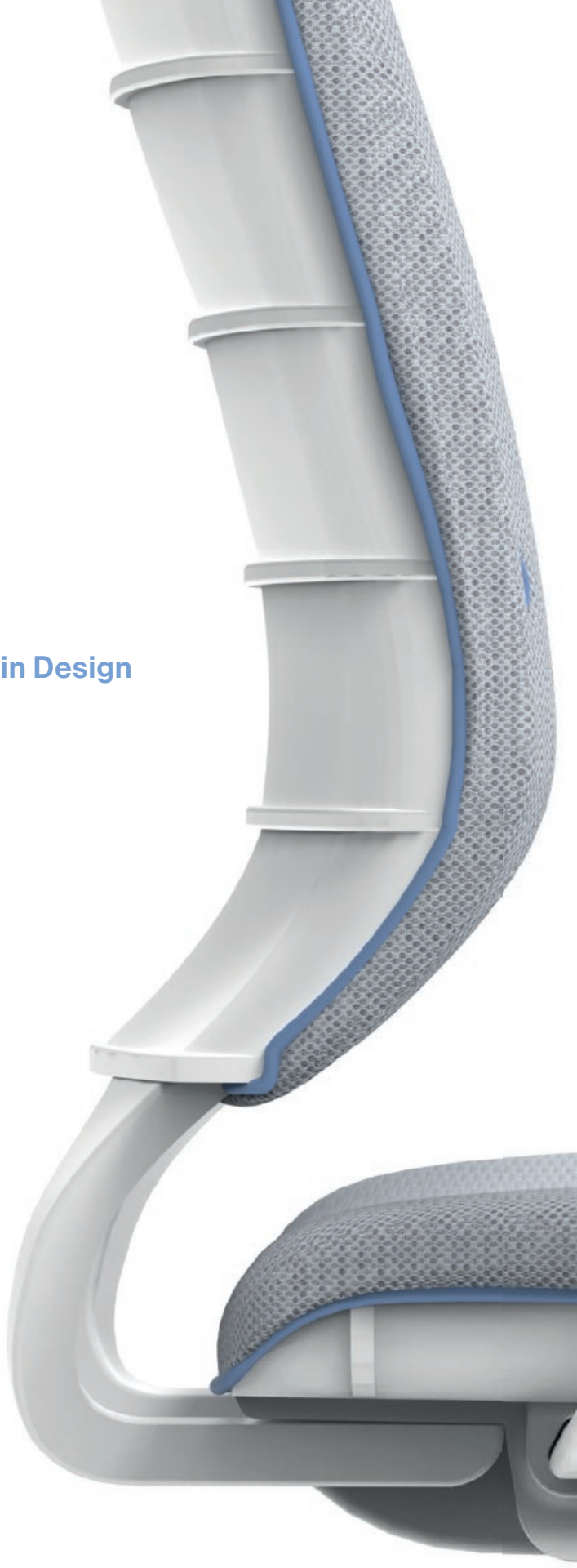
TUNDRA

Degree Project for Bachelor of Fine Arts in Design

Main Field of Study: Industrial Design

2023

Anna Persson



LUND UNIVERSITY

TUNDRA

PCM Cooling Office Chair

by *Anna Persson*

Degree Project for Bachelor of Fine Arts in Design

Main Field of Study Industrial Design

Lund University School of Industrial Design,
Department of Design Sciences

Examiner: Professor **Claus-Christian Eckhardt**

Course Supervisors: Professor **Claus-Christian Eckhardt**, Senior Lecturer **Charlotte Sjödell**, Lecturer **Anna Persson**, Senior Lecturer **Jasjit Singh**

2023

ISRN: LUT-DVIDE/EX--23/50628-SE

LUND UNIVERSITY

Abstract

In this bachelors project I am exploring how Phase Change Material can be applied into an office chair to give a cooling effect and reduce the need for air conditioning. The motivation for the project was to find solutions to lower the energy consumption. The design process includes research and ideation to a developed concept with a display prototype.

Acknowledgements

This project was made possible with the help of my peers, supervisors and the people I reached out to. I would like to thank my supervisor Jasjit Singh along with the other supervisors for pushing me forward and giving me meaningful feedback. I also want to give a big thanks to my classmates and the workshop staff for helping me with the project and prototype. Finally, I would like to thank Chuansi Gao and Climator AB for sharing their expertise and helping me with the PCM packages.

THANK YOU!

TABLE OF CONTENTS

INTRODUCTION

Background

My project started with a personal motivation to lower energy consumption in relation to the energy crisis. From personal experience the energy crisis had a large impact on everyday life and the perspective on using electricity. Home owners have had to cut down electricity consumption to be able to afford the bills, companies have had to size down offices and buildings. I feel like you always try to use as little electricity as possible, but during the energy crisis- it was a must. But since almost everything we use in our everyday life is electricity driven, it was difficult to avoid this. We have become so accustomed to using electricity that it is not something we can live without anymore. In finding solutions to lower energy consumption, I then started looking at what things that do not necessarily have to be powered by electricity and would not change our everyday life habits.

The area I landed on is the one with the most electricity consumption and cost in day to day life. This is heating and cooling systems. I did not want to replace the current systems but rather reduce the need for it.

Initial Brief

To make a product that can help keep people warm in their home and to then reduce the need for heating and cooling systems. The solution should be sustainable, non-electric and fit for everyday life.

Project Timeline

RESEARCH
Week 1

- Motivation
- Project Description
- Procedure
- Time Plan

ANALYSIS
Week 2

- Material Research
- Interviews
- Structure PCM
- Furniture design

SYNTHESIS
Week 5

- Concept Generation
- Mockups & Testing
- Construction

KICKOFF
Week 7

- Final Concept
- Functional Mockup
- User testing

REALISATION
Week 8

- Adjustments
- Final Prototype
- 3D Renders

PRESENTATION
Week 13

- Final Configurations
- Feedback

MOTIVATION

The Energy Crisis

The global energy crisis had its beginning in 2021, mainly as a consequence of the pandemic but also caused by other factors. It was blown into a full on energy crisis by Russia´s invasion of Ukraine in February 2022. Prices of natural gas, oil and fuel prices staggered dramatically and as a result so did the price of electricity. High electricity prices caused the ongoing inflation which slowed economic growth, forced families into poverty and even companies to close down.

The energy crisis could be seen globally, but was mostly centered in Europe. Everyone from families to companies was then left with extremely expensive bills that not all could afford. With the staggering prices, many opted to cut down on electricity consumption by shutting off electronic devices, using less heating and cooling systems and shutting off electricity during the most expensive hours. On social media, people even started sharing old methods or DIY methods to reduce the electricity consumption. It is clear that something needs to change in our everyday use of electricity in order to create an energy sustainable future.

80 million European households struggle to stay warm. Rising energy costs will make the problem worse

Italy puts 25C limit on air conditioning as Ukraine crisis forces energy rationing

Energy crisis fuels coal comeback in Germany

The cost of cooling: how air conditioning is heating up the world

Europe has avoided energy collapse. But is the crisis over?

One in four UK adults struggle to keep warm in their living rooms

European countries face an air conditioning Catch-22 after its red hot, record-breaking summer

Europe energy crisis: Italians told to turn thermostats down

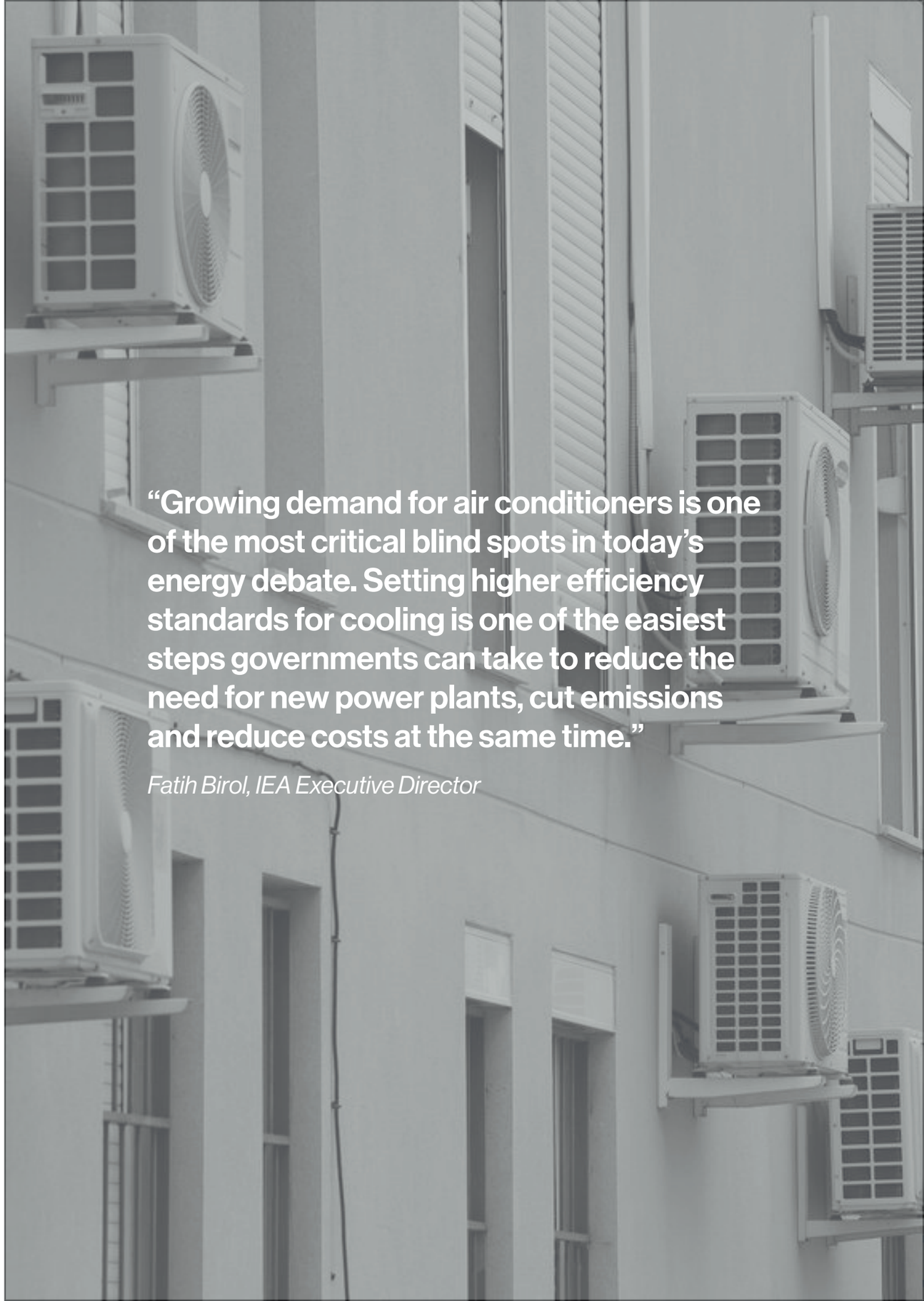
EU must cut back energy use now to avoid shortages in 2023: IEA COMMENTS

Spain Restricts Air Conditioning as Europe Swelters During Russian-Provoked Energy Crisis

Energy Consumption

The energy consumption is expected to increase in the future. As technology becomes more advanced and widely used, more electricity production will be necessary. Even though many countries are moving towards greener and renewable production, electricity still remains produced by 63.3% of fossil fuels as of 2020. It is important to lower the pressure on energy consumption in order to reach a greener world in the future.

As of 2018, nearly 20% of the total electricity used in building in the world consists of air conditioning and electric fans according to iea.org. This number is expected to increase rapidly in the years to come and by 2050 2/3 of the world's households could have air conditioning. So it is crucial that we find new solutions to stay cool during the increase of the world temperature due to climate change. This is most important in warmer climates where air conditioning will not only be a luxury, but a necessity.



Todays Options

My research started with looking at different possibilities with non-electric temperature regulation. This was important since the solution needed to be rather efficient and more environmentally friendly than electric powered systems. The options when looking at the market today with non-electric heating products (not integrated into building structure) on the market today are mainly kerosene heaters, halogen heaters, propane heaters and fire stoves. Most of these options are only recommended for emergencies and all of them are either a fire hazard, health hazard or do not have a good impact on the environment. When looking at non-electric cooling products there are not a lot of options on the market. The recommendations are commonly to dress with breathable clothing, cross ventilation, ice packs and other measures. Most of these options only offer temporary effects.

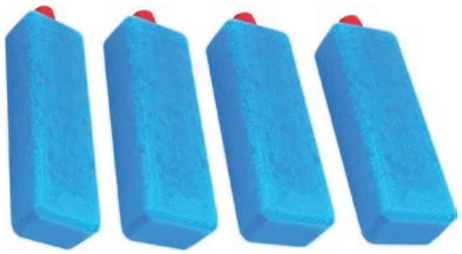
While researching different possibilities of achieving temperature regulation without electricity, I came across Phase Change Material. I wanted to explore the possibilities of different applications with this material and how it could reduce the need for electricity.

Kerosene Heater

Propane Heater

Pellet Stove

Catalytic Heater



Reusable Ice Pack

Instant Ice Pack

History

In today's use of temperature regulation indoors, it is almost always focused on heating or cooling the entire room or building. The problem with this system is that a lot of energy goes wasted. When spending time indoors, we rarely use and move around the whole room. Temperature moves around the room and is for most of the time not centered where we want it to be. If a single person were to be in a large room, it would be a waste of energy to heat up the room instead of keeping only the person warm. So I started to look more into the concept of local heating and cooling around the body. This is an old concept and was used a lot in earlier times, but it seems like it has been somewhat abandoned and forgotten. Back then, they used heat sources that only heated up certain parts of the rooms and created a microenvironment with temperature comfort. They commonly used isolated furniture, for example folding screens and hooded chairs. They also used personal heating sources to warm up specific body parts. The modern system we use today is focused on only heating the air (convection), but the old ways of warming/cooling like heat through electromagnetic waves (radiation) and heating through physical contact (conduction) are way more energy efficient. I wanted to use this old concept and implement it into my project.

Bed warming pan - typically filled with hot embers from fireplace

Children eating ice to stay cool

Phase Change Material

Phase Change Material (PCM) is a known material that is traditionally used in building isolation, cooling transportation, cooling of lithium batteries and used in military and firefighter vests. The properties of Phase Change Material are its capability to absorb, store and release large amounts of latent heat over a defined temperature range when the material changes phase or state (Phase Change Material, Science Direct). Considerably, the most known PCM is ice/water. Ice regulates the temperature to keep our drinks cold by absorbing heat and melting. The difference between ice/water and other Phase Change Materials like paraffin wax, non-paraffin organics and salt hydrates are mainly the melting temperature point. While ice melts at 0°C, other Phase Change Materials can have adjustable melting temperatures. These types of Phase Change Materials have the ability to melt slowly during a longer period of time depending on the surrounding temperature. PCM only gives effect when changing its state from solid to liquid or vice versa, this can however last for hours at time.

Different Phase Change Materials

Paraffin Wax

+ High heat of fusion
+ Non-corrosive
+ Stable thermal cycling
+ $$ Price
- Highly Unsustainable - made from fossil fuels (crude oil), contributes to climate change and destruction
- Medium weight
- Very low thermal conductivity
- Fire hazardous

Non Paraffin Organics

(fatty acids, polyethylene glycol, polyalcohol, polyethylene)

+ High heat of fusion
+ Relatively stable thermal cycling (but elevated temperature can cause decomposition)
- Mildly Corrosive
- Medium weight
- $$$$ Price
- Low thermal conductivity
- Highly fire hazardous

Hydrated Salts

+ High heat of fusion
+ High thermal conductivity
+ $ Price
+ Lightweight
+ Low environmental impact
- Corrosive (can be solved with additives)
- Unstable over repeated cycles (can be solved by additives)

Metallics

+ Very high thermal conductivity
+ Stable thermal cycling
+ $$ Price
- Medium heat of fusion
- Can be corrosive
- Heavy Weight

Conversation about PCM

Chuansi Gao, Associate Professor at Lund University's Faculty of Engineering (LTH) has researched and written numerous papers. Amongst other things he has researched and written about Phase Change Materials. We talked over email and later had a meeting to discuss the possibilities of using Phase Change Materials.

We discussed how to achieve the most effect from the PCM. "For a smaller amount of the material, it needs to be in close contact with the skin since the heat exchange works through conduction. For the material to heat up an entire room, the amount of PCM needs to be greater and incorporated into building structure (ex. walls and flooring)." he said. Dr. Gao also explained that conduction through skin contact is much more effective and faster than the PCM being in contact with air. It is important to create a microenvironment with the PCM, meaning that it needs a large contact area close to the body. This creates the most efficient use for the heat exchange.

Dr. Gao explained that for the PCM to give a warmer surface of a chair for example and transfer from the surface to our body through skin contact, it needs to have a higher melting point than our skin temperature (around 32°C). For the PCM to give a cooling effect, it then needs to have a lower melting point than our skin temperature. The PCM works automatically by melting and solidifying. The problem discussed with a heating effect is however that the PCM needs to be melted before, due to the melting point being above 32°C. It releases heat when solidifying so it would therefore need something to restart the melting process between uses. For cooling effect the PCM would have a melting point below skin temperature but above room temperature (22°C), this to avoid rapid fluctuations in the PCM ´s state.

The PCM would then melt when in contact with skin, for example sitting on a chair with PCM. It would then solidify and release the stored heat when in contact with room temperature.

I asked him: what type of PCM would be suitable for my project? "In one of my papers we used a type of Salt Hydrate, instead of paraffin. Salt hydrates can be better from a sustainability point of view. PCM does however have different melting temperatures. Room temperature and skin temperature are important to determine which PCM melting temperature to choose. If contact with air temperature (ex. T_room=22°C) PCM melting point should be higher than room temperature to warm up. If in contact with skin it should be equal to skin temperature or slightly higher to get a warming effect." he answered. The type of Salt Hydrate they used has additional substances which act as stabilizers and therefore make it stable over an extended amount of time. This type of PCM can be used in cycles (liquid/solid) over several hundred times to thousands of times. For the warming effect in skin contact he recommended the melting temperature to be 34-36°C. For cooling effect the PCM melting temperature should be 28-32°C.

I also asked him if incorporating material with high conductivity (ex. Aluminum) into the furniture piece could improve the effectiveness of PCM. He answered that incorporating this material could improve the heat exchange due to its high conductivity. Also that a structure could be needed for the PCM to keep its shape to fit into the furniture and the body contact area, since the PCM will become fluid and lose its rigid shape.

ANALYSIS

The Furniture Piece

To regulate the body temperature locally instead of the entire room, it was necessary to look into how people move around the room and spend the most time. I also looked into clothing and wearable items, but since I wanted the product to be fit for everyday use, it did not seem like the best application. The existing vests with PCM are for example not something that would be comfortable to wear at home or in a common work environment. This is why I started looking more into furniture. Furniture is always the central part of the room. In the living room we spend time on the sofa, in the bedroom we spend time in our beds, in the dining room we spend time in a chair and so on. To implement Phase Change Material into a furniture piece would therefore be an effective way to keep the temperature regulation local. From the brainstorming, I narrowed down the different options of furniture pieces in regards of these factors:

- What is used more often
- What is used for a longer period of time
- Where phase change material could be integrated effectively
- Where comfort is most needed
- Where PCM could give the most benefits

I then ended up at the office space and more specifically; Office Chairs. This space is where people spend long hours and very often can experience discomfort. To feel comfortable and productive when working is necessary for both physical and mental health.

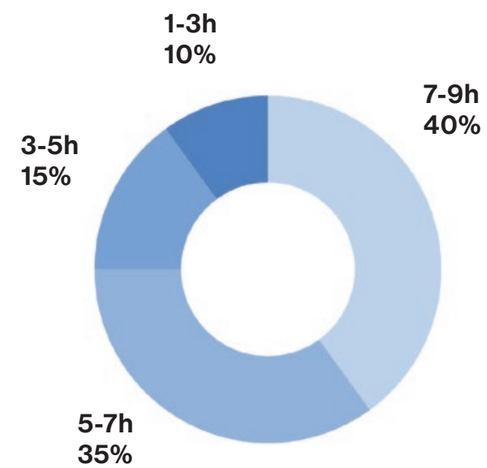
It is also common with open-plan offices. They can be difficult to regulate temperature-wise, as air conditioning systems struggle to maintain a consistent temperature across a large area. As a result, some parts of the office may feel too cold, while others may be too warm. People who sit near air conditioning vents or in drafty areas may feel colder and more dependent on air conditioning to maintain a comfortable temperature.

ANALYSIS

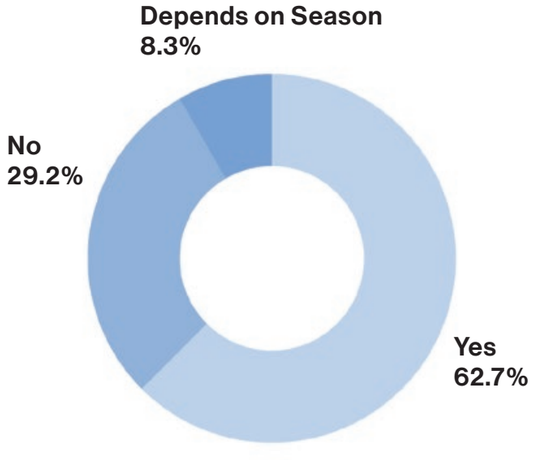
Survey

I conducted a survey to see if there was a need for the product and to see what functions that was desired. The survey was targeted towards people working/studying in an office environment.

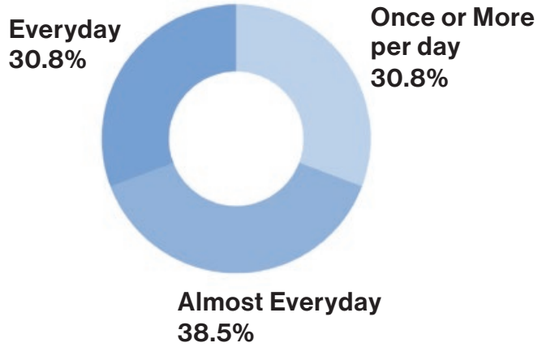
How long do you typically sit in your office chair each day?



Do you often experience feeling cold/warm when sitting in office chair?

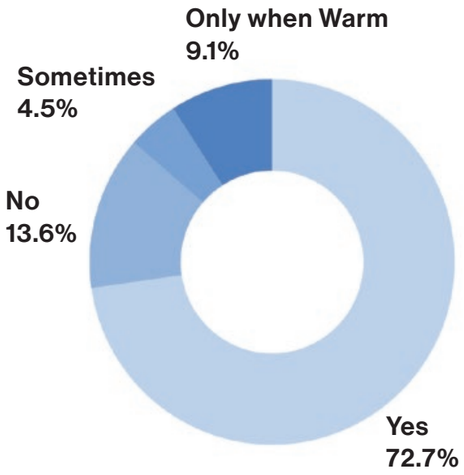


If yes, how often?

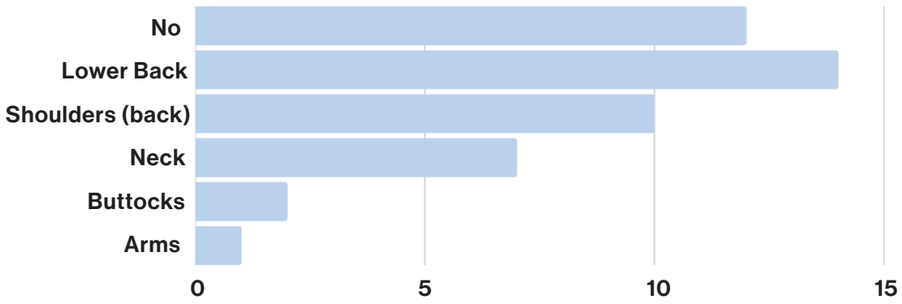


ANALYSIS

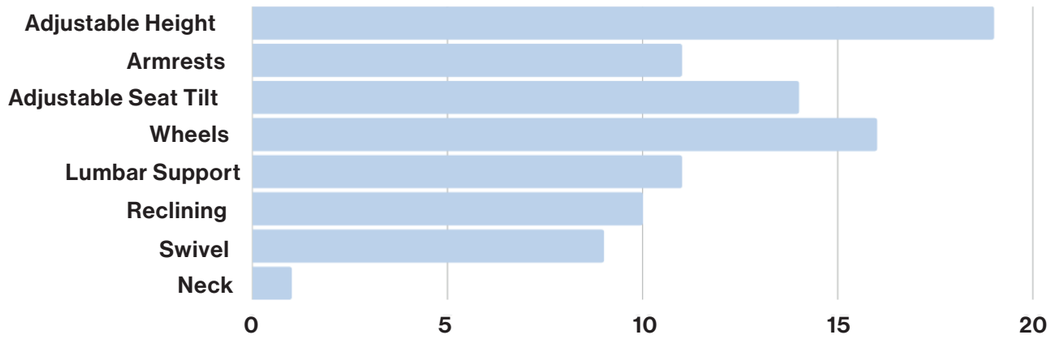
Does feeling too cold/warm affect your focus and productivity?



Have you experienced pain or discomfort in your current office chair? If yes, where?



What features do you consider important in an office chair?



“I would not want it to look too much like a gaming chair. I would want it to be subtle and lightweight looking”

“Feeling cold is fine, too warm would be bad for my focus and productivity”

The PCM Packs

I had a conversation with Thomas Lyck at Climator Sweden AB to get more knowledge about the PCM packages. Climator produces their own brand of PCM packages which is called ClimSel. ClimSel is stable over a long time, effective and environmentally friendly.I then got the information that ClimSel packages with a melting temperature around 32C or higher would not be suitable for the project. This due to the packages can expand when melting or solidifying, which can cause breakage and leakage. He then recommended using the ClimSel c28 (melting point of 28C) which would be effective with the furniture piece. This would however mean that it is below skin temperature (32C) and would give more of a cooling effect.

In the conversation I also learned that they have used the ClimSel c28 in a mesh cushion on their chairs during the summer. Which gave a comfortable cooling feeling. It also proves that it would be effective to use for my furniture piece. Since PCM acts through conduction heat exchange, one also can´t get sick from the cooling. This compared to air conditioning and other cooling systems which can lead to causing a cold.

This cooling effect is considered to give a pleasant cooling, not freezing, due to only 4C in temperature difference compared to skin. Studies also show that working in a slightly cooler and pleasant temperature has a good impact on productivity and focus, since it makes us more alert and awake. This cooling effect will also provide temperature comfort and avoid body overheating when sitting for long hours.

Updated Brief

To create an office chair that can reduce the need for air conditioning and cooling systems in offices or homes.

The solution should be non-electric, functional and fit for everyday tasks.

Target

The focused target for this project is office workers, the main focus on people who work at an office but also remote/home workers. These are people who spend numerous hours in front of the desk and can often experience discomfort in regards to temperature and ergonomics. The product is also targeted more towards people living and working in warmer climates.

Scenarios

1. Jane works in a modern office with a large open floor plan. She enjoys working there, but on hot summer days, the air conditioning can't keep up with the outside heat. Jane starts to feel sticky and uncomfortable in her chair, which makes it hard for her to focus on her work.

2. A CEO of an environmentally conscious company is facing complaints from employees about uncomfortable temperatures in their warm and sunny offices, despite running air conditioning constantly. The CEO is concerned about balancing employee satisfaction and productivity with the high cost of electricity.

Needs

- Keep body cooled down during hot seasons/environment
- Ergonomic- Comfortable for long hours
- Focus on correct posture, good lower back support and armrests to deload shoulders
- Easy to move around
- Aesthetically pleasing

Function Analysis

Temperature Regulation	MF
Be Comfortable	N
Lower Back Support	N
Armrests	N
Adjustable height	N
Wheels	N
Swivel	N
Soft Cushioning	D
Adjustable Seat Tilt	D
Adjustable Armrests	D
Communicate Function	N

Market Analysis

I made a market analysis of existing cooling office chairs. Two of the existing “cooling” office chairs I discovered, use Phase Change Material molecules in the fabric. This fabric can be found in different uses, for example in duvets and bed sheets. However using Phase Change material molecules encapsulated in a fabric gives such a small amount of the thermal exchange material that it does not give much effect. With the market analysis I learned that most of the office chairs today only offer fabric breathability or electric options, no thermal exchange and non electric products could be found. I therefore decided to move forward with my project.

Tempur-Pedic Cooling Technology Ergonomic Drafting Chair - with Outlast Phase change material padding/fabric

+Non Electric, Breathable

-PCM in fabric does not give much effect

ELEMAX- Cooling, heat and massage unit For X-Chair office chairs

+Lot of Functions, Comfort

-Battery driven, needs to be charged

Thermaltake X COMFORT AIR

+Efficient Cooling

-Powered by electric fans

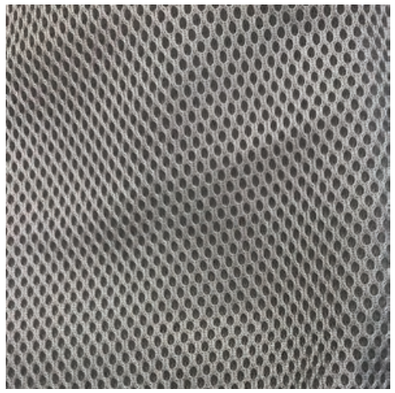
Eurotech Cooling Fabric Task Chair

+Comfort, Lightweight, Non Electric

-PCM fabric does not give much effect

Material PCM

These chosen materials for the office chair was with consideration to the PCM. The packages needs to be protected from taking damage, so it will be protected with a thin aluminum sheet. The aluminum also doubles as an amplifier for the material, since it has high conductivity. The office chair however needs to be comfortable to sit in, so it will have upholstery made in open cell latex foam. Open cell latex has high breathability and allows for temperature transfer compared to other foams that can act as an insulator. This will then be covered in a mesh fabric that also has breathable qualities.

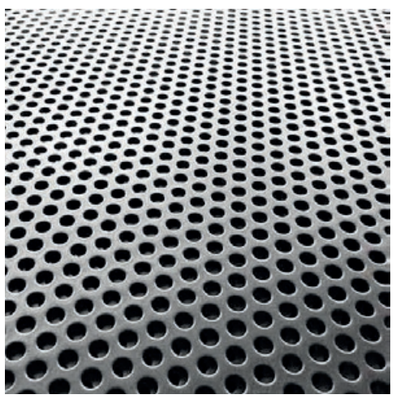


Mesh Fabric

The mesh fabric is breathable and allows for heat exchange. This fabric is often used for backpacks and shoes. It is very durable and somewhat elastic.

Open Cell Latex Foam

Open Cell Latex Foam gives high comfort and is breathable.



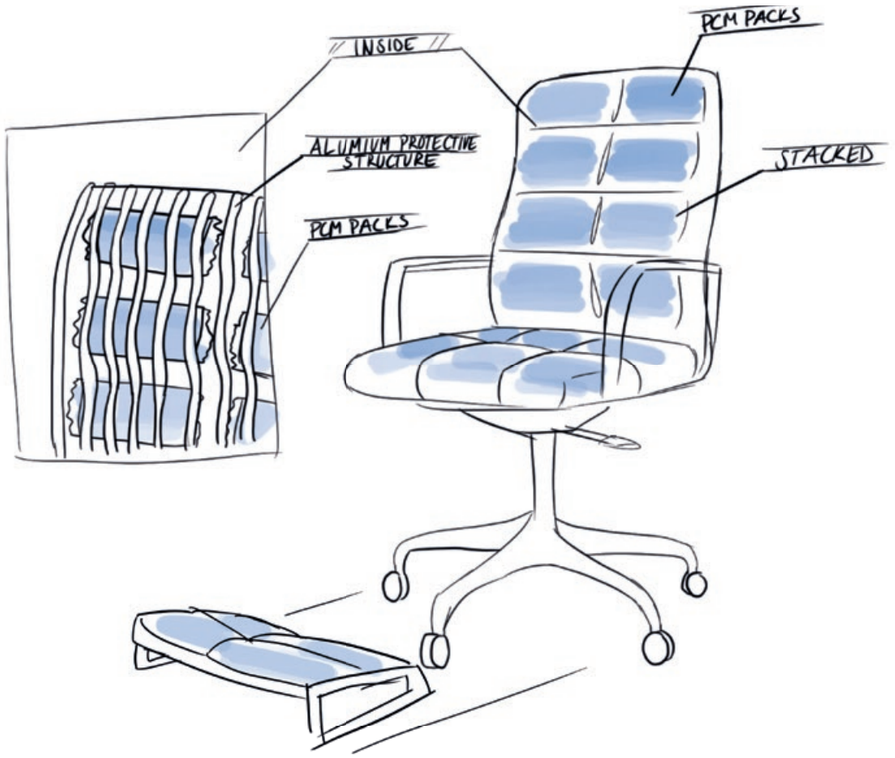
Perforated Aluminum Sheet

A thin aluminum sheet protects the PCM packs. With it´s high conductivity it also provides good efficiency for the heat exchange.

SYNTHESIS

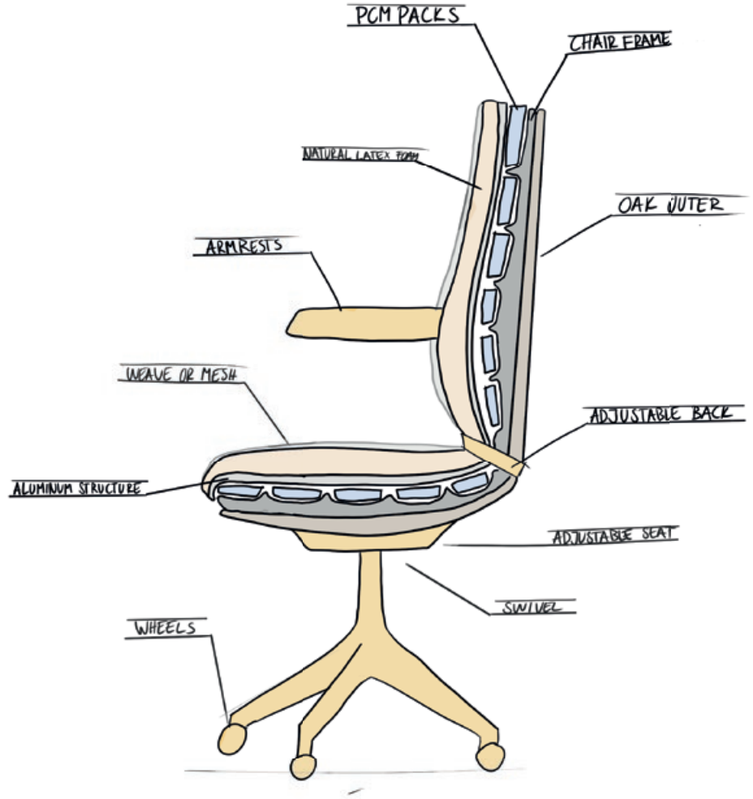
The Idea

My first idea to integrate the PCM packs was to stack them along the seating of the office chair. I had some initial ideas to show the packages in the design, as seen in the sketch. This idea stayed, but evolved during the process. My initial thought was also to include a footrest, this was however before I had to change the PCM melting temperature to a cooling effect. So I later decided to move on from the footrest and focus on the office chair. My first idea for the PCM structure was to use aluminum wires. This would however mean that the PCM packs would not sit secured and not fully protected, therefore I moved away from this concept.



The Sandwich Structure

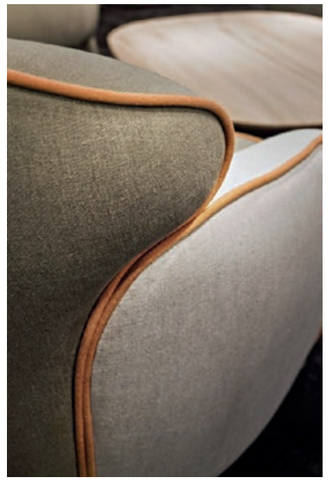
I gathered the research, explored further and came up with this kind of sandwich structure. This quick sketch shows the different layers and the desired functions of the office chair. The idea of the needed layers was; fabric cover (mesh or weave), foam padding (natural latex foam), protective sheet (aluminum), PCM packs, chair frame (also holds the PCM in place) and an oak outer shell. Here my idea was to use oak as a decorative and isolating material, which I later moved away from.

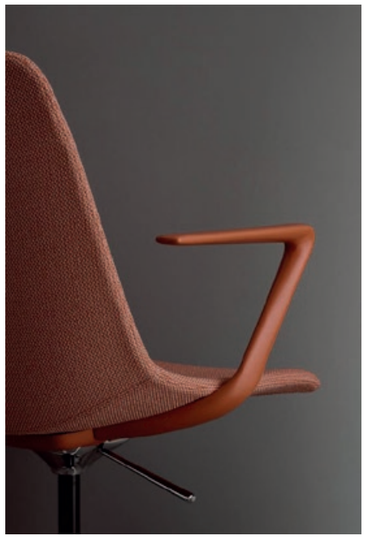
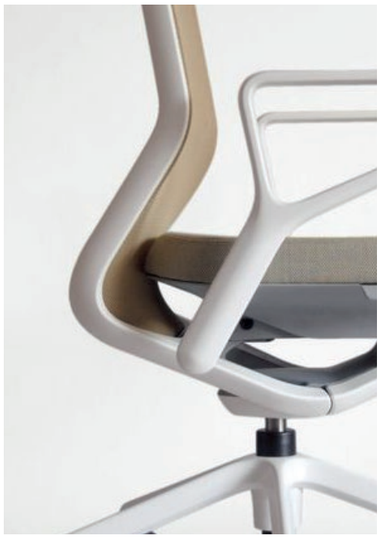


Moodboard

Inspiration for the office chairs shape and expression. Also for the stitching details and form.





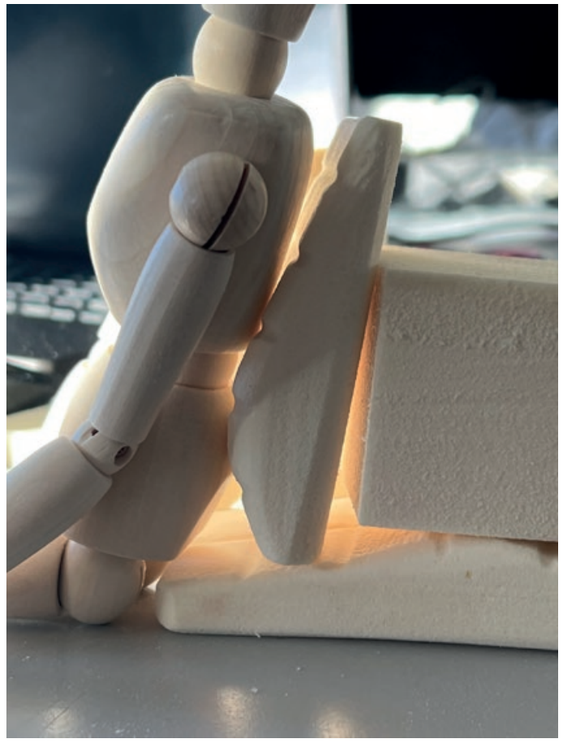




Shape Sketching

I explored the shape of the office chair through sketching various shapes and forms. I explored different forms in the seating, armrest and overall form language. At first I was fond of the first option (top left) because of its lightweight and see through seating. But when taking consideration of the PCM properties, it needed to have a closed shell to create a microenvironment around the body. I also explored closed armrests, but this would counter the office chair function to have adjustable armrests. I wanted the office chair to appear lightweight and the seating to almost follow the shape of the spine. It was also important for every part (backrest, seat and armrest) to have a coherent shape and direction. The one that I continued on with is the one on the bottom right.

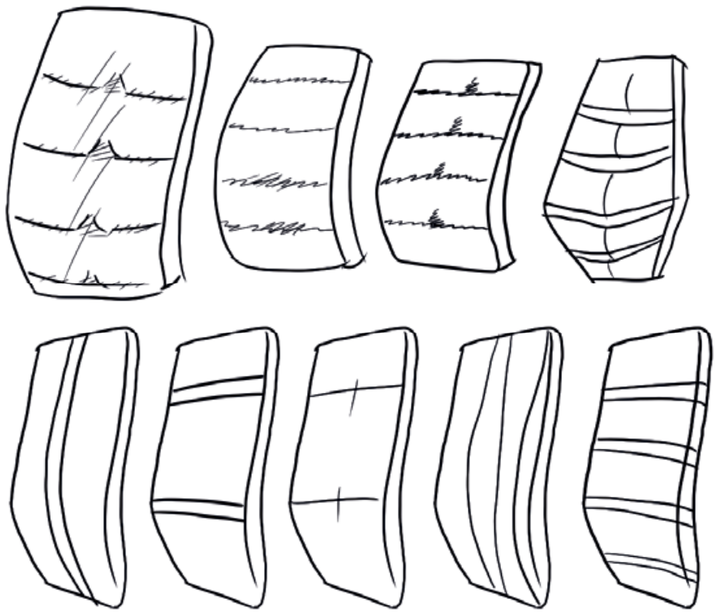
Form Exploration

I quickly moved onto making quick foam mockups to explore further and shape the seating of the office chair. Here I also found that some of the earlier ideas appeared too flat and thick, so I continued forming the foam to get more curvature. Here I also tested with some indents to visualize the stitching details. I also tested the foam shapes with a wooden doll, this to get an impression of how the form follows the back. The seating shape I continued with is the one on the bottom right, which has a soft yet structured shape with different curvatures.



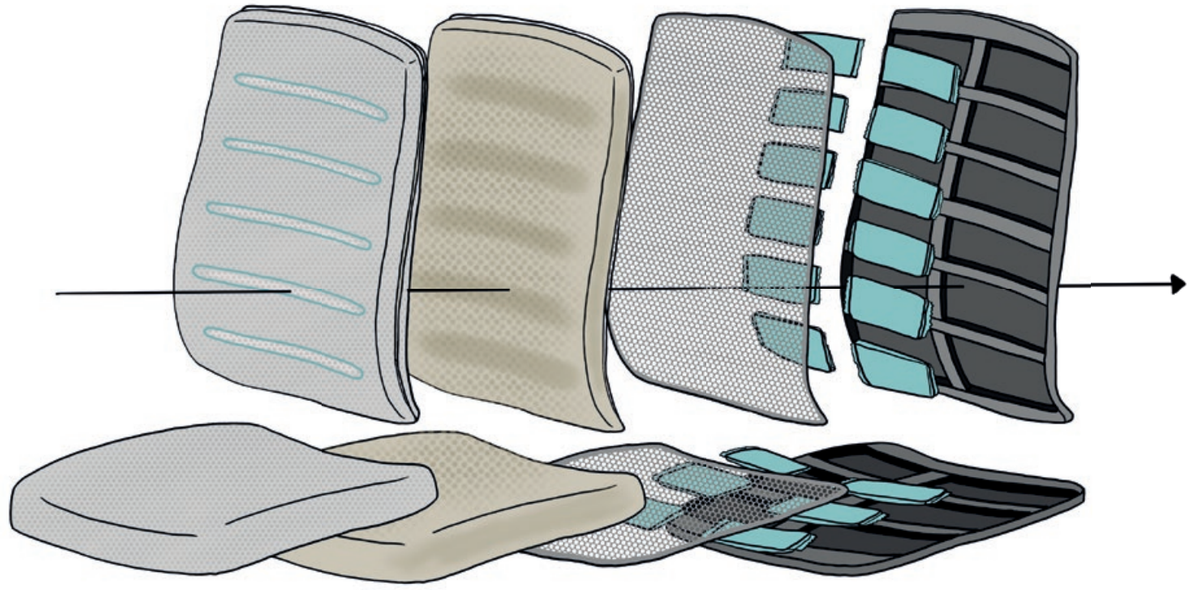
More Sketching

After making the foam models I went back to the drawing board. Here I wanted to explore further with the stitching details and the full shape of the office chair. I sketched quick and simple back seating details, my goal was to have the details communicating the inside working material but also follow the shape of the full chair. I also tested making cut out details in the chair. However again due to the PCM properties, this would not be suitable. The concept I came up with was long rounded rectangle shapes on the seating, which communicates the inside structure and sizing of the PCM packs. Here I came up with the backrests that follow the shape of the backrest and also the rounded detailed shapes. The backrests give an interesting silhouette and make it look more lightweight. The wheel-base should have a geometric shape with rounded corners and light-weight similar to the full seating. For the armrests I followed the shape of the backrests to give a unified form direction. The full shape of the chair gives a coherent expression and each part visually connects to the next.



Exploded View Concept

I made an exploded view of the structure to figure out the shape of the different parts and visualize how it fits together. I sketched the parts on separate layers in ProCreate to be able to pull it apart and put it together. The idea of the inside structure is a molded shell with pockets to secure the PCM packs in place. The horizontal structure communicates to the outside by the stitching details. It also works as the supporting and load bearing structure of the Office Chair.

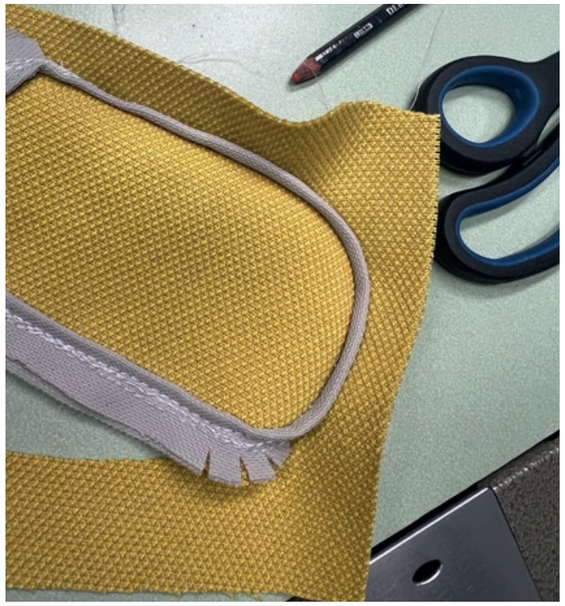


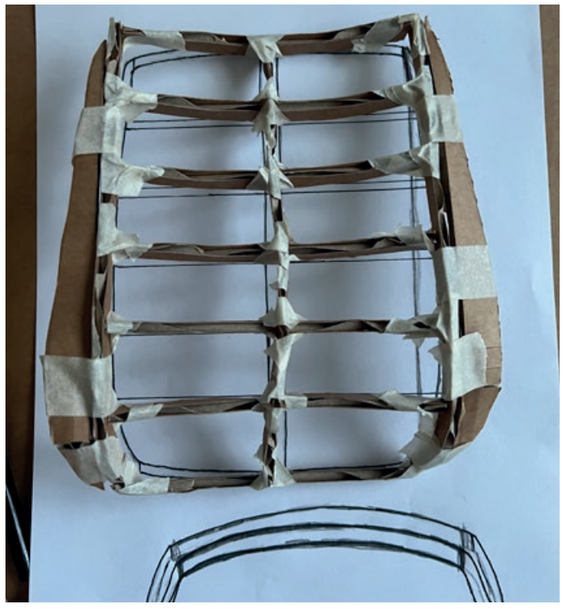
First Design Concept

This is my first design concept for the Kick-off presentation. The seating has a gray mesh fabric with stitching in a light blue color to symbolize the cooling effect. Here the back is covered with the same fabric and stitching details. The front and back are separated by a white splitline. After some feedback and thought, I came to the conclusion that the inside structure was not communicated enough. The fabric back makes it too similar to existing office chairs. So I continued to work on the design concept of the office chair.

Prototype testing

I started to plan on how to build the Office Chair prototype. I tested to sew the stitching details I had in mind for the seating (not in the intended fabric or color). The technique I used for this was to fold a strip of fabric and sew it to the two main pieces. It gave the right form that I had in mind, also gave a slight indent to the fabric. I then moved on to making a cardboard prototype for the frame. Here I noticed that the shape needed to be made in different sections and somewhat simplified. I divided it so that the full shape could be made by flat cutout pieces. Then connected these together to create the full shape.



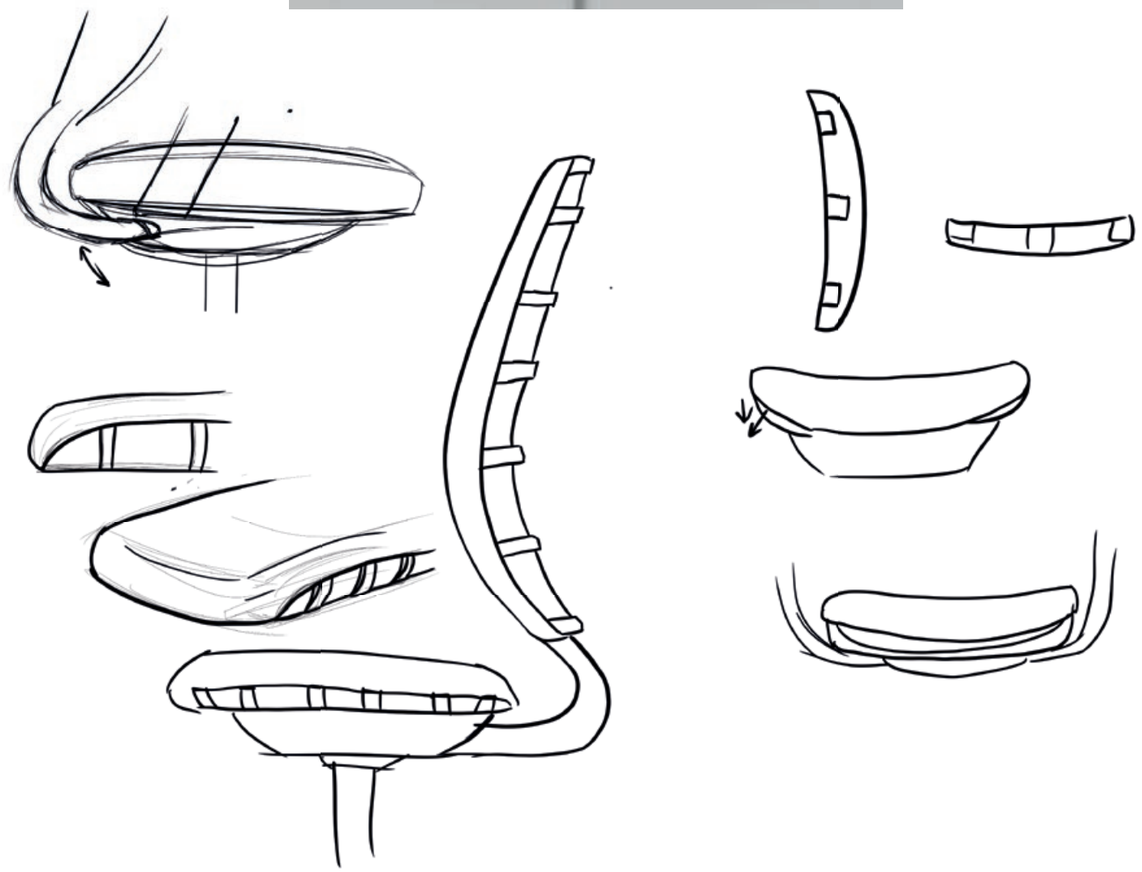


Structure Testing Prototype

I decided to make a full scaled prototype of the frame structure. I opted to laser cut this out of MDF, this is however thinner than intended to be. This gave me a better impression of the measurements and form. When making this model I noticed that I needed to further improve the different sections. The difficulty was to create the outside form from the side as well as the front. I decided to extend the “ribs” (horizontal structure) beyond the flat ends, this to give it more shape. One concern I had with the design was that the curvature of the back may be too aggressive.
So I added a soft foam onto the frame and asked people to test it. It was tested by putting the back onto a chair (in the correct height in consideration to back support measurements) and testing to lean back onto it. I got the feedback that the curvature actually felt comfortable and provided good support for the lower back. It also helped to achieve good posture.

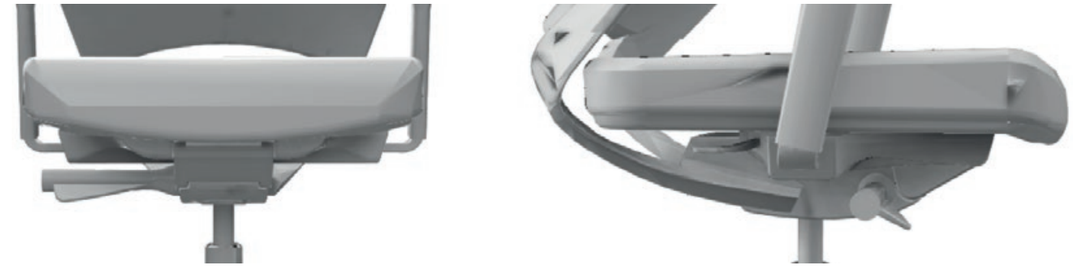
Rethinking the Shape

I sketched more on how to communicate the inner structure to the outside more clearly. I sketched and thought about different alterations to the overall form. The one I decided on is the bottom sketch. This make the back into a hard shell and to pull out the “ribs” onto the back. I did the same on the sides of the seat to create a similar form language. These extended lines gives a more colder and protected impression. I found that this also separated the structure from the fabric and foam seating which further visualized the layers.



Mechanism

My main focus for this project was the seating of the office chair. But to create the full product I also had to look at the mechanism. For my project I decided to take inspiration from existing office chairs. There is a wide variety and alternatives of existing office chair mechanisms that include different functions. Since my Office Chair should be comfortable for long hours and therefore contain more advanced functions (adjustable height, back, armrests, seat tilt and depth), I looked at office chairs that had similar functions. I took inspiration from CAD models from different Kinnarps office chairs. A lot of office chairs also use covers over the mechanisms, for example IKEAs office chairs, which is something I also took inspiration from. My intention is that an existing mechanism should be used for my office chair Tundra.



Drabert Esencia

Kinnarps 5000 Synkron

Kinnarps Capella FreeMotion

IKEA Långfjäll

Ergonomics

To achieve an ergonomic chair with the right support points and seating shape, I looked at several existing office chairs. With the existing office chairs I gathered the general measurements for the height of the seating, armrests and backrest. I also looked at the curvature and height of the lumbar support. When observing these chairs I also gathered what components were necessary for my chair. This gave me much more information to make the chair as ergonomic as possible.

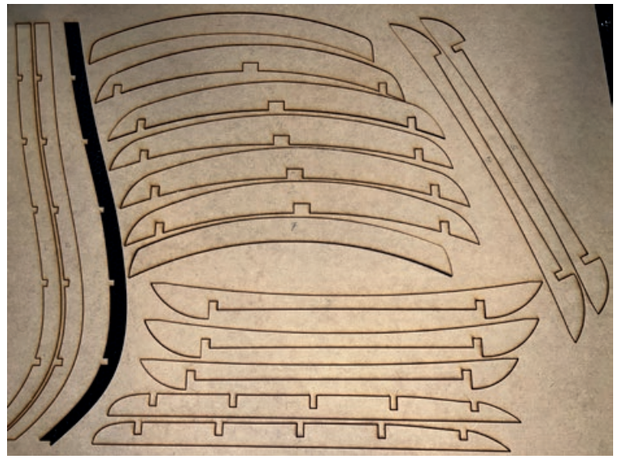
REALISATION

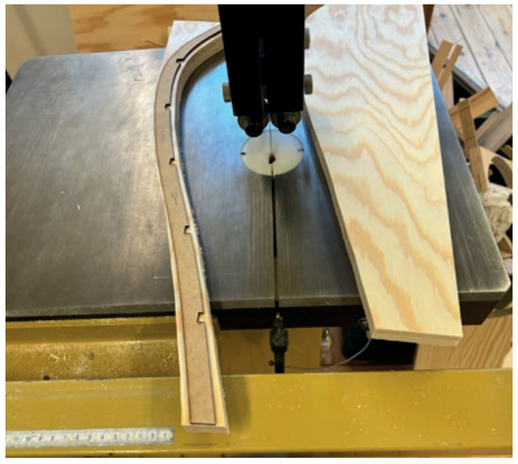
Wheel Base Model

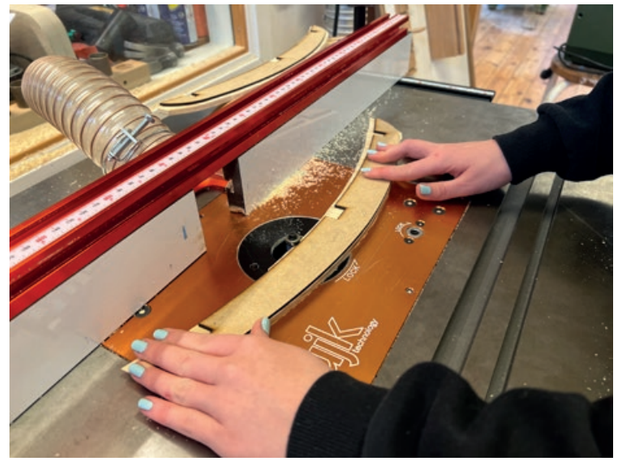
To create a full scaled prototype of the office chair, I decided to use a wheel base from a broken existing office chair. The metal wheel base has functional wheels, however the other parts from this office chair would not be usable for my prototype. This wheel base had a similar shape to what I had in mind for Tundra. The only differentiation was the rounded edges on the ends. I therefore decided to use an angle grinder to cut away the excess material and since the ends were in solid metal, this would not affect the stability or function. I then evened out the form with a fine metal putty and sanded everything down.

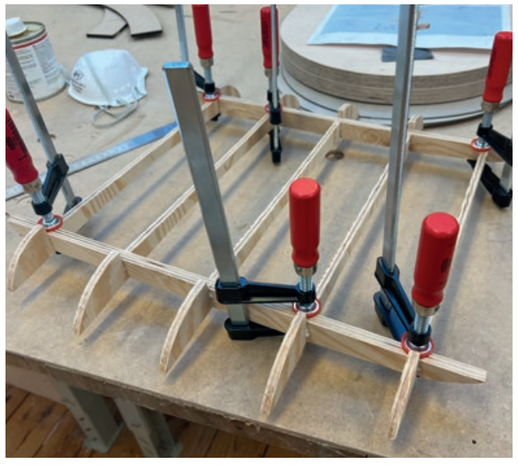
Frame Model

For the frame, I talked to the people in the workshop and tried to figure out how to build it. Since it is somewhat limited to make a plastic or metal molded piece in the workshops, the simplest way to get a relatively strong and hard shape was to make it in wood. This is not the material that would be used for manufacturing the office chair, but was the only solution for me to be able to build it due to the time limitation. I started with laser cutting all the templates for the parts. These are the frames for both the back and the seat. The solution to put them together was to make a so-called “Half-Lap Joint”. For the parts to be as strong as possible, I used plywood. I cut out all the pieces by using bandsaw, milling and wood chipping tools. I then sanded them to make them fit together. The parts were then glued together.



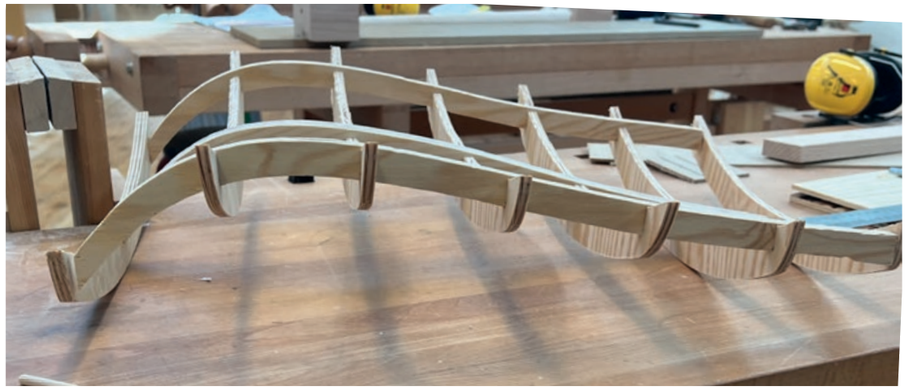






Frame Model

This is the finished frame for the backrest. It got the shapes and curves I wanted for the model. To then make the shell, I also talked a lot with the people in the workshop. Since the frame had a double curve, it was difficult to make this in certain materials like wood. So I then opted to 3D print out sections of the shell to create the full form of the backrest. The printed parts fit into the back of the frame and are then glued together.

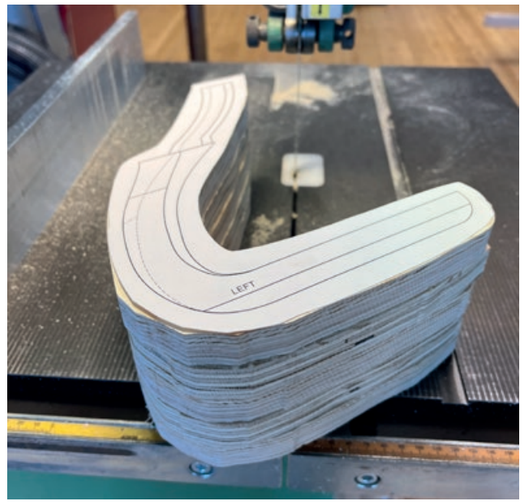


Mechanism Base

The base or mechanism part is where all the different parts are connected together. It was therefore important to have a strong base. After a lot of thought, I did not have many options but to mill it out. I considered getting an existing mechanism for the model, but decided that the appearance was more important than to be functional. Given the other parts are made in wood, it would also allow it to be easily connected together. So I milled out the shape with a CNC machine.

Back Supports & Armrests

I explored different ways on how to create the back supports and armrests. This since I at first wanted the model to be strong enough to sit in and lean into. After looking into different materials and techniques that I can do in the workshops (ex. Metal piping covered in 3D printed shell, metal sheets, epoxy etc.), I again came to the conclusion that wood would be the only option. Wood for these parts were however somewhat difficult to make, but in the end I achieved the shape I wanted. I made the backrests using plywood (stronger) and the armrests in solid wood. I started by gluing the pieces together and cut them out by using bandsaw, jigsaw, belt sander, spindle sander, rasping and much more. I then sanded them down by hand to get a really smooth surface.

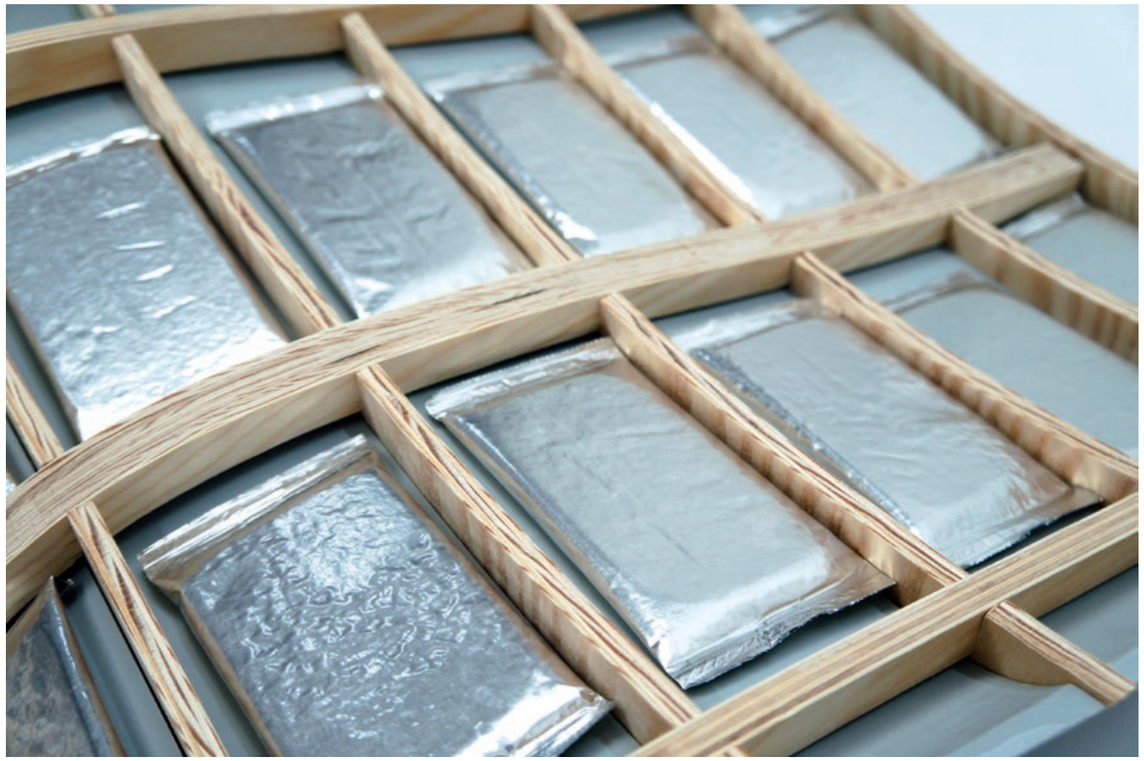


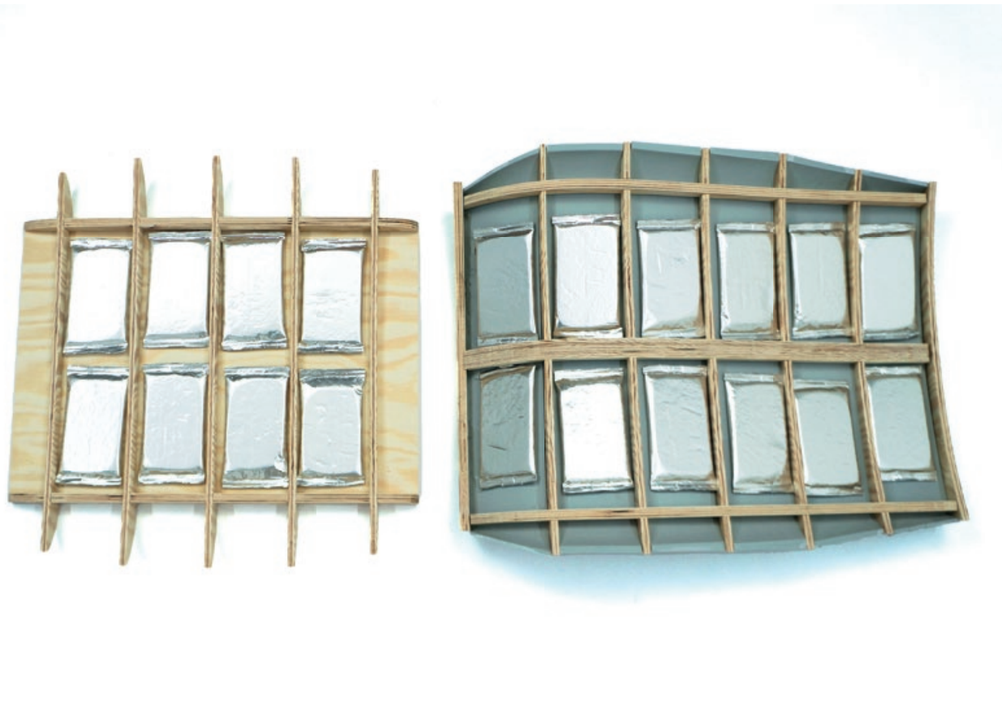
Model Parts

These are all the parts for the office chair model. The backrest and seat consists of wood and a 3D printed plastic shell. The seat frame is connected on a plywood board which is then connected to the base. The wheel base attaches to the base with a metal pipe that has been cut out to achieve the right seating height.

PCM integration

The Phase Change Material packs fits perfectly into the pockets of the model structure with some tolerances. This allows for the packs to melt and solidify without moving inside the office chair. The packages are also protected inside the shape. The 3D printed shell creates the full shape of the backrest.

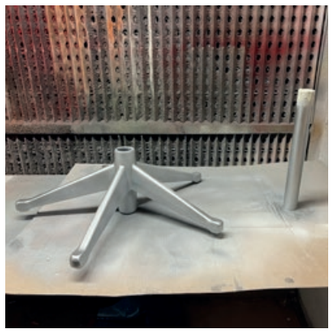




Finishing Prototype

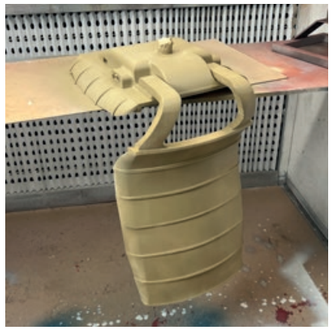
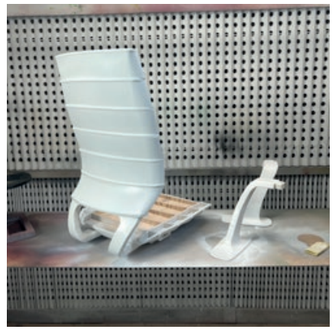


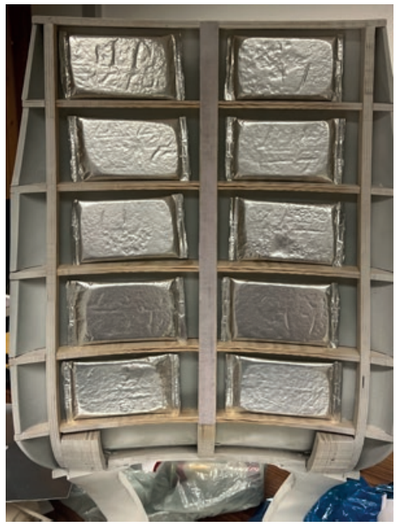
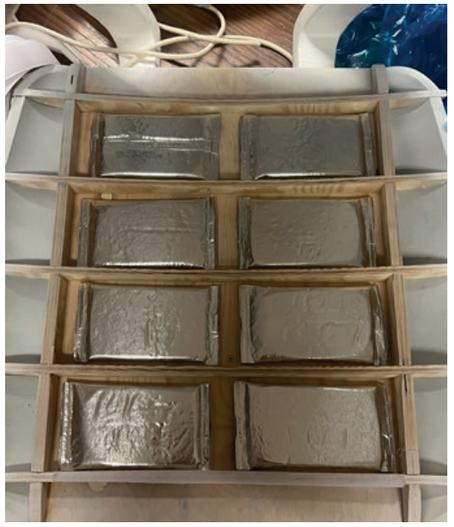


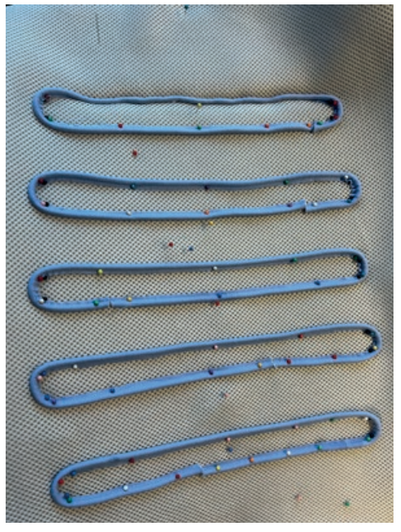






FINAL RESULT

TUNDRA

PCM COOLING OFFICE CHAIR

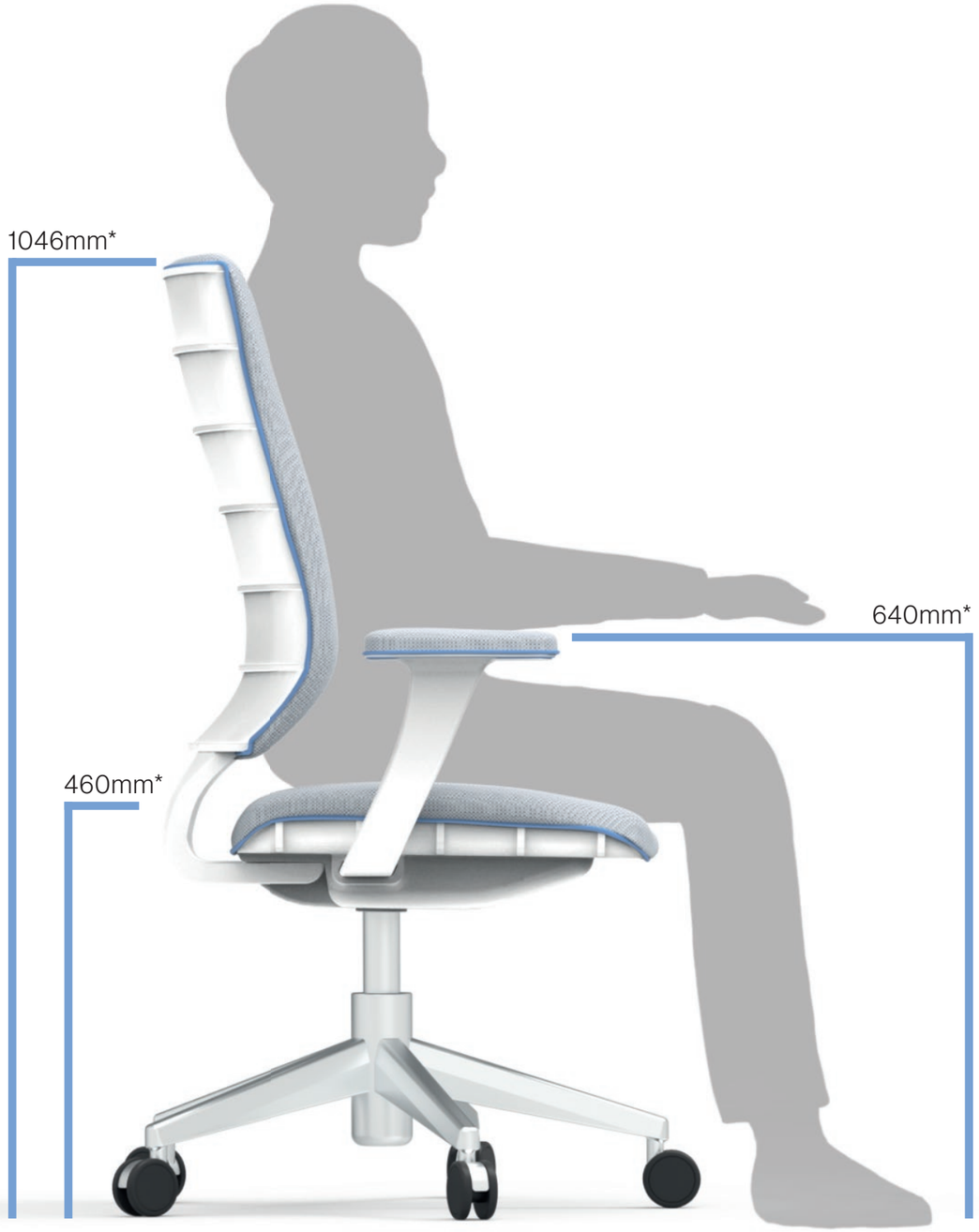
BY ANNA PERSSON

FINAL RESULT

Functions

The Tundra office chair offers temperature control with a cooling effect at 28C with the integrated Phase Change Material packs. It uses no electricity and can lower the need for air conditioning and cooling systems. The cooling effect gives comfort during long work hours, which can also improve concentration and productivity.

It offers ergonomic comfort with lumbar support in the back. With the wheels and swivel it offers mobility and efficiency in the workspace. The office chair also allows for adjustable height, back, armrests, seat depth and tilt to be customizable for each person's needs.

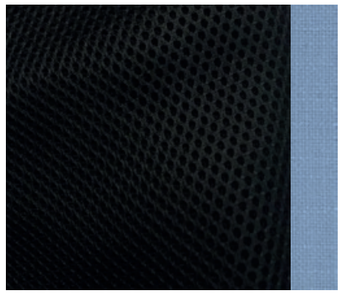


*General measurements, can be adjusted

FINAL RESULT

Details & CMF

There are two color options for the office chair, one in a black and one in white with light gray fabric. The detail stitches are in a light blue color to easily communicate the cold element. The back has extruded ribs that communicate the inside to the outside. A blue stitching split line brings the hard and the soft together and also communicates that there is something in between. The form of the back supports and armrests follows the shape of the chair for a coherent look.

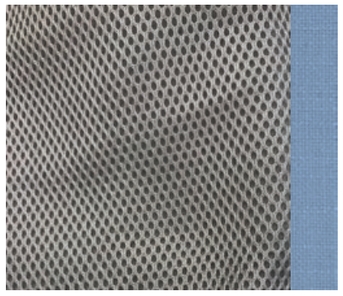


DARK

Black Fabric: #080807

Blue Fabric: #708baa

Black Shell: #313233



LIGHT

Gray Fabric: #c7c9c7

Blue Fabric: #708baa

White Shell: #f2f2f2

FINAL RESULT

Materials

An exploded view of the structure of the Tundra office chair and all its materials.

PCM PACKS

Phase Change Material packs with a melting point of 28C. The ClimSel28C is very effective and long lasting.

MOLDED PLASTIC

Back and seating structure is made in plastic due to it being lightweight, durable and flexible.

ALUMINUM

The back supports, armrests and wheelbase is in aluminum due to strength and durability. The back supports connect into the plastic structure.

OPEN CELL LATEX FOAM

The foam's open cell structure allows for temperature to pass through. It is more breathable than commonly used foam which often is more isolating.

MESH FABRIC

The 3D mesh fabric is breathable and durable. This fabric is comfortable and also often used for backpacks.

PERFORATED ALUMINUM SHEET

Allows for air transfer and has a good thermal conductivity, which transfers and spreads thermal energy more efficiently to and from the PCM. Protects the PCM packs.

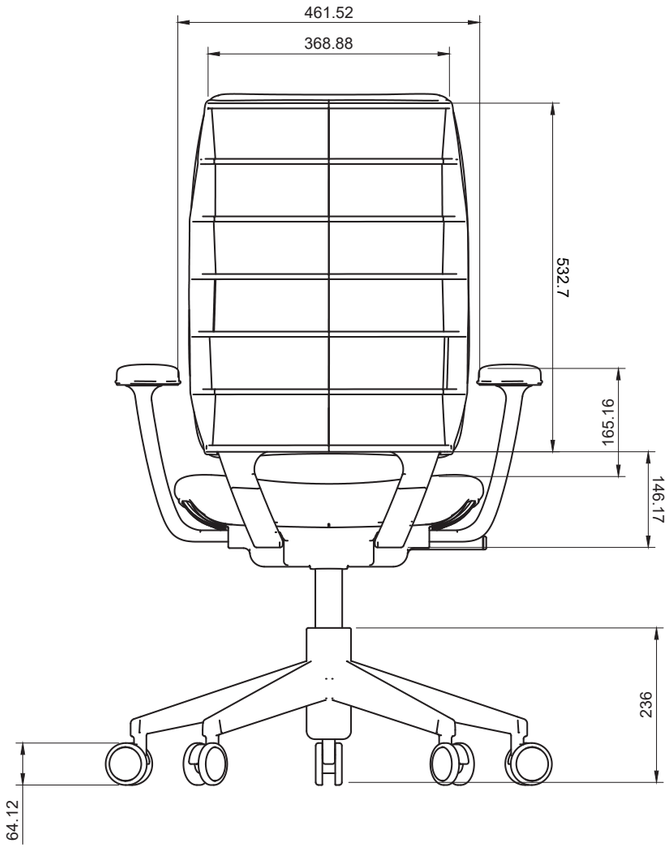
FINAL RESULT

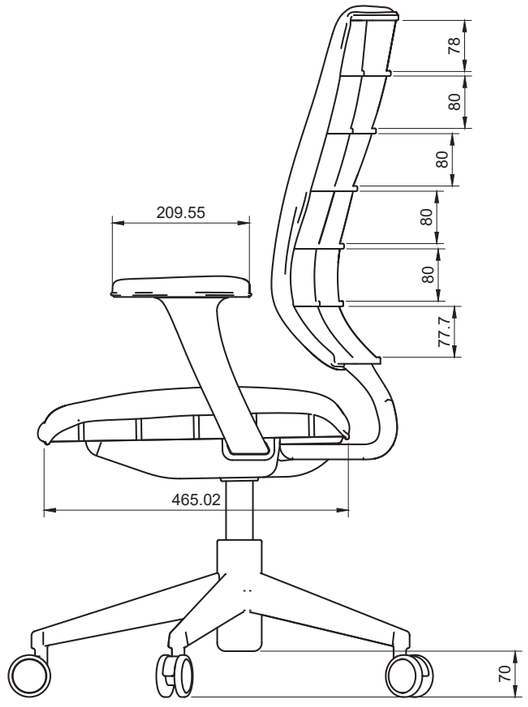
The Prototype

This is the finished prototype of TUNDRA. The prototype has working Phase Change Material packages inside (ClimSel28) and functional wheels and swivel.

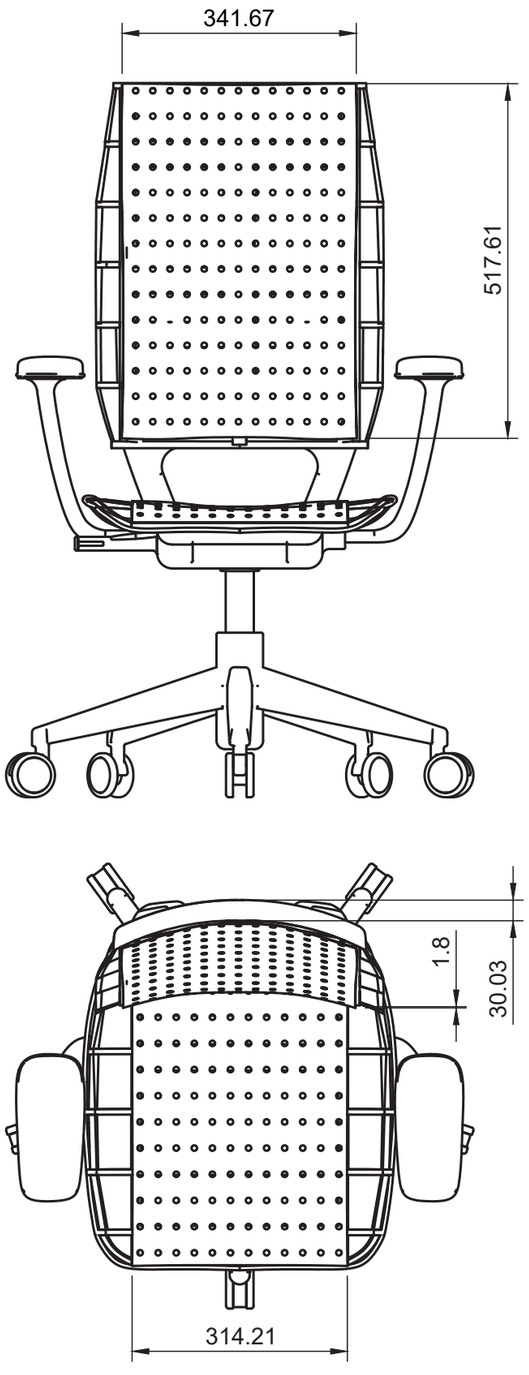
FINAL RESULT

Technical Drawings

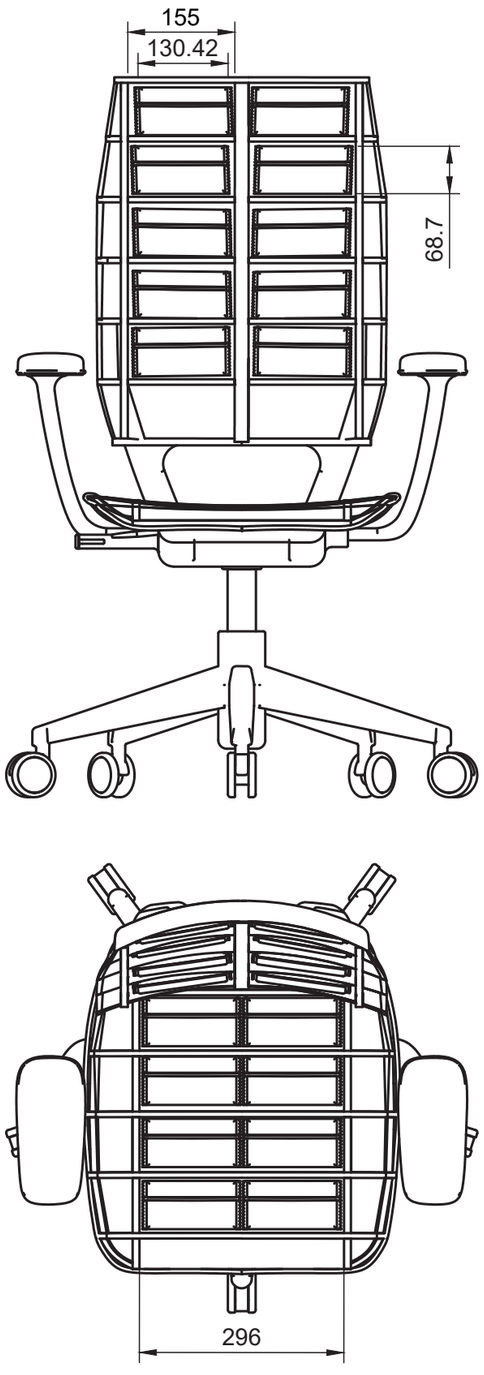




Without fabric & foam



Without fabric, foam & aluminium



Reflection

I am very pleased with my project, the finished result as well as the project process. I achieved my goals that I set up for my project, such as to explore how to integrate phase change material into a furniture piece and also to create a full scaled prototype.

In the beginning of the project I had some ideas of what furniture piece to make, however it was good that I instead decided to let the research and process lead me to the chosen area. To research different areas of furniture and uses made it more clear of where the integration of PCM was most needed and effective. Through the ideation process I discovered a lot of restraints due to the Phase Change Material, what materials to choose, how to make the structure work with the chair shape etc. Researching and exploring changed my path of the design process widely throughout the process, the largest change probably being the change from warming to cooling PCM. It was not as I first intended, but to gain this knowledge early helped a lot. This shows how important it is to contact expertise throughout the process. I believe that the changes throughout the project refined the whole concept and finished product.

The timeline I made in the beginning proved to be a little too optimistic for this project. I believe this is because it is easy to underestimate the time that each part of the projects take. Also, it does not include the changes that I had to make, for example sketching and altering the form, layers and details to 3D prototyping, prototyping and back and forth again. Researching Phase Change Material, how to integrate it, ergonomics and office chairs also took more time than expected. The prototype building also took A LOT more time than expected, this due to a complex shape with numerous materials and components. Due to every part being connected, it was also difficult to finish one part without the other. It felt like a messy process with a lot more work than I expected. I believe that making clear goals throughout the process, quickly adapting to the changes and “putting one foot in front of the other” kept the project going forward.

Further Application & Development

This project had its main focus on exploring how to integrate Phase Change Material into furniture. I believe that this could be a helping solution to an energy efficient future. I think that it could be explored further, for example I think that further testing would move this project forward. Testing different materials and different integration structures would give a more exact result of the effectiveness of the thermal exchange. Applying this material in other areas I explored somewhat like public transportation would be really interesting.

I think that the shape and functions of the office chair could be revisited. The shape and details could be pushed even further to really communicate the layers of the chair. Make it look even more different than other office chairs to really show the cooling function. I think that the overall shape could have an even colder and aggressive look. The functions of the office chair could also be more defined, adding a working mechanism and testing the ergonomics further.

Conclusion

I learned a lot when working on this project. It has taught me knowledge about PCM, thermal exchange and the use of electricity. It also gave me more experience with Fusion 360, woodworking, metalworking, sewing fabrics and much, much more. I´ve also had to have a lot of patience during the project with parts breaking or not working out as I hoped. I found that it was important to keep moving forward, even if it is one step forward or two steps back, really helped me reach the end result.

REFERENCES

REFERENCES

IMAGES

News titles:

https://www.bbc.com/news/world-europe-63173533

https://www.theguardian.com/environment/2021/jul/25/air-conditioning-climate-crisis-global-heating (11/4/2023)

https://www.cnbc.com/2022/10/08/heat-wave-crisis-in-europe-grows-as-locals-lack-air-conditioners.html (11/4/2023)

https://www.theguardian.com/world/2022/apr/20/operation-thermostat-italy-limits-air-conditioning-amid-energy-crisis-fears (11/4/2023)

https://www.reuters.com/markets/commodities/energy-crisis-fuels-coal-comeback-germany-2022-12-16/ (26/1/2023)

https://apnews.com/article/politics-europe-russia-government-business-5ad9451c167845e384bbab0723f1dfae (11/4/2023)

https://www.cost.eu/80-million-european-households-struggle-to-stay-warm-rising-energy-costs-will-make-the-problem-worse/ (26/1/2023)

https://www.theguardian.com/business/2022/dec/15/one-in-four-uk-adults-struggle-to-keep-warm-in-their-living-rooms (26/1/2023)

https://www.euronews.com/2022/12/12/eu-must-cut-back-energy-use-now-to-avoid-shortages-in-2023-iea (26/1/2023)

https://www.ecowatch.com/spain-air-conditioning-energy-crisis.html (11/4/2023)

https://www.bigissue.com/news/social-justice/plant-pot-candle-heater-tiktok-safe-do-they-work/ (26/1/2023)

https://assets.bwbx.io/images/users/iqjWHBFdfxIU/iY.uhhB_Zx7w/v1/1200x-1.jpg (29/03/2023

https://m.media-amazon.com/images/I/81CN6OGnvrL._AC_UF894,1000_QL80_.jpg (22/4/2023)

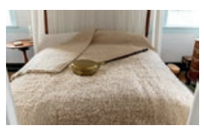
https://media-www.canadiantire.ca/product/playing/camping/camping-living/0763638/mr-heater-18-000-btu-big-buddy-portable-heater-c2ac12de-5892-434c-932b-03504a86893f.png (22/4/2023)

https://www.englander-stoves.com/static/a81be648b60188453155ee1db35cb4bf/f3dad/ESW0023_25-CB120_Right.png (22/4/2023)

https://cdn-tp1.mozu.com/17063-m1/cms/files/39d64b97-66fe-46a5-8e63-1480f09921fe (22/4/2023)

https://m.media-amazon.com/images/I/610ortcRJWL.jpg (22/4/2023)

https://img.fruugo.com/product/5/47/600870475_max.jpg (22/4/2023)



https://mtv-main-assets.mountvernon.org/files/callout/text-image-block-full/image/washington_chamber_winter_2019-3.jpg (16/3/2023)

https://www.accuweather.com/en/weather-news/5-ways-people-stayed-cool-before-air-conditioning-was-invented/367576 (16/3/2023)

https://www.ikea.com/se/sv/p/langfjaell-konferens-stol-med-armstoed-gunnared-beige-vit-s09252791/ (23/04/2023)

REFERENCES

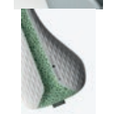

https://www.healthyback.com/media/catalog/product/cache/c5ac09672db702071a5f8b8e40502b7c/e/l/elemax-cooling-product.png (10/04/2023)


https://cdn.shopify.com/s/files/1/0271/3917/8585/products/TP200-1806_800x.jpg?v=1588609734 (10/04/2023)

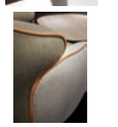

https://m.media-amazon.com/images/I/41v2VF-aJ7L._AC_UF894,1000_QL80_.jpg (10/04/2023)


https://pl.thermaltake.com/x-comfort-air-black.html (10/04/2023)


https://www.pinterest.se/pin/762375043189646911/ (19/04/2023)


https://www.pinterest.se/pin/28710516365949988/ (19/04/2023)


https://artemest.com/en-us/products/teti-desk-by-giovanna-azzarello (19/04/2023)


https://www.behance.net/gallery/80465751/LETS-USE-IT (19/04/2023)


https://www.pinterest.se/pin/337347828349518401/ (19/04/2023)

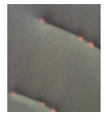

https://www.pinterest.se/pin/337347828349518383/ (19/04/2023)


https://www.pinterest.se/pin/337347828349564891/ (19/04/2023)


https://www.pinterest.se/pin/337347828349838771/ (19/04/2023)


https://www.pinterest.se/pin/337347828349518417/ (19/04/2023)


https://www.pinterest.se/pin/ATUvZ_Lh0hnUUNpgCt3lWbx-FJ9emxcfnX6dQLHuYhA8e8_uyWawJt34/ (19/04/2023)


https://www.pinterest.se/pin/337347828349606509/ (19/04/2023)


https://www.pinterest.se/pin/707205947759855777/ (19/04/2023)

https://www.friluftstyger.se/sv/material/tyger/meshtyg/meshtyg-3d-3mm-tjockt.html

LINKS

Gao, C., Kuklane, K. and Holmér, I. (2008) The heating effect of phase change material (PCM) vests on a thermal manikin in a subzero environment. Available at: https://lup.lub.lu.se/search/files/5425932/1480602.pdf (Accessed: 22/01/2023).

PCM – FASFÖRÄNDRANDE material (no date) Temperaturkontroll. Available at: https://www.climator.com/sv/temperaturkontroll (Accessed: 21/02/2023).

Burrows , L. (2022) In a hotter world, air conditioning isn't a luxury, it's a lifesaver, Harvard School of Engineering. Available at: https://seas.harvard.edu/news/2022/07/hotter-world-air-conditioning-isnt-luxury-its-lifesaver (Accessed: 11/04/2023).

IEA (2018) The future of cooling , IEA. Available at: https://www.iea.org/reports/the-future-of-cooling (Accessed: 11/04/2023).

De Decker, K. (no date) Heating People, not Places, Low Tech Magazine. Available at: https://www.lowtechmagazine.com/2015/02/heating-people-not-spaces.htm (Accessed: 11/04/2023).

REFERENCES

Phase change material (2022) ScienceDirect . Available at: https://www.sciencedirect.com/topics/engineering/phase-change-material (Accessed: 22/01/2023).

What is a phase change material? (no date) Concept Group LLC. Available at: https://conceptgroupllc.com/glossary/what-is-a-phase-change-material/ (Accessed: 28/02/2023).

Phase Change Material (PCM) Selection (no date) Advance Cooling Technologies. Available at: https://www.1-act.com/products/pcm-heat-sinks/pcmselection/ (Accessed: 23/03/2023).

Rousselet, M. (2019) Info: Why are paraffin wax candles so bad for us?, ARTISANE. Available at: https://artisane-nyc.com/blogs/news/why-are-paraffin-wax-candles-so-bad-for-us (Accessed: 20/03/2023).

Contacts

Email: **anna.persson01@hotmail.com**

Instagram: **arsp.design**

Linkedin: **annastefansdottirpersson**