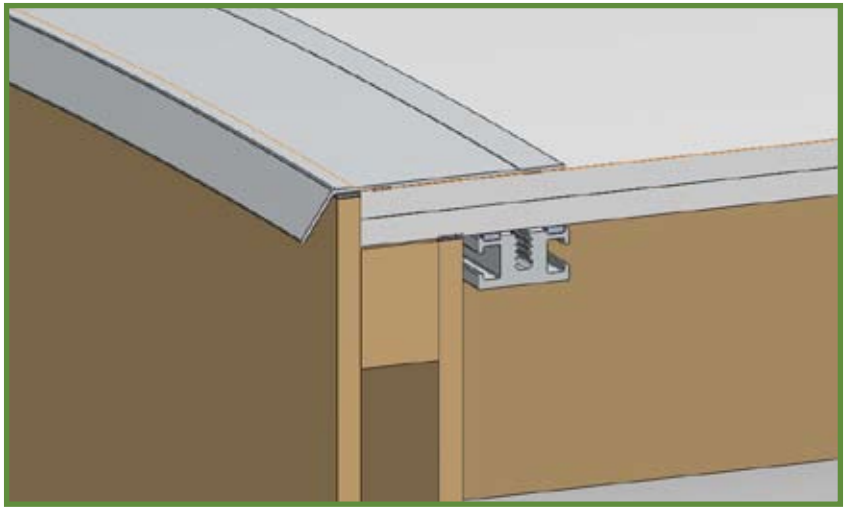
The solution for the end gable will be used in both ends of the skylight to simplify the production and assembly process. The gable meeting with the opening window drives the solution because of the movement.

The proposal presented at the 2nd regarding the Motor / Hatch sub system relation can be seen in overview and detail in ill. 3.30 – 3.31.

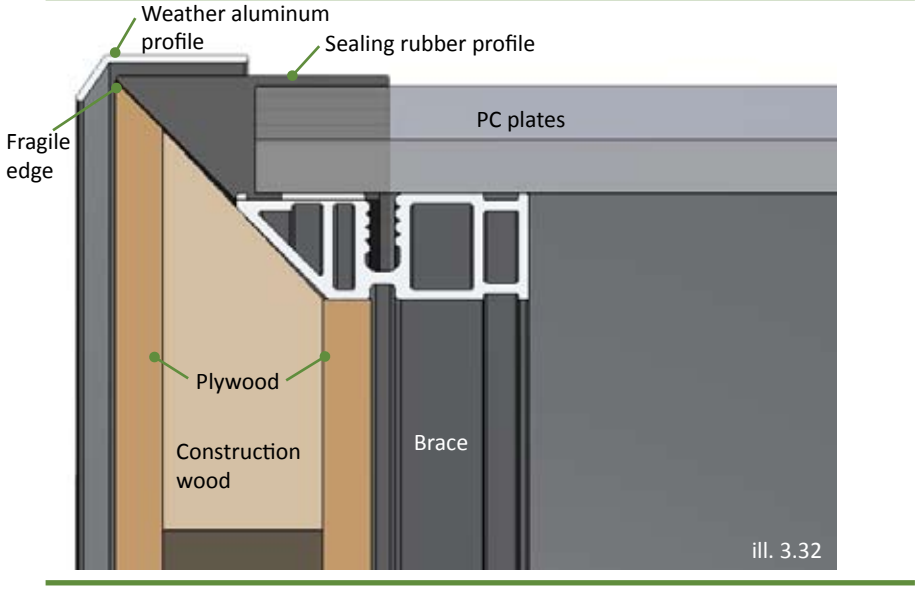
On the following pages a selection of sketches will explain the development in sequence from the 1st meeting at Domex towards the stage presented at the 2nd meeting.

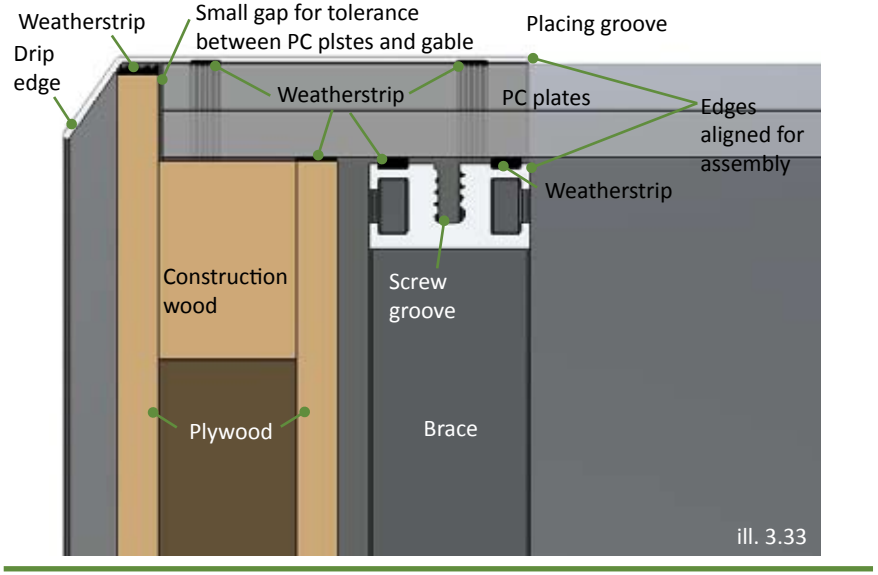


ill. 3.30 - An overview of the area in focus in Hatch / Fixed window detailing.



ill. 3.31 - A close up of the proposal for how the hatch and fixed window meets as shown to the 2nd meeting.





Angled joining

The first solution has taken inspiration from the early proposals for a solution to the meeting between the hatch and the window – trying to utilize the angled braces that were intended to be used in the middle of the skylight (ill. 3.32).

However the use of an angled brace and rubber list will require cutting the gable in a 45-degree angle. This complicates the manufacturing process of the end gable as it will require high precision and a manual working with Domex's current machines. Furthermore it creates a fragile edge that easily can break.

Due to this – and the fact that the angles braces have been deselected in the Hatch / Fixed window sub system development – it is chosen to discard this proposal before it is completely developed and look for another solution.

Step solution

The 45-degree angle is removed to eliminate the fragile edge. This also eliminates the need for the rubber profile, which is exchanged with weather strips to seal the joint (ill. 3.33).

The brace is changed to the one being selected between the hatch and the fixed window in order to use the same brace in the entire window – thereby reducing costs work processes needed to prepare parts for the skylight.

The weather aluminum profile is made longer to reach over the brace so it can be joined with the underlying brace with a screw. Furthermore the drip edge is made longer to better protect the joint from water and wind.

This solution for the sub system relation between the hatch and the end gable represents the solution presented at the 2nd meeting with Domex.

Recapitulation

The developed sub system relation between the hatch and the end gable offers a very simple construction and in essence this end gable can be viewed as a variation of the end gable currently used as Domex as it differ very little from the current end gable.

Due to the material shifts in the developed construction there are no thermal bridges except from the ones being created by the screws fastened in the brace.

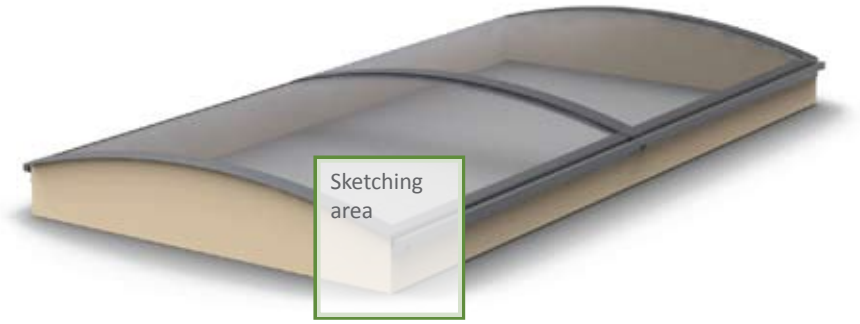
With the establishment of the Hatch / End gable sub system relation the design of the remaining sub systems and sub systems can take place.

Corner

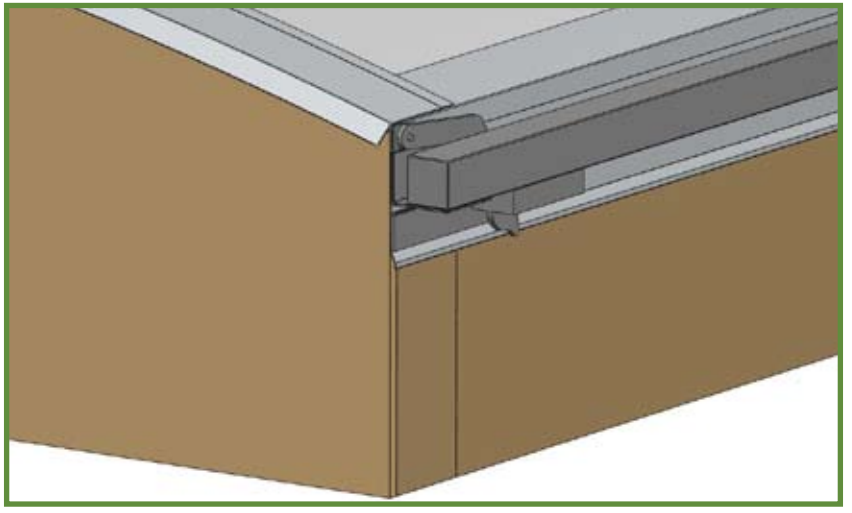
The design process of the corner is a meeting between the end gable, hatch, side frame, and motor. Due to this the design of the corner is a critical area that needs to ensure that the different sub systems can meet in the corner without inducing changes that will affect the functionality of the individual sub system and the relation to other sub systems.

The proposal presented at the 2nd regarding the Corner sub system relation can be seen in overview and detail in ill. 3.34 – 3.35.

On the following pages a selection of sketches will explain the development in sequence from the 1st meeting at Domex towards the stage presented at the 2nd meeting.



ill. 3.34 - An overview of the area in focus in Corner detailing.



ill. 3.35 - A close up of the proposal for corner as shown to the 2nd meeting.

Corner solution

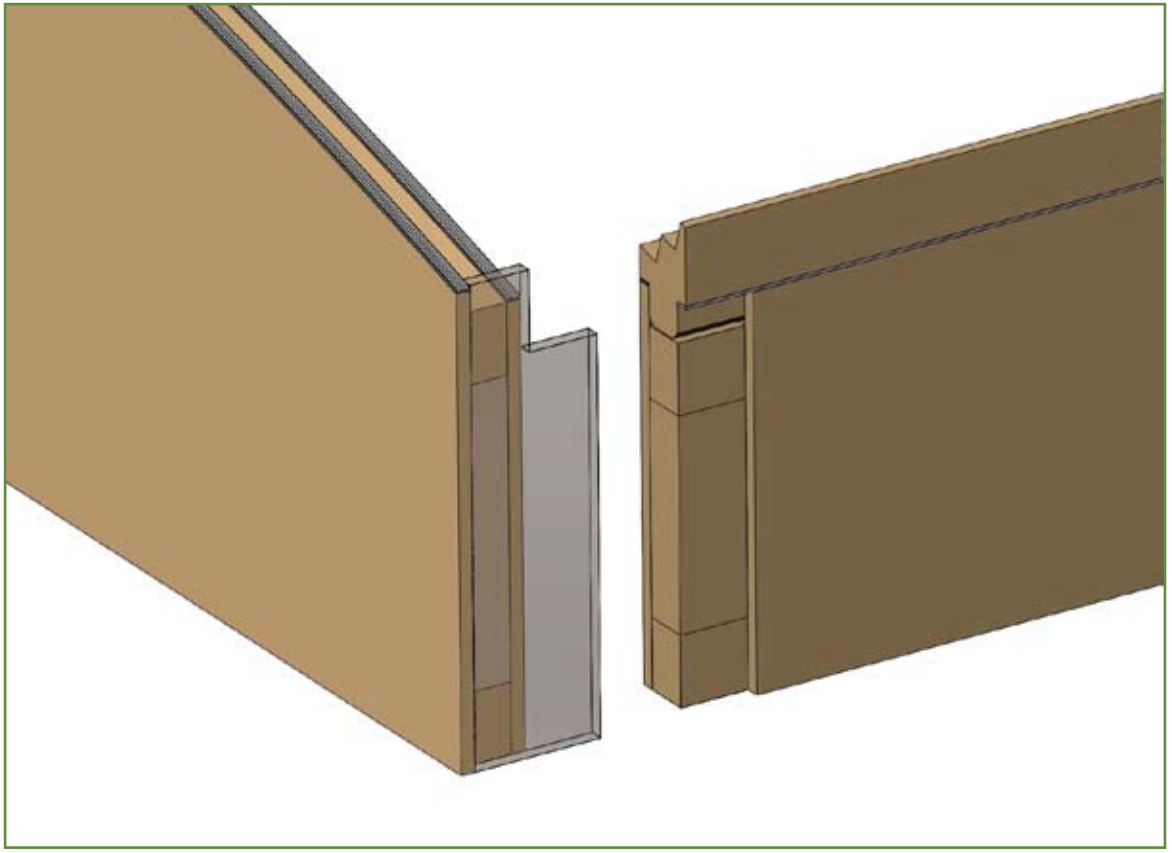
Through the process of developing the prior presented sub systems and sub system relations the corner solution has always been in focus, but the project group has not been able to have a very long development process for the corner up to this point.

This is due to the fact that the corner solution has depended on the development of other plausible sub systems and sub system relations in the skylight.

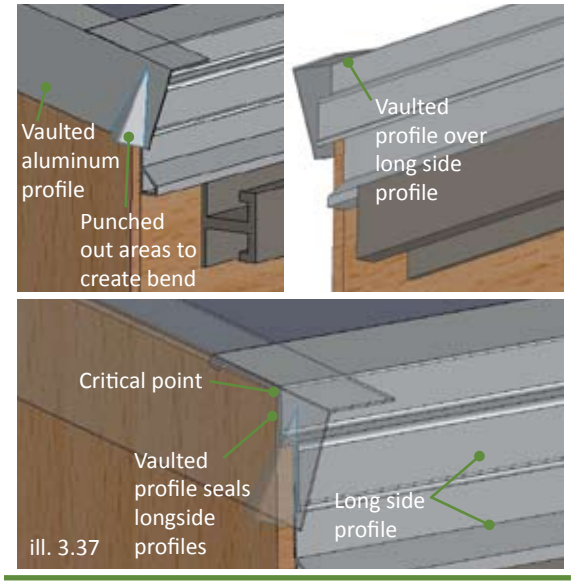
However the project group has developed a solution for the 2nd presentation – a solution that can function as a solution with the developed sub systems and their relations.

Based on the feedback received at the meeting with Domex it is the intention of the project group to finish the development of the corner solution along with the rest of the skylight.

The corner principle presented at the 2nd Domex meeting can be seen in ill. 3.36.



ill. 3.36 - The developed corner solution for the frames as presented to the 2nd Domex meeting.



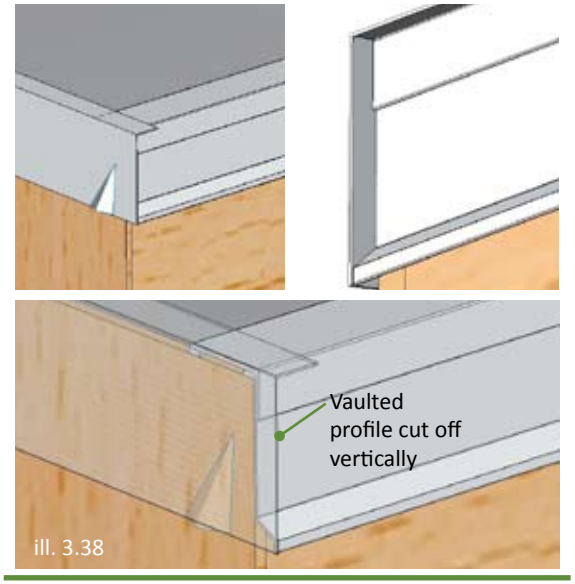
Alu profiles

The project group has also developed a proposal for how the outer corner should be sealed properly while ensuring that the opening movement can be performed.

Since the project group from early on in the process has been interested in using the current frame for the on-site assembled light row as the starting point for the development it has been natural to look at the current solution for sealing the corner (ill. 3.37).

The starting point is therefore Domex's current solution where a vaulted aluminum profile closes the corner by reaching past the profiles on the long side and over the sealing aluminum profile on the long side.

The solution appears plausible to seal the corner in the new skylight although the visual finish needs some processing.

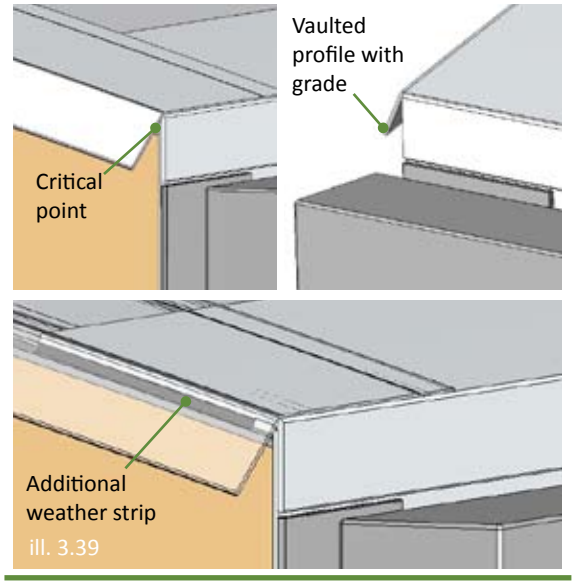


Visual improvement

The visual appearance is improved by cutting the list off parallel to the frame. The profile does not reach as far out reducing the risk for tearing clothes when mounting the skylight (illx. 3.38).

As this and the previous solution are developed prior to the movement path of the opening window is fully determined the result is that they cannot be used. The window can simply not open with the vaulted profiles that are currently used at Domex.

This is due to the opening movement that cannot be performed with an alu profile in 90 degree up against the hatch and end gable.



New profile

The opening path of the hatch entails a profile that does not lean up to the frame but has an angle corresponding to the movement path (ill. 3.39).

Changing the profile exposes the corner to the weather. Therefore an additional weather strip is needed at the end of the long side profile. Based on the meeting with Domex it will be determined if this solution is adequate or if the design must be altered.

This solution for the exterior corner represents the solution presented at the 2nd meeting with Domex

Recapitulation

The corner solution for the relation between the side frame and the end gable has not been given the same time for development as the remaining areas in the detailing, but based on the other sub system developments and their relations it has been possible to develop a functional solution to the meeting with Domex.

Solutions to the exterior corner have developed so the hatch of the skylight can be opened in the developed opening movement. That has entailed a solution for the closing alu profile that most likely is insufficient regarding weather protection of the top of the end gable.

The corner will therefore in all probability need a further development in order to reach a sufficient solution. Possible solutions and problem areas regarding this solution will be discussed in the following meeting with Domex.

Succeeding the 2nd meeting with Domex a further development the skylight will be presented - based on the collected feedback and reflections from the meeting.

Second Domex Meeting

After the development of the sub systems and the sub system relations the result is presented to Domex.

Employees attending the meeting are the CEO, construction manager, production manager, and key accountant (ill. 3.39).

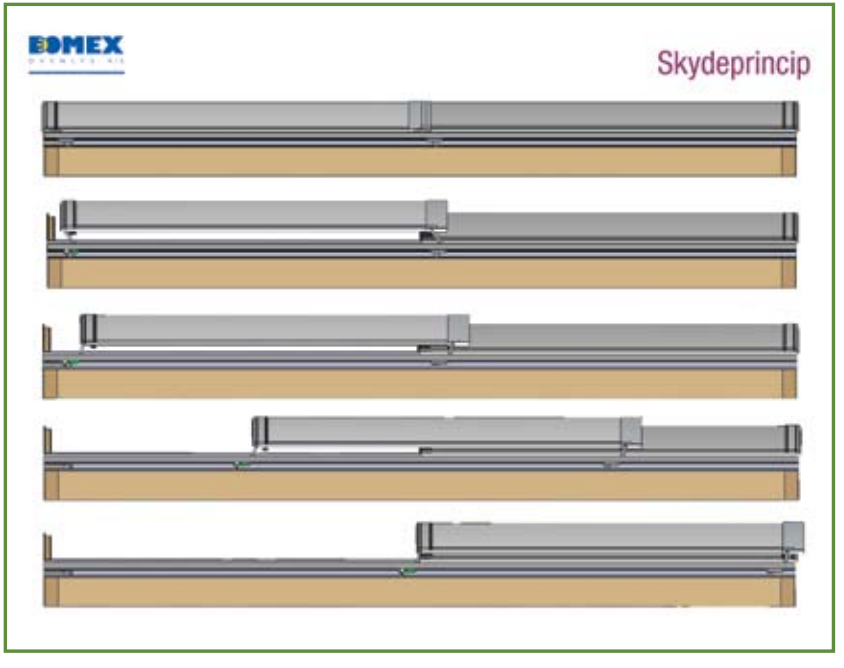
The product proposal is presented according to the selection and development following the 1st meeting where the concepts were presented.

Also the joining of sub systems and problems that need to be solved are presented – the same areas that have been presented previously in the detailing phase.

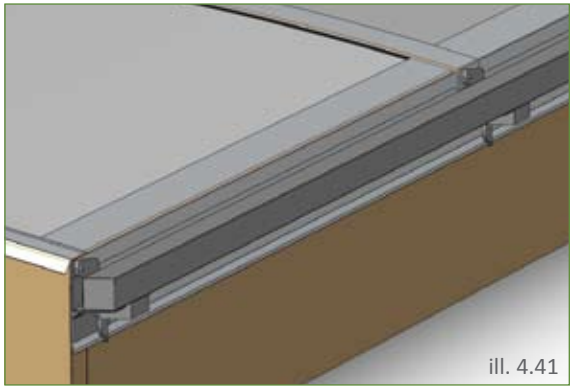
A few selected slides from the presentation can be seen in ill. 3.40.

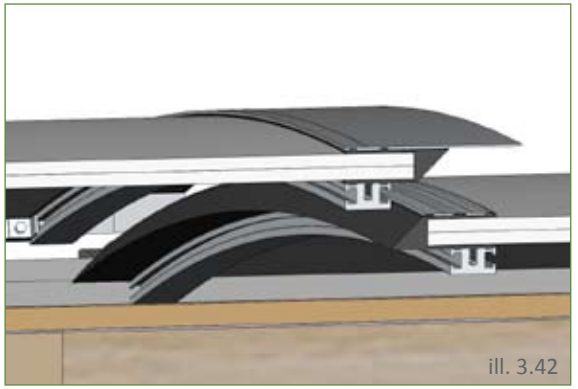
The full presentation can be seen in appendix 8.

ill. 3.39 - Second meeting at Domex with CEO, key accountant, construction manager and production manager.



ill. 3.40 - Selected slides from the second presentation at Domex.


ill. 4.41


ill. 3.42

Feedback and reflections

Following is feedback from Domex and reflections on the feedback from the project group.

The proposed solution generally receives very positive feedback from Domex - especially the opening mechanism is found interesting and how the principle of creating a rotational movement from a linear movement works.

The feedback is divided into areas according to previously presented sub system relations.

Motor

Domex:

- The opening principle is a differentiating factor as the competitors mainly offers solutions that resemble the current skylight from Domex.
- The relocation of the motor offers a selling point both regarding the inflow of light but also regarding aesthetics.
- Domex points out that they would prefer to mount the motor from the factory, as it may be precision work.
- Domex points out that it is important to add a list that makes sure the hatch does not reverse the rotational movement due to wind.

Project group:

- A motor mounted from Domex is important for the structure of the frame's long side, as the motor cannot be mounted on top of the felt roofing due to imprecision.
- A separate list could easily be mounted to maintain the desired position of the hatch during the sliding part of the opening.

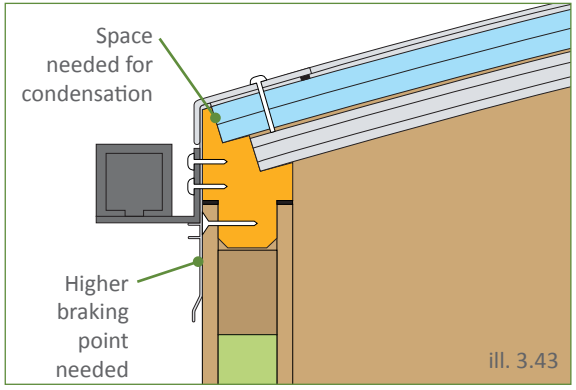
Hatch / Fixed window

Domex:

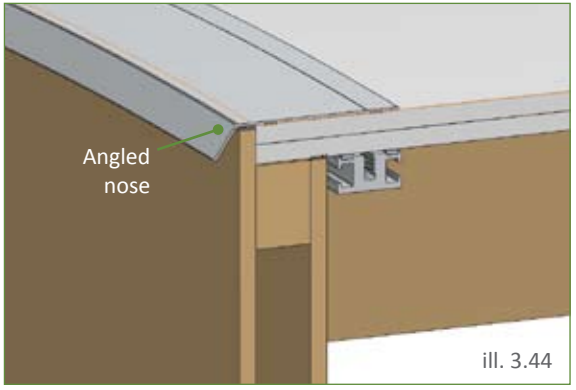
- The joining between the hatch and the fixed window is considered to be a plausible solution for the joining based on the opening movement.
- The placing slits, screw grooves etc. are recognized by Domex as a clear advantage in the assembly process.
- Furthermore the sealing of the developed solution is considered adequate to keep the joining between the hatch and fixed window tight in a closed position.

Project group:

- Based on the positive feedback regarding the relation between the hatch and the fixed window it is the intension of the project group to maintain this solution in the final proposal.



ill. 3.43



ill. 3.44

Hatch / Side frame

Domex:

- The aluminum profile protecting the felt roof on the side frame should have a higher breaking point so the felt roof can be welded higher up on the frame.
- Furthermore the length of the alu profile after the break should be longer since the mounting height of the felt roofing can vary up to 3 cm in height.
- There should be a little spacing between the PC plates and the placing area for the PC plates in the top frame profile. This is because condensation needs to be able to exit the channels in the PC plates.

Project group:

- If the protecting alu profile is divided in two it will benefit the felt roofing procedure, as a lower alu profile could be clicked on after the felt roof is welded onto the side frame – instead of the current procedure- bending the alu profile, welding the felt roof and bending the alu profile back into position.

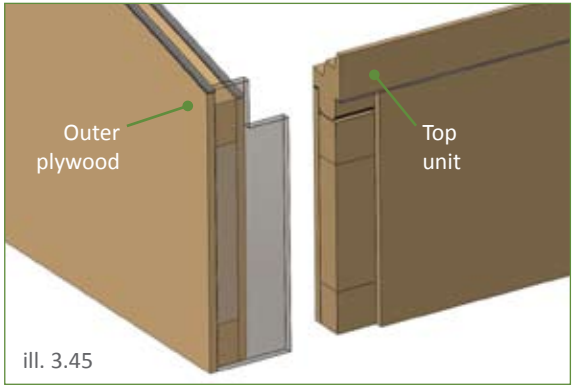
Hatch / End gable

Domex:

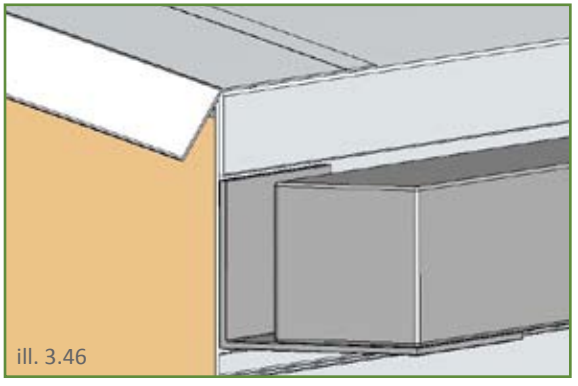
- The angled nose should be larger if this solution should protect the joint from the weather.
- Domex suggests an alternative solution – a small fixed window is mounted in the end where the hatch currently meets the end gable. By doing so the current sealing procedure used in the meeting between the hatch and the large fixed window can be used.
- Furthermore it is suggested that the gables are divided in two parts – upper and lower like the long sides. This induces that a skylight could be assembled in two main parts from Domex – a complete window part mounted onto the top frame units and a complete lower frame assembled from all lower frame parts.
- By doing the above more units can be transported on a truck.

Project group:

- A fixed window on both sides can induce an opening window identical on both sides - making production and assembly more efficient and cheaper.
- If the skylight gets delivered in two parts, a crane should be used to lift the two parts into place since the weight of two main parts will succeed the max of 25 kg a workman is allowed to lift. Alternately the skylights could be delivered in an assembly kit as the light row.



ill. 3.45


ill. 3.46

Corner

Domex:

- The solution for the corner gets discussed along with the solution for the meeting between the hatch and the end gable. With the proposal for a small fixed window where the hatch meets the end gable Domex finds it natural to apply a solution where the top unit of the side frame goes all the way out to the outer plywood of the end gable (ill. 3.45).
- Thereby the sealing solution between the PC plates and en gables that is used in the current window can be used for the new window.

Project group:

- The change towards a small fixed window and the utilization of the current sealing solution between the end gable and the hatch is seen as proposals that can induce a change to the current solution between the end gable and side frame.
- This change is considered as one that could be made to resemble the current solution in the corner quite accurately – meaning minimized process changes in manufacturing.

Recapitulation

The second meeting with Domex has given a lot of valuable feedback on the design of the skylight – both regarding the solutions Domex found suitable for the skylight but especially regarding the areas that have not been fully developed.

In the following chapter the design proposal will be further developed based on the feedback from Domex and the reflections from the project group.

Product Refinement

Based on feedback from Domex and reflections from the project group the skylight is developed further. As the remaining development is about refinement of the solution the project group finds that it is suitable to name the skylight.

The name Contego (Latin for “Protect”) is chosen for the skylight relating to the protective and preventive purpose of the fire ventilation skylight.

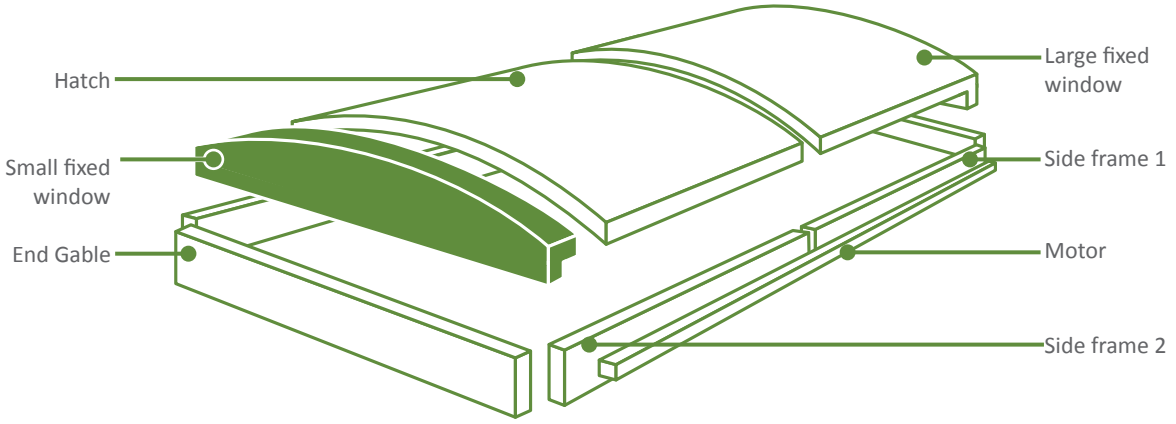
In the meeting Domex suggested that the end gable should be divided into two parts and that a fixed window should be on both sides of the hatch.

On the basis of this the sub system structure needs to be revised in order to define new modules that maintain the modularity of the light row.

In the new structure one fixed window module is added and the upper part of the end gables are moved into the fixed window modules.

Furthermore the side frame are divided in two to make it fit to the modular system currently used in the light row – a system the project group will use as inspiration for the new light row. (ill.3.47).

With the new sub system structure set, Contego can be developed further to accommodate these changes and refine the construction.



ill. 3.47 - The new sub system structure of Contego. The highlited modules represent the new module developed based on the 2nd meeting with Domex.

ill. 3.48 - The current state of the developed skylight - named Contego.

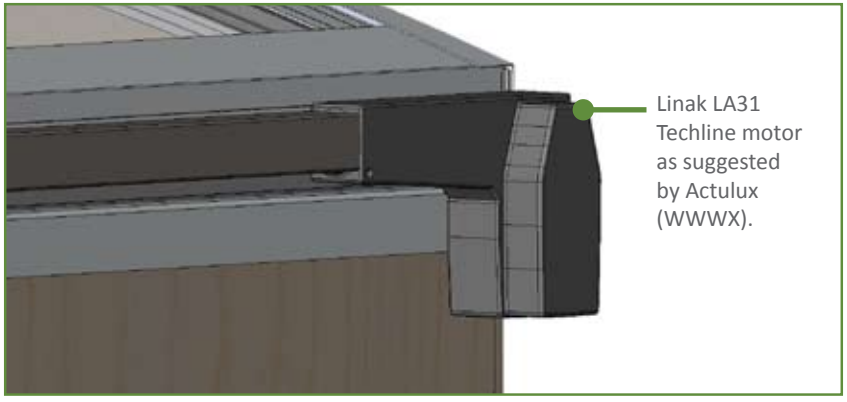
Motor

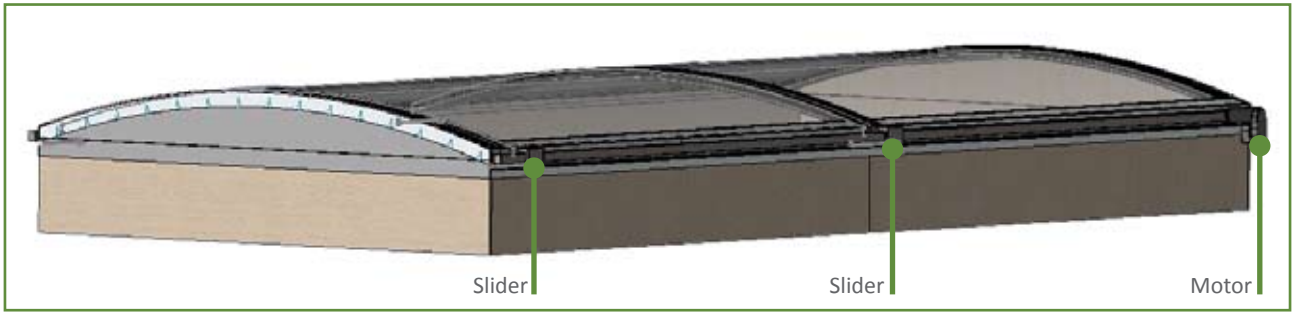
Domex finds – as mentioned earlier – the proposed opening principle interesting and acknowledges that it can improve the skylights inflow of light and aesthetics. Therefore the project group reviews earlier feedback from Actulux.

Based on feedback from Actulux and reflections from the project group the motor principle is changed from a motor running on the spindle to a fixed motor turning the spindle (ill. 3.49).

This change simplifies the motor principle and solves issues mentioned in the feedback from Actulux. For instance is the need for a cable holder is eliminated.

In order to create harmony along the skylights frame side the motor is placed opposite to the sliders – resulting in a visual spread of the two arms and the motor along the track.(ill. 3.49).





ill. 3.49 - The motor shown in detail and overview.

Swing Arm Dimensioning

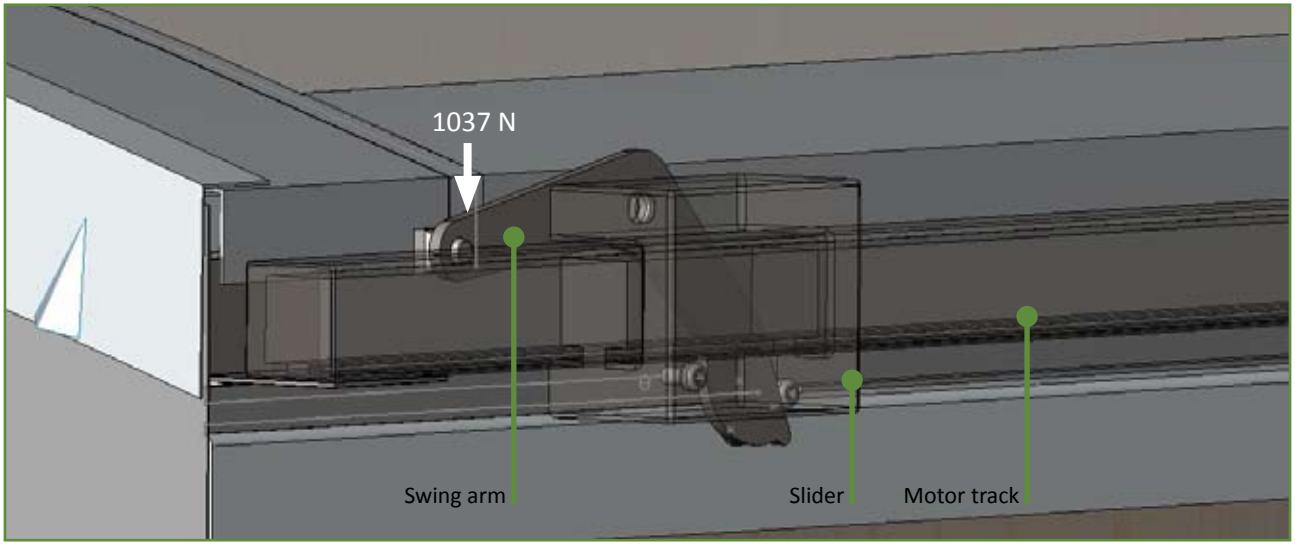
In the feedback from Actulux it is clear that the motor principle can be solved without major problems.

Despite that the project group defines the swing arm on the motor as a critical point as all forces reacting on the hatch run through these arms.

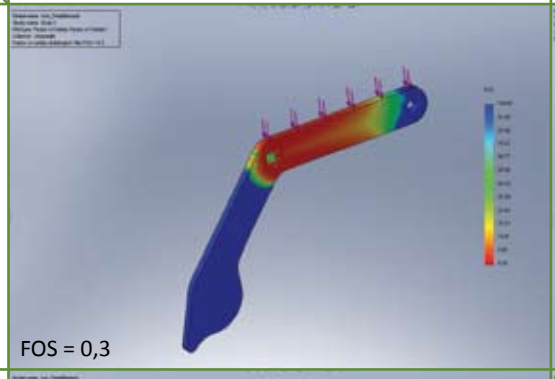
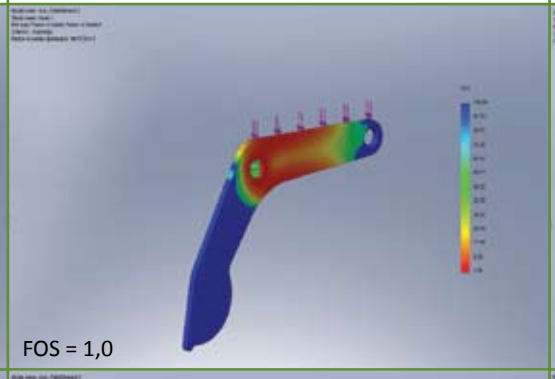
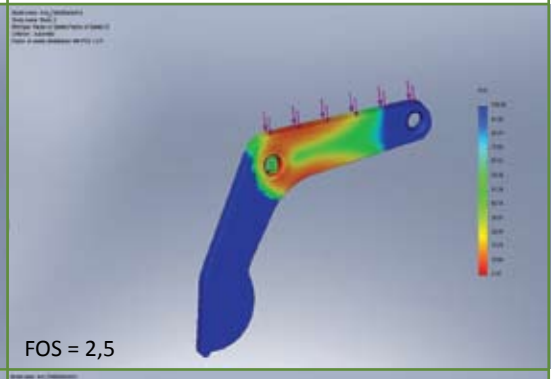
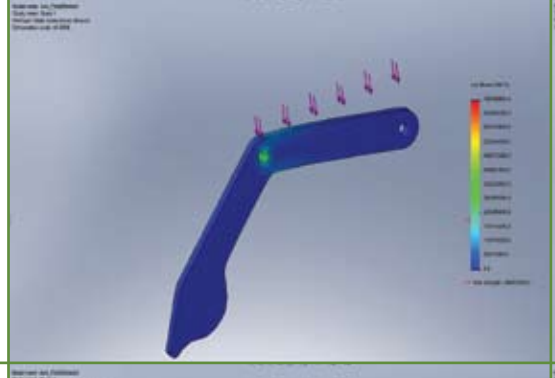
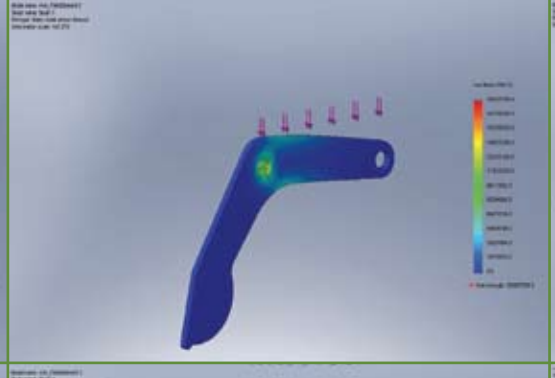
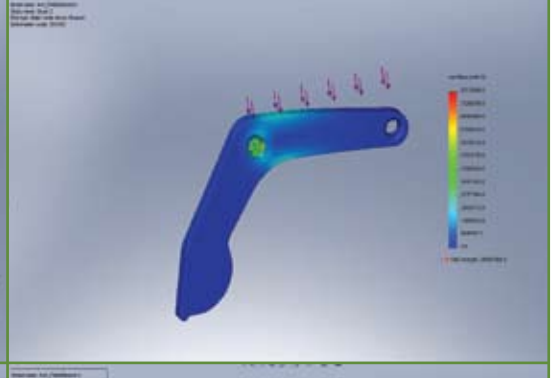
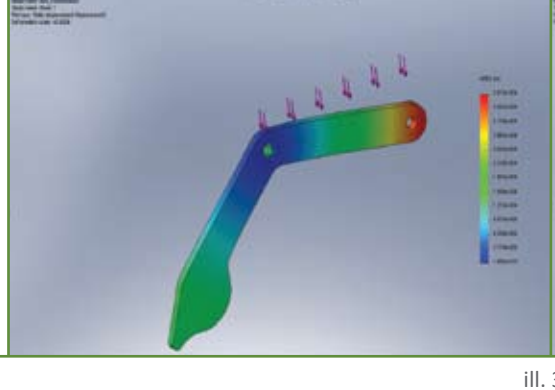
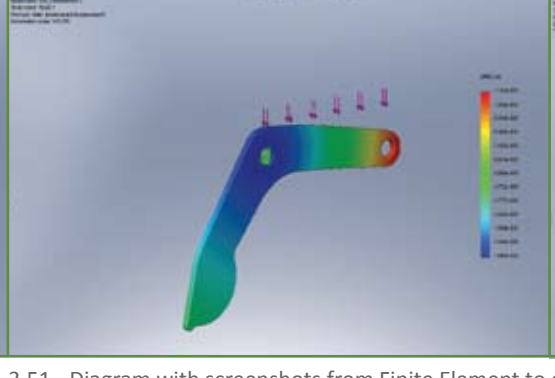
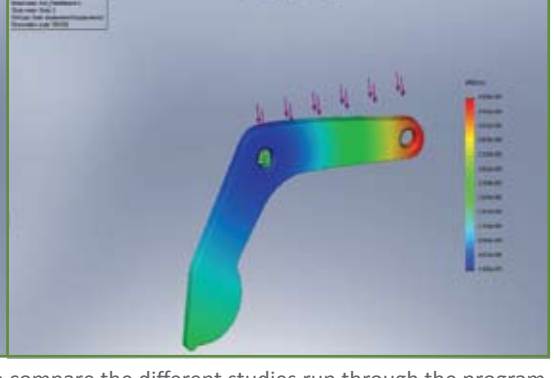
Furthermore the building regulations state that a skylight with daily ventilation shall be able to open/close 10.000 cycles and that the hatch should withstand a load of 720 N/m^2, which is 1037N per arm.

The project group assesses that this induces FOS of at least 2,5 for the swing arm due to the frequent open/close cycles and the moderate harsh environment.

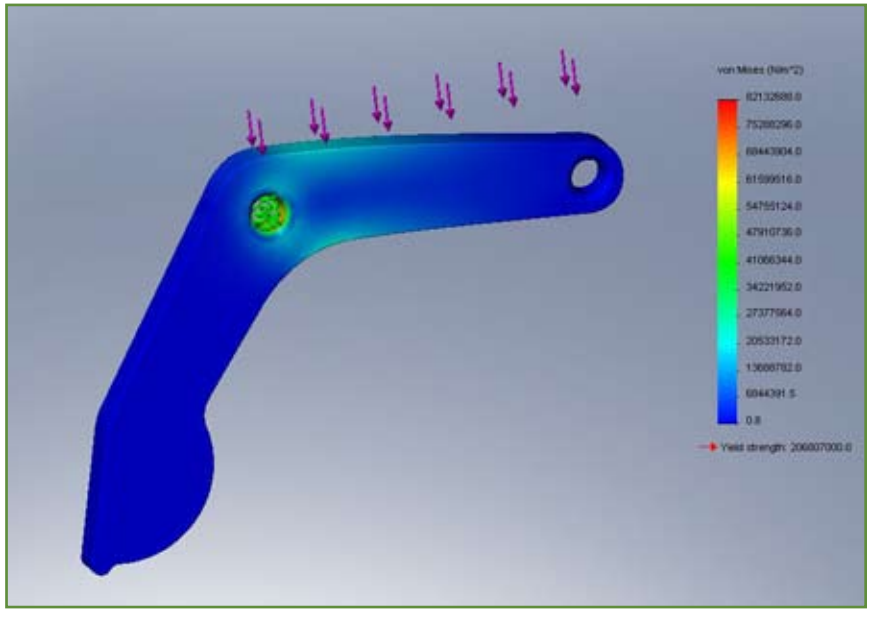
Furthermore the arms should be made of stainless steel where the project group has specified the type to AISI 304 (www8), which is one of the most common stainless steel types in production.



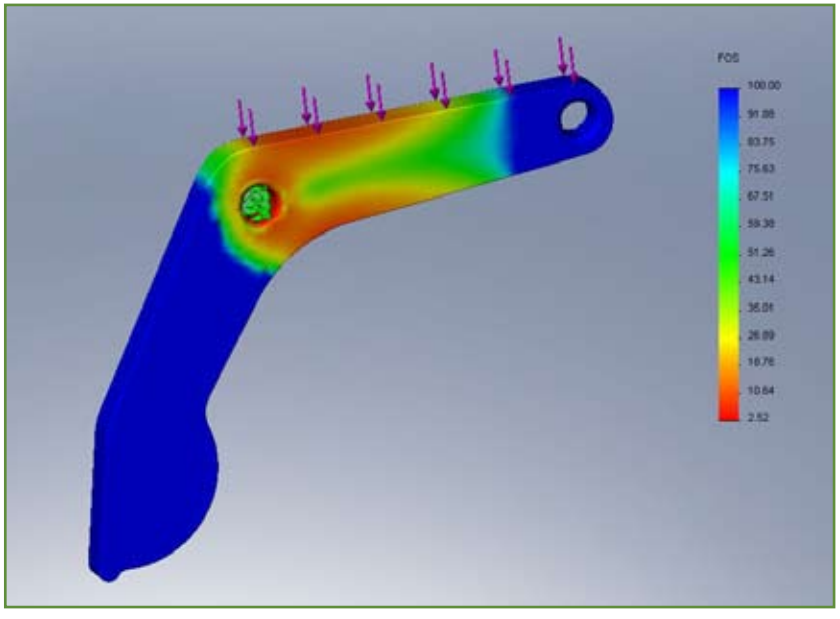
ill. 3.50 - The project group finds the swing arm a critical point as all forces reacting on the hatch run through the arm.

Study / Test	Study 1	Study 3	Study 4
	Parameters: Arm thickness: 5mm Hole diameter: 5mm Fillet on hole edge: 1mm	Parameters: Arm thickness: 5mm Hole diameter: 10mm Fillet on hole edge: 1mm	Parameters: Arm thickness: 12mm Hole diameter: 10mm Fillet on hole edge: 2,3mm
Factor of safety (FOS)			
Stress concentration			
Degree of deformation			

ill. 3.51 - Diagram with screenshots from Finite Element to compare the different studies run through the program.



ill. 3.52 - Stress concentrations in the swing arm from study 3.



ill. 3.53 - FOS in the swing arm from study 3.

Finite Element

The arm is calculated with Finite Element in Solid Works to evaluate the design. Comparison of the different studies is presented in illustration 3.51. The fixed surface is indicated with green arrows and the reaction force is indicated with purple arrows.

Study 1 shows a solid arm with holes of 5mm in diameter. The study shows stress concentration around the fixed surface, which also is the hinged joint to the motor. Furthermore the study shows that the FOS is only 0,3 on the holes edge.

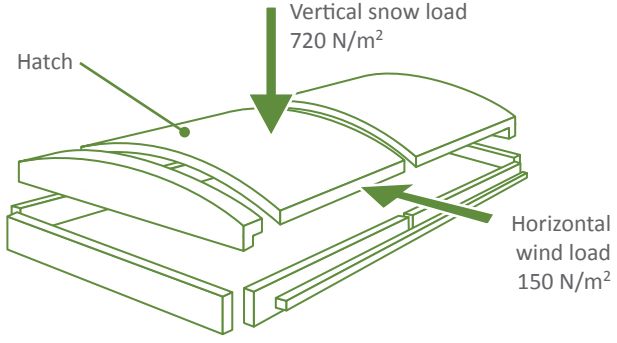
In study 2 material is added around the hole to compensate for stress concentration. Furthermore the hole's diameter is increased to 8mm to increase the safety factor, which now is 1,0.

In study 3 the arm is thickened to 12mm as the fillet on the fixed hole's edge cannot be increased further to improve the FOS. The fillet is then increased to 2,3, which gives the FOS 2,5.

Furthermore the hole's diameter is increased to 10mm since the project group assesses that a hinge of 8mm material thickness is too little for the forces going through the joint.

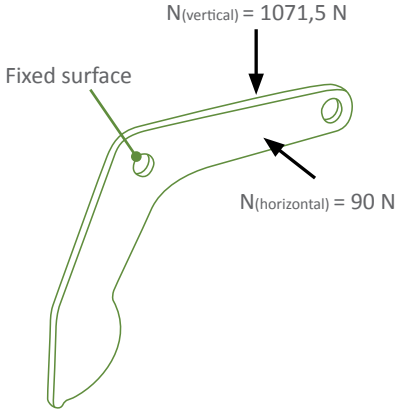
Hand calculations

As the swing arm has been tested in Finite Element the results are checked with hand calculations. The swing arm needs to withstand a vertical snow load of 720 N/m^2 (www3) and a horizontal wind load of 150 N/m^2 (www9) (ill. 3.54).

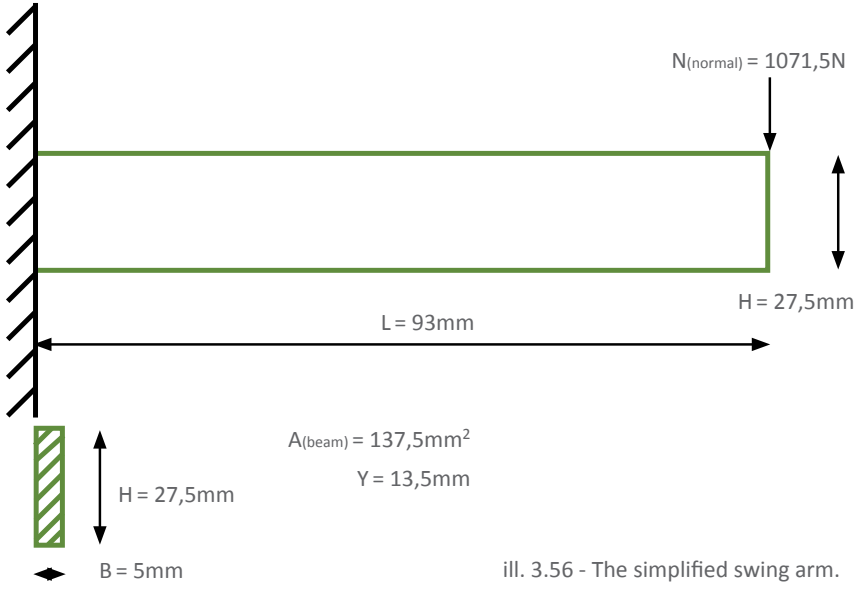


ill. 3.54 - The loads shown on the skylight.

In order to calculate the stress in the swing arm it is fixed in the motor hinge (ill.3.55). Furthermore the arm is simplified as in illustration 3.56.



ill. 3.55. - The swing arm shown with fix point and loads.



ill. 3.56 - The simplified swing arm.

$N_{(vertical)}$ = hatch weight + regulation

$$\text{Hatch weight} = \frac{138\ N}{4} = 34{,}5\ N$$

$$\text{Regulation} = \frac{720\ N \times 5{,}76\ m_2}{4} = 1037\ N$$

$N_{(vertical)} = 34{,}5\ N + 1037\ N = 1071{,}5\ N$

$Moment = L \times N_{(vertical)} = 99649{,}5\ Nmm$

$$\text{Moment Inertia}_{(beam)} = \frac{B \times H3}{12} = 8665\ mm^4$$

$$\sigma_{(normal)} = \frac{N_{(vertial)}}{A_{(beam)}} = 7{,}8\ N/mm^2$$

$$\sigma_{(bend)} = \frac{Moment \times Y}{I_{(beam)}} = 155{,}3\ N/mm^2$$

$\sigma_{(vertical + bend)} = 163{,}1\ N/mm^2$

$$\text{Safety Factor} = \frac{210000\ N/mm^2}{163{,}1\ N/mm^2} = 1287{,}6$$

ill. 3.57 - Snow load calculations.

Snow load calculations

Calculation are made for when the hatch is exposed to the required snow load of 720 720 N/m^2. The calculations are shown in ill. 3.57.

Identical calculations are done for wind load. The results are the following:

- $N_{(horizontal)} = 90\ N$
- $Moment = 29880\ Nmm$
- $Moment\ Inertia = 3437{,}5\ mm^4$
- $\sigma_{(normal)} = 0{,}7\ N/mm^2$
- $\sigma_{(bend)} = 21{,}7\ N/mm^2$
- Safety Factor = 9375

Evaluation

The difference between the FOS in Finite Element and the hand calculation is big despite a material thickness of 5mm in the hand calculation. Furthermore the dimensions on the swing arm in study 3 are very severe.

The project group estimates the hand calculations should be trusted instead of Finite Element. Therefore the swing arm is left at 5mm in the final proposal. Further calculation on the swing arm and the remaining product must be made in a product maturing phase.

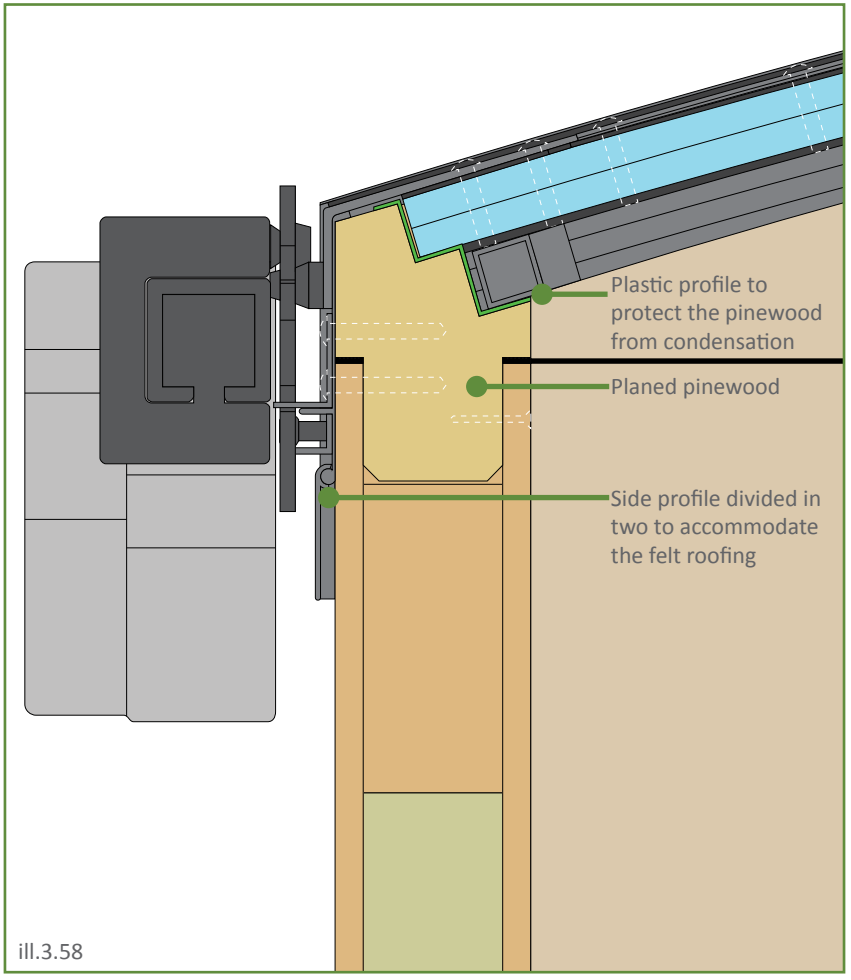
Side Frame

After the meeting with Domex some changes are made to the side frame to accommodate the mounting of the felt roof and to lower the production price.

The upper part of the frame is changed from plastic wood to pinewood because of the plastic wood's high tooling cost – 25.000 Euros for an extrusion tool (App. 9).

The pinewood is planed and cut in lengths, which is much cheaper than plastic wood – 7,3 kr per planed meter stated by Davinde Savværk in Odense.

The project group assesses that the pinewood does not need to be pressure proofed as other wooden parts in the skylight are not.



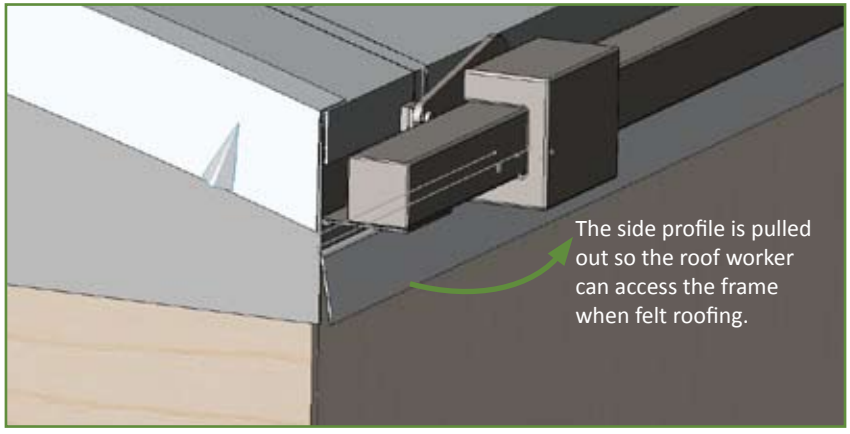
ill.3.58

But if this is needed the proofing should be done to the core because of the planning and cutting processes (www10).

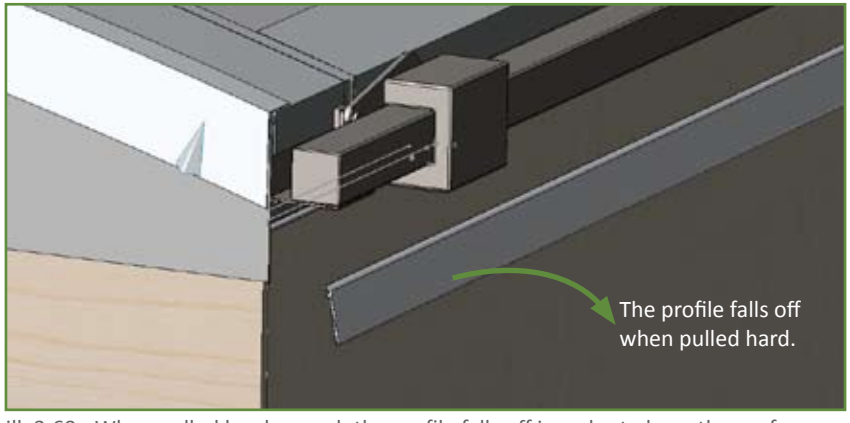
On top of the pinewood a plastic profile is placed to protect the wood from condensation as the condensation channel is incorporated in the frames structure (ill.3.58).

To accommodate the roof felting the side profile is split in two. Instead of bending the profile it falls off when the roof worker pulls it away from the frame. Afterwards the lower profile can be clicked onto the upper profile (ill. 3.59 – 3.60).

A mounting procedure will be shown in the brochure “Contego by Domex”



ill.3.59 - The side profile has been divided in two parts so the bottom half can be removed when mounting the felt roof.



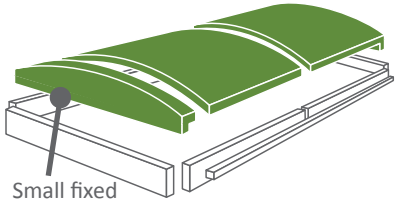
ill. 3.60 - When pulled hard enough the profile falls off in order to keep the roof worker from bending it. Afterwards he can click the profile back on.

Hatch / Fixed Windows

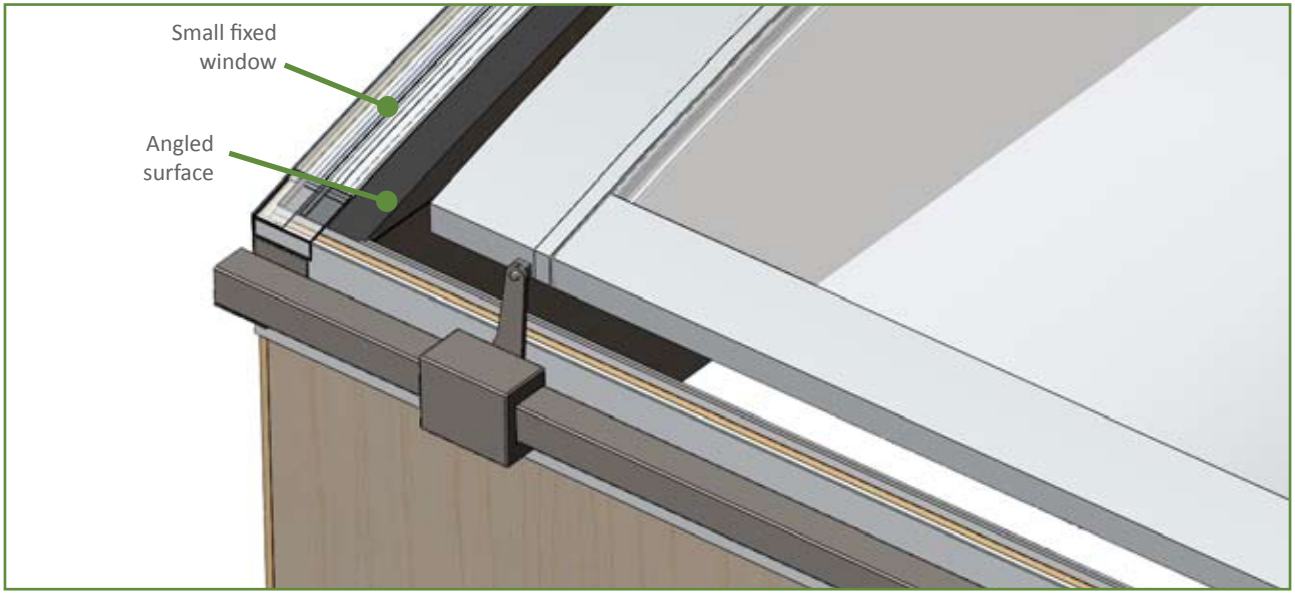
In the new sub system structure a fixed window is on both sides of the hatch. Therefore the hatch needs to be shorter in order to make room for the fixed window (ill.3.62).

This induces that the hatch can be made identical on both sides, which simplifies the production and assembly procedure by eliminating the risk of placing the hatch incorrectly and minimizing errors in production (ill. 3.63).

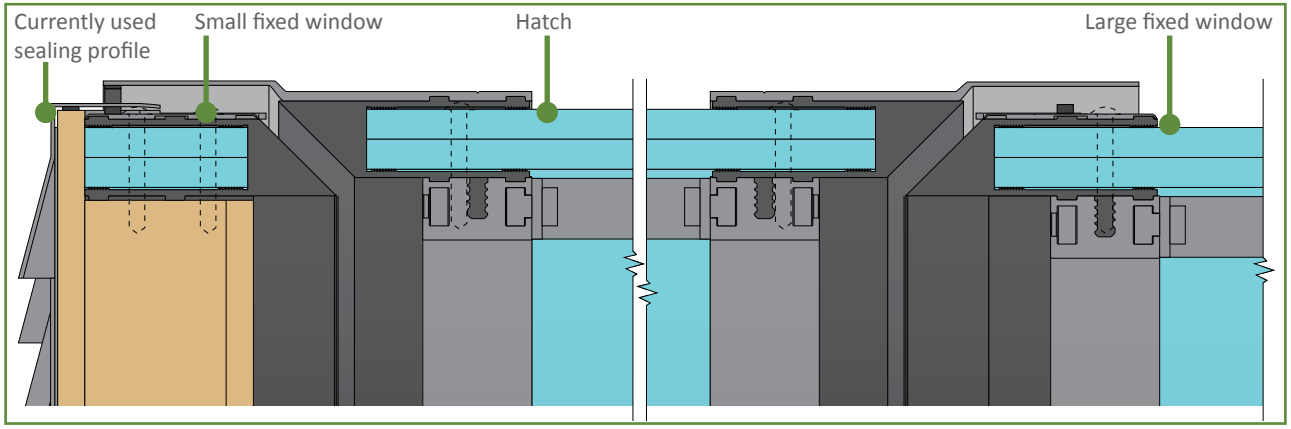
Adding a fixed window to the other side of the hatch induces that a fixed window meets the



ill.3.61 - Sub systems refined in the chapter



ill.3.62 - The small fixed window is very small and rarely noticable but induces that the hatch can close on an angled surface.

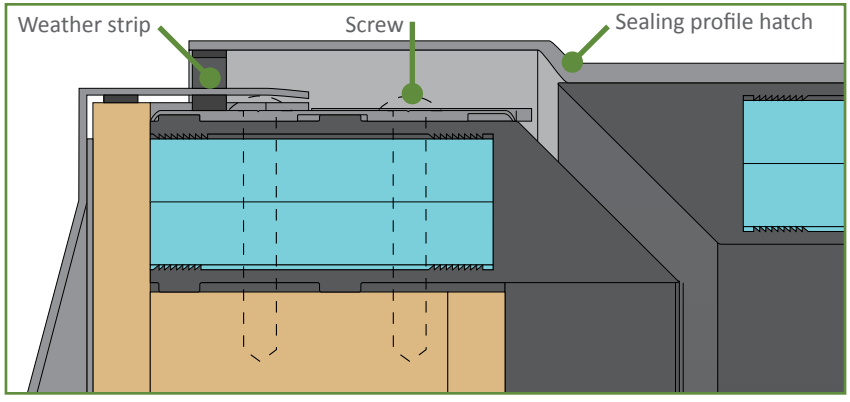


ill. 3.63 - Partial section cut on the long side showing how the hatch meets the small and large fixed windows.

end gable on both sides of the skylight. Therefore a similar solution to Domex's current solution can be used.

This solves the sealing issue of the end gable as the same profile is used to seal the joint of the gable and PC plates (ill. 3.63).

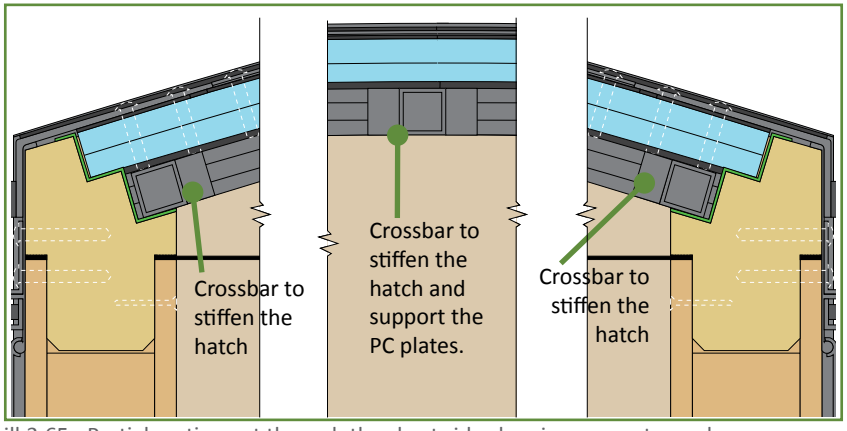
Furthermore the sealing profiles on the hatch are altered in order to make room for screws and weather strips. The weather strips also protect the aluminum profiles that otherwise would touch screws and other profiles in a closed position (ill. 3.64).



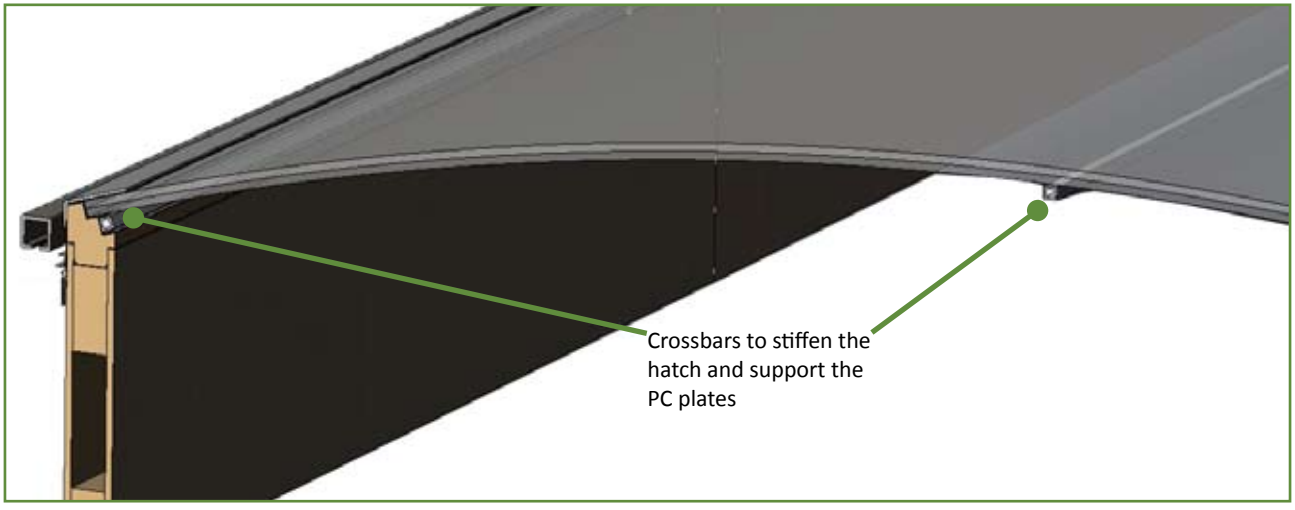
ill. 3.64- The sealing profile on the hatch is altered to make room for screw and weather strips.

In order to strengthen the hatch and keep it stable when moving supporting crossbars are added between the braces (ill. 3.65 – 3.66). Three are added to the hatch – one in the middle and two down at the side frame.

The crossbars keep the hatch stable and support the PC plates when loaded with snow.



ill.3.65 - Partial section cut through the short side showing support crossbars.

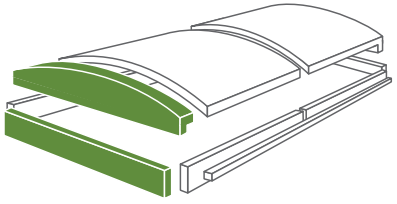


ill.3.66 - Partial section cut through the short side showing support crossbars.

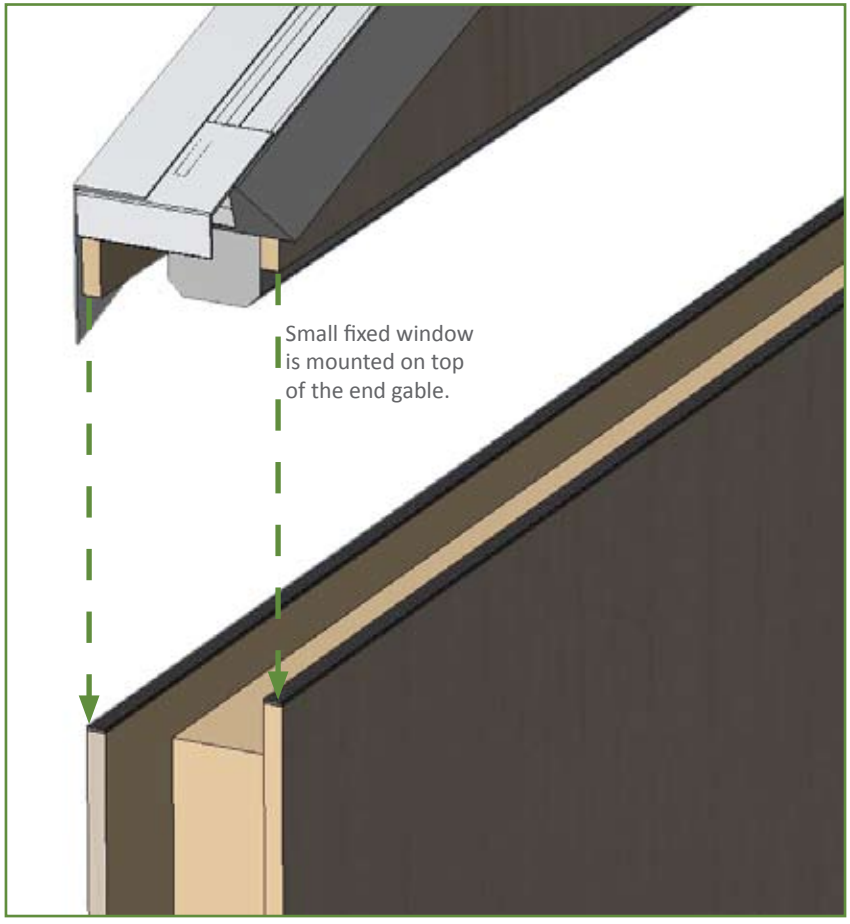
End Gable / Small Fixed

As experienced through the meeting at Domex it is beneficial to divide the end gable into two parts and create one module of the end gable's lower half and one module consisting of the end gable's upper half and the fixed window (ill. 3.67).

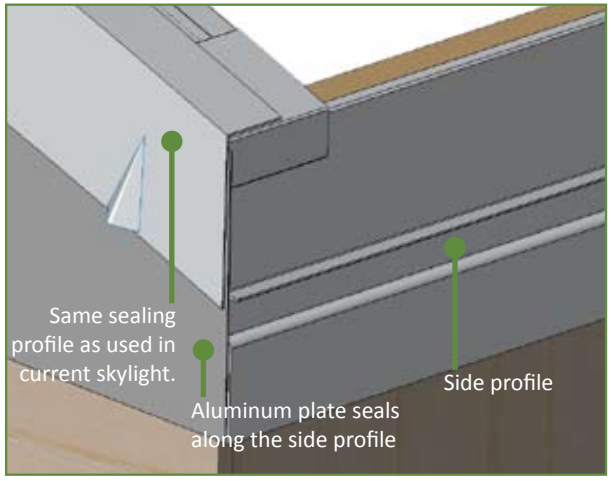
The small fixed window is mounted to the lower end gable in the same way as the upper side frame is mounted to the lower side frame. (ill. 3.68)



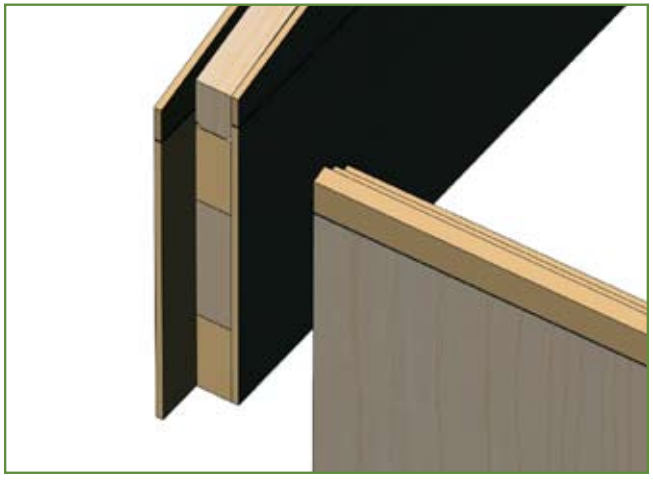
ill.3.67 - A new relation is created between the end gable and the small fixed window as the end gable is changed to a two part module..



ill.3.68 - The small fixed window is mounted on the end gable the same way the upper side frame is mounted on the lower side fram.



ill.3.69 - The sealing of the corner is solved similarly to Domex's solution as the same vaulted profle is used.



ill.3.70 - The joining of the side frame and the end gable is similar to the solution in the current light row.

By dividing the end gable in two pieces Domex's solution can be used to seal the upper half of the end gable and the PC plates. Accordingly the current solution to seal the corner can be used (ill. 3.69).

Furthermore the corner joining between the side frame and the end gable can be altered to a solution very similar to the current solution used in the light row (ill. 3.70). Thereby solutions familiar to the production team and mounting crews can be utilized in Contego.

Modularity

In prior solutions the project group has proposed a modularity solution that can accommodate both the pre-assembled skylight and light row. Modules organized like the sub systems.

In the meeting with Domex it is experienced that it is not beneficial to deliver the fixed sized skylights to the mounting site in as small modules as the light row because of the mounting procedure.

This is due to the fact that the fixed size skylights are often ordered in large quantities so the mounting procedure will be too time consuming and expensive with so small modules. Therefore Domex delivers their fixed size skylights in modules of two – the frame and the hatch.

Based on this Contego will be delivered in four modules pr. skylight in a bundle of two skylights – similar to what Domex currently does (ill. 3.71).

By doing so the three window modules will be easier to handle than the current 1-module windows due to the fact that the heaviest module only weighs 23,5 kg and that smaller modules will be easier to handle. Subsequently only the frame will need to be lifted into place with a crane.

Despite the fact that the fixed size skylights will be delivered in four modules it is decided to maintain the sub system modularity presented at the beginning of the chapter.

By doing so the same modules can still be used for both the skylights and the light row and the modularity also ensures that the production team at Domex only has to manually handle modules that comply with the Danish work environment regulations regarding weight.

The mounting procedures for the skylights are presented in the brochure Contego by Domex.

Modularity & Stock

Another benefit with modularity is that Domex can choose to assemble certain sub modules and stock them.

Thereby being able to deliver faster if they receive an urgent order or if a period with many simultaneous orders puts a pressure on the capability of the production.

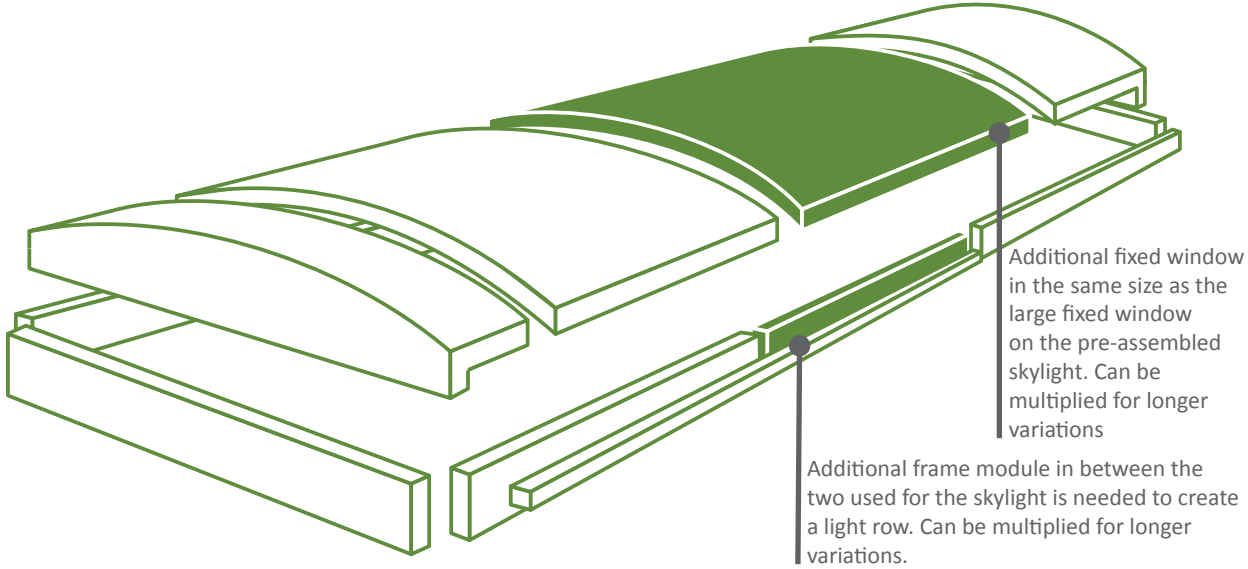
ill.3.71 - Pre-assembled skyligths on a truck packed in a bundle of two. Two frames are nailed together on top of each other and two window modules on top of that.

Light Row

The project group has focused on developing a solution that works for the pre-assembled skylight. This has been done to develop a standard unit that afterwards can be multiplied to form a light row. At this point the pre-assembled skylight is acknowledged by Domex so the light row can be developed.

As the light row is based on the pre-assembled skylight only a slight change is needed in order to create the light row system.

Two additional modules make the system function as a light row – a side frame and fixed window module (ill. 3.72).



ill.3.72 - The modules marked with green are the additional modules in relation to the pre-assembled skylight.

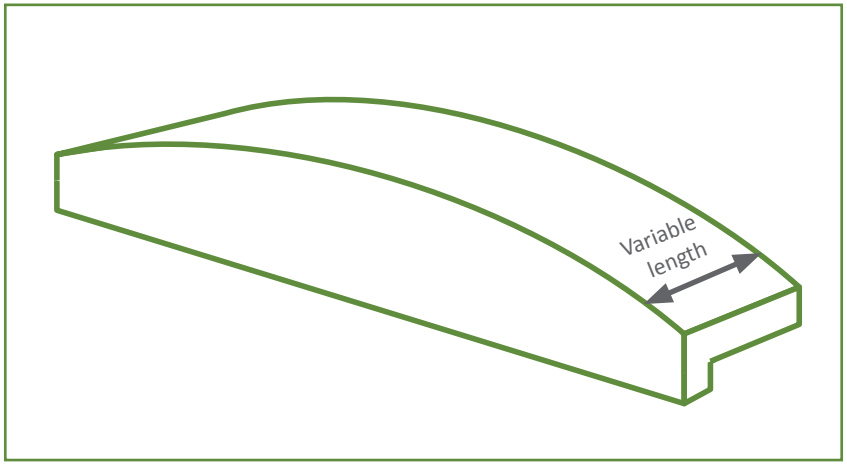
Light Row Variations

In order to accommodate the need for light rows in different lengths the fixed window modules on the ends are made in variable sizes according to the given order while other modules are kept in a fixed size (ill. 3.73).

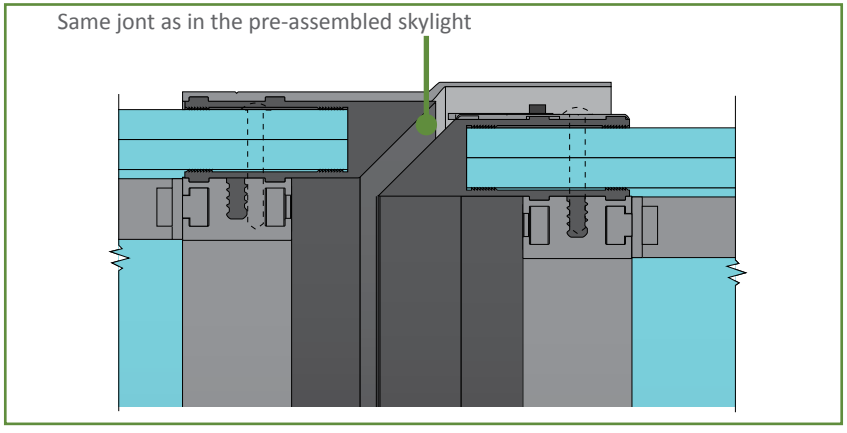
Joints between the hatch/fixed window and fixed window/fixed window are solved identically to the pre-assembled skylight (ill. 3.74).

The greatest difference however lies in how the skylight is delivered as the light row is delivered in production modules and not partly assembled.

The delivery and mounting procedure is described in the brochure Contego by Domex.



ill. 3.73 - Fixed lights in the ends are made in variable sizes.



ill.3.74 - Partial section cut on the long side showing how the hatch meets the small and large fixed windows.

Product Maturing

As the project has been developing Contego the focus has varied between areas and some areas have been left out for the product maturing phase.

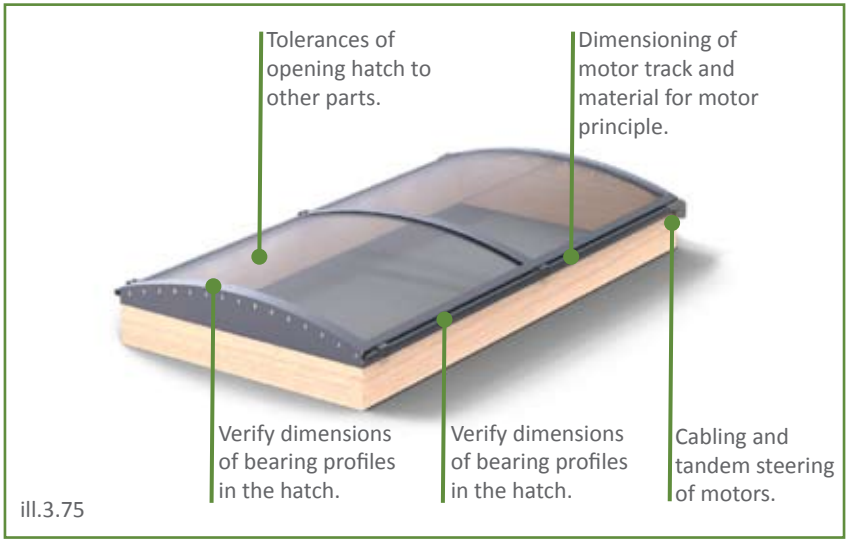
Areas that need to be developed further in both the pre-assembled skylight and the light row are the following (ill. 3.75):

- Cabling to motors
- Dimensioning of motor tracks
- Tandem steering of motors
- Verify dimensions and numbers of alu profiles in the hatch
- CW factor calculations
- Joints between plastic condensation channels in the light row
- Tolerances in the whole skylight

Those are the main areas that need attention in a further development of Contego. Some of those areas will be examined by the project group after handing in the reports as the group wants to commence the building of an alpha prototype.

In the prototype a light can be shed on respectively tolerances and dimensioning of aluminum profiles if the prototype is equipped with a functional hatch.

On the following page the final proposal for Contego is presented in renderings – both as light row and skylight (ill. 3.76)

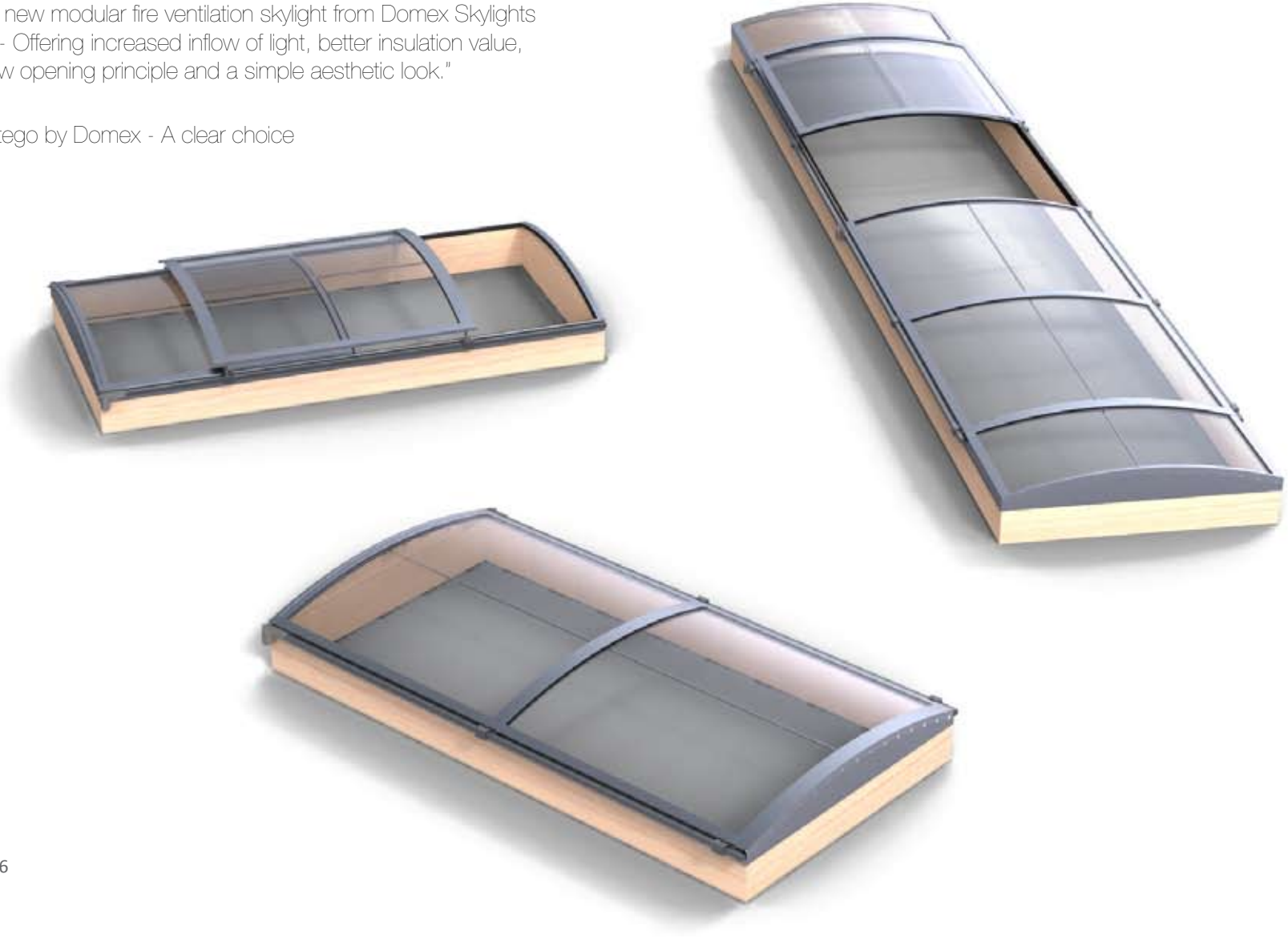


ill.3.75

Contego
by Domex

"The new modular fire ventilation skylight from Domex Skylights A/S - Offering increased inflow of light, better insulation value, a new opening principle and a simple aesthetic look."

Contego by Domex - A clear choice



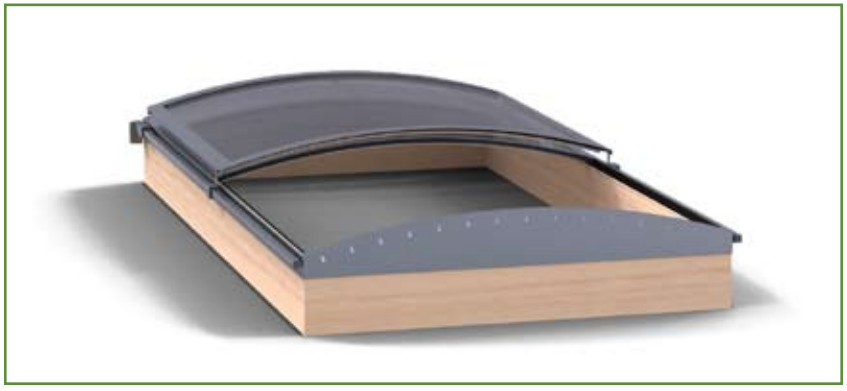
ill.3.76

Product Comparison

In this chapter Contego will be compared to the current skylight and light row.

Aesthetics Comparison

Viewed from the outside Contego is more cohesive in appearance than Domex's current skylight. It is simpler in expression with no variation between the hatch and fixed lights.



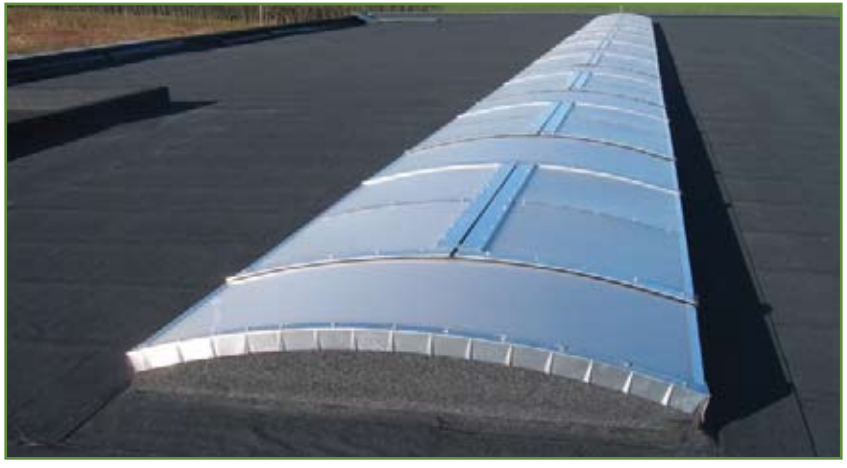
ill. 3.77 - Contego pre assembled skylight.

ill. 3.78 - Contego light row.

ill. 3.79 - Contego pre assembled from inside.

Viewed from the inside Contego is also more cohesive and simpler. Elements are gathered in groups for cleaner aesthetics and the motor is removed completely from sight.

This has also increased the inflow of light in the pre-assembled Contego by 4,5% compared to the current pre-assembled skylight (Appendix 10)



ill. 3.81 - Domex's current light row.

ill. 3.80 - Domex light row from the inside.

ill. 3.82 - Domex's pre assembled skylight.

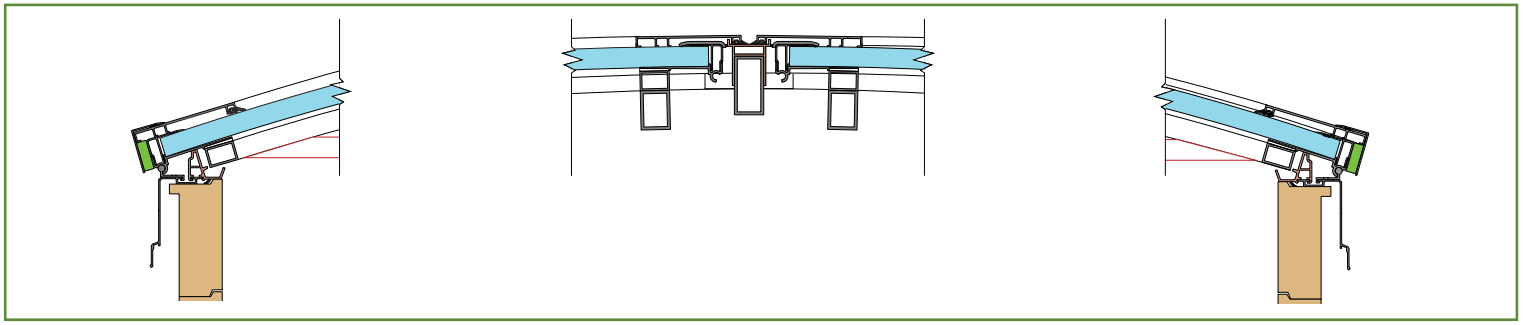
Construction Comparison

By zooming in and viewing Contego and Domex's current skylight through section cuts it becomes clear that the construction of Contego is simpler and contains fewer elements than Domex's current skylight (ill. 3.83 – 3.86).

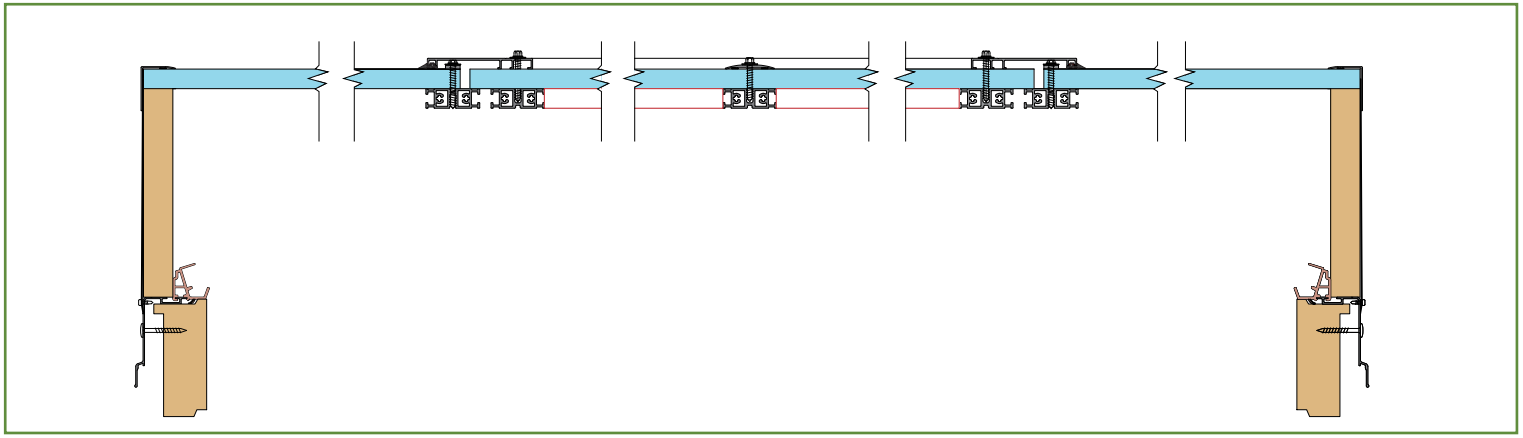
Only 12 different profiles are used in the pre-assembled Contego compared to 19 in the current pre-assembled skylight (Appendix 11).

This induces a simpler assembly process- both to the building of modules and assembly of modules.

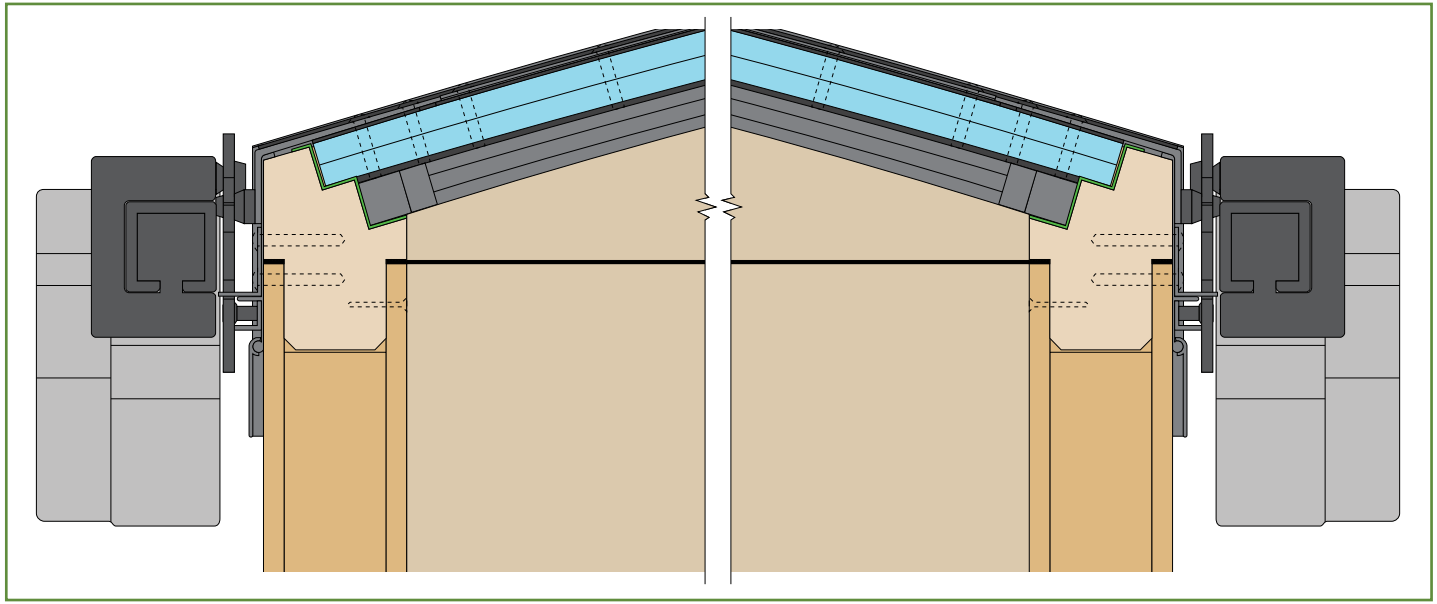
Furthermore the new construction has no thermal bridges except screws, which increases Contegos insulation ability.



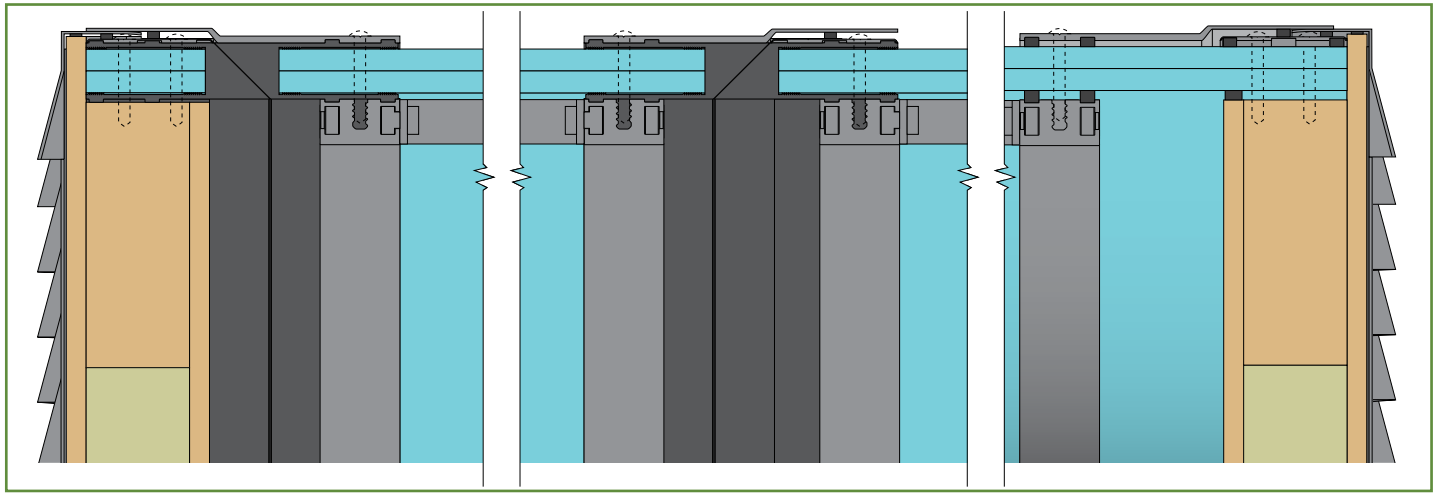
ill. 3.83 - Partial section cut through the short side of Domex's current skylight.



ill. 3.84 - Partial section cut through th elong side of Domex's current skylight.



ill. 3.85 - Partial section cut through Contego's long side.



ill. 3.86 - Partial section cut through Contego's short side.

Insulation Comparison

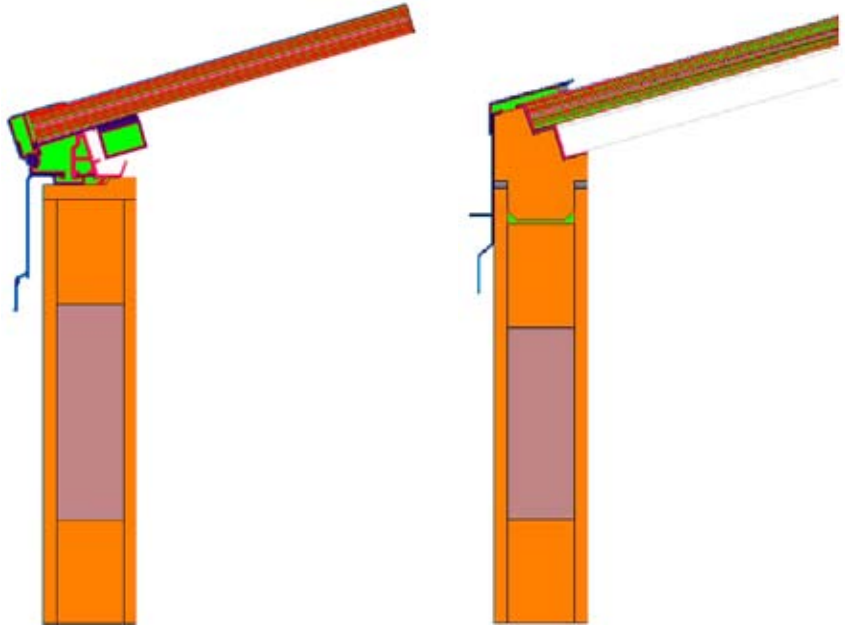
Through the development the project group has worked towards eliminating thermal bridges in order to lower the U value. To compare Contego's thermal value to Domex's current skylight they are run through Therm – an insulation calculation program.

Therm is used to compare the U value of the skylights relatively, as it is hard to hit the correct value of Domex's current skylight in Therm. Furthermore Bent Lund Nielsen, employee at Danish Technological Institute, suggests that Therm is used to compare the values relatively by using the same settings for both skylights.

Screenshots from Therm of Domex's skylight and Contego can be seen in illustration 3.87.

The value in Therm for Domex's current skylight is 2,15 W/m^{2}K and 1,45 W/m^{2}K for the project group's skylight. A percentage calculation adjusting the value for Domex from 2,15 W/m^{2}K down to 1,8 W/m^{2}K equals a value of 1,2 W/m^{2}K for Contego.

Thereby it indicates that Contego goes below the coming demand of 1,5 W/m^{2}K – a fact that could be a strong selling point.



ill. 3.87 - Screenshots from Therm showing Domex's skylight on the left and the projects group skylight on the right.

Recapitulation

Through the comparison of Contego and Domex's current skylight it is clear that many improvements have been made to Domex's current skylight. Insulation, inflow of light and weight have been improved and the construction and aesthetics are made simpler.

Beside that some areas are subject for further development such as the motor, joints between condensation profiles in the light row, tolerance considerations and profile dimensioning.

All in all the project group finds that the design solution is a plausible solution and that - through a product maturing process can be developed to a state where the mentioned areas can be addressed and solved.

This concludes the product refinement – in the following chapter reflections on process and learning in this phase can be found.

Following the whole process and solution is evaluated and put into perspective.

Process & Learning

Process

With the selection of one concept for further development the concept is divided into five sub systems. This is done to initiate the modular approach to the skylight development. Throught the established sub systems the project group therefore defines the intended modular system of the skylight.

Furthermore the division gives a better overview of the design process and it creates awareness about the important relations between sub systems in a modular construction.

To maintain a strong focus on the modular principles and the importance of joining between sub systems the development is built up around the five most important sub system relations.

Through the development of the five sub systems and the five most important sub system relations a combined proposal for skylight is developed – a proposal that is designed to meet the requirements pinpointed through the pinpointed weak areas and the mission statement trough a focus on simplification and modularization.

The design proposal is presented for Domex and feedback is given. The feedback that is predominantly positive and constructive – provides the project group with an overview of which solutions can be implemented in the final proposals as they are and which solutions should be developed further.

Especially regarding the solutions needing further development the feedback provides the project group with a number of concrete ideas that can be used in the further development.

In the further development the solutions that need further iterations to become plausible solutions are evolved one by one – ending with the final product proposal for this project and an identification of which areas should be in focus in a product maturing process.

Subsequently the product proposal for the skylight is compared to the current fire ventilation skylights from Domex.

Methods

The method of sub system division has been used as inspiration to how the project group could divide the product into modular sub system and how to keep track of the development of modular sub systems and their inter relations.

Systematic sketching has been applied as a methodical approach to keeping track of the implications of changes made in sketches / CAD during the development of the sub systems and the sub system relations. The development has mainly been in CAD.

Hand calculations and Finite Element has been used to verify and develop a selected area of the skylight –the arm connecting the motor and the hatch.

Therm has been applied as a tool for comparing the insulation value between the current skylight from Domex and the new skylight proposal.

Lastly meetings / presentations has been used to communicate the ideas of the project group and to gather valuable feedback regarding benefits and possible improvements.

Learning

Through the development of the skylight the project group has gotten a deep insight into the relations between elements within a product where the parts are very integrated – meaning a product where one element rarely can be modified without inducing a change in the majority of the entire product.

This experience has also presented the project group with the possibility to go in depth with nearly all the parts of the skylight- a process necessary to ensure that the modular system of the skylight could be designed to function.

With the very detailed approach the project group has also gained experience in assessing and evaluating part solutions up against manufacturing- , assembly- and handling processes since the aim of the project to a high degree has been to address problem areas within these fields.

In general the detailing phase of the project has been one the project group has found very giving in relation to the coming profession as an industrial designer.

Evaluation

Conclusion

Process

Through the collaboration with Domex Skylights A/S the project group has gained an understanding of how to collaborate with a medium sized production company that has no prior experience in working with designers.

Especially experience is gathered on how to build up a dialogue across different competences/ approaches, and how to interpret and evaluate both existing procedures, products and traditions within the company.

Very early in the process a direction was set for the project through a methodical approach in analyzing Domex, their products and the market.

This made it possible for the group to select the products that should be in focus in the product development – a decision that made it achievable to investigate the selected products in depth prior to the concept generation.

Based on the thorough investigation into production and mounting procedures of the selected products, the group got an insight that has been invaluable in the concept generation phase.

For one it enabled the group to sketch very detailed based on the intimate knowledge about the current solutions, but it also made it clear where current solutions could be used/refined and where new solutions were necessary.

Subsequently the concept generation phase was very quick – founded in the prior investigation. This made it possible to select a concept quite early in the process- a fact that provided more time to get into details with the selected concept.

In the detailing phase it proved to be a benefit that the project group divided the product into sub systems and focused on sub system relations in the development of the product.

Thereby the focus was kept on the relation between the different elements – an important factor that has proved to be essential in the design of the fire ventilation skylight.

Through the detailing phase the group has tried to get as much into detail as possible – spanning from production, assembly, handling and mounting.

However it was not possible to begin an alpha prototype before the end of the project period due to time issues – a fact the project group regrets since it would have been a benefit to present our learning when translating the design into reality.

However the project group still feels the process has been a learning experience due to the acquired level of detail and the experience in collaborating in depth with a production company where the design and production of the products are done in-house.

Product

Initially the project group set out to discard a large part of the solutions used in the current skylight and develop a new skylight with solutions very different to the current ones.

However – through the investigations into fire ventilation regulations, market, production and mounting – the group became aware that the fire ventilation skylight would be a somewhat difficult product to innovate.

Especially based on the many regulations, insulation requirements, sealing requirements and load demands. Furthermore many of the solutions in the current product proved to be very sound in background – despite how the solution was carried out.

Based on this the group had to find other parameters for the product development and took it as a challenge not only to improve the current solution but to develop a next generation product for the fire ventilation skylights – keeping the current product platform and the re-useable solutions and then building from that.

In the development of Contego is was a challenge for the group to find that the fire ventilation skylights does not have a specific consumer or a specific end user - utilizing and interacting with the product on a daily or weekly basis.

There were the internal users (Production crew) and the external users (Mounting crew) but none of them were users of the final product.

Furthermore the group found that - to the contractor/owner and the employees in the building - the fire ventilation was just a required part of the building that was of little importance to them.

Therefore the project group has tried to accommodate the production crew and mounting crew to a high degree in the development process – while still aiming at introducing features that are selling points to a developer and people working in the building where the skylights are installed.

Contego offers a modular solution based on a simplifying principle that is intended to simplify production and assembly - and present the customer with a price competitive product that offers benefits regarding insulation, inflow of light and aesthetic simplicity.

With the development of Contego the project group feels the aim of the mission statement has been fulfilled to a satisfying degree and the development process of Contego has been a valuable experience for the coming profession as an industrial designer.

Perspective

In a possible product maturing phase, prototypes of Contego skylights and light rows must be built, in order to determine to what degree the CAD design can be translated into reality. Especially there are issues regarding tolerances and clearance in the product.

Furthermore the part solutions of Contego must be calculated in order to define the dimensioning of the elements – particularly the dimensions of braces and the connection between the hatch and the motor must be determined since they make up the bearing structure of the skylight.

A functioning prototype of the motor must be developed in collaboration with Actulux – verifying if the current design can be produced at a reasonable price and if the dimensioning and movement of the opening can be performed as intended.

With the above mentioned steps required in a product maturing phase it is uncertain if Domex intends to put Contego into production.

Regardless of this the project group feels that Contego contains solutions and ideas that with a high probability can act as solutions or inspiration for future fire ventilation skylights and light rows from Domex Skylights A/S.

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Illustrations

Graphic material produced by the project group will not be mentioned in the illustration list. Neither will images that have been distributed under the creative commons licence or images aquired directly from Domex Skylights A/S.

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