Aalto-yliopisto
Taiteiden ja suunnittelun
korkeakoulu

Aalto-yliopisto, PL 11000, 00076 AALTO
www.aalto.fi

Taiteen maisterin opinnäytteen tiivistelmä

Tekijä Kaisa Takala

Työn nimi Supermaterials. Inspiring sustainable materials for the concept elevator car of the 2020.

Laitos Muotoilun laitos

Koulutusohjelma Tilasuunnittelu

Vuosi 2013 **Sivumäärä** 161 **Kieli** englanti

Abstract

This thesis is a research of sustainable materials that could be used in elevator car design in near future. Thesis objective is to provide visionary concept, which functions as an inspiring tool for KONE.

The theory part of the thesis is divided into three parts. First part presents forecasts of current megatrends and visions made by different organizations how to create sustainable world. In the second part of the thesis is mapped how construction and building industries and cities are already working on sustainable development. Third part of the thesis concentrates on materials, how they are classified and strategies to choose sustainable materials.

Based on the findings in these three parts, is formed a sustainable future scenario from elevator car perspective. How does future look like in aspects of power & decision-making, cities, buildings, ownership and most importantly how are natural resources used? The scenario sets requirements for near future elevator car concept – how it should be to become a forerunner of its time in 2020?

Material research is focusing on finding suitable materials that have potential to be used in the future concept elevator car. Materials were searched from literature, online material libraries, websites and blogs. Material samples were collected to a sustainable materials library. Findings were evaluated based on a strategy from Ashby's (2009) book on Materials and the Environment.

Most potential materials found can be divided into two groups: those that are applicable right away and those that need development. Since this thesis is about a future concept, two of the most promising of the latter group were chosen for closer collaboration and material testing. In the end, wall paneling reflecting the ambience of the future elevator car was designed.

Deliverables of the project were materials sample library, material samples from collaboration, a scale model presenting the ambience and a written document. Material samples were developed in collaboration between KONE and Zelfo Technology GmbH. Some small tests were also made with Ecovative Design.

Avainsanat biobased materials, environmental schemes, ecocities, sustainable cities, future scenario, sustainable development, sustainable materials, megatrend, natural resources

SUPERMATERIALS

Inspiring sustainable materials for the concept elevator car of the 2020

Kaisa Takala
Aalto University School of Arts, Design and Architecture
Department of Design, Master's Degree programme in Spatial Design
2013

"As an architect you **design for** the present,
with an awareness of the past,
for a **future** which is essentially unknown."

-Norman Foster-

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Picture 1. Elevator shafts in the office building in Tokyo.

Thank you

For my family, especially Vesa and Lilia, for understanding and supporting me in this project.

Paula Bello and Anne Stenros for suggesting the thesis. You are inspiring and amazing.
And thank you for the magnificent KONE people helping me during the research:
Hanna Uusitalo, Elina Laitinen, Timo Manner, Shang Yan.
Timo Ripatti for listening and being a great tutor. Katrin Koit for nice chats.
Hye Jin Ahn for helping me with 3D modelling. I owe you one!

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1. Introduction

What kind materials are used to make an elevator car in a world where natural resources, energy and water are a scarcity? How is everyday life changing? What kind of lifestyle people have? How are buildings becoming smarter? These are some of the questions this thesis is asking and answering.

Over a quarter of elevator environmental impacts come from material production. With share of 26,2%, materials are the second largest environmental impact right after use phase, 56,2%. (KONE Sustainability report 2011, 22). Over 90% of materials used in elevators are different metals, mainly steel and cast iron (KONE Sustainability report 2010, 35). While metals recycling rate and durability are good, they are energy and water intensive materials.

About 70% of all new products are based on new materials. Today materials have a key role in innovation in both society and business. Growth is strong in novel and innovative materials. (Peters 2010, 4).

Future companies must be able make their products from a fraction of natural resources as compared today. For this reason the research is emphasizing biobased materials, which are sourced preferably from waste materials like agricultural byproducts. This study has focused on finding materials that are not only just sustainable, but also lighter in weight. Lighter materials can indirectly decrease environmental impacts through lower energy consumption in use. The objective of the thesis is to provide selection of revolutionary materials to inspire KONE on their way to zero footprint elevator.

Theory section of the thesis is divided into three parts. First part is a general introduction to megatrends that are key drivers of sustainable development. In addition it is presented two future scenarious how lifestyles should change so that people are able to live well in 2050. Second part is concentrating on mapping the sustainability movement in built environment. Topics include e.g., organisations promoting sustainable development in buildings and cities, the most common building certification schemes and their requirements for materials. Third part goes through consumption of natural resources in general. It suggests how materials should be categorized differently in sustainable world and introduces strategies to choose sustainable materials. Examples of sustainable concepts from automotive industry are introduced in this part. Automotive industry was chosen for benchmark, because cars share similar strict requirements as elevators like lightness and durability.

Information gathered in theory part is then applied to LessElevator concept. First, chapter five demonstrates the current environmental profile of the elevator from material perspective. Chapter six leads the reader to future scenario and to LessElevator concept that is based on the scenario. Chapter seven reveals the results of the material screening that support the LessElevator concept. Two most interesting materials were chosen for further testing. Chapter eight reviews the design process and presents the ambience of the LessElevator concept car. Chapter nine wraps up the

1.1 Thesis scope

The scope of the thesis is to make a research of sustainable materials suitable for elevator car interiors. Material research is primarily focusing on biobased and waste based materials, which is a fast developing business.

In this research walls, roof, floor and accessory materials are included as elevator car materials. All other elevator materials are excluded from the research. These are for example equipment in the shaft and "the buttons", Control Operator Panel (COP). Assumption is that materials should suit for low residential or office buildings elevators. Material research was done from global perspective. Global perspective is important, because sustainability, environmental issues and things affecting them are global. They can not be examined without a broader view. Because biobased and waste based material business is still small, it could be misleading to limit the screening process to a certain geographical area.

The thesis focused on finding sustainable future materials. This means that these materials are not necessarily in the market yet and they can be still in the development phase or they are just entering the market. It also means that they might not meet strict elevator standard criteria today, but might very well do so in near future. Elevator standards vary by area and it would have been impossible to include them all here. That is why the thesis leanes on European standard.

The most important part of the thesis is material screening. Besides material research, the thesis is concentrating on future visions. A few of the future scenarios are introduced closely from the elevator perspective. From the ambience perspective, the concept elevator car is reflecting what is possible in near future, but designing ambience is secondary compared to material screening. Main emphasis is to create the big picture and where elevator car design should strive to. The thesis is taking for granted the elements of sustainable design and it will not go through e.g., environmental product labels. It is rather concentrated on what requirements does building certification system set for materials.

Comparison to find out how much more environmentally friendly biobased materials are compared to current materials were excluded. Reasons for this are that there are not enought information to make comparison realiable. Comparisons are often complex and ardeous and simplified comparison would not produce useful information.

This thesis aim to create a visionary concept of future to work as an inspiring tool for KONE. Ambitious goal was to find one to two materials that could be used to for entire car.

Picture 2. Going through material samples in Hyvinkää.

1.2 KONE

KONE is a Finnish company manufacturing elevators, escalators and automatic doors. KONE objective is to provide its customers the best People Flow™ experience. The People Flow™ experience stands for services and solutions that allow "people to move smoothly, safely, comfortably, and without waiting in buildings within a rapidly urbanizing environment". (KONE Corporate Responsibility Report 2011, 2)

Kone was established in 1910 and today it is one of the leading companies in its field. The company employs about 40 000 people around world and operates in Europe, Asia-Pacific and North and Middle America. It has over 1000 offices around the world and products are sold to over 60 countries. KONE is listed in NASDAQ OMX Helsinki Ltd. In 2012 the annual net sales were EUR 6.3 billion. (KONE 2013a). In general, it is considered as one of the most admired companies in Finland.

Key drivers of KONE business are rapid urbanization, ageing population, safety and environmental issues. Innovativeness is one of company's success factors. In 2011 and in 2012 U.S. based business magazine Forbes listed KONE as one of the most innovative companies in world. It was only company in top 50 in its field (Forbes 2013).

Kone key customers are builders, building owners, facility managers, and developers. Other key parties in decision-making are architects, authorities and consultants. The main market segments are residential buildings, hotels, office and retail buildings, infrastructure, medical buildings and special buildings, for example ships and industrial properties. (KONE 2013a).

Picture 3. The Lantern at Shanghai World Expo in 2010.

1.3 Elevators

Elevators, what are they? Is it a product, service or space? What part of the building does it belong to? Is it a combiner of public and private spaces of the building? Is it part of building service technologies? Is it a transportation system? Is it part of building's architecture? The final detail waiting to be revealed for the world and passengers saying "wow"? Or is it just a stainless steel box to moving people efficiently up and down?

Elevator is a very confusing space. It is the only moving space in a building. It is likely one of the most used spaces in the building. It is an emotional space. There are not many spaces in building that have such psychological ambience. Looking at the square meter, elevators are the tiniest bits in building but among of the most expensive ones. Still quite often elevator interiors are neglected. In most of them, it seems, their interiors are not considered as much as they could have been.

Picture 4. Stairs of KONE test tower, Kunshan China.

Everyone has personal relationship with the elevator. Some people get claustrophobic. Some people are scared of them. That's maybe because how movies have shown elevators falling or maybe having a bad experience of being stuck. In real life elevators are safest vehicles on earth. It is more likely to be hit by a lightning than die in elevator. Statistically the elevator is safer than walking the stairs (Lampugnani et al., 57). Opposite for being scared are those passengers who are enthusiastic about elevators. There are fan clubs and societies spotting elevators. Then there are the functional users who might not have great emotions towards elevators, but they just want them to run efficiently and smoothly. And when this does not happen all users get frustrated. During my thesis I noticed that some people like to take photos of their fashionable outfits in elevators. Elevator is probably a perfect compact, anonymous space without distraction in background. It emphases only the trendy outfit, but don't reveal your home or neighbourhood. Or maybe the elevator just had great mirror.

Picture 5. View from KONE test tower, Kunshan China.

Elevator is also special in sense how people behave in them. The etiquette seems to be quite universal: do not talk or if you do, speak quietly, look towards the doors, do not go too close to you travelling companions, any kind of negative physical features like bad smell is not appreciated, let people out first before rushing in, do not cover the buttons and hold the doors open... Naturally it varies between cultures what kind of density is understood as annoying. In Finland people might not share an elevator with their neighbours just because it is uncomfortable to travel and try to come up with conversation. But sometimes elevator is a place to have small talk. In business life is known common term "elevator pitch", a short description of something like a project or business that describes easily what you are doing in few seconds. In movies and TV-shows elevators often are scenes for long discussion or action.

Picture 6. Art of not touching anyone.

In low built Finland it is rarely though how elevators have revolutionized buildings. Without elevators urban landscape would look completely different. Elevators allowed high-rises to be built. Meaning of the elevator is different in high-rise and low-rise. In high-rises elevators' features like speed and fast response are much more important. Imagine for example the situation where most of the people are leaving to work and returning home approximately same time. Waiting time might be a lot different than in 5 story residential building where you can always take stairs.

Picture 7. Enthusiast at work.

Picture 8. Elevator as information channel.

It must go without saying that people with disabilities are more dependent on elevators than others. Elevator allows people to live in their homes in such special situations. It is also a necessity for families. It is not my favourite sports to carry down a huge stroller with baby in it from the fourth floor. But then I think my friend who lived in 26th floor in Shanghai and the day all six elevators in their building were out of order. The family left out trusting that in the afternoon they would surely work. They didn't. Carrying strollers back to 26th floor sealed the decision to move to an apartment in 5th floor.

I was not very much fond of elevators before. I got stuck in one when I was a child. It explains my emotions towards the box. I do not like sliding doors that always seem to close too fast either. I get frustrated when people do not follow the etiquette, like letting people out first. But during projects for KONE I have witnessed a change in me. I am becoming an enthusiast who takes pictures of cool elevators and always checks the brand.

1.4 History of elevators

Elevators have been around for centuries. Even Louis XV had one "Chaises Volantes" (The flying chair) built in 1743 in Versailles. Earlier elevators did not really have an interior. They were more like moving platforms. (Goetz 2003, 61). There are three innovations that transformed previous elevators into modern passenger elevators: an automatic safety brake, electric drive and friction as drive. The safety brake prevented elevator to fall down. Elisha Otis introduced it in 1853 in New York World Fair. The safety break was sensational, because it changed elevators from lifting freight to passenger elevators.

Two Germans Werner von Siemens and Johann Georg Halske invented the electric drive in 1880. It made elevators cheaper. Friedrich Koepe invented friction as drive in mining industry in 1877. Friction prevents cables from slipping and elevator became safer. (Lampugnani et al. 1994, 57-61)

Earliest public elevators did not have great interiors. Most of them took people up to places like observation towers so their main mission was to open passengers a new perspective and view to world through windows in them. When elevators became common and popular in new buildings (early 20th century) they were becoming more like pieces of jewellery. They were fitted into building architecture. Naturally the purpose and "wealth" of the building was a factor. Elevators were usually positioned at the center of the staircase and it ran openly or had ornate metalwork or gilded cage around it. Elevators still had windows to staircase and seats. Their interior was decorated with wallpaper, ornate wooden walls and ceiling and even with chandeliers. Windows became smaller during the time. (Goetz 2004, 61- 65)

Human operator first ran elevator. Automation of the elevator started already in the end of 19th century. At that time push-button elevators could take only one call at the time, which meant that passenger were taken to destination without a stop and waiting times were long. (Goetz 2004, 65- 65-67)

Slowly weight, cost and safety reasons made beautiful wooden elevators to take step aside to let other materials like steel replace it. Elevator interior became fast simple. Windowless apartment building elevators started to remind more of a closed box. Today almost all elevators have mirrors in them. One of the reasons is to make space look larger and give something to do for the passengers. Shiny and reflecting materials help to make elevators look more spacious. It is also proofed that there is less vandalism when elevator has a mirror. Modern elevators even have screens for sharing information. (Goetz 2004, 71). In the 21st century glass is becoming increasingly popular. It opens the view again - like in the "old times". Transparency is also good for waiter as they can see, if the elevator is moving. The faster and more automated elevators have become, more inpatient are their passengers. Transparency increases the feeling of space and also improves feeling of safety. (Goetz 2004, 75)

Elevators looks have stayed same for decades. What is the future ambience of the elevator?

Picture 9. Elevator girls at Stockmann department store, Helsinki.

1.5 Definitions

Bio-based materials are materials where products main substance or substances are derived from living organisms. As biobased material can be classified natural materials like wood and leather. Typically it refers to modern materials, which have been industrially processed. (Sustainability Dictionary 2013a). Bio-based materials contain 20-100% renewable resources (Peters 2011, 32). In most cases bio-based materials are derived from plants, but it includes also materials that are derived from animals. In this thesis as bio-based materials is understood only materials that are plant-based.

Certification scheme, certication system is an environmental program aiming for certification performed by unbiased third party. With a certification organisation can prove that it is operating in specified way, which is approved and valued. There are different type of certification schemes for different purposes. For this thesis are relevant building certification schemes and most common of those are LEED and BREEAM. Building certification schemes recommend and require using renewable, recycled and reused materials. For example many bio-based construction materials contribute to achieve more points in certification process.

Eco-efficiency in simplified form could be described as "more for less". In practice it means creating more value through technology and process changes while reducing resource use and environmental impact throughout the product and/or service's lifecycle (Sustainability Dictionary 2013b). World Business Council for sustainable development defines eco-efficiency as "a management philosophy that encourages business to search for environmental improvements that yield parallel economic benefits" (WBCSD 2013d). In this thesis eco-efficiency is understood as combination of these two defitions that support each other.

Footprints like consumption, ecological, carbon and water footprints are often used to decribe the environmental impacts of consumption in easy-to-understand form. In general footprints usually describe how much something is needed/consumed/produced to produce a service or a product. Ecological footprint means the area used to support a defined population's consumption. Carbon footprint means the demand on biocapacity required to sequester the CO2 emissions. In the climate debate carbon footprint means how many kilogrammes or tonnes CO2 emissions is produced. The consumption footprint includes the area needed to produce the materials consumed and the area needed to absorb the carbon dioxide emissions. (Global Footprint Network 2013).

Green building is a comprehensive process where the entire lifecycle of the building is considered to minimise environmental impacts of the built environment on human health and the natural environment. Different lifecycle phases are siting, design, construction, operation, maintenance, renovation and demolition of the building. Green buildings are energy-, water and resource efficient, healthy and increases peoples productivity, reduces waste, pollution and environmental degradation. Other terms that are often used are e.g., sustainable building, eco-efficient buildings and high-performance building. (EPA 2012)

Sustainable development, sustainability was first introduced and defined by Bruntland Commission (World Commission on Environment and Development) in its report in 1987. The definition is still most used phrase to decribe sustainability. According to the report sustainable development is "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs". (Bärlund 2013).

Sustainable city, ecocity expressions can be used for entire city or just for an area in urban environment e.g., a district or a suburb built around sustainability philosophy. It is hard to find one clear definition for sustaible city. That's why this thesis is trusting on Wikipedia's (2013) defition, which is "a city designed with consideration of environmental impact, inhabited by people dedicated to minimization of required inputs of energy, water and food, and waste output of heat, air pollution - CO2, methane, and water pollution.".

Picture 10. Shopping street in Shanghai.

PART I

Visions of Future

2. Visions of the future

2.1 Worldwide megatrends

Fashionable word megatrend describes a widespread phenomenon, usually recognised worldwide. It forms very slowly and especially in the beginning megatrend can be hard to identify. Megatrends typically have a huge impact on society, government and peoples' lives. They function as a mother ship for smaller trends that lasts shorter time and does not have necessarily large impact on society. As an example, a megatrend could be increasing safety and as trends related to this megatrend could be all kind of equipment improving safety like portable survival packs for natural disasters, safety rooms in houses, wearing reflecting vests in dark streets.

Before megatrend is recognizable, there are usually weak signals indicating of some larger growing phenomenon. If megatrends are hard to identify, weak signals are even harder. Only time will tell if spotted weak signal develop into something bigger.

Many of the current megatrends that have major impact on world's development are related to demographics. It includes population growth, ageing, rapid urbanization and emerging middle class. These demographic changes will also have great impact on environment. KONE mentions first three and safety as its key drivers in its business (KONE Corporate Responsibility Report 2011, 9). Increasing amount of people and urbanization together lead to increasing amount of higher buildings with elevators and escalators. Ageing increases need for accessibility.

Picture 11. Piece of 500m2 scale model of city of Shanghai.

2.1.1 Population growth: How many are we?

No one really knows how many we are on this planet. There is not a way to calculate population of the entire world. But there are several independent estimates on world population growth. Despite the many sources they all predict the same. There are approximately 7 billion people on world. According to United Nations figure was reached in October 2011 (UN News Centre 2011) U.S. Census Bureau estimates that 7 billion was reached on March 12, 2012 (Goodkind 2011).

United Nations has made several forecasts on population growth all the way to year 2300. There is variation between different forecasts. In general, UN predicts world population to grow to 9-10.1 billion by 2050. (World Population to 2300, 3). The most important message is to realise that, if population would grow close to 9 billion by 2050 it would mean 47% increase when compared to year 2000. (World Population to 2300, 4). Population growth is strongest in countries in Africa and Asia. It is estimated that population of Asia will keep on growing until 2050 and in Africa it would not stop before year 2100. Elsewhere in world growth is slowing down earlier and even declining by year 2100. (UN Press release 2011, 3).

Early 1800 it took 123 years to add 1 billion to population. In 1927 it took only 32 year. Today it takes only 12 years. Growth would be more than twice of current population of China.
(UNFPA State of the World Population 2011, 2)

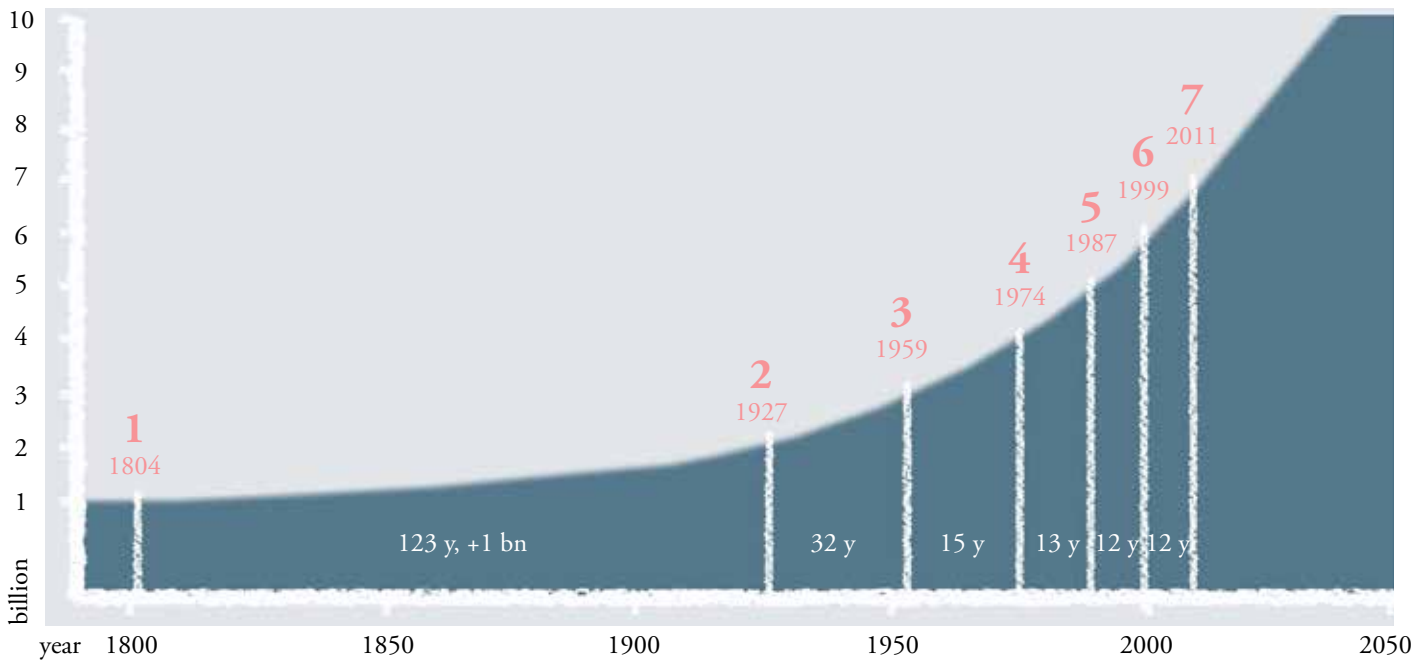


Chart 1. Increase of world population. Adapted from UNFPA state of the world population 2011, 2-3

2.1.2 Ageing: How long will we live?

Globally, growth of proportion of elderly people is faster than population growth. People in age of 60 years or older are classified as old. The world is going through a demographic transition, which means that emphasis of age groups is changing from young to old. (World Population Ageing 2009, xxvi, 5).

Average global life expectancy today is 67,5 years when in 1950s it was 46,5 years. It is estimated that it would rise to 75,5 years by 2050. Naturally there is variation between life expectancies by regions where people live. In more developed regions life expectancy would be 83 years and in less developed regions it would be 74 years. (World Population Ageing 2009, 7-8). Looking the phenomenon in longer time span, global average life expectancy is projected to increase from current 68 years to 81 in 2095-2100 (UN Press release on World Population Prospects 2010, 6-7). Far in the future, in year 2225, life expectancy is amazing 92.8 years (World Population to 2300, 15).

Amount of older people has tripled since 1950s and it will triple again by 2050. In 1950 there were 3 countries with more than 10 million people 60+ years. In 2009 number of countries increased to 12. In 2050 there will be 32 countries and in five of them have over 50 million older people living.
(World Population Ageing 2009, 11)

Fastest growing age group of "the old people" is people over 80 years. Today they present 14% of all people over 60 years and by 2050 their share will be 20%. (World Population Ageing 2009, xxvi-xxvii). Group of 100 years or older is growing even faster. In 2000 there were about 170 000 people 100 years or older, in 2100 there will be 17,6 million. (World Population to 2300, 68).

Millions of people born already will be here for the next turn of century.
(World Population to 2300, 68)

Despite the rapid population growth the fertility is decreasing. It is estimated that in 2045 the proportion of older people in world will exceed the proportion of younger people. However, this transition happened in more developed regions already in 1998. (World Population Ageing 2009, xxviii).

Ageing is one of the megatrends that will affect world most. It will require far-reaching economic and social adjustments in most countries. It will not affect just political and economical systems. It will effect on health care, family composition, living, housing, and migration, provided services, consumption and so on. (World Population Ageing 2009, xxv)

Picture 12. Ageing is happening everywhere.

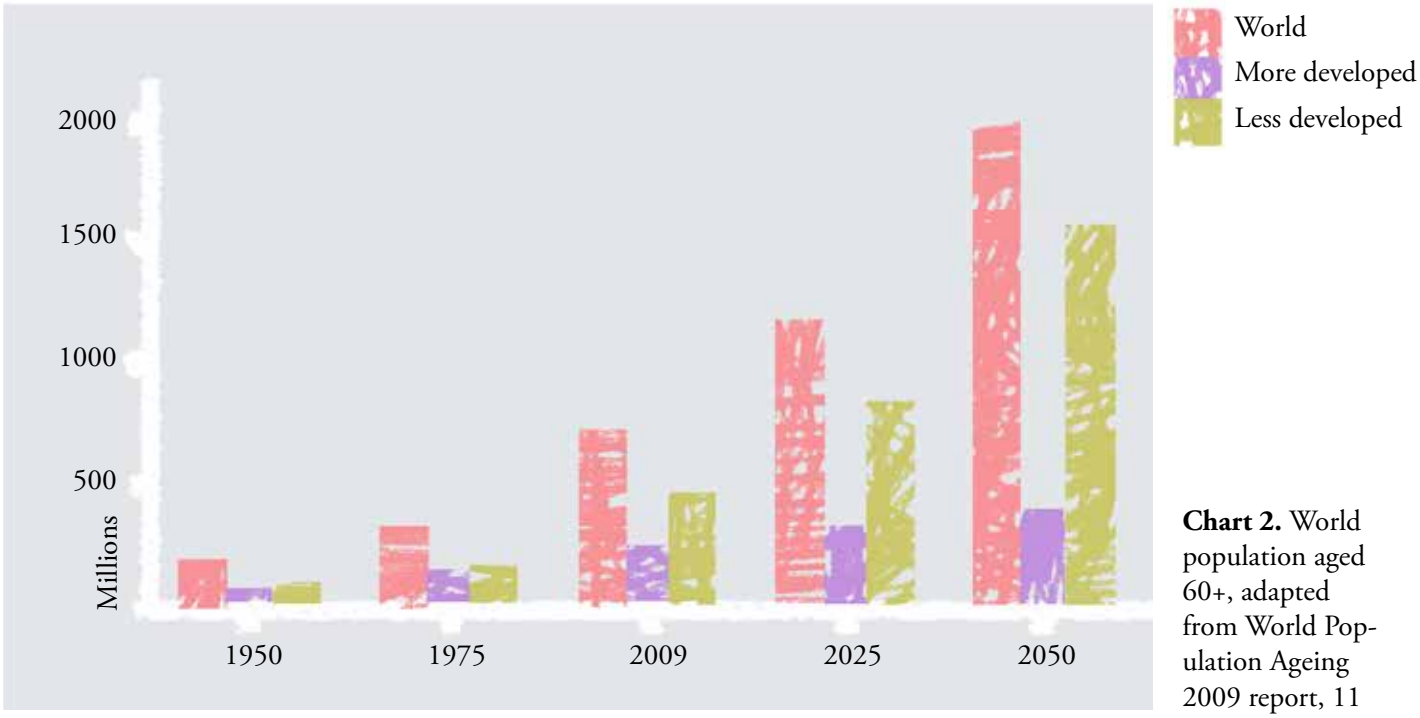


Chart 2. World population aged 60+, adapted from World Population Ageing 2009 report, 11

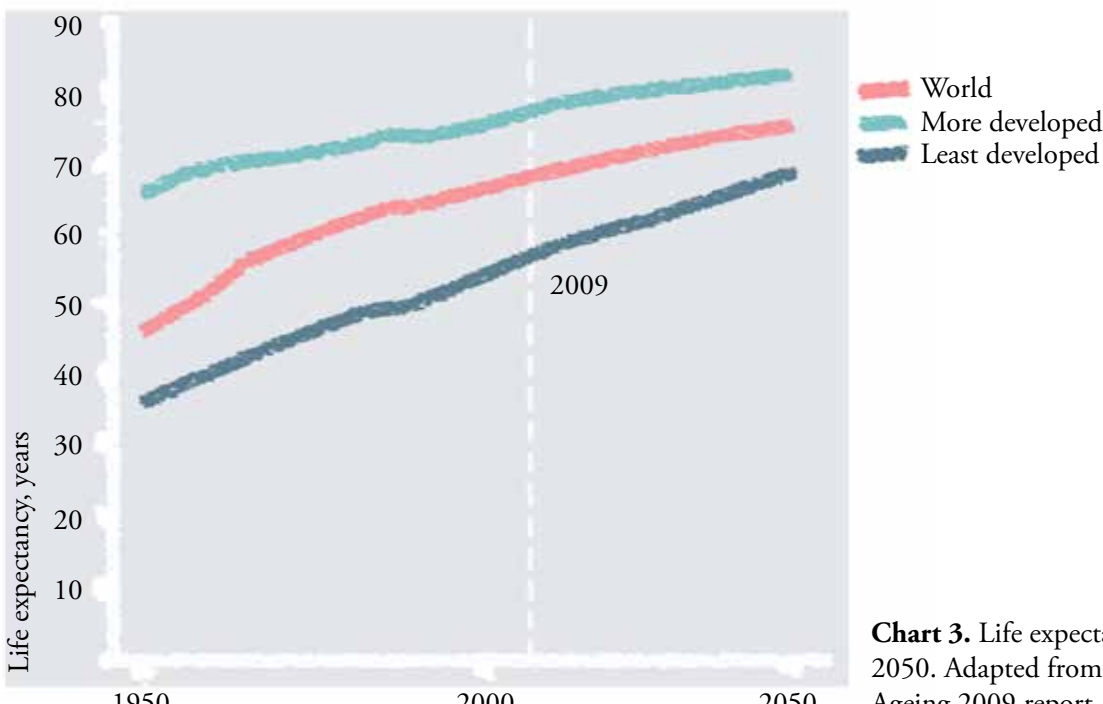


Chart 3. Life expectancy between 1950-2050. Adapted from World Population Ageing 2009 report, 7

2.1.3 Urbanization: Where will we live in 2050?

Rapid population growth is inevitably leading to higher density. If we look at world as whole, there have been living more people in urban areas than in rural areas since 2009. Urbanization is tied to development of the region and in reality it is very country specific, when there will be more urban than rural people. For example in some more developed countries urbanization percentage was 53 already in 1950s. In China the turning point was reached in 2011. (World Urbanisation Prospects 2009, 2).

By 2050 it is expected 84% increase to amount of urban people.
(World Urbanisation Prospects 2009, 4)

In 2050 it is expected that there will be 6.3 billion urban people. Most of the people are not moving to the megacities. They are moving to smaller cities and towns with less than 0,5 million inhabitants. United Nations defines as megacities cities, which have 10 million or more inhabitants. World has got many new megacities during past few decades. Still cities with 1-5 million inhabitats are growing most rapidly. (World Urbanisation Prospects 2009, 4-6)

Density varies between different areas. Asia has highest density and it is estimated to peak in 2065. Europe is the only area where population density is stable. It has stayed almost same since 1950s and will not remarkable grow after 2050. (World Population to 2300, 62-63)

Reasons for urbanization

People are moving to urban areas because of better income and for better living. Approximitely 80% of world's gross domestic product (GDP) is generated in urban areas. (World Urbanisation Prospects 2009, 14). Cities tempt new residents, because they provide better paid jobs, better access to goods, services and facilities. Cities usually offer easier access to health care services and education and seem to offer better quality of life. (The European environment — state and outlook 2010, 24)

Cities are responsible for 70% of worlds CO2 emissions and 75% share of consumption of earth's resources (More with Less 2012, 8). On one hand expanding cities are seen as great potential for reducing environmental impacts. On the other hand, when urbanization is not controlled, it causes major environmental damage. Rapid, uncontrolled, poorly managed urbanization has also negative social impacts. Phenomenon of urban poverty is increasing especially in less and least developed countries. Moving to city after better life does not automatically provide better life. (European environment — state and outlook 2010 2010, 29-30)

World megacities:
1975 - 3 megacities
2009 - 21 megacities
2025 - 29 megacities
(World Urbanisation Prospects 2009, 6)

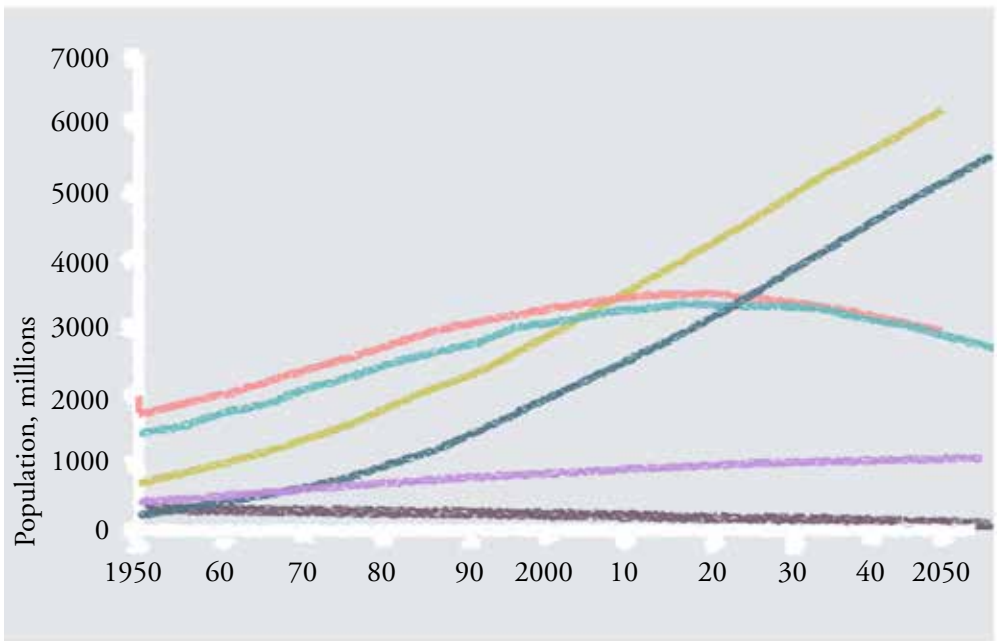


Chart 4. Urban and rural population. Adapted from World Urbanisation Prospects 2009, 2-3

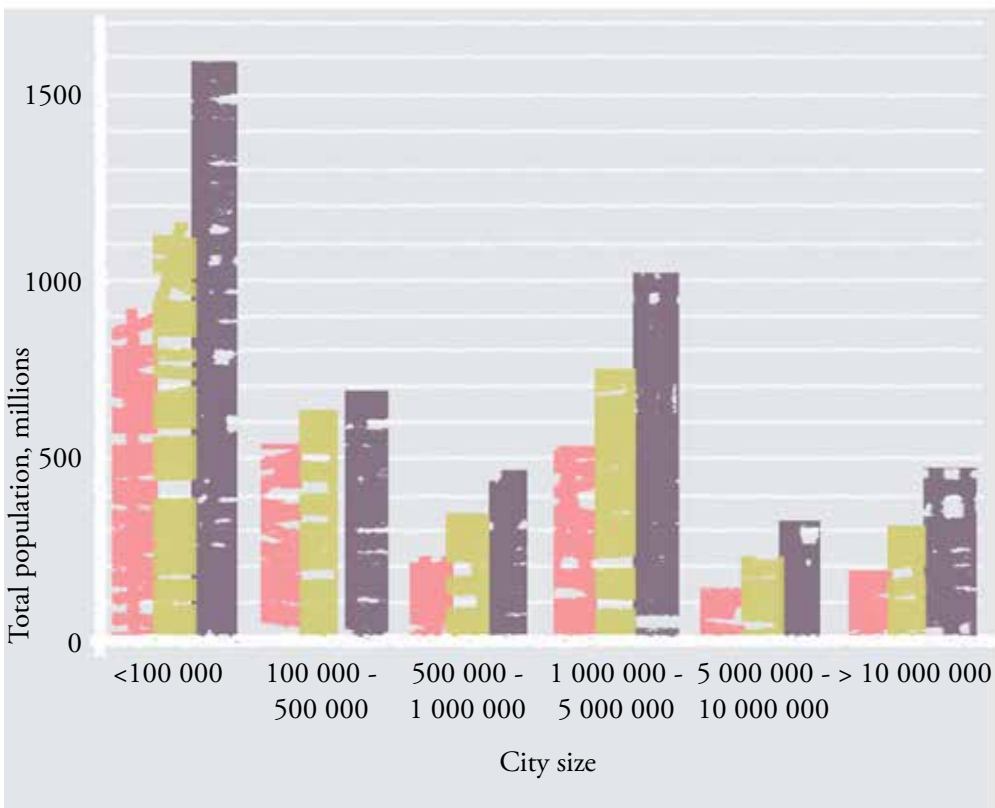


Chart 5. Total population in millions by city sizes. Adapted from World Urbanisation Prospects 2009, 5.

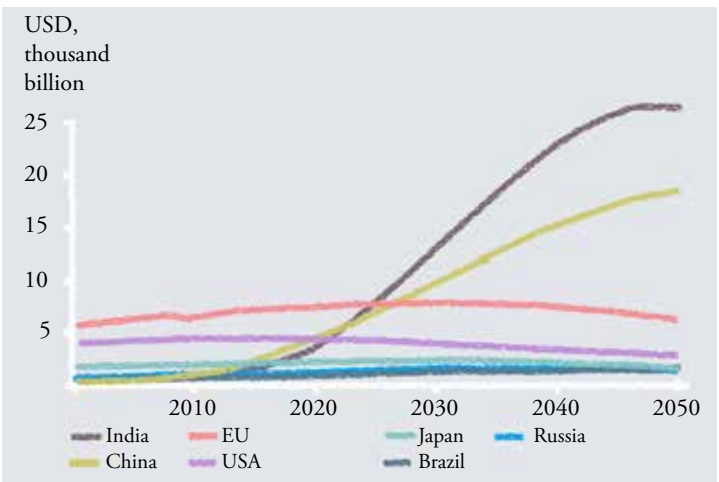
2.1.4 The emerging middle class: How will consumption change?

At the same time while population is growing, ageing and getting urbanized they are also getting wealthier. Size of the middle class consumers is growing. Currently there are 1,8 billion people categorised as middle class in the world. By 2020 their amount is increasing to 3.2 billion and by 2030 there will be 4.8 billion. This means that in less than 20 years time 60% of world population is part of the middle class. Most of this growth is happening in Asia. (Kharas 2010, 27).

It is estimated that BRIC countries (Brazil, Russia, India, and China) middle class consumption will increase from current $6,7 trillion per year to $20 trillion in next decade. It is twice as much as USA consumption. (Court & Narasimhan 2010). At the same time, energy demand is increasing by 40% and water demand is exceeding supply by 40% (World Economic Forum 2012).

Picture 13 (right). Class differencies in Shanghai, China.

Chart 6. Projection of changing consumer spendings of the middle class. Adapted from European environment — state and outlook 2010 report 2010, 27



14


15


16

2.1.5 Safety

Safety is increasing in all areas of life. Think for example solutions developed to improve safety: automotive industry is aiming at 0% accidents, safety certification schemes at workplaces, ID passess at companies, technical solutions to prevent human mistakes, strict safety procedures when flying, personal safety equipment like reflective vests, safety shoes, alarm devices for the old folks. This is just to mention few.

Interest towards material safety have increased along green building and strict regulations like RoHS. Materials should not harm health or environment. Consumers have become more aware of hazardous materials. For example people are interested to buy ecological clothing. Dye in clothes can risk employees' health and cause deathly diseases. Since consumers are paying more attention to food and clothing, it is predictable that these values will breakthrough in construction and interior design materials too. Building industry is already checking Volatile organic compound (VOC) emissions of materials.

Safety is important megatrend for KONE. It is estimated that 80% of elevators in residential buildings in Finland do not meet the safety requirement of modern elevators. Elevator's safety is always compared to standard of the time, when it was installed and there is not regulation to do otherwise. Modernisation of the elevator is usually decision of the condominium or elevator owner. Elevator manufacturer and maintenance company do not have decision making power on it, because the responsibility of the elevator safety is owner's. (Rakennus-lehti, 10.1.2013)

Pictures 14-17. Elevator ambience is important when creating feeling of safety.

17

2.2 What about natural resources?

All megatrends described earlier have led to growing demand for natural resources. It is a well-known fact that developed countries are consuming more than there are natural resources. The consumption of less developed regions is increasing because of population growth and emerging middle class. What will happen to already depleting natural resources in future?

World ecological footprint was last measured in 2007. To cover the current need of natural resources, there should be 1,5 planets. It is estimated that if consumption is continuing at current pace, in 2030 there would be need for 2 planets and by 2050 requirement for 2,5 planets. (WWF Living Planet Report, 8-9; Global Footprint Network 2012a)

Global Footprint Network (GFN) announces annually Earth Overshoot Day. It means the day, when annual global demand of natural resources exceeds amount of natural resources Earth can produce during one year. GNF considers natural resources as an annual budget and when it is consumed people are on "overdraft". It is like people withdraw more money from the natural resources bank account than there is. In 2011 The Earth Overshoot Day was celebrated, if we can say so, on September 27th. In 2012 the day was over a month earlier, on August 22nd. (Global Footprint Network 2012b)

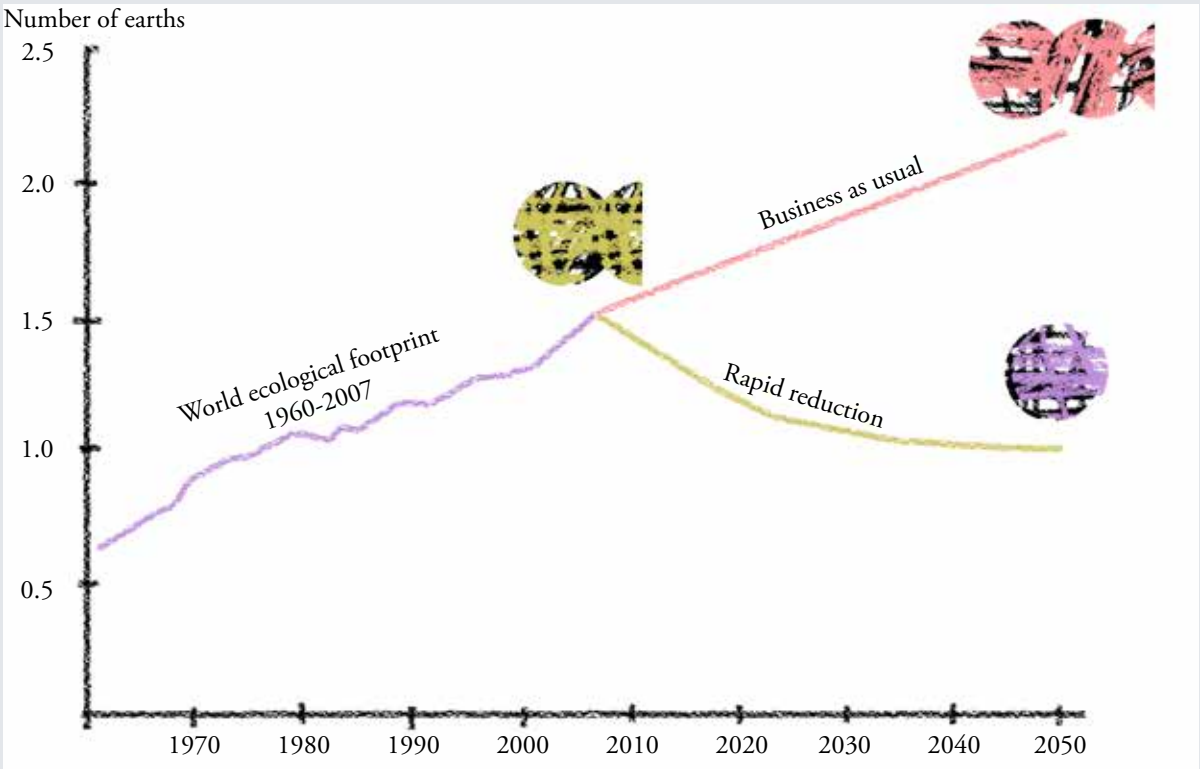
Chart 7. How many earths are needed to provide everything we need. (Global Footprint Network 2012)

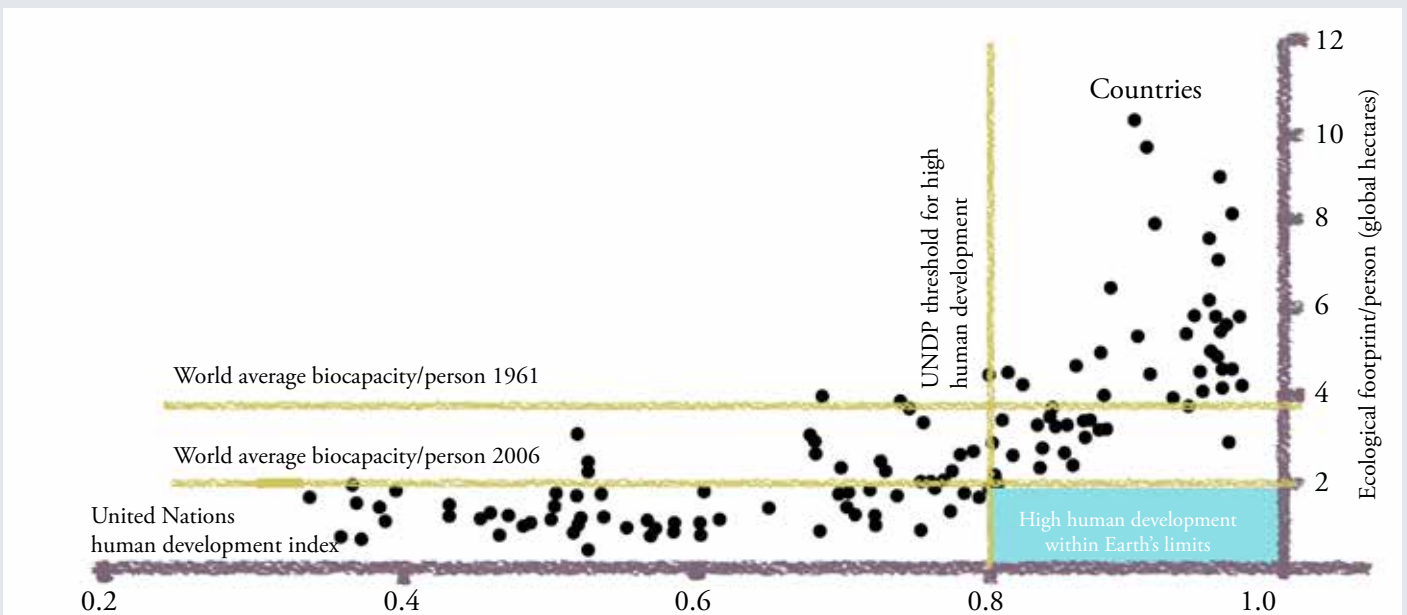
WWF predicts that societies will face several challenges in future. One is how land is allocated for biomaterials, food, fuel, fiber, carbon storage and conservation. Another challenge is that the biocapacity needs to be increased. (WWF Living Planet Report, 86). According to McKinsey and Company nearly 30% of the demand for natural resources in 2030 could be met with improvements in resource productivity. Solutions for these improvements already exists. (Dobbs et al. 2011, 2)

Chart 8. Meeting human demands within the ecological limits of the planet.
Adapted from Vision 2050, 4

Besides these two, people's diet should change to vegetarian. Scientists are already warning that during the next 40 years people are forced to turn into vegetarians due to facing food and water crisis, which are caused by population growth. There is not enough water available for current croplands, if population reaches 9 billion. Today 20% of people receive their protein from animal-based foods. This should drop to 5% by 2050. Vegetarian diet is one solution to avoid food and water shortages. Meat-based diet consumes 5-10 times more water than vegetarian diet. Also 30% of arable land is currently used for growing food for animals. Vidal 2012).

Closer look on natural resources and their use is taken in the part III.


Number of earths
2.5
2.0
1.5
1.0
0.5
Business as usual
World ecological footprint
1960-2007
Rapid reduction
1970
1980
1990
2000
2010
2020
2030
2040
2050


Countries
UNDP threshold for high
human development
World average biocapacity/person 1961
World average biocapacity/person 2006
United Nations
human development index
High human development
within Earth's limits
Ecological footprint/person (global hectares)
12
10
8
6
4
2
0.2
0.4
0.6
0.8
1.0

Picture 18. Ice fishing competition, Säkylä, Finland.

After reading statistics future seems depressing.

Are there possibilities **to create better future?**
How do we find there?

There are many **scenarios**
presenting visions how things must change to be able

to live good life in future.

On following pages is introduced few of them
from those parts that are related to the thesis topic.

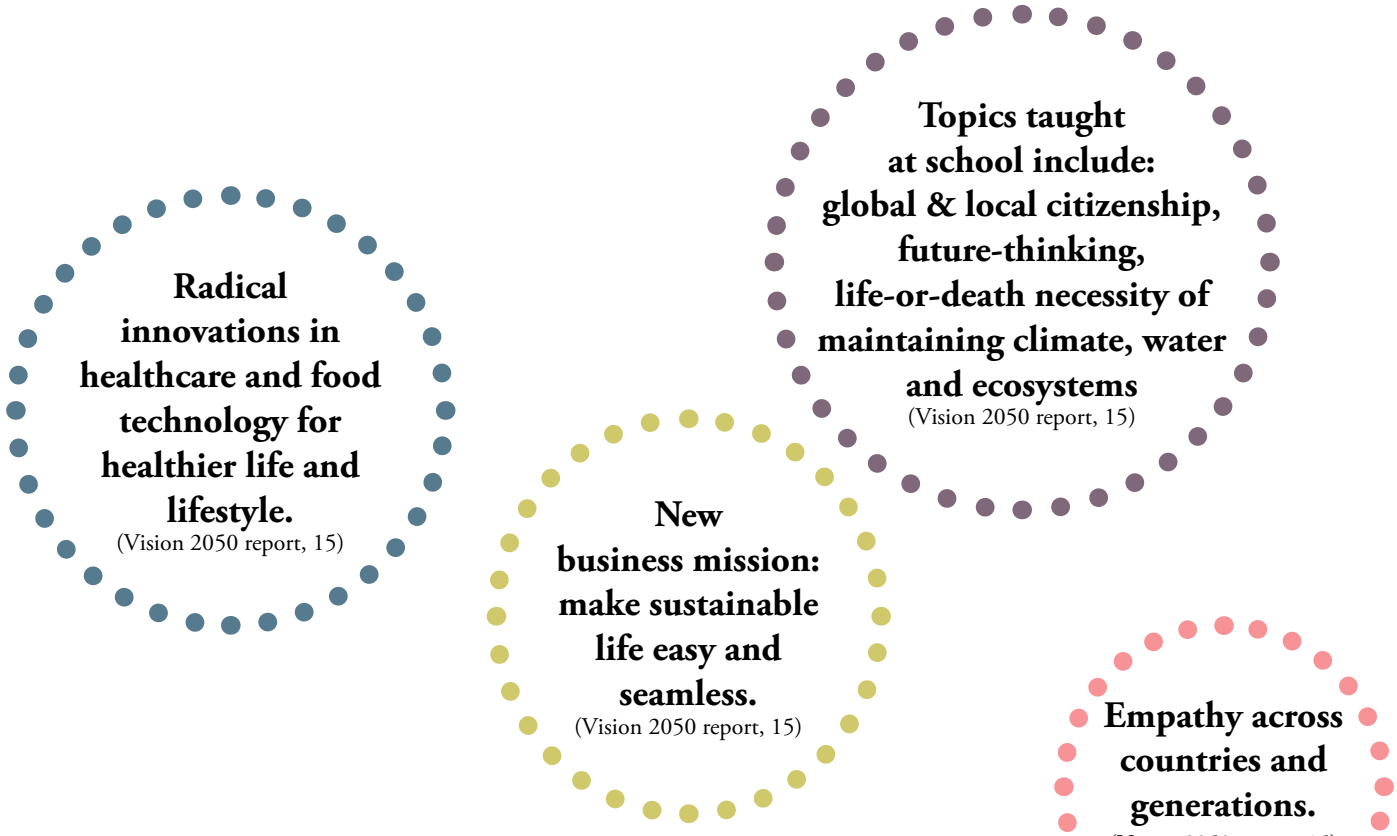
2.3 The WSDBC vision 2050

The World Business Council for Sustainable Development (WBCSD) is an organisation where forward-thinking companies are working together to create sustainable future for business society and the environment. They share best practices on sustainability and create innovative tools to improve it. The WBCSD was founded in 1992 and it has 200 member companies. Companies come from all continents and all business sectors. The WBCSD has a network of 60 national and regional business councils and partner organisations. (WBCSD 2012a)

The Vision 2050 is a report compiled by the WBCSD. To the project participated 29 global leading companies from 14 different industries and hundreds of representatives from business, government and organisations. The report defines how business (and world) should change so that people could live well in the 2050 with the natural resources world have. The Vision 2050 aim to challenge companies to rethink their products and services, and seeing the opportunities of placing sustainability at the center. (WBCSD 2012b)

The vision 2050 report includes a pathway with nine critical areas that need to be met to achieve the vision. These nine areas are values and behaviours, human development economy, agriculture, forests, energy and power, buildings, mobility and materials. (Vision 2050, 10)

The time frame is divided into two time periods (Vision 2050, 10))



People's Values: One World - People and Planet

In the Vision 2050 is presented that "One World - People and Planet" ideal becomes a globally practiced lifestyle. Ideal emphasises interdependence among people and people's dependence on natural resources. Awareness and responsibility of actions to natural resources, other humans and future generations spreads. (Vision 2050, 14). Conflicts and crime and such things still exist but societies are able to cope and overcome them better and quicker. (Vision 2050, 6)

It is mainstream fashion to live well in sustainable way within the limits of natural resources. Sustainability is seamlessly integrated to everything and it is a standard. All products and services are "green" and meet customer needs. Business integrates closed-loop systems and efficiency principles. (Vision 2050, 15)

The risk is that scale of change is so large that all people might not agree with it (Vision 2050, 32). It is hard to change people's values. The Vision 2050 assumes that change is possible through education. It is maybe little idealistic, but on the other hand, who would have thought Wall of Berlin would be torn down and Soviet Union wouldn't exist.

“Corporate buildings are showcases for energy and emissions saving technology.

Corporations document best practices and open their facilities to raise awareness and educate the public.”
(Vision 2050 report, 26)

“By 2030 countries are completing the mandatory energy labeling of all appliances.”
(Vision 2050 report, 27)

“By 2020 mandatory standards for buildings’ thermal integrity and heating systems are set across the OECD”
(Vision 2050 report, 27)

Building standards become global by 2030 and continue to tighten over the following decades”.
(Vision 2050 report, 27)

Campaigns to promote awareness of sustainable energy use in buildings and promoting behavior change.
(Vision 2050 report, 26)

Buildings: Close to zero net buildings

Transmission Time is an era of Smart buildings. In fact, all new buildings are zero net energy and existing buildings are fast retrofitted towards the same goal. For this reason all appliances are energy efficient. It is ordinary that buildings have energy saving operations. New and refurbished buildings are using information and communication technology like sensors to make building energy use optimal. For example typical tools are on-site renewable energy generation, incentives to lower energy consumption and penalties for excessive energy consumption. Energy meters and energy labelling for all appliances are mandatory. (Vision 2050, 26-27)

Along with smart buildings go smart users. Energy issues have become very important for tenants. All these changes mean that whole building industry will change and this change will make possible to create many new jobs. (Vision 2050, 26)

The main risk to achieve this vision is the bad market situation. Environmetal performance of existing buildings and new buildings should be improved around the world. There is great variation in legislation between countries. The incoherent market situation and lack of incentives can lead inadequate results. (Vision 2050, 32)

“Closed-loop recycling, making the concept of waste obsolete, is normal business practice, and societies have a circular approach to resources.”
(Vision 2050 report, 30)

“The eco-efficiency of materials has on average improved by a factor of 10.”
(Vision 2050 report, 30)

“Advanced materials enable resource hyper-efficiency in key sectors, for instance in lightweight transport and renewable energy.”
(Vision 2050 report, 30)

Materials: Not a particle of waste

During the transformation time the material loop becomes closed. Closed loop designs are mainstream for industries and people will accept that they need to limit the annual use of non-renewable materials to 5 tonnes per person. Decrease is going to be remarkable. In US alone the annual consumption of non-renewable materials per person was 85 tonnes in 2009. Waste becomes more valuable and all waste is inventoried so it could be recycled when there is a technique for it or when it is feasible. Already during the Turbulent Teens times waste is made obsolete e.g. through tightening legistlation. (Vision 2050, 30-31)

“Accounting is based on true value of materials.”
(Vision 2050 report, 30)

Presumably it is suggested that products should last longer, use materials efficiently and in general be much more efficient in every way. Landfills should become a source of materials already by 2020, which is quite short time. Urban mining will grow into a larger business. Urban mining is defined as “The process of reclaiming compounds and elements from products, buildings and waste” (Urban Mining 2012). Cost structure of materials is changing and report proposes that accounting should be based on true value of the materials. (Vision 2050, 30)

“Greenhouse gas emissions, energy and water use are no longer constraints on the materials industry.”
(Vision 2050, 30)

According to report material sector is increasingly transferring from commodity-based to service-based portfolio and boundaries between different industries are fading. In general, all business models are changing towards service based business models. During the 2020-2050 different metals will reach mining limits and that is driving industries to find alternative solutions. Material supplier sector is seen as part of biodiversity and they are seen as ecosystem services. (Vision 2050, 30-31)

The main risk of material vision is that recycling can end up being too expensive and difficult (Vision 2050, 33). For example recycling nuclear waste or making nuclear waste obsolete is probably impossible. Running out of natural resources like water can in extreme case lead to global catastrophes and even to wars.

"Holistic mobility management involving all key actors lowers the number of transport deaths to close to zero, and negative environmental impacts are substantially reduced."
(Vision 2050 report, 28)

"CO2 emissions are reduced by some 30-40%"
(Vision 2050 report, 28)

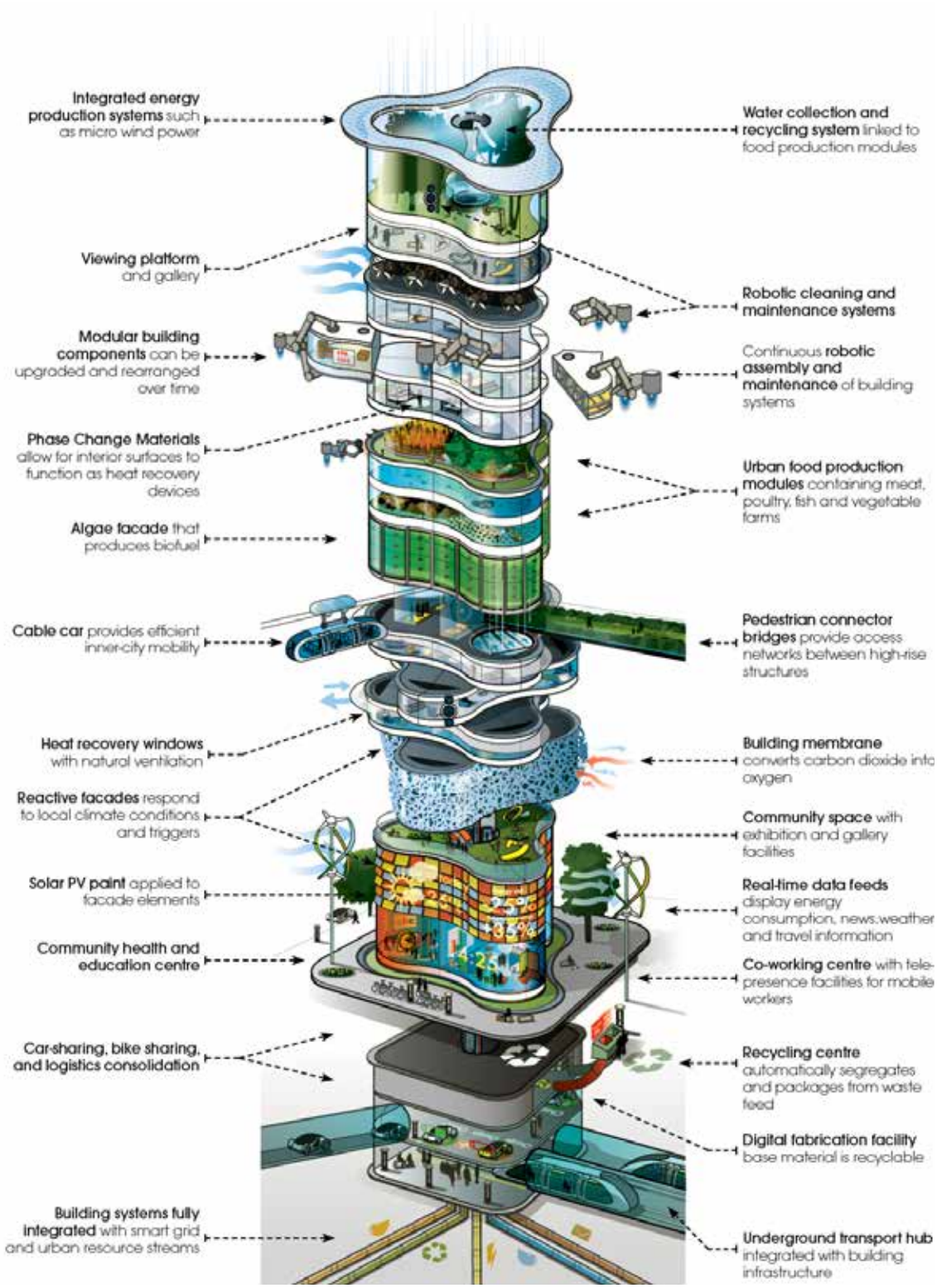
GHG intensity is reduced 50-80% in different modes of tranportation.
(Vision 2050 report, 28)

Mobility: Universal access to safe and low-impact mobility

In future tranportation will base increasingly to effective public transportation network. High-speed electric rail system will be most practical and popular way to travel between cities. Through effective planning public transportation is attractive choice and most likely private vehicles are not as necessary like today. Other forms of transportation are also in use. Car sales is dominated by hybrids, electric and fuel cell vehicles. Fossil fuel consumption will drop during Transformation time and alternative fuels become competitive. Also aviation uses biofuels and in 2030 it increases its biofuel use up to 30%. Information and communication technologies (ICT) are widely applied to transportation. Intelligent transportation system (ITS) is set up to allow people to choose best mode of transportation. ITS enhance the efficiency, speed and reliability of public and private transport. (Vision 2050, 28-29)

Risks and possibilities that could harm the vision
(Vision 2050, 32-33)

- Natural systems act unexpectedly and there is not full understanding of everything. For example, global warming can lead to different consequences than expected.
- Cultural differences, ideological block and running out of crucial natural resources can lead to severe conflicts and wars.
- Disagreement in valuing the environment
- The unexpected risks of new technologies. There is great pressure to quickly find sustainable solutions to replace unsustainable ones. There might not be enough knowledge on how to manage them.
- Extended economic recession or economic depression
- Due to global warming the risk of natural disasters increase.
- Increased population and density itself can cause severe damage and risk the entire development.



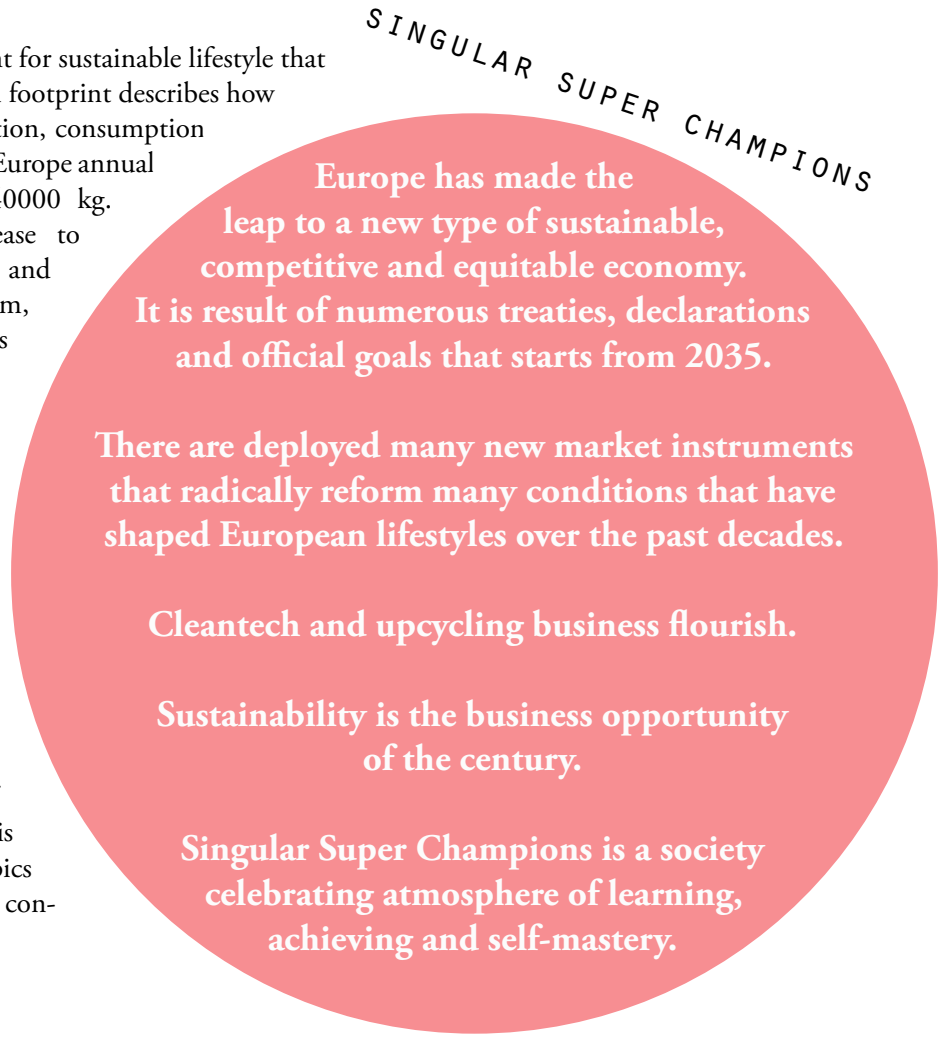
Picture 19. Illustration of Arup's vision of how urban buildings will look and function in 2050 (Hargrave 2013, 3).

2.4 SREAD SUSTAINABLE LIFESTYLE 2050

SPREAD Sustainable Lifestyle 2050 is a two-year European project that started in the beginning of 2011 and ended in December 2012. Project participants include different stakeholders (business, research, policy & civil society) who together developed vision for sustainable lifestyles in 2050 and a roadmap how to get there. Project aims to maintain or improve quality of life while at the same time reducing remarkably consumption to reflect bio-capacity of the planet. (SPREAD sustainable lifestyles 2050, 3).

SPREAD project defined a material footprint for sustainable lifestyle that Europeans should achieve by 2050. Material footprint describes how much resources are engaged during production, consumption to end-of-life as a result of consumption. In Europe annual material footprint per person is 27000-40000 kg. According to SPREAD it should decrease to 8000 kg including household goods, food and beverages, everyday mobility, tourism, electricity, heating and housing. This means huge changes in lifestyle and attitudes. (SPREAD sustainable lifestyles 2050, 8).

SPREAD developed four scenarios of sustainable lifestyles and how new lower material footprint is achieved in these scenarios. These four scenarios are called Singular Super Champions, Governing the Commons, Local Loops, and Empathetic Communities. Each scenario is taking a closer look on changes in education, work, city, health, living, food, mobility, consuming economy, sense of security, leisure time. In this chapter is presented a compact chart of topics relevant to the thesis (city, living, mobility, consuming and economy).



Information in bubbles from EU Sustainable Lifestyles Roadmap and Action Plan 2012, 11

GOVERNING THE COMMONS

Digital reality helps
people to break free from
many cultural constraints and helps
to reach sustainability.

Ubiquitos computing helps with smart
use of resources. At the same time it redirects
people's behaviour and focus of attention to
interaction in the digital realm.

Many familiar institution from 20th centure
are abandoned. People liberate themselves to
live meaningful lives and engage in
new forms of collaboration.

EMPHATHETIC COMMUNITIES

Western world
has faced crisis, but result has been
more fruitful than expected.
In the crisis global economy fails and it
paralysed nation states and the entire political
decision-making structure.

The crisis lead to lifestyle where community and
neighbourhood are important. New forms of governance
and collaboration make cities and towns most
powerful level of decision-making.

Best parts of global culture and technological
innovations are enjoyed. People focus on
communicating and developing
solutions on local level.

LOCAL LOOPS

Radical energy
crisis forces people to
re-evaluate the foundations
of well-being.

Local loop is a technical concept that can
be applied in the context of local and regional
production cycles. Lifestyle and ways of
belonging are built around work. Techbology
is better adapted through local design
solutions. Ethos of craftmanship and
professional communities shape lives
and organize people's work
and leisure time.

Changes between 2012 and 2050

	Singular super champions (17)	Governing the commons (27)
City	10-15 highly urbanized metropolies in Europe. Extremely dense. Lots of new infrastructure. New specialised areas of excellence.	Cities based on already existing infrastructure. Office and school buildings converted into flats and public spaces. Urban experiences are enriched by augmented reality. People find personalized solutions, on both the physical and virtual layers.
Living	Location compensates size of the flat. New materials and design. Price drives density.	People live in small flats & work in new office lofts. The digital layer is key to provide people with quality in their lives. Smart homes, austere furniture and digital services characterize domesticity.
Mobility	New rail systems within and between metropolies. Personalized rapid transport systems. Smart mobility solutions. High prices.	Mobility greatly reduced by the use of digital tools. Commuting minimized. Construction of new traffic infrastructure is unnecessary. Smart public transit and car sharing are the main forms of transport.
Consuming	Meanings and symbols get consumed more than products. Education and self-projected me. Price mechanism.	3D-printing personalises consumption. Material consumption reduced by using modular appliances enabling do-it-yourself (DIY) repair and upgrade of products. High degrees of appliance personalisation, virtual consumption and recyclable generic materials form new design and producer cultures, helping to reduce the overall number of appliances.
Economy	Large multinational firms. Efficiency. Competition. Eco-industrial revolution. Standardized transparent data.	Micro-tasks characterise economic organization. New businesses are created in and by data-rich environments. Open source, open data and free distribution of information drive new innovation. Personal optimisation, DIY, peer services and manufacturing are drivers of the new economy.

	Local loops (37)	Emphatetic communities (47)
City	Cities are multicentred and formed into their own loops. Guilds working and living in the loops lay their own strong characteristics on their loops.	Village infill from sprawl to farm village. Parking lots turned into places of food production. The public space gains great significance. Villages within cities are key elements in the urban fabric.
Living	Living in the loops is characterized by shared spaces, existing infrastructure and co-working spaces. Guild members often live in the same neighbourhood.	Farming opportunities raise property values. People live in shared apartments and make use of shared spaces.
Mobility	Transportation is about walkability and cycling. Existing infrastructure is optimised. Intercity mobility is needed less and services are home-delivered. Local tourism and long vacations are favoured by people.	Local mobility emphasised, less road space devoted for private vehicles. Old and new infrastructure adapted to cycling.
Consuming	Consumption drivers include a mass quest to reduce the overall volume of appliances needed through sharing schemes and replacement services. Products are made with high-quality local materials and design. Availability of foreign goods is limited. All products are repairable.	Consumption geared towards meeting people's basic needs. Sharing, swapping and renting succeed private ownership.
Economy	The economy is based around local user-centric adaptations and efficient local clustering.	The economy organised around the self-sufficiency of small units. Food production prioritised. Experimentation happens on the local level and community activities highly valued.

Table 1. Information adapted from SPREAD sustainable lifestyles 2050, 56-57.

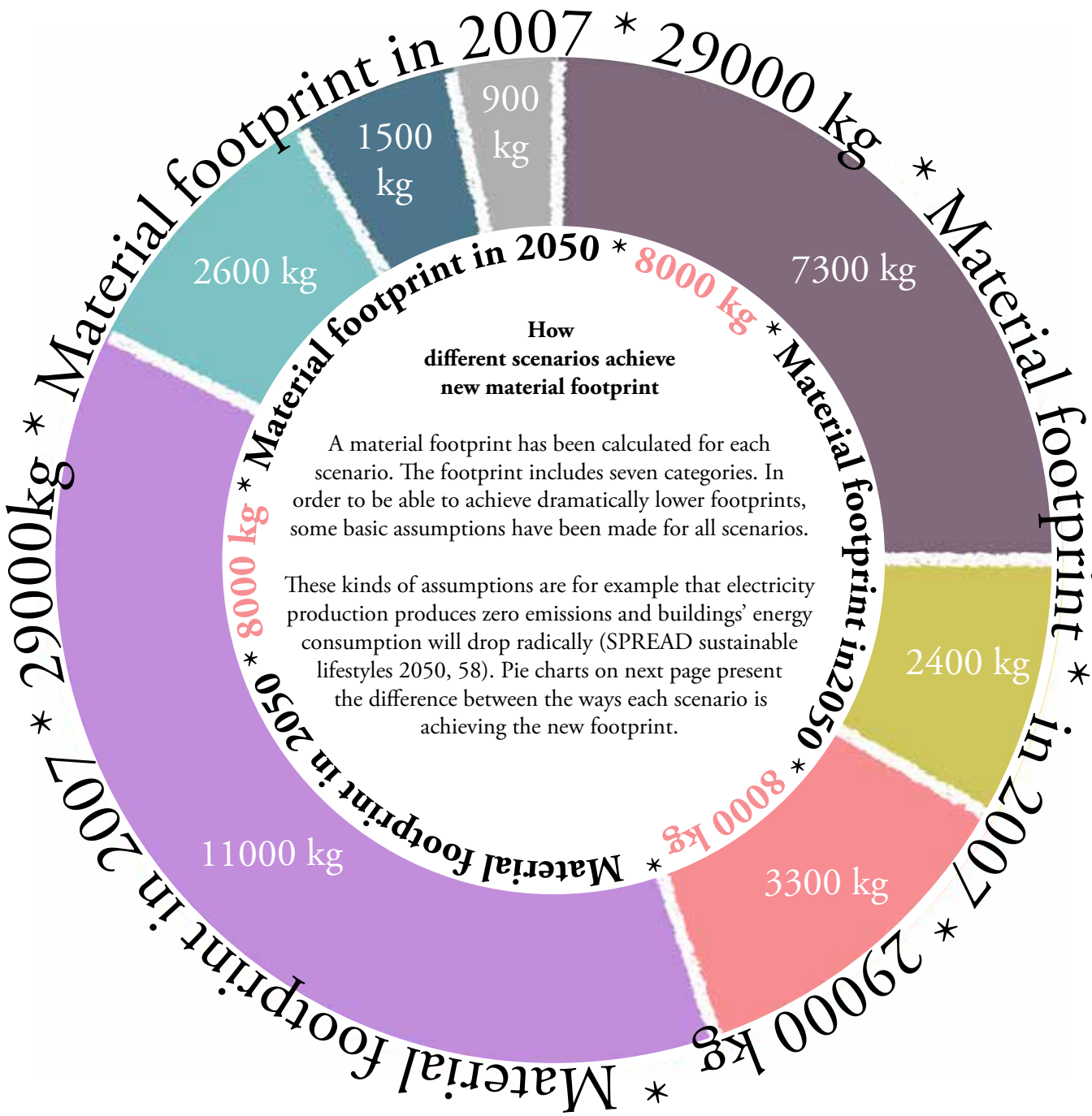


Chart 9. How much material footprint should decrease? Based on SPREAD lifestyles 2050. 24

SCENARIO MATERIAL FOOTPRINT IN 2050
8000 KG

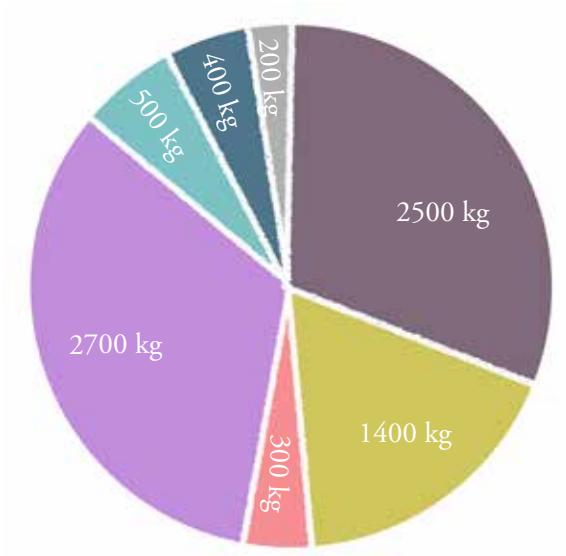


CHART 10. GOVERNING THE COMMONS

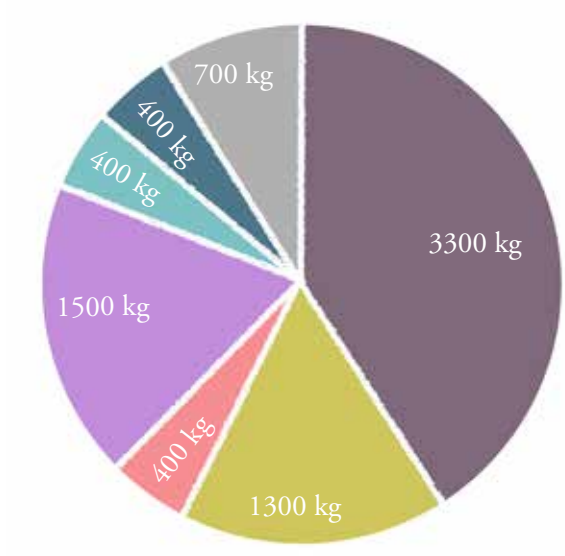


CHART 11. LOCAL LOOPS

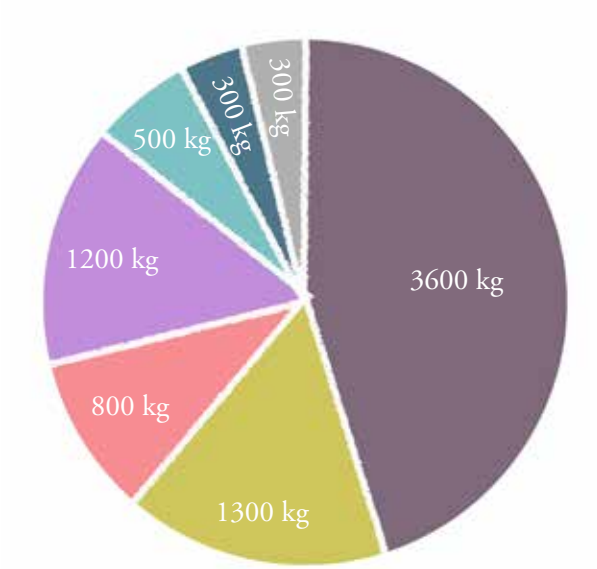


CHART 12. EMPATHETIC COMMUNITIES

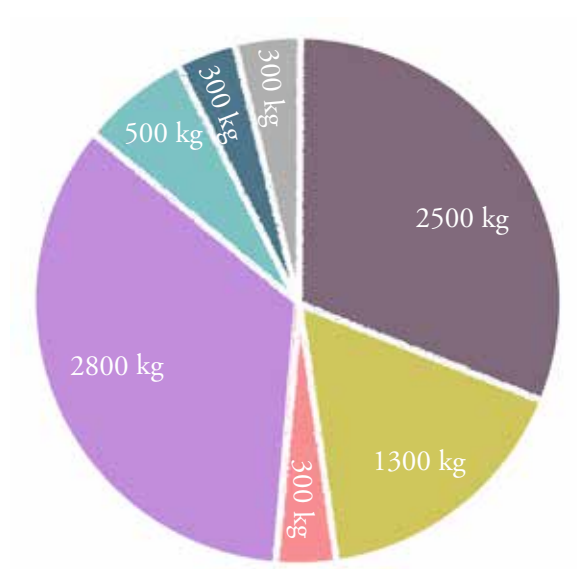
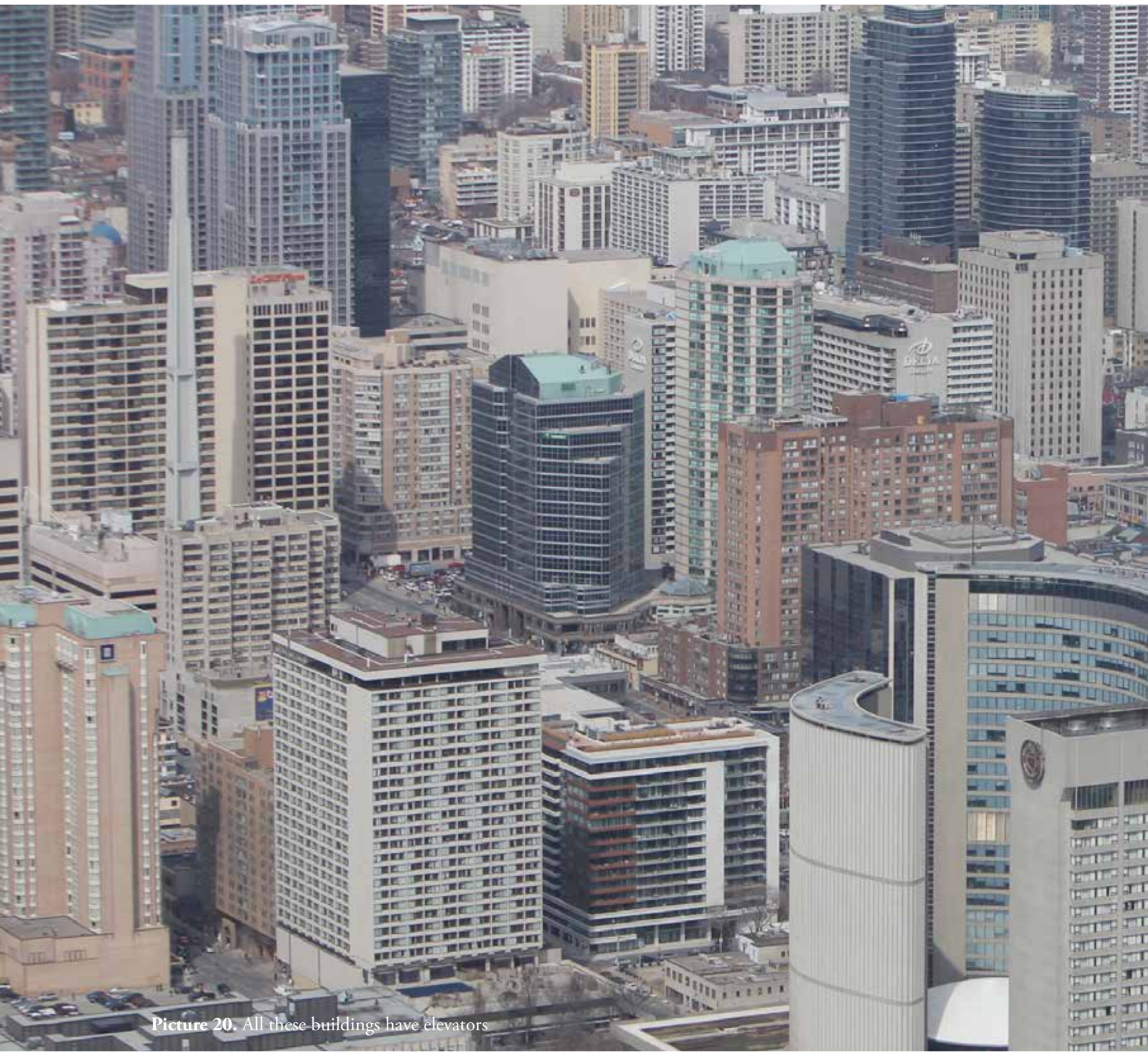


CHART 13. SINGULAR SUPER CHAMPIONS

Food
Housing: electricity
Product consumption
Others
Housing: building
Mobility
Leisure time

Charts based on information in SPREAD sustainable lifestyles 2050, 24, 34, 44, 54



Picture 20. All these buildings have elevators

PART II

SUSTAINABILITY IN BUILDINGS

3. SUSTAINABILITY IN BUILDINGS TODAY

3.1 Trends in international agreement in general

It is almost overwhelming to map agreements, regulations, actions, working groups and organisations established to change the directions towards sustainability. However there can be identified four different types of trends in international environmental regulation and governance. These trends are

- Increasing regional cooperation and integration. Chart 14 shows how popularity of international agreements has dramatically grown in the past. Yet in the last decade multilateral agreements have decreased and there is increasingly regional collaboration and countries cooperating together, for example harmonising environmental regulations. European Union is considered to be first mover in these kinds of actions.
- The growing importance of groupings of leading countries such as the G8 and G20; The way of making agreements is changing from organisations like UN to group of countries. This is making the field more fragmented and diverse. Contradictory another major trend is globalisation of administrative laws meaning that there is increasing uniformity and integration in norms and standards.
- Increasingly diverse approaches to regulation and a stronger role for softer forms of policy coordination like guidelines, frameworks and codes.
- The growing relevance of non-state actors and hybrid forms of public-private governance. International policy processes are more and more influenced by private actors such as global corporations or non-governmental organisations (NGO). They operate as important sources of information and knowledge. Governments, corporations and NGOs are often co-regulating.

(European environment — state and outlook 2010, 91-96)

Chart 14. International spread of environmental policies across OECD and Euopean countires. Adapted from European environment — state and outlook 2010, 95

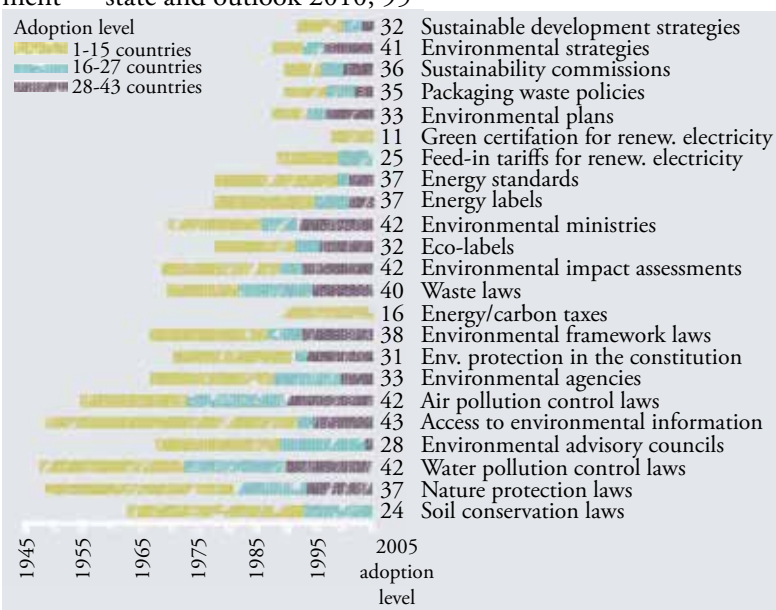
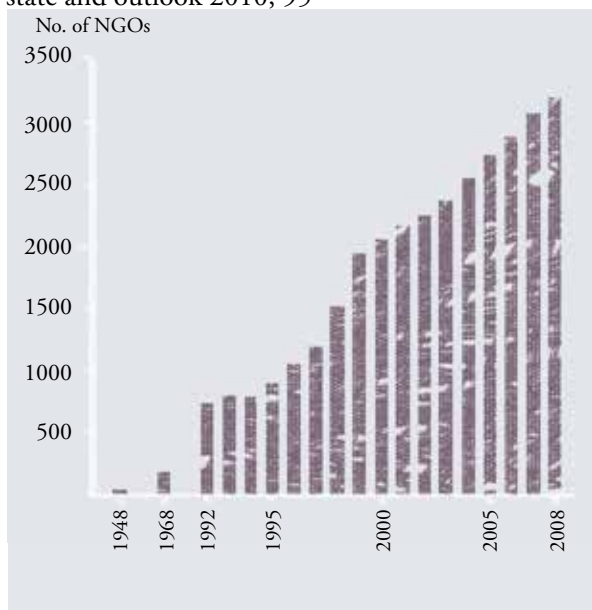


Chart 15. Growing relevance of non-state actors as advisors, adapted from European environment — state and outlook 2010, 95



3.2 Laws and regulations

According to several sources world's buildings consume about 40% of the entire energy consumption (e.g., WBCSD 2012c, UNEP 2012a). If construction materials like steel, cement and aluminium are included to energy consumption, buildings consume more than 50% of global primary energy (WBCSD 2012c). According to some estimates buildings own share of 25% global water usage and 40 % global resources. Buildings also emit over 30% o global greenhouse gases (UNEP 2012a). These are reasons why buildings are seen to have great potential for reducing energy consumption and reducing CO2 emissions. Many regions, countries and cities are setting up regulations to strive buildings towards sustainability. There are plenty of organisations, where cities are working together to decrease their environmental impacts locally, for example C40 and ICLEI. These are introduced later. Most important laws and regulations in Europe affecting construction business and buildings are:

European Energy Performance of Buildings Directive (EPBD)

The EPBD (Directive 2002/91/EC) was published in 2002. It obligates all countries to enhance building regulations and introduce energy certification schemes for buildings. (EPBD 2012a)

The EPBD was updated in 2010. Now EU is aiming to nearly-zero energy building by 2020 in both new and retrofitted buildings. Public buildings should meet the new requirements already in 2018. (EPBD 2012a). Nearly-zero building means a building, which is extremely energy efficient. The energy consumed should be from renewable sources produced on-site or nearby. (Directive 2010/31/EU, 18).

20-20-20

All EU countries will

Reduce green house gas emissions by 20% below 1990 levels

20% of energy consumption is covered by renewable resources

Energy efficiency is increased by 20%

To support these targets EU accepted "the Climate and Energy Package". It includes so called "Effort Sharing Decision" where the industries excluded from European Union Emission Trading System are obligated to reduce emissions to achieve targets. Industries like housing, incl. construction, heating and living, are affected by it. (EC 2012a)

3.3 Voluntary organisations

There are also several international organisations, associations and initiatives working for more sustainable building industry. Here is introduced the most common organisations

World Green Building Council (WorldGBC)
The WorldGBC is a coalition of national Green Building Councils. It is the largest international organisation influencing the green building market place. Their mission is "to facilitate the global transformation of the building industry towards sustainability through market driven mechanisms". WorldGBC was founded in 1999 and it currently has national GBC in over 80 countries. (WorldGBC2012)

World Resource Institute (WRI)
WRI is a global environmental think tank. It does not only research but also executes ideas into action. WRI was launched in 1982 and it has four programs that it is concentrating on. These programmes are: Climate, Energy and Transport; Governance and Access; Markets and enterprise; People and Ecosystem. (WRI 2012)

Sustainable Building Alliance (The SB Alliance)
The SB Alliance was founded in 2008 by six organisations from Europe and Brazil. VTT from Finland is one of the founders. Currently alliance has 26 members in 13 countries. The SB Alliances purpose is to accelerate the sustainable building. They have developed SB Core Metrics, which is a set of indicators for building performance assessment and rating. Indicators are primary energy, water, indoor air quality, thermal comfort, carbon emissions and waste. (SB Alliance 2012a). SB Core Metrics is still in quite early stage. SB Alliance has included internal transport in to the SB Core Metrics, but at least in first phase it was mentioned to be optional. SB Alliance is co-chair of UNEP-SBCIs steering committee and BRE is one of the founding members (see below).

United Nations Environment Programme - Buildings and Climate Initiative (UNEP-SBCI)
UNEP-SBCI works globally to promote sustainable building policies and practices. Its mission is to create a common language for and definition for sustainable buildings, especially in developing countries. UNEP-SBCI is a partnership of major public and private sector stakeholders in the building sector. (UNEP 2012b). In 2010 was established Sustainable Buildings Steering Committee, which is currently developing the UNEP-SB Index. The index is going to be a globally consistent framework to understand, measure, report and verify buildings sustainability performance. The results will be annually gathered into global report to show how sustainability of the building stock is developing. Thus the index is not a rating system but more like a steering tool. Committee's work is focusing on six aspects where e.g. materials is one aspect. UNEP-SBCI is collaborating with similar initiatives organisations like Global Reporting Initiative (GRI). (UNEP SBCI 2010, 3, 5).

World Economic Forum (WEF)
World Economic Forum describes itself as "an independent international organisation committed to improving the state of the world by engaging business, political, academic and other leaders of society to shape global, regional and industry agendas." (WEF 2012b). Environmental sustainability is one of the five key areas WEF works in.

Between years 2008-2010 WEF executed a SlimCity Initiative. As a result was produced SlimCity Knowledge Cards to identify key trends and best practices. In SlimCity Initiative sustainable buildings go beyond energy-efficiency. They take advantage of local resources using materials that are recycled and reused. Sustainable buildings are "regenerative, actively contributing to local biodiversity and food security". They adjust and develop with climatic, economic and social change and secure human health and well-being.

One of WEF's new research areas is to find sources for financing retrofits. WEF sees that achieving reductions in energy consumption and carbon emission through improving existing buildings is getting more important. Global new building turning rate is only 5% and currently new building construction has been slowing down due to economic crisis. (WEF 2012c).

World Business Council for Sustainable Development: Energy Efficiency in Buildings (EEB)
EEB was launched in 2006 as a project of World Business Council for Sustainable Development. In its vision 2050 WBCSD introduced recommendations and roadmap for building sector to reach an 80% cut in energy use by 2050 in economically and socially acceptable way. Since 2011 EEB has been working on implementation of the roadmap. (WBCSD 2012c).

EEB has published a manifesto and short implementation guide on improving energy efficiency in buildings. Already 113 out of WBCSD's 200 members have signed the voluntary manifesto, for example construction company Skanska.

The United Nations Human Settlements Programme, UN-HABITAT
UN-HABITAT is promoting socially and environmentally sustainable urban areas. They have ambitious goal of providing sufficient shelters for all people living in urban environment. (UN-HABITAT 2012). UN-HABITAT is focusing more on eliminating negative sides of urbanization and decreasing the environmental and social impacts of cities and towns. For example, slums and cities and their role in climate change.

BUILD UP - Energy solutions for better buildings
BUILD UP is a European web portal aiming to reduce energy consumption in buildings. It is focusing on sharing best practices with building professionals, public authorities and building owners and tenants. Provides for example case studies, tools, events, news and shares updates in EU energy policy for buildings. (BUILD UP 2012)

The Global Buildings Perfomance Network (GBPN)

ClimateWorks Foundation created GBPN in 2011. It has a global center in Paris and regional hubs in China, USA, India and in Europe. GBPN is an international organisation, which fills "an important gap as the first global center that is regionally organised, elevating local expertise and policies that feed into an international network". GBPN focuses on building energy efficiency, performance and GHG policy by offering expertise for political and business leaders and promoting best practices. It also has its own research and analysis work. (GBPN 2012a). Has partnerhips and collaborations with Buildings Performance Institute Europe, The Institute for Market Transformation (USA), China Sustainable Energy Programme and Shakti Sustainable Energy Foundation (India). (GBPN 2012b)

The Energy Efficient Buildings European Initiative (E2B EI)

Another European Union based organisation focusing to "deliver, implement and optimise building and district concepts that have the technical, economic and societal potential to drastically decrease energy consumption and reduce CO2 emissions in both new and existing buildings across the European Union". E2B EI is industry driven research and demonstration programme helping to achieve EUs 20-20-20 targets. It has many members from large and SME construction companies, public promoters, agencies and research organisations like VTT from Finland. (E2B EI 2012).

The European Network of Construction Companies for Research and Development (ENCORD)

ENCORD was founded in 1989 and it has 19 members around the Europe. It is Europe based, but it states that it operates worldwide. Members include large construction companies like Skanska, Bilfinger Berger, Ferrovial, Balfour Beatty and Zublin. ENCORD is a research, development and innovation network providing services to its members. (ENCORD 2012a). Among many other things, ENCORD is focusing on sustainability and CO2 issues. It has compiled a Sustainability Charter, which member companies signed in 2011. Supports E2B EI. (ENCORD 2012b).

The United Nations Global Compact (The Global Compact)

The Global Compact was launch in year 2000 being currently world's largest citizenship and sustainability initiative. It has over 8000 participants from over 6000 business and 135 countries around the world. The Global compact gathers all actors around the same table from companies to government, labour, NGOs and seven UN agencies. Its operation is based on ten universally accepted principles in the areas of human rights, environment and anti-corruption. (UNGC 2012a)

Under Global Compact's Environmental issues operates for example a Caring for Climate Initiative. It includes a Low Carbon Leaders Project, which again is collaboration with WWF. The Low-Carbon Leaders project is a multimedia platform sharing low-carbon solutions by presenting case studies and providing toolkits. (UNGC 2012b). Living and buildings are one of the areas included to platform. Solutions related to buildings are solar energy, optimizing indoor temperature, biomimicry for optimal water temperature and smart lightings. (Transformative Solutions 2012)

3.4 Most widespread building certification schemes

Certifying sustainable buildings has become one way to tell people and business of sustainability. Building certification shares same problem with environmental labels. It is very typical that each country or region has its own system, which makes the field of schemes confusing and complex. There are still few certification schemes that are globally acknowledged. LEED is probably the most widespread certification scheme. It is used in Americas and other parts of world, e.g. in Europe. Second comes BREEAM, which is mostly used in UK and Europe. Japanese CASBEE and U.S. Environmental Protection Agency's Energy Star are also known, but not nearly as widespread as LEED and BREEAM. Other certification schemes are Green Star in Australia and New Zealand, NABERS (Australia), Green Globes (North America), BEAM (Honk Kong and China), DGNB (Germany) (Moxon 2012, 56-58).

Worldwide trend is that cities require specified buildings to have certification. This topic is talked about in chapter Cities taking actions.

Certifications are becoming popular in Finland too. LEED is dominating the market in Finland, but BREEAM is increasing its popularity. While buildings are getting more efficient, role of greener materials are becoming more important. Not just because of having less environmental impacts but also because of better indoor air quality in buildings. (Rajakallio 2013).

Next are shortly introduced LEED and BREEAM as examples of most popular certification schemes. In addition is introduced Living Building Challenge, which has new approach. Last is taken a look of Ska Rating, which is meant for interior design. In each certification is also listed what kind of requirements they set for materials even though they might not apply to elevators.

Picture 21. Logos of the green building schemes.

3.4.1 LEED

Leadership in Energy and Environmental Design (LEED) is a certification system for buildings, homes and neighbourhoods. Certification verifies that the certified site was designed and built to achieve high performance in areas of human and environmental health, sustainable site development, water savings, energy efficiency, indoor environmental quality and material selection. U.S. Green Building Council (USGBC) developed LEED in year 2000.(USGBC 2012a)

LEED rating system is divided into 9 categories: New construction, existing buildings: operation and maintenance, commercial interiors, core & shell, schools, retail, healthcare, homes and neighbourhood development. In the LEED certification the building is evaluated by giving points in fields of sustainable sites, water efficiency, energy & atmosphere, materials & resources, indoor environmental quality, location and linkages, awareness and education, innovation in design and regional priority. Maximum amount of point is 100 and buildings can achieve additional bonus points. Certified sites are classified on how many points they have gained into four classes: Certified, Silver, Gold and Platinum. (USGBC 2012b).

Certifications are not just a way to differentiate real estate in the market. USGBC states that according to studies LEED certified real estates have higher occupancy, sales and rental prices. Even that construction costs for green buildings are usually higher, investment of 2 % in green building designs results in life cycle savings of 20% of the total construction costs. (USGBC 2012c)

LEED for New Construction Rating System defines requirements for materials and resources. Basic idea is that materials should extent building lifecycle, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts even in material manufacturing and transporting (USGBC 2009, 50-51). Some of the requirements are related to recycling materials during the construction, renovation and usage of buildings. Elevators can not contribute much on achieving credits in such areas. Even though elevators do not have large role, it is still important that product is holistically environmentally friendly. Materials should not cause any environmental or health problems for customer during installation, usage, renewal or end-of-life phase.

LEED 2009 for New Constructions and Major Renovations were updated in July 2012. Out of total 100 points 14 are related to materials and resources and 6 to design innovations. On next page is introduced most important ones.

In further inquiry from Green Building Certification Institute none of the material requirements mentioned on next page apply to elevators. Reason is that compared to structural and finish materials, special items like elevators or mechanical and electrical equipment, have higher monetary value compared to amounts of material used in them. Because calculations are cost based, including them into credit would skew the results. This is why e.g. materials used in elevators are excluded from LEED material specifications. (GBCI, 18.9.2012). On the other hand, there are still two perspectives why offering ecological elevator materials can benefit customers. First, ecological materials can be lighter than usual materials and indirectly reduce elevator energy consumption, which is beneficial in LEED. Secondly, ecological materials can support customer's environmental values and using ecological materials also in elevators creates consistency to final detail.

MR Credit 1.2: Building reuse – maintain interior non-structural elements
1 point

Interior non-structural elements mean for example interior walls, doors, floor covering and ceiling systems. To gain 1 point at least 50% of area of completed building and possible new additions must use existing interior non-structural elements. If additional new floor area is more than 2 times more than existing area, this credit is not applicable. LEED recommends replacing contaminous and hazardous materials with better ones and improving e.g. energy efficiency. (USGBC 2009, 51)

MR Credit 3 for reused materials
MR Credit 4 for recycled materials
MR Credit 5 for regional materials
each valid for 1-2 points

In all of them certain percentage of total material costs (5-10%, 10-20%) used for such materials entitle to credits. Unfortunately in all these cases elevators are excluded and only materials that are permanently installed are included to calculations.
(USGBC 2009, 53-55)

MR Credit 7 Certified wood
1 point

At least 50% (based on cost) used wood in the project must be FSC certified. Only materials permanently installed are included to calculations.
(USGBC 2009, 57)

MR Credit 6 for Rapidly Renewable materials
1 point

LEED encourages using materials that are rapidly renewable. There are two requirements to achieve the point. First is that 2.5% (based on cost) of total value of all building materials and products used in project are spent on rapidly renewable materials. Second one is that renewable material or product must be made of from agricultural products that are harvested within a 10-year or shorter cycle. LEED recommends considering materials like bamboo, wool, cotton, agrifiber, linoleum, wheat- and strawboard and cork. (USGBC 2009, 56)

3.4.2 BREEAM

Building Research Establishment Environmental Assessment Method (BREEAM) is a standard for best practices in sustainable building design, construction and operation. BREEAM consists of recognised measures of performance to evaluate building's environmental performance. Building Research Establishsment (BRE) founded BREEAM already in 1990 in the United Kingdom. Since then it has grown into an internationally recognised certification scheme. In the BREEAM system is awarded points by evaluating following aspects: energy, management, health & wellbeing, transport, water, materials, waste, pollution, land use and ecology. Scores are broke down into five categories with star rating: pass (*), good (**), very good (***), excellent (****), outstanding (*****). (BREEAM 2012a)

Difference between BREEAM and LEED is that BREEAM is taking local conditions into considerations and there are for example country-specific schemes. (BREEAM 2012b). In this research is referred to BREEAM International Bespoke. It is is applicable to those buildings that fall out from BREEAM Europe Commercial or country specific schemes. BREEAM International Bespoke can be applied to design, construction, initial occupational and refurbishment stages of the building. (BREEAM 2012c)

BREEAM sets requirements for elevators and escalators, but the requirements are related to energy consumption (e.g. lighting, standby mode) and only few credits can be achieved. (BREEAM Bespoke 2008, 151). BREEAM requirements for materials are presented below. Sections Mat 2-4, 6, 8 were left out, because they were not relevant for elevators.

Over all, there aren't many requirements for elevators when considering materials. Only requirement is for robustness, which is already common requirement even without certification scheme. Like in LEED, offering ecological materials can support customers' ecological values and create energy saving, if it lighter material than other materials.

Mat 7: Designing for robustness.
This section includes elevators. It emphasizes the protection of exposed parts by minimising need for replacements of materials. To achieve point BREEAM requires identifying where is heavy traffic in building caused by e.g. people, vehicles, and trolleys. Secondly there must be specified suitable measures for durability and protection or design features to prevent damage from heavy traffic. Elevators are mentioned as one example of such area that needs to be protected. BREEAM suggests some suitable measures. It also emphasizes that especially materials used in common/public areas should "provide protection against malicious or physical abuse as far as it is possible." (BREEAM Bespoke 2008, 252-253)

Mat 1: Material specification for major building elements.
This section is referring Green Guide rating. Green guide is a directory for sustainable living and does not include elevators.
(BREEAM Bespoke 2008, 222)

Mat 5: Responsible sourcing of materials.
Is not applicable to elevators, but there are plenty of requirements and instructions on responsible sourcing.

3.4.3 Living Building challenge

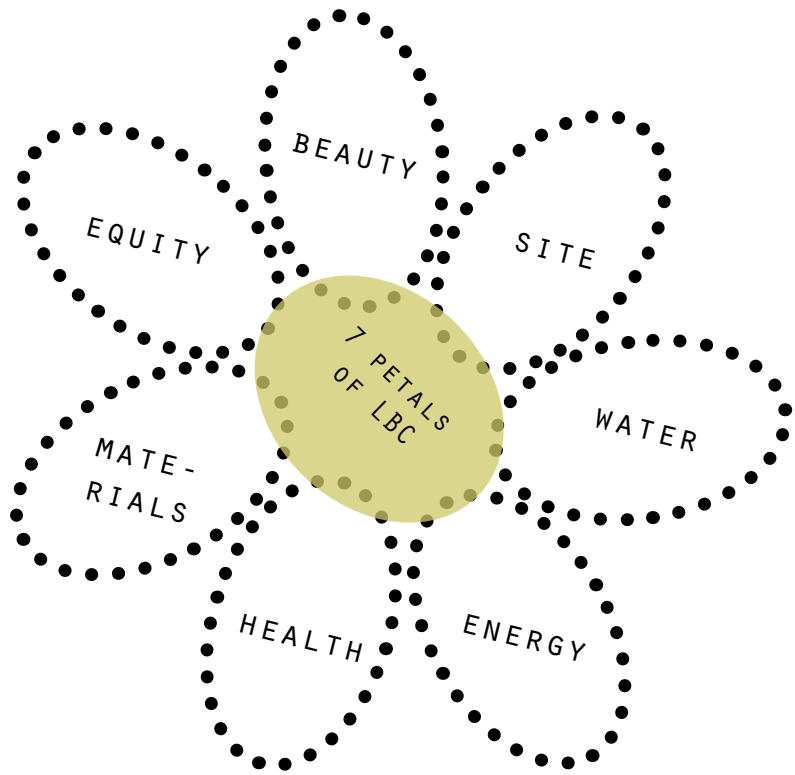
Living Building Challenge (LBC) is owned by The International Living Future Institute. It is a non-governmental organisation "committed to catalysing a global transformation toward true sustainability". The institute claims that it has "redefined the green building movement" and is "substantially raising the bar for the true sustainability". The Institute also owns three other programs Cascadia Green Building Council, The Natural Step Network USA and Ecotone Publishing. (Ilbi 2012a)

LBC is clearly different from other certifications, because it is performance based. It is a certification, but also a philosophy and advocacy tool. (Ilbi 2012b). LBC goes beyond other existing popular certifications like LEED and BREEAM. It is focusing on actual performance, which is why system based on LBC must have been in use at least 12 months before it is evaluated. This way is ensured that building is truly ecological.

Living Building Challenge can be applied to various types of projects: landscape and infrastructure, partial renovations of a building, complete renewal of a building, new construction, neighborhood and community design. There are six different Living transect categories and each project must be referred to one of them. In transect categories e.g. urban zones are divided into general, center and core zones. (Living Building Challenge 2.1, 9).

LBC does not set any specific requirements for elevators and escalators. But it is seen that its requirements for materials and accessibility applies for elevators and escalators. All LBC buildings are net-zero energy, which have impact on decision-making when choosing elevators. It is likely that LBC buildings will have elevators with lowest possible energy consumption. (Connelly 8.9.2012)

Living Building Challenge focuses on seven performance areas or petals as the institute itself calls them. In each petal LBC presents what are the ideal conditions that LBC projects should strive to and also what are current limitations for achieving them. (Living Building Challenge 2.1, 4, 8). Next is introduced LBC requirements (petals) for energy and materials, which are most related to the thesis.



Energy petal

Intent: "The intent of the Energy Petal is to signal a new age of design, where in the built environment relies solely on renewable forms of energy and operates year round in a pollution-free manner. In addition, it aims to prioritise reductions and optimisation before technological solutions are applied to eliminate wasteful spending – of energy, resources, and dollars."

Ideal situation: Safe, reliable decentralised power grid based solely on renewable energy, incredibly efficient buildings. **Limitations**: Current costs; energy technology is still developing

Requirement: Net Zero Energy . "One hundred percent of the project's energy needs must be supplied by on-site renewable energy on a net annual basis."

(Living Building Challenge 2.1, 21-22)

Material petal

Intent: "The intent of the Materials Petal is to induce a successful materials economy that is non-toxic, transparent and socially equitable."

Ideal conditions: All materials are replenishable and have no negative impacts at all, decisions are made based on precautionary principal. **Limitations:** Consumer attitudes are changing but market doesn't support it as good as it could e.g. no comparable data on green products, existence of green washing and lack of transparency.

Requirements: "The Red List", a list of chemicals that materials can not contain. There are exeptions, because material selection is limited at the moment. Calculate total footprint of embodied carbon from construction through one-time carbon offset. Responsible industry. Raw materials like stone, rock, metal, minerals and timber must have third-party certified standards. Placed-based solutions in material sourcing meaning materials and services should be sourced locally. LBC offers a table with distances or zones how far materials and services can be sourced (table 2). Material conservation and reuse. LBC obligates to strive to reduce or eliminate the production of waste during entire lifecycle from design phase to end-of-life phase in order to conserve natural resources. It for example sets levels on how much waste during construction must be diverted and does not allow incineration.

(Living Building Challenge 2.1, 27-34)

Other interesting things where LBC goes beyond other certification schemes is that it pays attention to for example humane scale and humane places (requirements for parking lots, streets and free-standing signs), emphasizes car-free living and sets requirements for beauty. Also LBC includes biophilia, meaning it has six Biophilia Design Elements that must be represented for every 2000 m2. These six elements are for example natural forms and shapes, and place-based relationships.

LBC seems to have very humane approach to building and presents more a future way to certify building. LBC is fairly new scheme and it had its first projects certified in 2010. That is why it can not compete in popularity with widespread certifications. But it could be considered as weak signal for where we are heading. Still LBC is spreading fast having over 100 projects mainly in North America (Connelly 8.9.2012). It will be interesting to see how this scheme will succeed.

Picture 22. The Declare. LBC recommends using its own green product declaration called "The Declare" and Pharos Project to help to choose materials. It provides a platform for manufacturers to communicate sustainable features of their products. Declare is voluntary program where any product can participate. Participation does not require International Living Future Institute acceptance. In other words Declare is based on mutual trust, honesty and open communication. However, the label must be renewed every 12 months and it includes a fee. (Declare 2012a). Consumers can "Request to Declare Template" to urge manufactures to encourage to use Declare for their products. (Declare 2012b)

Pharos Project is a platform for building material products. Products in Pharos platform are not only environmentally friendly, but they also pay attention to health and social equity aspects. (Pharos 2012)

Table 2. LBC emphasises placed-based solutions. Adapted from Living Building Challenge 2.1, 31.

Zone	Max. distance, km	Materials or services
7	20 004	Ideas
6	15 000	Renewable technologies
5	5 000	Assemblies that actively contribute to project performance and adaptable reuse once installed
4	2 500	Consultant travel
3	2 000	Light or low-density materials
2	1 000	Medium weight and density materials
1	500	High or high-density materials

3.4.4 Ska Rating

Ska Rating is a certification scheme solely for interior designs. It is one of the kind and therefore worth to mention. Ska Rating was created and is developed by Royal Institute of Chartered Surveyors (RICS) in United Kingdom. It is a relatively new scheme and currently they have a scheme for offices. One for retails is under development. Categories included in scheme are energy and carbon, waste, water, materials, pollution, wellbeing, transport and other. Each category has its own good-practice measures, which are optional. Ska Rating has four ratings: unclassified, bronze, silver and gold. (Moxon 2012, 57)

Ska Rating seems to be very detailed and flexible. When it comes to elevators, Ska Offices scheme does not include them in it, because they are rarely part of fit-out package. Instead Ska Retail scheme covers elevators, especially when they are installed by the tenant. Ska Rating sets requirements for energy efficiency of elevators and escalators. Material finishes in elevators and escalators follow the requirements set for floor and finishes. (Robinson 2013). In addition, it is also required that elevator energy consumption is included to building's automatic and monitoring system, which measures energy consumption of each listed item. (Ska Rating 2011, 25). In near future Ska Rating is looking at embodied energy and carbon of big items like elevators and escalators and their chain of custody through BREs BES6001 (The Framework Standard for the Responsible Sourcing of Construction Products).

In general, for example Ska Offices Scheme sets following requirements for all materials installed as part of the the fit-out. At least 80% of materials installed must meet one of the criterias (Ska Rating 2011, 39)

Contain at least 80% recycled or recyclable content

Have A or A+ rating in BRE's Green Guide to Specification
(related to BREEAM)

Are reused of reclaimed

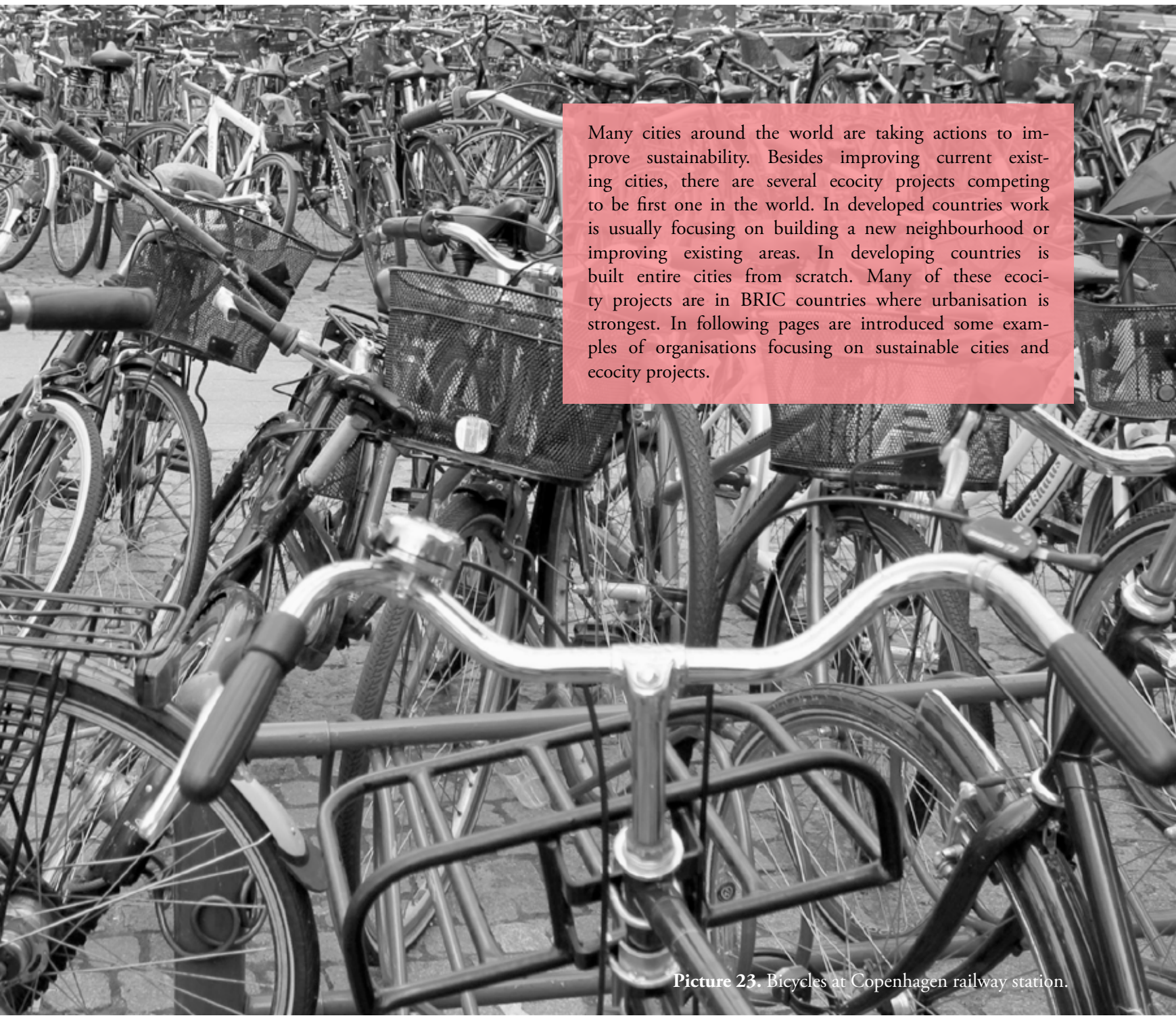
Have A or A+ rating in BRE's Green Book Live database
(related to BREEAM)

Are supplied with environmental product declaration (EPD) written in accordance with ISO 14025 standards

Like other certifications shemes, also Ska Rating gives specific requirements for materials. These requirements in offices scheme include e.g., having a certifcation for sustainable sourcing, being reused or have certain amount of recycled content and similar requirement as mentioned above. Ska Rating also appreciate environmental labels like EU Ecoflower. (Ska Rating 2011 51, 55, 56, 66, 78, 86). Ska Rating goes to details. That's why it has requirements for example for raised flooring systems, brics, suspended ceilings, joinery, insulation, kitchen fittings, different kind of furnitures and accessories.

Ska Rating gives guidance for each criteria. Guidance include for example instruction where to find materials that meet requirements or what is preferable, if there are alternatives. It also shares examples how to meet the criteria. In some cases Ska Rating prefers for example materials that are sourced close to site.

3.5 Cities taking actions



Many cities around the world are taking actions to improve sustainability. Besides improving current existing cities, there are several ecocity projects competing to be first one in the world. In developed countries work is usually focusing on building a new neighbourhood or improving existing areas. In developing countries is built entire cities from scratch. Many of these ecocity projects are in BRIC countries where urbanisation is strongest. In following pages are introduced some examples of organisations focusing on sustainable cities and ecocity projects.

Picture 23. Bicycles at Copenhagen railway station.

3.5.1 The C40 Cities Climate Leadership Group (C40)

C40 is a network of large cities around the world. These cities are committed to implement locally sustainable actions to stop climate change globally. C40 was founded in 2005 by Mayor of London, Ken Livingstone. It operates in partnership with President Clinton's Climate Initiative (CCI) cities program. (C40 2012a). C40 describes itself as "an effective forum where they can collaborate, share knowledge and drive meaningful, measurable and sustainable action on climate change". Collaboration of cities is seen as a quicker way to execute actions against climate change. It is faster for cities to apply initiatives compared to governments. C40 members think that cities have power to decrease climate change. Other reasons why many cities are concerned is that most of urban areas are located on shore. Results of climate change, like sea level rise and storms, are already causing tremendous problems. (C40 2012b)

"Cities occupy only 2% of world's landmass, but they consume 2/3 of the world's energy and produce 70% of global CO2 emissions."

C40 consists of steering committee cities (10), participating cities (40) and affiliate cities (18). Steering committee cities are Berlin, Hong Kong, Jakarta, Johannesburg, Los Angeles, London, New York, Sao Paolo, Seoul and Tokyo. Affiliating cities are smaller than participating cities, but are seen as leaders in preventing climate change. Singapore operates as observer city. (C40 2012 c). There are six non-C40 cities in the program. (CDP Cities 2011, 5)

In the C40 Baseline Report it is said that on average 45% of C40 cities CO2 emissions come from buildings, but there is large variation between geographical areas (chart 16). Over half of the C40 cities reported that their city governments own and operate in municipal buildings, offices and have municipal housing. Nearly half of them have stated to have power to set policies and regulation for private sector. Cities have already taken 1343 actions to reduce CO2 emissions from their buildings. (Climate Action In Megacities 2011, 6).

C40 participants have different focuses on how they are lowering CO2 emission and energy consumption from buildings. In developed countries is likely that over half of the existing buildings are still in use in 2050 and that is why actions are based on retrofitting and refurbishment. Work is focusing on new buildings in developing cities that grow rapidly. (Climate Action In Megacities 2011, 35-36). Most popular way to change new construction among the cities is to change their own building standards and codes. They use mostly energy performance rating for buildings and they have reported using several different green building standards as guidance. Many cities have eco district developments, where policies, incentives and projects are applied to decrease CO2 emissions. (Climate Action In Megacities 2011, 80)

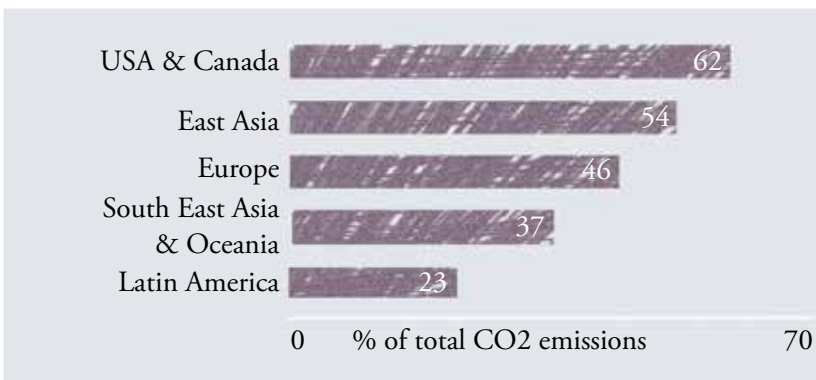


Chart 16. Proportion of city emissions from buildings in C40 cities
(Climate Action In Megacities 2011, 35)

3.5.2 Council for local environmental initiatives (ICLEI) Local Gorvernments for sustainability

ICLEI was founded in 1990 by 200 local governments from 43 countries. It is an association of cities and governments working on sustainable development. Organisation consists of 12 megacities, 100 supercities and urban regions, 450 large cities, 450 small and medium sized cities and towns from 84 countries. Just like C40, ICLEI is supporting local actions for global sustainability. (ICLEI 2012a)

ICLEI is a large movement having 200 employees and 14 offices around the world. Amount of memberships is increasing 10% annually (ICLEI 2012b). There are 15 cities and towns as members in Finland only (ICLEI 2012c). ICLEI has partnerships with for example, United Nations, Clinton Climate Initiative (CCI), World Economic Forum (WEF) and World Bank (ICLEI 2012d).

ICLEI provides programs for members to participate. Programs have key themes that are: Rio +20, Biodiversity, Climate, EcoMobility, Management Instruments, Procurement, Resilience and Adaptation, Sustainable Cities, Water and ICLEI Future City Leaders. (ICLEI 2012e). Other provided services are training, conferences, consultation and research (ICLEI 2012f).

ICLEI and London School of Economics and Political Science (LSE) Cities programme performed a survey of how cities are going green and building on the green economy. Survey included 53 cities from five continents and had nine key areas under three topics, e.g., building the green economy. (Going Green 2012, 4). Majority of cities see new green buildings and green retrofitting of buildings very important in their economic growth (Going Green 2012, 26)

3.5.3 World Green Building Council awarding best cities

WorldGBC Government handed out Leadership Awards first time in 2011. The 22 nominees competed under a theme “Excellence in City Policy for Green Building” and six cities were awarded. (Excellence in city policy for green building 2011, 2). Most of cities were concentrating on engaging new and existing buildings into green building certification programs. Also energy efficiency was an important topic. Frankfurt am Main in Germany had forerunning approach. It stated to be the World Capital City of Passive Houses. Since 2005 all municipal service and residential houses in Frankfurt has been constructed according to passive house standards. In 2011 Frankfurt had over 1500 dwellings and over 100 projects designed to passive house standards. (Excellence in city policy for green building 2011, 22). WorldGBC GovernmentLeadership publication offers 22 examples around the world on how cities lead green building.

3.5.4 Masdar in Abu Dhabi

Masdar aims to be the most sustainable city in the world. It is located close to Abu Dhabi. It states to be completely carbon-free, producing no waste, is car-free and uses only renewable energy. After it is completed it will offer homes for 40000 people. There are elements that make Masdar different from other ecocity projects. It is like a sci-fi version of ecocity.

Masdar has engaged companies into the building work. Global companies like GE, Siemens, BASF and Schneider are involved. Also acknowledged Massachusetts Institute of Technology (MIT) is participating. Companies and MIT are having their own buildings (e.g. headquarters) in Masdar and they will continue operating there after the ecocity is completed. Masdar is not only a place to live, but it will be a clean tech cluster that creates jobs, business and expertise in sustainable living.

The Future Build is an initiative of Masdar City. It provides tools and services for different stakeholders (architects, engineers and contractors, developers and owners, manufacturers and suppliers) to achieve green building targets, whether it is related to materials or achieving a certification for a building. The Future Build has developed for example a carbon-tracking tool to measure carbon in construction including the building materials and their manufacturing. (The Future Build 2011, 3). The Future Build supports LEED and Arabian green certification system Estidama Pearl Building Rating System (PBRS) (The Future Build 2012a).

The Future Build offers a portal for sustainable materials. It is based on materials used in Masdar City. Materials in the portal are assessed through twelve green criteria. The criterias are recycled content, renewable energy, reusable, biobased material, recycled packaging, VOC content, embodied carbon, durability, maintenance/cleaning, availability, code of conduct, indicative price. For each material, portal offers a short product description, supplier contact information and assessment based on the criteria. (Masdar City 2012a). The Future Build rates materials using A-C classification where A presents the best possible sustainability. Rating makes products comparable in sustainability perspective. The Future Build recommends to require LCA and/or Environmental product declaration (EPD) from suppliers. (The Future Build 2012b). Masdar City has a testing center where companies can test their materials in hot, humid and dusty climate. (Masdar City 2012b)

Picture 24. PRT with passengers.

Masdar takes the advantage of Abu Dhabi's lightrail and metrosystem. Inside Masdar is built a Personal Rapid Transit (PRT) system and Freight Transit System (FRT). PRT is automated single-cabin vehicle that lets its passenger to move from a place to another without any stops and in privacy. (Masdar City 2012c). Experience could be compare to a taxi ride. PRT runs with electricity and without tracks. It is operated by computer system. Masdar PRT is initial system and currently has only 13 pods (the "car") running. They hope to expand it in near future. Masdar PRT is not the only one in the world. Similar pods are used for example at Heathrow airport. This could be interesting possibility for elevator manufacturers to find out how pods and elevators could cooperate. Pods can be installed on tracks and rooftops and they are computed to their routes. Could it go vertically up and operate as a personal elevator?

Picture 25. During the day umbrellas cool down Masdar. Night time they provide heat.

Picture 26. PRTs waiting in Masdar.

3.5.5 Tianjin ecocity

Another large ecocity project is ongoing in China. Tianjin is located 150 km from Beijin in the area, which is of the fastest growing areas in China. Tianjin will be completed in 2020 and it will accommodate 350000 people. It is said to be half of the size of Manhattan. (Tianjin 2012a) Tianjin is built in cooperation with Singapore.

What makes Tianjin unique is the size of the city (which is small in Chinese standards) and that it is all built from scratch. Another thing is that Tianjin is aiming to be build in affordable costs so the model could be replicated anywhere in China or abroad. It can be considered as an export product. Tianjin, like many other ecocities is relying on renewable energy and car free living with good public transportation. Tianjin encourages people to cycle or walk and public institutions like schools are located near residential buildings. Also work places are going to be close to residential houses. Idea is that people who will work there could also find home close to work. Tianjin seems to seek for simple, inexpensive solutions. BBC World News is showing an Eco Cities series where reporter Adam Shaw asked if Tianjin is an ecocity or is it just a city with eco features. At least Tianjin is an experiment like Masdar. Maybe in countries where urbanisation is happening in large scale, examples like Tianjin present a new approach emphasizing design for people. (BBC 2012)

Picture 27. Tianjin city.

Picture 28. Tianjin has lots of green areas.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Picture 29-34. West Harbour in Malmö represents sustainable building and living in developed countries.


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Picture 35. Flooring materials with recycled content.

PART III

MATERIALS

4. Materials

4.1 Consumption of materials

Materials are needed for everything people do and it has been so for thousands of years. Otherwise nothing tangible would exist. Expression use materials describe well how self-evident materials are thought to be. Ashby thinks the expression is misleading. People do not just use materials, but are in fact dependent on them (Ashby 2009, 6)

Another aspect is how material is valued, when it is needed. When it becomes obsolete, it turns into waste. As waste is understood something with no value. But also that is misleading. Waste and its treatment is a major problem causing environmental impacts. Waste is something that everyone wants to forget and hide. However increasing consumption is causing multiple increase in waste streams. Waste is becoming expensive and many countries are running out of space to store waste. (Ashby 2009, 249)

The materials and the energy to transform them into products are taken from natural resources, which are limited. Natural resources can be divided into non-renewable resources and renewable resources. Before industrial revolution it was used mostly renewable natural resources and the non-renewable natural resource usage was so little that they were practically inexhaustible. 300 years after the revolution dependence has changed. Non-renewable resources are the main resources consumed. Chart on next page describes the tranformation in material use. (Ashby 2009, 6-8)

Radical increase in material use is linked to rapid growth of population and emerging consumption. In developed countries consumption has stabilised but there are many emerging economies where consumption is growing strongly. (Ashby 2009, 10). Consumption of most materials is growing 3-6 % annually. Exponential growth has unfortunate consequences. One of them is decreasing natural resources and the other one is the increasing prices due to scarcity. (Ashby 2009, 34-35)

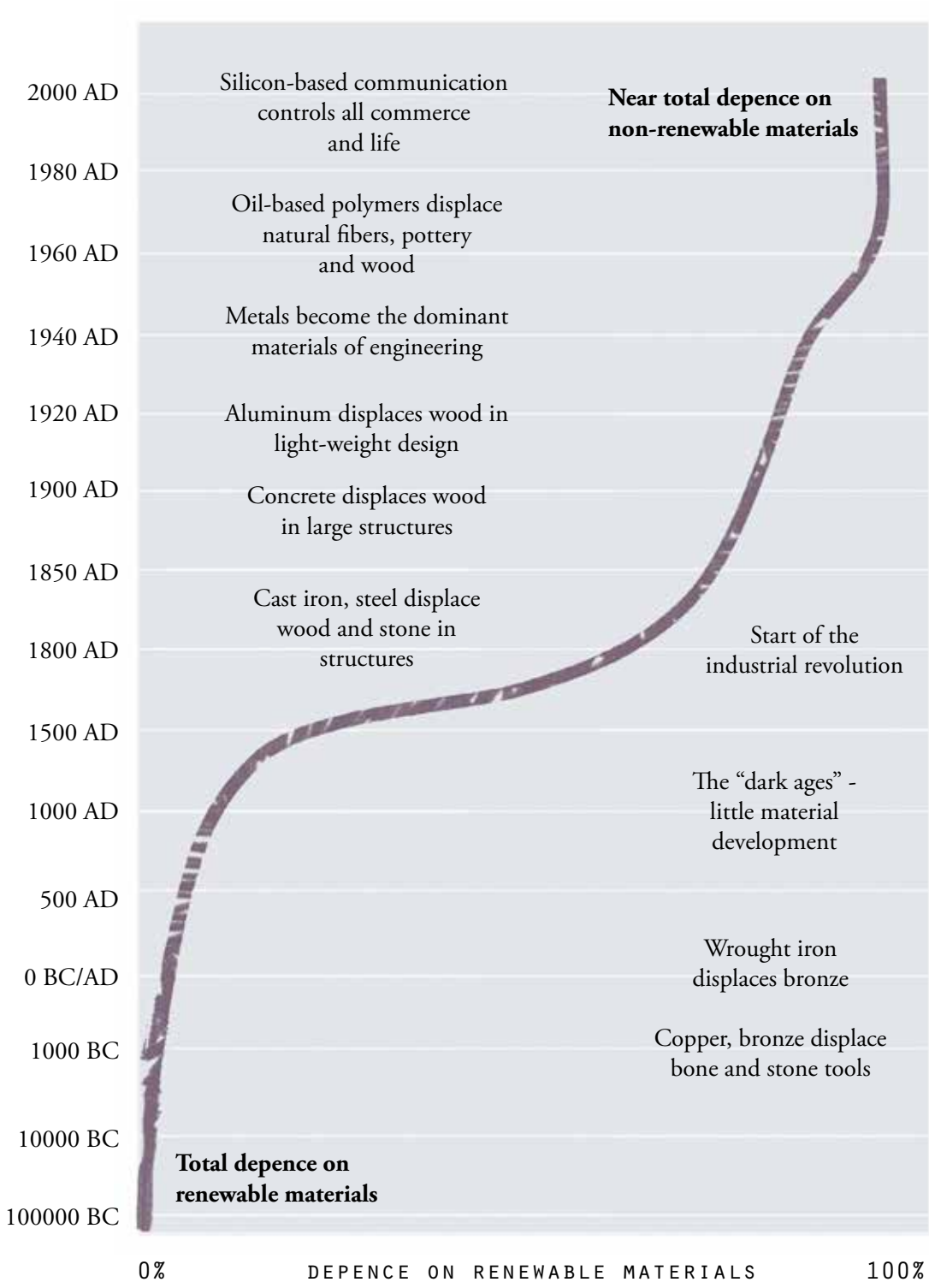
Many natural materials are considered as infinite, which is not exactly true. Some of them regenerate so slowly that they can be considered almost finite. Stone is an example of slowly generating material. Metals are often considered as infinite source, but metals like lead, zinc and copper are estimated to run out within the next half-century. Running out of material causes chain reaction. If world looses one material, also other materials derived from it will eventually disappear. Think for example fossil fuel and plastics. (Moxon 2012, 84)

Another problem related to materials is their processing into products and in the end to waste. This entire lifecycle embodies huge amount of energy and water. And the energy needs to be produced somehow either using natural or manmade power sources.

Materials can be also hazard to health. For example people stay most of the time indoors. Indoor air has become polluted due to off-gasses from interior materials. According to a study made in US indoor air levels of pollutants can be almost three times higher than outdoor levels. This is partly why allergies and asthma has become more common. Hazardous materials have part in Sick Building Syndrome too. (Moxon 2012, 12)

Annually global consumption of materials is about 10 billion tonnes, which makes in average 1,5 tonnes per person. Most used materials in world are oil and coal, concrete and wood. (Ashby 2009, 16-17)

Chart 17. Dependence on non-renewable and renewable materials (Adapted from Ashby 2009, 8)



4.2 Traditional material classification

Materials can be classified in many ways. Traditional way is to divide materials into metals and alloys, polymers and elastomers, ceramics and glasses and finally to hybrids.

Metals and alloys

Metals used in product design are usually alloys. Steel is the most used metal. Almost 90% of World's metal consumption is steel. Steel is iron with carbon and a host of other alloying elements to enhance its attributes. Other most consumed metals in order are aluminium, copper, nickel, zinc, titanium, magnesium and tungsten.

Metals are stiff, strong and tough. Downsize is that they are heavy. Metals have high melting point so they can be used in high temperatures. All metals, excluding gold, are vulnerable for corrosion. Metals can be shaped in many ways (rolling, forging, drawing, extrusion, many ways to join, machine with precision) which makes it very flexible material. Metals are energy intensive, but they can be recycled efficiently. Energy required to recycle metals is much less than what is required for primary production. (Ashby 2009, 269)

Polymers and elastomers

Polymers are divided into three different categories: thermosetting polymers, thermoplastic polymers and elastomers. Synthetic (industrial) polymers are often oil based. Lately polymers that have been synthesized from agricultural products (starch, sugar) have increased popularity. In ecological point of view these biopolymers are problematic, because food-crops are used as raw material. There are also natural polymeric materials that have been used for centuries like amber and natural rubber. (Ashby 2009, 292-293)

Using plastics is always problematic. Plastic does not biograde. Another problem, which is rarely known, is that certain plastics break down very fast, when it is in water. A group of scientist collected water samples from oceans around the world. All samples contained derivates from plastics meaning chemicals that do not exist in nature. Plastic is a new source of chemical pollution in oceans and there is not yet knowledge how it affects nature and humans. (Barry 2009). Annually is produced approximately 260 million tonnes of plastics. From that amount 10% end up to oceans and gathers to plastic patches. Largest of them is located between U.S and Hawaii and is size of Texas. (Handwerk 2009). It is estimated that about 80% of all waste in oceans is plastics. Currently there are 6 times more plastics in oceans than plankton (Algalita 2009).

Ceramics and glasses

Ceramics are the most durable of all materials. Ceramics are exceptionally hard and they tolerate higher temperature than any metals. Ceramics are divided into high-performance technical ceramics; traditional, pottery-based, ceramics and hydrated ceramics used for construction. All ceramics are hard, brittle, have high melting point and low thermal expansion coefficients. They are good electrical insulators. Still, tiny flaws can lead to cracks reducing the strength. Glass is one of the oldest materials in world. Glass is coloured by adding metal oxides. (Ashby 2009, 328-329

Picture 36. Sample with plastics from South Atlantic Gyre.

Hybrids - Composite materials

Objective of composite materials is to combine best properties of two or more materials. Combinations form new materials, which have improved properties and efficiency. First human made composites were for example cobs that were made of combination of straw and mud. Some common everyday materials like plywood, cement and concrete are also categorised as composites (Kula & Ternaux 2009, 78). There are composites developed by nature. In some extent solid wood can be considered as one. (Kula & Ternaux 2009, 74). Most of the industrially made composites like glass fiber and carbon fiber, are hard to recycle. On the other hand composites can create advantages that reduce environmental impacts indirectly. For example in transportation vehicles lightweight composites reduce fuel consumption. (Ashby 2009, 342-343)

Composite materials have two constituents, a matrix and a reinforcement material.
a) Reinforcements are often fibers. Typically used fibers are glass fiber, carbon fiber, polyamide fiber (Kevlar) and metallic fibres. Many of these fibers are expensive, but they create remarkable properties. (Kula & Ternaux 2009, 74).
b) The most common matrix materials are thermoset or thermoplastics. There are for example epoxy resins, metal matrix materials, carbon matrix materials and ceramic matrix materials. (Kula & Ternaux 2009, 74-76). Lately there have been lots of development of composites made of natural reinforcements like wood fibres, plant fibres, starch, flax. Matrix material is traditional or biobased. Biobased matrix means oil derived from plants.

Sandwich structured composites are common composite materials. Sandwich structure is built of at least two elements: Facing material, which is visible outside and inner core material. Facing material gives the composite its stiffness. Core material and its structure define the characteristic of the material. (Sauer 2010, 41). Depending on usage purpose of the materials, third element can be decorative layer. Sandwich materials often have excellent acoustic and thermal insulation properties. (Sauer 2010, 27). Sandwich materials can be made from one material or from many different material combinations. (Sauer 2010, 41). Common sandwich composites used in interior design are for example laminates where kraft paper and polymer sheets are combined as decorative layer. (Kula & Ternaux 2009, 76)

In nature occures often foam structures. They are robust, stabile, lightweight, have good insulating and acoustic properties. Foams are created e.g., by using some foaming agent (gas, air), granules with air chambers inside or creating a negative mold with granules that melt away. Foams are made from e.g. wood, glass, metals and ceramics. (Sauer 2010, 37-41)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Pictures 37-40. Different types of composites.

4.3 Sustainable material classification

On the way to more sustainable material use maybe the material classification should be changed too. In sustainable material classification materials are divided into groups by their ecological properties. It is possible that one material could be included to more than one class. Here are mentioned few classes that are relevant for the thesis.

4.3.1 Re-materialisation

Growing trend in materials is re-materialization. Especially in future giving a new life to already used materials is essential.

Re-materialization used to be very common before industrialisation. Today it is more common in poorer areas of the world, where all raw materials are valuable. For example people collect valuable materials from waste in landfills to sell it.

According to Sauer (2010, 193) a person living in industrialized country produces over 50 metric tons of waste during the lifetime. Most of the waste is still produced by building industry although it has managed to reduce waste amounts. Building industry is already using lots of recycled materials. For example steel production already uses 45% of scrap steel.

Regrown materials are creating new future possibilities. Grown material is fastly renewable and usually easy and harmless to dispose. Their production consumes less energy than non-renewable materials. The old methods of using natural materials in construction are now applied back to ecological buildings. Materials like flax, hemp, sheep wool, grass, and seaweed can be used as insulation and are produced into industrial products. (Sauer 2010, 216-220).

Besides the traditional ones, new types of materials are developed. United States based company Ecovative Design growns e.g. insulation boards and packaging materials out of fungus. (Sauer 2010, 220).

Into re-materialization is included
(Sauer 2010, 193)

Reuse
materials are used as they are for second time without processing. They can remain same purpose or have completely new one.

Recycling
the material into something completely new.

Renewable or regrown material
are usually plants or their constituents. Typical for renewable and regrown materials is that they are from fast-growing sources, are easy to replace and are easy to dispose for example by composting.

Picture 41. BIO-LUMINUM™ made from 100% post-consumer recycled aluminium from reclaimed aircraft parts.

4.3.2 Biobased materials

One of the most emerging areas of materials is biomaterials. Some of them could be even called re-materialisation. Materials are biobased when it contains 20-100% renewable resources (Peters 2011, 32). Automotive and other transportation industries are already replacing metal and conventional plastic parts with biomaterials to decrease weight and improve recyclability. Most important groups of biomaterials are bioplastics and biocomposites.

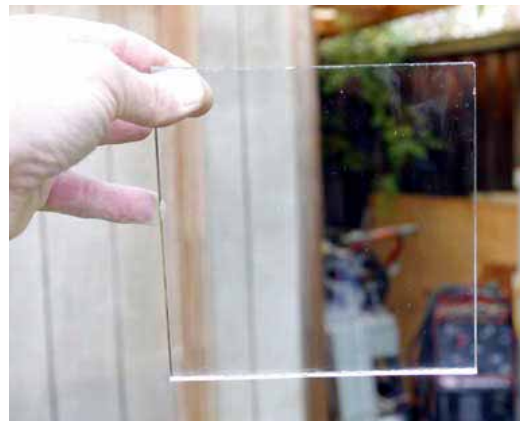
Bioplastics

Bioplastic is probably the fastest developing and most common area of biomaterials. They can be used for many purposes. The renewable sources vary and new ones are appearing all the time. Most common ones are starch, cellulose, vegetable oils, lignin, algae. It is estimated that in future oil will loose its significance in plastic production. Forecasts say that annual growth of bioplastics until 2020 is approximately 20-30%. Besides packaging industry, automotive industry is one of the largest users. Usage of bioplastics in automotive industry has increased between 2005-2010 by 380%. (Peters 2011, 32-33)

Table 3. Forecast trends in bioplastics up to 2020, consumer goods industry and automotive industry (Peters 2011, 33)

	Consumer goods industry	**Automotive industry**
Total market 2005	1,8 to 2,7 mio tons plastic consumer goods	Total amount plastic in vehicles 800 000 tons Approx. 400 000 tons plastic as interior vehicle fittings
Bioplastics, t	2005: < 100 tons 2010 forecast: 24 000 tons (1% of total market) Forecast 2020: 290 000 tons (10% of total market)	2005: < 10 tons 2010 forecast: 48 000 tons (10% of vehicle interior fittings) Forecast 2020: 230 000 tons (40% of vehicle interior fittings)
Bioplastics, €	2005: < 300 000 2010: 35 meur 2020: 440 meur	2005: < 30 000 2010: 72 meur 2020: 350 meur
Market growth	2005-2010: > 160 % 2010-2020: ~ 29 %	2005-2010: > 380 % 2010-2020: ~ 17 %

Examples of bioplastics



Picture 42. Acrylic glass made of sugar.

Acrylic glass from sugar. Researches have been able to produce acrylic glass aka "plexiglass" out of natural raw materials like sugar, alcohol and fatty acid. Now researchers are trying to produce acrylic glass by using an enzyme found in a bacterial strain. The acrylic glass from renewable resources has same properties as traditional acrylic glass. It is clear and does not splinter. (Peters 2011, 43)

Picture 43. Alginsulate.

Algae-based bio-plastics. Technical University of Graz in Austria have been successful in growing an alginsulate foam out of fast-growing algae. It can grow even one meter per day. Its production does not produce any air pollutants and requires only air for foaming. In the end-of-life it can be safely composted or recycled with waste paper. Alginsulate does not dissolve in water and is not vulnerable for fungi, mold or insects. It has good flame resistant and thermal insulation qualities. It is seen as possible future material in car interiors, building products and replacing EPS. (Peters 2011, 41-42)

Picture 44. Alginsulate.

Bioplastics based on cellulose. Cellulose can be found on cell walls of every plant. It is a natural biopolymer and suits well for producing translucent components. Typical applications are different handles e.g. for tools, spectacle frames, vehicle steering wheel covers and toys. There are for example cellulose acetate foils in flats screen monitors and displays. (Peters 2011, 38)

Picture 44. Moniflex, an insulation panel made of cellulose, was used already 60 years ago in trains (Peters 2011, 38).

Biocomposites

In biocomposites materials at least one of the substances is from natural origin (Harlin et Al. 2009, 56). The reinforcement of biocomposites is based on natural fibers from plants (cotton, flax, hemp, jute or cellulose). The matrix is made either from conventional synthetic thermosetting and thermoplastic materials or from natural plants (starch, lignin, vegetable oils). Natural-fiber-reinforced polymers are up to 30 % lighter than conventional fiber composites. Also their manufacture is less energy consuming than glass or carbon fiber. (Sauer 2010, 22)

Demand for biocomposite materials are growing in Europe. In 2010 there were used 2.4 million tonnes of composite materials. By 2020 this figure is supposed to increase to 3 million tonnes. Share of biofibers in European composite industry is predicted to grow from 13% in 2010 to 28% in 2020. Production will grow from 315000 tonnes to 830000 tonnes. Most remarkable growth is happening in extruded and injection moulded natural fiber parts (flax, jute, kenaf, sisal and cork) used for example in construction and automotive industries. Currently their use is very small, 5000 tonnes in 2010, but it is estimated to grow 20-times bigger to 100000 tonnes by 2020. Use of wood plastic composites (WPC) is going to triple from 120000 tonnes to 360000 tonnes. Typical industries using WPC are construction, automotive and furniture industries. (Eco Composites 2012)

Currently construction industry and automotive industry form main markets for biocomposite materials. Applications in other industries have been limited. Restricting legislation especially in Europe is seen to increase of use of biocomposites. Especially in automotive industry End of Life Vehicle (ELV) directive and electronic industry Waste Electrical and Electronic Equipment (WEEE) Directive are driving companies to find new materials. Biocomposites offer more sustainable alternative for traditionally glass-fiber reinforced composites.

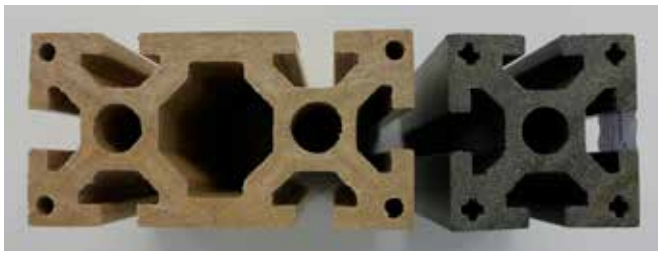
Biocomposites greatest impact on environment usually stems from used polymer matrix, which can be synthetic or natural. Despite the matrix, biocomposites in general are sustainable when considering end-of-life phase. Natural fibers are easier to recycle, reuse and some of them even biograde. Biocomposites often win in other lifecycle phases too: production consumes less energy & water and they are lighter than traditional composites. Manufacturing techniques of biocomposites are mainly based on existing techniques so they are easy to apply (Harlin et Al. 2009, 57).

Picture 46. Sustainable plastic manufacturer Cereplast has made plastics from algae.

Most common biocomposites are plastics reinforced with natural fibers, wood-plastic composites or wood-polymer composites and cork-polymer composites. (Peters 2011, 32, 44). Biocomposites are made from almost anything that is locally achievable, for example almonds, coconut, algae and banana leafs.

Examples of biocomposites

Natural Fiber Composites (NFC). NFC contain fibers from plants like hemp, flax, kenaf, abaca, coconut, jute, ramie, sisal and even carrots. NFC is a cost-effective replacement for technical plastics like ABS. NFC can be made completely oil-free and biogradable. So far NFC has been used in products like helmets, profiles, car parts (door, rear shelves). (Peters 2011, 55)



Picture 47. NFC profieles made by Hiendl.

Wood Plastic Composites (WPC). One of the developing areas of biocomposites. Wood plastics contain usually 50-90% wood fibers. Fibers are mixed with plastics like polypropylene (PP) or polyethylene (PE). (Sauer 2010, 223). In future the plastics can be replaced with vegetable based plastics (Lindfors 2012). There are several different kinds of wood plastics and many producers. In general WPC is used in casings for electronical equipment, handles, furniture, outdoor surfaces, building components and car interiors. (Peters 2011, 44). WPC has good acoustic qualities, rigidity and bending strength, and moisture resistance.

Picture 46. Fibrowood for automotive industry made by Johnson Controls

Linoleum is an old innovation, which is predicted to experience comeback in becoming years. It is made of natural materials like linseed oil, natural resins and color pigments. Linoleum is suitable for spaces with high hygienic requirements and is non-slip surface. Linoleum is durable, compostable and but not suitable for wet rooms. (Peters 2011, 57)

Picture 49. Linoleum stairs.

4.3.3 Lightweight materials

Lightweight materials are becoming more popular especially in construction business and transportation industry (aviation, automotive, rail, space). Many light materials used in transportation industry are expensive and often hard to recycle creating increasing amount of hazardous waste on landfills. Legislation and regulation require better recyclability. Another perspective is that fuel prices are rising. At the same time CO2 emissions need to be decreased. These two things have lead to a need to decrease fuel consumption. In construction business requirement for zero-emission and passive house building are increasing the popularity of more ecological material sources and material in lighter weight. Light weight is good in many ways. Naturally it decreases energy consumption in usage phase, but it usually lowers energy need in other phases too, like manufacturing and transportation. Many times lighter materials need less material resources. Lightweight materials are often composites. Most common way to make material lighter is to have hard surface and light core materials. Good examples of these are honeycomb-structures.

Metal foams were invented already 30 year ago. There are two types of foams: open and closed-cell foams. Metal foams can be made of any type of metal. It is rigid, lightweight and provides air purifying, sound and heat absorbing properties. Metal foams are mainly used in vehicles. Foams can be made of ceramics too. Ceramic foams are used building industry, aircrafts and space travel. (Peters 2011, 103-104)

Examples of lightweight materials

Picture 50. Metal foam.

Hollow sphere structures has been used in industrial context and could be used in future in architecture and design. Hollow sphere structures are suitable e.g. crash absorbers, sound absorbers and light weight reinforcement elements. Hollow sphere structures can be made almost from any metallic or ceramic material.

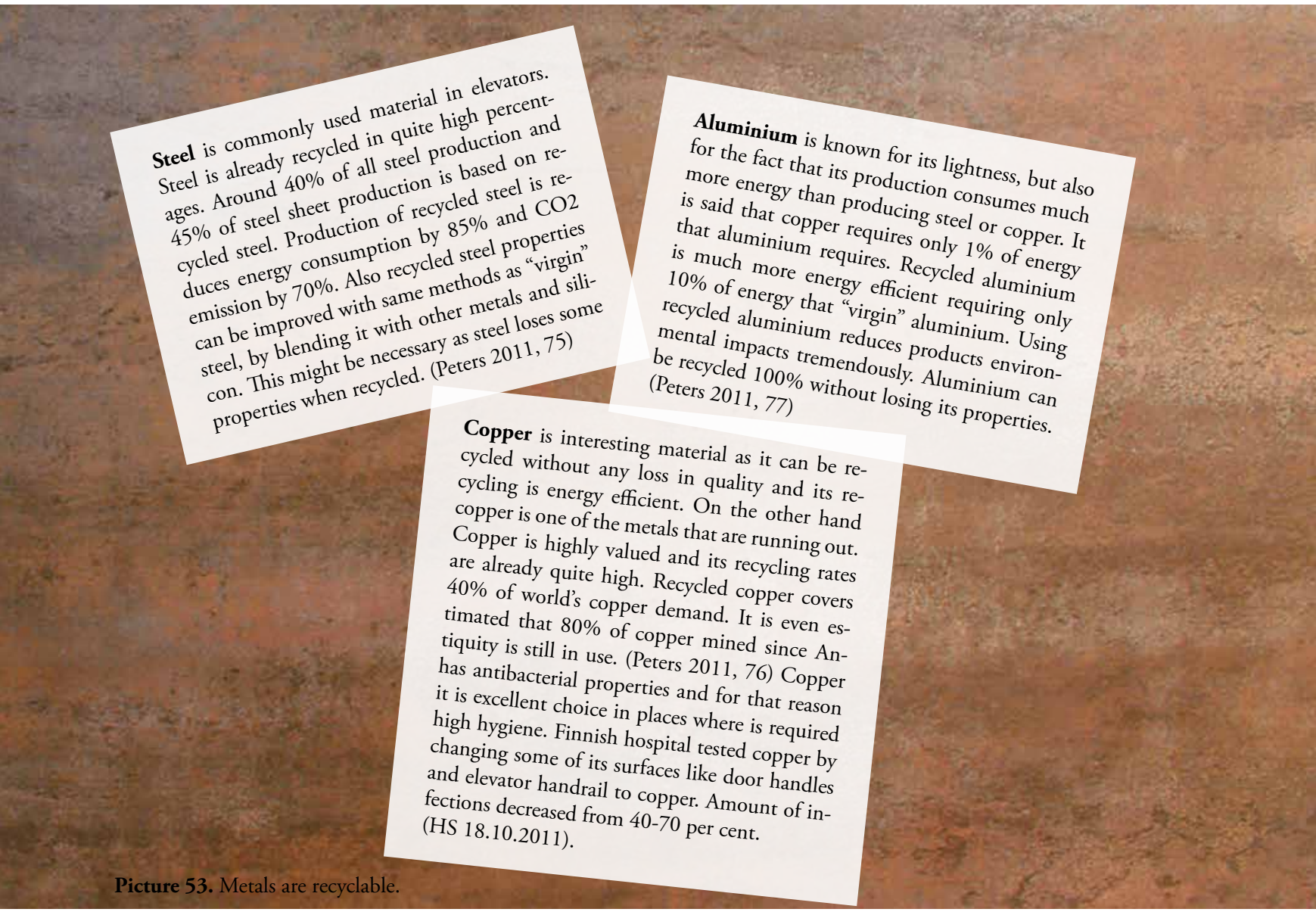
Picture 51. Hollow sphere structures.

Basalt fiber-reinforced materials. Basalt is a volcanic stone containing fibers that can be extracted. Basalt fibers are used for example in aviation, automotive and building industry as an alternative for metal parts. Basalt fibers are light, rigid and chemical resistant. Basalt is naturally sourced and recyclable. (Peters 2011, 101)

Picture 52. Hanging chair made of basalt.

4.3.4 Recycling metals

Recycling materials is becoming more and more important, especially in those areas where world is running out of them. Often attention is paid to oil resources, but rarely it is talked of metals that are running out. Some of them, like gallium, neodymium, titanium and indium, are very important for future technologies. These are used in energy efficient flat screens and hybrid vehicles. (Peters 2011, 70). Producing metals from scratch takes lots of natural resources. They need to be mined from ores that means lots of resources are wasted before even getting the actual material from the ground. Metals consume much energy in production phase. Good thing is that metals are easy to recycle.



Picture 53. Metals are recyclable.

4.4 How to choose sustainable materials?

Choosing sustainable materials is not easy. There are many aspects that need to be taken into consideration and often one sustainable aspect is not good for another. For example some material might have very high-embodied energy in production phase, but its qualities in usage phase might make product long lasting or material maybe lighter in weight, which decreases energy consumption.

Ashby confirms the common understanding that eco-properties are hard to measure. First of all, eco-properties are missing comparable international standards and guidelines. It is very easy to collect basic information on materials and engineering properties. There are international standards, handbooks and databases to indicate those. Existing international environmental standards related to eco-properties, e.g. ISO 14040, are considered hard to apply and they are quite vague. Secondly, there are so many factors that have influence on materials eco-properties that it is very difficult to create comparable standards or guidelines. There can be a large difference between materials embodied energy or carbon footprint. Decision making is harder when the difference is small and other material attributes such as recycled content, durability and recyclability become more significant. (Ashby 2009, 266). There is also a third problem with sustainability measurements, which Ashby has not mentioned. It is the variety of different kind of certifications, labels and standards. Everyone is trying to develop their own label and most of them are unknown for consumers. Some of the labels are acknowledged and taken their place on markets. Still often labels, certifications and standards behave like fashion. They come and go. Certain sustainability topics are fashionable for short period and then it is overruled by a new topic, but the actual problem has not disappeared. Think for example how ecological rucksack was talked about 5-10 years ago. Today CO2 emissions, carbon and water footprint et cetera are more popular topics.

Picture 54. Zelfo is a sustainable material.

4.5 Sustainable materials

There different definitions for sustainable materials. According to Fuad-Luke's definition ecomaterial is "one that has a minimal impact on the environment but offers maximum performance". (Fuad-Luke 2009, 278)

According to Ashby's definition only sustainable materials are those that are truly renewable. It means that natural resources used for material grows as fast as it is used or it reverts to its original state in an acceptable time. Challenge is that not many materials can meet these constraints. Ashby mentions wood and natural fibers like hemp and cotton as an example. Problem with these are that currently forests are cut too fast and trees do not grow as fast as they are consumed. Using natural fibers like hemp takes land from farming food. Ashby also names group of quasi-sustainable materials. By those he means materials that are often considered sustainable because there is so large resource base that they are not exhausting. These kinds of materials are for example iron and aluminium. Processing natural resources into materials consume energy no matter how sustainable or renewable it is. Excessive energy consumption combined with unsustainable power production are key elements in current environmental problems. That is why materials embodied energy is often compared and considered, when choosing materials (see table 4). The deeper from the crust raw materials are mined, the more energy is consumed and waste is produced before they are usable. (Ashby 2009, 240-243). It is also good to remember that energy prices are getting higher meaning that energy intensive materials are likely to get more expensive.

In this thesis it has been mentioned often that world's energy need is increasing. Almost all energy currently produced is based on fossil fuels. Only few countries in world have large reserves of fossil fuels on, which the rest of the world is depended on. (Ashby 2009, 258). It is admitted that these reserves are running out, but it is unsure when this will happen. For example UK Energy Research Council estimated in its Global Oil Depletion Report (2009, x) that it is likely that peak in conventional oil production will happen before 2030 and there is a significant risk that it will happen already before 2020. But at the same time new wells are found. In entire world energy is mostly produced in unsustainable way. Many say there are not enough renewable sources to provide all the energy world needs. There are also controversial ways to produce energy, like nuclear power. It might reduce carbon emission, but the possible accidents and released radioactivity are very damaging for people and environment.

Ashby categorises two kinds of influences that are driving materials and design in near future: concern-driven and opportunity-driven influences (see next page).

Chart 18. Influences that drive materials and design in near future. Adapted from Ashby 2009, 257, 259-260.

4.6 Principles to select materials

Many books provide guidance on how to select sustainable materials. There are simplified and more complex models. In the end they usually ask similar type of questions. Ashby has created principles on how to select sustainable materials. In his material selection strategy there are five steps, which are presented in adapted figure below. (Ashby 2009, 165-166)

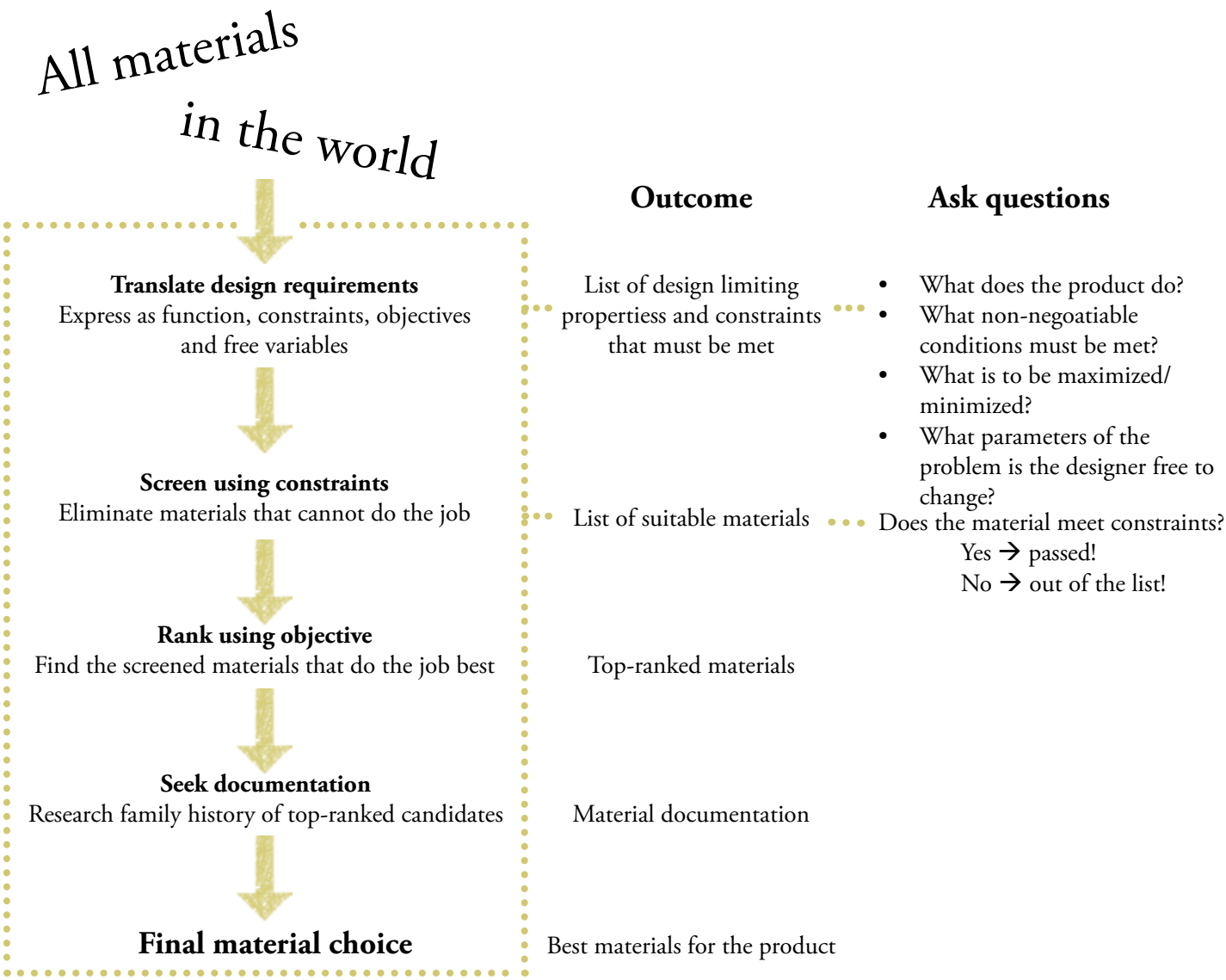


Chart 19. Principles to select materials. Adapted from Ashby 2009, 165-170

Below, there are compiled questions that many books on sustainable material selection have listed. These questions could be used also when Ashby's strategy is applied. Questions help to define material contraints and objectives. Questions are based on books by Sian Moxon (2012, 92), Fuad-Luke (2009, 278), Nadav Malin's article in Green Design book (2011) and Lettenmeier & Autio (2002, 70) book on eco-efficiency.

- Will it look and feel good?
- Is it affordable?
- Is it from a renewable source?
- Does its production have low environmental impact?
- Does it have low embodied energy and water?
- Does it have recycled content?
- Is it reused or reclaimed?
- Can it be reused or recycled at the end of the project?

- Will material serve its purpose?
- Is the material needed?
- Does it improve performance?

- Can materials with high environmental impact be replaced?
- Is it possible to save material by simplifying production methods?
- What is the most simple possible material composition for the product?
- Is weight of the product lowest possible?

- Is the material easy to get, in sufficient quantities near the location?
- Is it sourced and processed near the site?
- Is it non-toxic and low emitting during installation and use?

- Does it have minimal or recyclable packaging?
- Will the material last long enough?
- What will it take to keep material clean and functional?
- Do its application, treatment and finishes have low environmental impact?
- Does it require little maintenance or cleaning, and by non-toxic methods?

As said earlier one important medium to compare materials is their embodied energy. Fuad-Luke presents in his book a table for most common materials. The table suggests that more industrial processing means more embodied energy. That is why many traditional composite materials and metals embody much energy.

Material	Typical embodied energy, MJ/k
Ceramic minerals (stone, gravel)	2-4
Wood, bamboo, cork	2-8
Natural rubber	5-6
Cotton, hemp, silk, wool	4-10
Wood composites (particle boards)	6-12
Glass	20-25
Glass fiber	20-150
Carbon fiber	800-1000
Titanium-carbide matrix	600-1000
Alumina fiber reinforced	450-700
High-density aluminium (foam)	300-350
Carbon steel	60-72
Aluminium, cast	235-335
Copper	115-180
Gold	5600-6000

Table 4. Examples of embodied energy in different materials. Adapted from Fuad-Luke 2009.

Another interesting way to compare materials with each other is to use MIPS (Material Input per Service unit). MIPS is developed by German Wuppertal Institute. In nutshell its idea is to calculate how much raw materials, energy and so on is consumed to produce one one kilogramme of the material. Wuppertal institute provides material input (MI) factors to help with calculating "the ecological rucksack" for products. Ecological rucksack means the real amount of natural resources that is needed to make one product.

MIPS is calculated for five categories of natural resources: abiotic raw materials, biotic raw materials, water, air and soil movements in agriculture and forestry (SLL 2013a). MIPS is a great tool to open eyes and share easy-to-understand information, but it has not succeeded in becoming a popular tool among companies and consumers. Calculating ecological rucksack is complicated. For example all MI factors are mostly calculated for European and German conditions. Some MI factors should be always country-specific and this can cause lot of work or produce misleading information. If competitors are not providing ecological rucksack, products are not comparable. If the rucksack is "heavy", it can also create negative image.

It is still interesting to know how many kilogrammes of natural resources are needed to produce one kilogramme of material. On the next page, a few examples of materials has been listed. Factors presented are in simplified form. More specific and up to date factors can be found on Wuppertal Institutes webpage.

Table 5. Examples of simplified MI factors. (Autio & Lettenmeier 2002, 66-67)

Material	MI factor kg/kg
Aluminium, virgin	85
Aluminium, recycled	3,5
Aluminium, 30% recycled	61
Silver	7500
Chrome	13,5
Gold	540000
Copper, virgin	500
Copper, recycled	10
Copper, 40% recycled	300
Iron	5,6
Steel	7
Steel (17% Cr, 12% Ni)	24
Platinum	320000
Palladium	400000
Diamond	5300000
Concrete, B25	1,3
Concrete, light 500kg/m3	2,3
Granite, polished tile	1,9
Plywood	2
Spruce, stave	2,2
Beech, in furniture	7,1
Epoxy resin	13,7
Cork	14
Rubber	5
Linoleum	2
Paper	15
Cotton	22
Cellulose	12
Water	0,01
Electricity (Finland)	0,41
Electricity from windmills	0,07
Transportation, road	1
Transportation, train	0,9
Transportation, sea	0,006
Tranportation, air	2,5
Waste handling at landfill (Austria)	1,1

4.7 Benchmarking transportation industries

Automotive industry like manufacturers of other transporting vehicles e.g. airplanes and trains, have high interest in decreasing fuel and energy consumption. One way to do this is to decrease vehicle weight. At the same time they need to pay attention to safety and costs. (Harlin et Al. 2009, 58). Requirements for vehicle materials are strict. These perspectives are similar to elevator industry.

Due to European Union strict policies to decrease waste and CO2 emissions, automotive industry has been improving car design towards sustainability. European Union (EU) published already in year 2000 End Of Life Vehicle (ELV) Directive that is affecting all manufacturers in Europe but also outside Europe who want their vehicles to be sold in Europe. This is how European directives are powerful way to influence product design. Previously similar directives have "changed" design world through WEEE and RoHS (The Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment).

ELV Directive aims to reduce the waste from vehicles. Other purpose of the directive is to improve reuse, recycling and recovery of end-of-life vehicles and components including materials used in these vehicles. Directive also forces manufacturers to use recycled materials. (Europa 2011). ELV directive has set following targets for vehicles that they should meet by 2015

- The rate of re-use and recovery should reach 95.
- The rate of re-use and recycling should reach 85 %.

(Europa 2011)

The directive is seen as part of extended producer responsibility (EPR) policy that already involves many industries individually or cross the industries, e.g., electronics and electrical goods, energy using products, batteries, packaging waste. In the future, extended producer responsibility could easily expand to many other industries that produce waste that can be considered hard to dispose, for example furniture and construction industry.

Automotive industry has long history of concept cars where technological innovations, inspiring designs and new features are introduced to public. No other industry is so enthusiastic to show new concepts. Concept cars do not usually end up into production as they are, but some of the properties might very well do that. Next it is explained what kind of ecological concept cars in materials perspective has been introduced in recent years. Most of car manufacturers develop ecological car concepts. Great deal of them rely on new sources of energy. Amount of composite material has been increased to lower the weight. Another big trend is small electric vehicles. It is overwhelming how many projects around the world aim at developing small, electric cars for short distance travelling.

Ford Soybean Car

Metal has been dominative material in automotive industry, but sourcing for an alternative, lighter and cheaper material has been an interest for long time. Revolutionary Henry Ford researched a possibility use plant based plastics in car. There were couple of reasons why Ford started the research. First he wanted to combine innovations of industry with agriculture. Secondly, he thought plastic was safer material than steel. Third, during the time there was shortage on steel and he was hoping to find a replacement for it. In 1941 Ford introduced "The Soybean Car", which had tubular steel frame with plastic parts attached to it. The car weighted 1/3 less of what traditional steel car at the time weighted. The formula for Ford's plastic is unknown, but has been rumoured to contain plants like soybeans, wheat, hemp and ramie among other ingredients. The Soybean Car never made it to the production due to World War II, which suspended all car production. Unfortunately also the prototype has been destroyed. (The Henry Ford 2012). Besides soybean car, Henry Ford developed other materials too. In 1920s he introduced Fordite including for example wheat straws and it was used in steering wheels. (Ford 2009)

Picture 55. The soybean car and its proud driver.

EDAG Light Car - Open Car

EDAG is company working with automotive, commercial vehicle, aerospace, rail and renewable energies industries. (EDAG 2013a). In 2009 EDAG released "Light Car – Open Car" concept. The Concept car works on electricity and is widely using OLED technology throughout the car. It d has wide possibilites for personalizing. For example, driver can modify a personal cockpit like a computer desktop and create unique appearance for the car by designing shape of head and rear lights. Car-to-car communication is possible through OLED screens in rear window. Its communication includes traditional breaking light warnings and e.g., sharing safety information like if there is a pedestrian front of stopped car or a traffic jam. (EDAG 2009a). Car is made lightweight by using basalt fiber composite. Car chassis is 100% recyclable. Last but not least, Light Car is open source idea. EDAG has set it as platform and source of innovation. Partners can integrate their technology into the vehicle. EDAG is constantly looking for partners to develop the concept further. (EDAG 2009b). Since 2009 EDAG has released new version of the concept annually. Year 2011 concept was concentrating on rental car system.

Picture 56. EDAG and its communicative rear window.

Mercedes-Benz

Mercedes-Benz BIOME concept car was shown in Los Angeles Design Challenge. The idea of the concept was to create an ultralightweight car that is in symbiosis with nature like leaves in tree. The car would be grown in Mercedes-Benz "nursery" from a material called BioFibre. It is a material that does not exist yet. BioFibre would be lighter than currently used metal or plastic, but stronger than steel. It is biogradable. This means that car could be composted after usage. Car would be from "the DNA" in "the Mercedes Star". Customers can modify the star to its requirements and vehicle is grown according to these genetic codes. If it did not get too futuristic yet, the fuel solution does so. BIOME runs on "BioNectar4534" which stored in BioFibre. BioNectar4534 is a fluid that is formed through energy from sun and chemical bonds. BIOME releases only oxygen. (Williams 2010).

Picture 57. Futuristic BIOME mock-up in LA car show.

BMW

BMW released GINA light visionary model in 2008. During the process was asked questions like "Why do we need to rethink automotive construction?", "What are people's expectations of mobility in the future?", "Does the body shell have to be made of metal?" At least to last question answer is no. Securing safety can be made in another way. (BMW 2012). As an end result was created GINA, car like a sculpture, made out of fabric where surfaces form smooth entity. Fabric is stretched on movable metal frame. Driver has opportunity to change car shape. Fabric is polyurethane coated Lycra, which is resilient, durable and water resistant. Fabric is opaque so lights shine through it. Using fabric has many sustainability aspects. First it creates really a lightweight structure decreasing energy consumption. Secondly it reduces materials consumption, for example painting is not needed, and production and assembly need less resource. Transportation is less consuming. (Peters 2011, 214).

Picture 58. GINA's light shine through the fabric.

Picture 59. Zip it!

Lotus Eco Elise

In 2008 Lotus released the Eco Elise project. Eco Elise project paid special attention on sustainable materials and technology. Renewable materials contain hemp, eco wool and sisal. Composites in body panels were made of locally farmed hemp and car's lightweight seats contain hemp too. (Lotus 2012)

Pictures 60 (right), 61 (left). Realistic looking Lotus Eco Elise is made of renewable materials. Solar panels on roof provide energy.

Urbee

Canadian KOR EcoLogic is developing Urbee, a hybrid car for two. It is designed to be inexpensive, easy to repair and running on renewable energy. Urbee has progressive material policy. In the car is used materials that are produced close to where car is build. They use only durable materials that can be recycled many times. (Urbee 2012) In 2010 was released Urbee prototype, which car body was produced using 3D printing. Just like many ecocars from large manufacturers, Urbee is meant for short trips.
(Stackpole 2010)

Picture 62. 3D printed Urbee prototype - in real size.

Peugeot

Peugeot Metromorph concept car was published in 2009. This futuristic concept is a car, elevator and balcony. In Metromorph concept building facades are transformed into vertical roads so everyone can park their car on building facade. Facade has rails on them allowing car to change directions from horizontal driving position to vertical elevator position. Each apartment have individual door to entrance and exit the car. Concept was inspired by the movie Minority report. (Neff 2009)

Picture 63. Metromorph parked on facade.

Picture 64. Metromorph parked on ground.

4.8 Has anyone tried to change elevator cars?

Elevator cars' shape has stayed same almost since elevators became popular. Not many elevator manufacturers have tried redesign elevator car shape. Part of it is probably because elevator business is a business of centimeters and millimeters. All space is very valuable. Naturally there are always unique projects where elevators are designed to look different. For example in Tokyo 21_21 Design Sight Museum, designed by architect Tadao Ando, has an elevator car in shape of trapezoid.

An elevator manufacturer Kleemann Lifts hired industrial designer Andreas Zapatinas to design their Kleemann Design line. In Future Trend collection Zapatinas has given elevator cars a new shape. (Kleemann Lifts 2012)

Pictures 65-68. Future Trend collection by Kleemann Lifts.

THE CONCEPT ELE

Picture 69. General Research Store wall in Nagameguro, Tokyo.

70

71

72

73

74

75

STARTING

76

77. LIFTnewyork provides customized elevators and paintings to the shaft.

78

79.

83.

Pictures 70-75. Fashion inspired by elevators and escalators. Louis Vuitton arranged entire show around escalators and elevators in Paris (pictures 70, 72, 73).

Pictures 76-88. Art and elevators.
79: Maurizio Cattelan. 80-82: Sperone Westwater gallery, New York. 83: Oded Hirsch.
84-88: Leandro Erlich.

80

81

82

84.

85.

POINT

87.

86.

88.

5. Starting point

5.1 Current environmental profile of the elevator

KONE MonoSpace Elevator life cycle analysis shows that most environmental impacts of the elevator are formed during the usage. Second largest environmental impact is materials production with a share of 26,2 per cent. Most used materials in elevator are different types of metals like steel, aluminium and copper. It seems that there is some potential to reduce environmental impacts through materials. Still it must be kept in mind that this life cycle analysis is for entire elevator and the thesis is just considering impacts of an elevator car materials. (KONE Sustainability report 2011, 22)

Because most of the materials used in elevators are metals, it means that elevators are already highly recyclable. Over 90% of elevator car materials can be recycled. At the end of the life cycle, over 50% of the elevator materials can be sorted and reused without pre-prosessing. Recycling reduces need for raw materials. Other car materials are either directed to energy recovery and only few per cent of all waste from KONE is landfilled. KONE sources its materials only form sustainable sources and provides certificates for its customers on a request. (KONE Sustainability report 2010, 34)

Kone has a list of restricted substances. The list includes substances like radioactive materials, lead or cadmium pigments in paints, ozone layer depleting chemicals, mercury (excluding lighting and batteries). KONE is actively working to reduce the use of VOCs in its products and processes. KONE complies with the EU's REACH (Registration, Evaluation, Authorisation & Restriction of Chemicals) directive and is voluntarily working to achieve compliance with the RoHS Directive (The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment). (KONE Sustainability report 2010, 35)

Chart 20. KONE MonoSpace elevator LCA
KONE Sustainablity Report 2011, 22

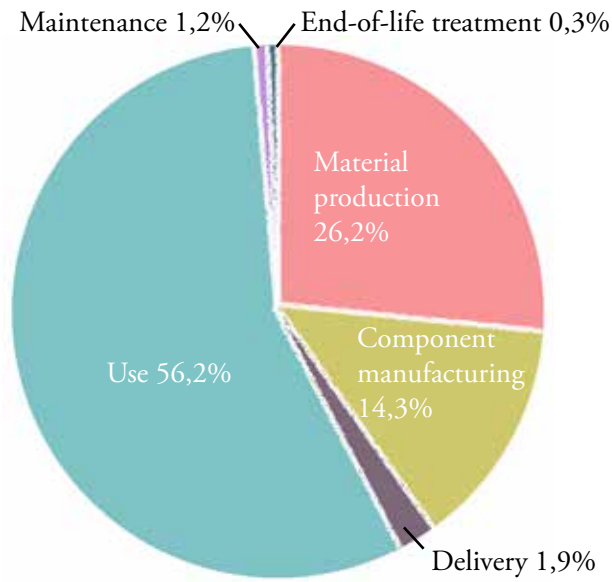
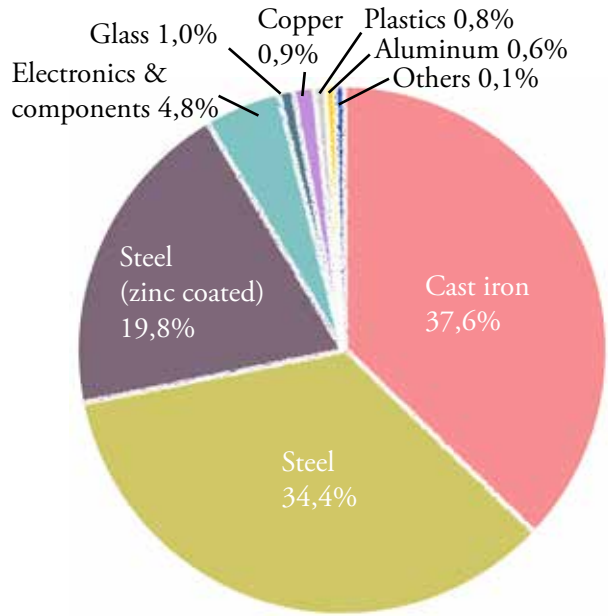


Chart 21. KONE MonoSpace material weight, %
KONE Sustainability report 2010, 35



5.2 KONE Sustainability principals

KONE wants to offer its customers energy efficient and environmentally friendly products that are suitable for next-generation green buildings. Company sees that it has an important role in decreasing environmental impacts of buildings through providing better products. The company is actively involved with in the working groups that define new standards and guidelines for its field and works in cooperation with green building associations. (KONE Sustainability report, 28-29).

KONE lists in Corporate Responsibility Report (2010, 27) as its sustainability principals following topics

5.3 Design elements and ambience

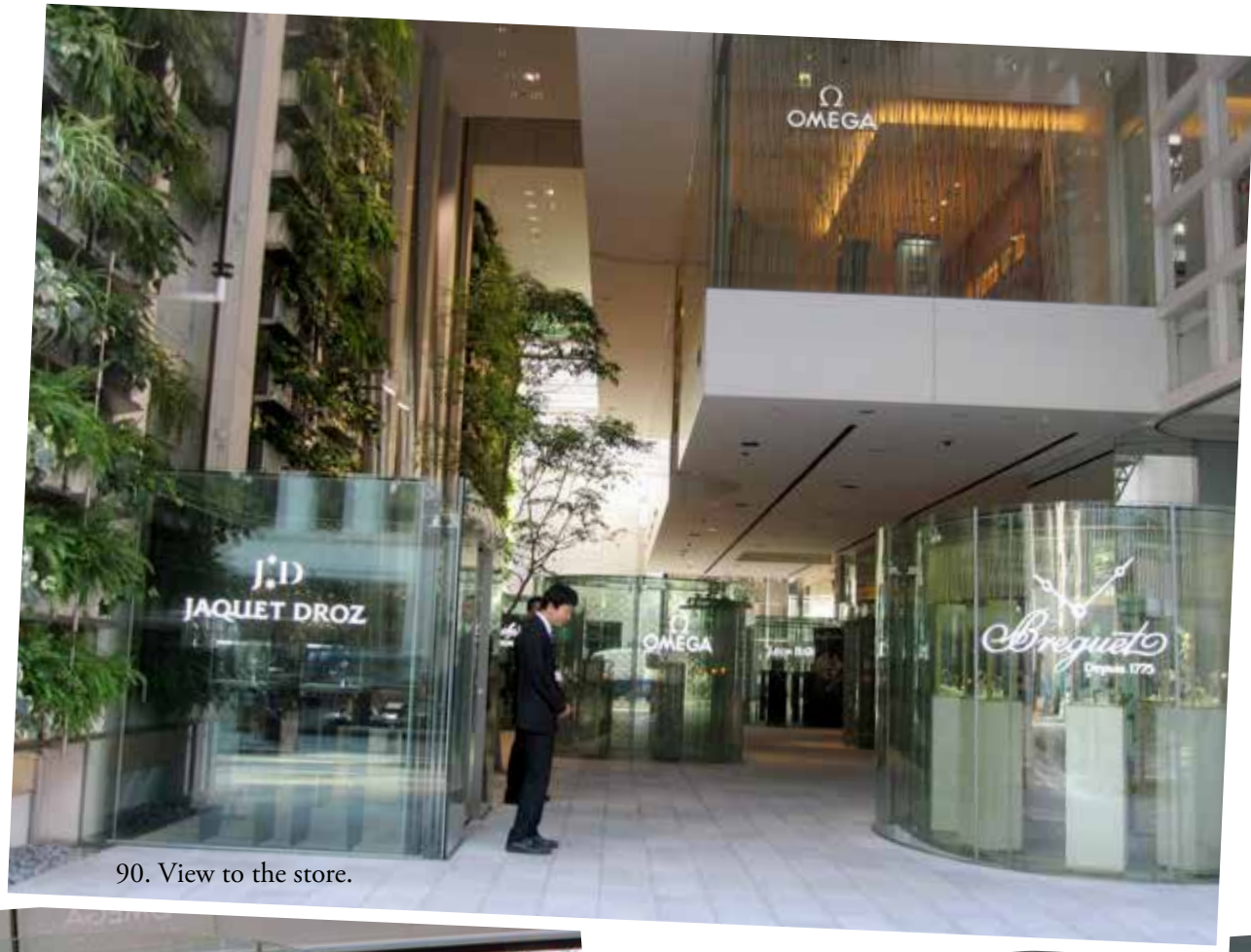
Elevator car interior design is very important part of how elevator is showing to the user. Main goals of elevator car design is to create positive experience for its users. KONE localizes product ambiences to different cultures and markets. Design is a tool for KONE to differentiate from other elevators in the market. Design is used to support accessible, functional and sustainable design. (KONE intranet 2013)

Design objectives at KONE are

- To create functional, safe and aesthetic car interiors to different markets
- To fulfill customer and end-user needs by providing optimal car interior solutions to different segments and architectural contexts
- To strengthen KONE brand with unique design approach in the industry (KONE intranet 2013)

Picture 87. The main design elements of KONE elevator car are colors, materials, finishes in entire car and in addtion:

Chart 22. Mindmap. Some of the first thoughts during the project. Bolded ideas continued to concept.



90. View to the store.

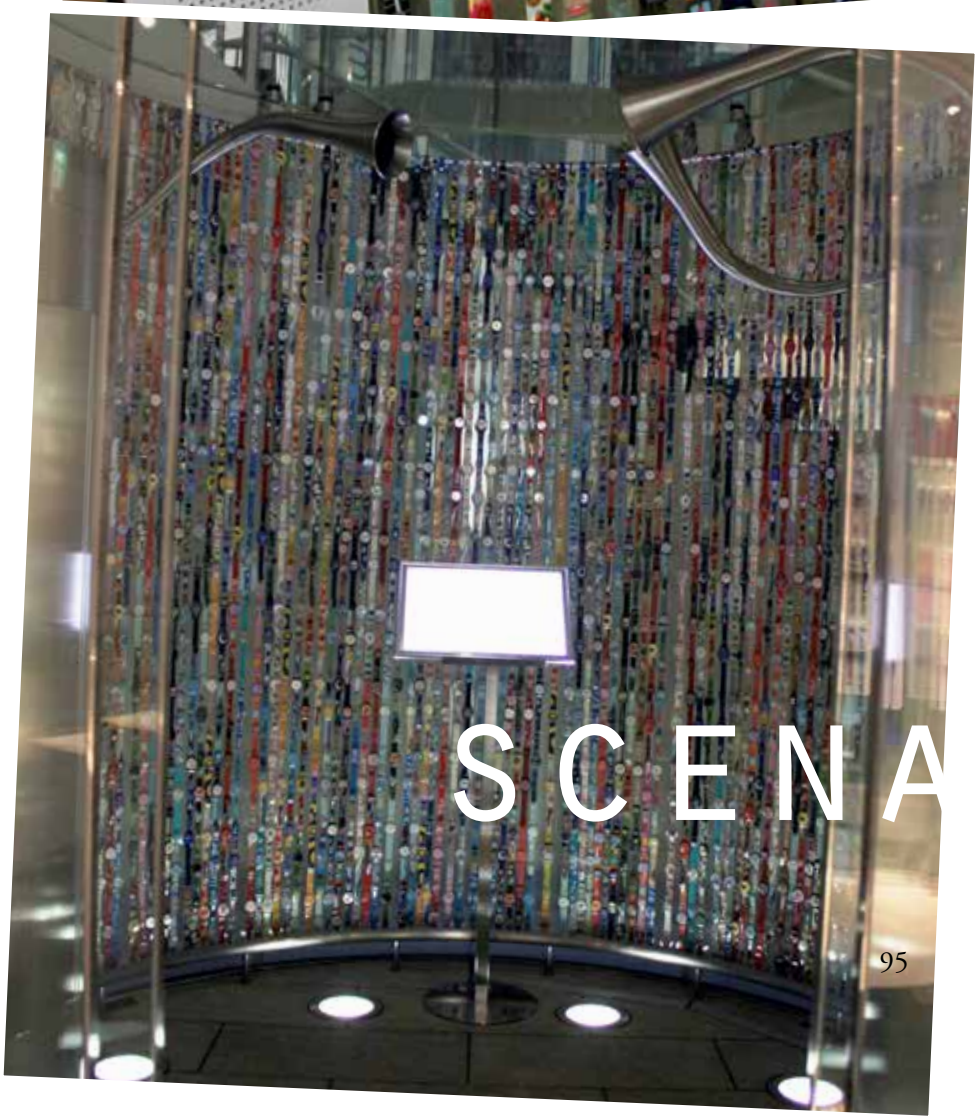
91

92

FUTURE

Pictures 90-96. Nicolas G. Hayek Center in Tokyo's fashionable Ginza area has dedicated own elevator for each watch brand it represents. Seven elevators decorated to match the brand and having small showroom in it takes customers straight to right floor.

93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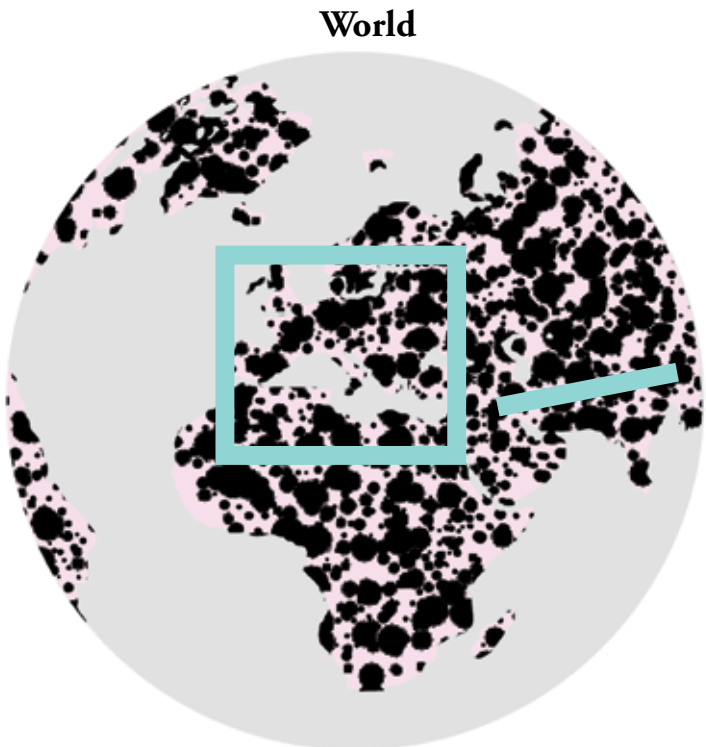
99

SCENARIO

6. Future Concept elevator car 2020

6.1 Future scenario

The elevator concept car 2020 should be forerunner of its time.
That why the concept scenario looks beyond year 2020. The scenario decribes years between 2025-2030.



The eco industrial revolution is happening. Sustainability and transparency in decision-making are becoming standard. Countries are loosing their borders. Power is increasingly used by regional clusters and groups consisting of for example of NGOs and companies. Collaboration is flourishing and people are overcoming cultural differencies.

The world population is getting closer to 8 billion. It will not be long when population is going 9 billion and challenges of feeding all people are getting real. Decision-makers are planning to set regulations to increase popularity of vegetarism. Fresh, drinkable water is “the new oil”.

60 per cent of the population is belonging to middle class. World will soon celebrate one billion people being 60 years or older. People in general are healthier and “older” people are actively involved in society. Retirement age is closer to 70 years.

Markets are rapidly changing due to many reasons. First, middle-class rising in developing areas like BRIC will create completely new balance. Second, companies are large and multinational, but they are still operating locally. “Glocal” business model is new normal. Third, ageing is shaping many products and services.

Cities

Most people have alreay lived in urban areas for a while. Most of the people live in middle sized cities with 1-5 million inhabitants. In BRIC area density is getting extremely high, but Europe has always stayed quite stable.

Cities are forming to multi-centered loops, especially in areas with high density. Project to integrate different regions' infrastructure as one big shared system in process. For example, cities' transportation systems are in process of global integration and it has been agreed to build up an effective worldwide high speed rail system that will fully working by 2050. It is seen as most convenient way of travelling from one region to another. Flights are restricted and becoming inconvenient. Planes take off only, when the flight is full and it means unsure time schedules.

In quite many places cities are smaller villages close to each other. Moving in and between the villages are done using Personal Rapid Transportation system and similar systems, which Masdar applied already in 2012. Cars start to disapper. It's becoming unfashionable to own a car. Parking lots and road are slowly released for new purposes like food production.

Buildings

In 2025-2030 buildings have proved to be efficient way to reduce CO2 emissions. All new buildings in Europe become zero energy buildings by 2020. Now entire construction business is working to improve existing buildings and one by one they are transformed into zero energy buildings. One of the key drivers for development work is the high fines for excessive energy consumption. By 2050 buildings are rather producing energy than consuming it. Building industry's innovation business is flourishing through new opportunities in sustainability. Different types of metering and certifications are mandatory. All development work will result SuperSmart Buildings by 2050.

Increasing density is leading to smaller and flexible apartments. Even concepts of shared apartments are developed in areas with highest densities. Sharing services and spaces with other dwellers is becoming fashionable. Many spaces that were considered private before are now shared. For example, new buildings don't have private yards. Land must be allocated wisely for different purposes like farming own food.

Location of the apartment is important. Principle is to live in walking or cycling distance from work, schools and so on. Old office buildings are turned into apartments, because people work from home offices or shared working spaces. Sustainable interior materials are taking over. Just like organic food and clothing took over before 2020.

Lifestyle

Lifestyle is defined by sustainability. People adapt to sustainable lifestyle that means "to live well in sustainable way within the limits of natural resources". In practice sustainability is mainstream fashion. People do not have to choose between "green and non-green" products. Majority of the products and services are presumably green and those that are not, are loosing their markets. There are weak signals that dematerialisation is becoming worldwide trend. Dematerialisation lifestyle is "Low to No material" living.

Daily life is flexible. People work from homes when they can and virtual work organisations are usual. Ownership has lost its meaning when it comes to consumer goods. When possible, people rather buy services than collect stuff to their homes. Owning doe not have the same value as in early 2000 and the trend is to fulfill the needs by sharing, renting and so on. Services are more and more delivered to homes. Personalisation and uniqueness has entered to new levels through 3D printing. New design rights are currently applied. 3D printing became common early 2020s. Shared printers are everywhere. 3D printing is used for nearly everything. It is part of the reasons why many companies are opening their products for open source development process and different stakeholders are actively involving to that. New worldwide movement is founded. It focuses on collaboration, unity and sustainability beat cultural barriers and state borders.

People's travelling habits are changing. One option is to be modern and use technology for "virtual travelling". More traditional way is to actually go to the destination, but spend there at least a month. Short trips are not an option anymore. It is seen as waste of time and resources. Majority of the world population are practically vegetarians and for most of them it has not been voluntary option. Meat is valued.

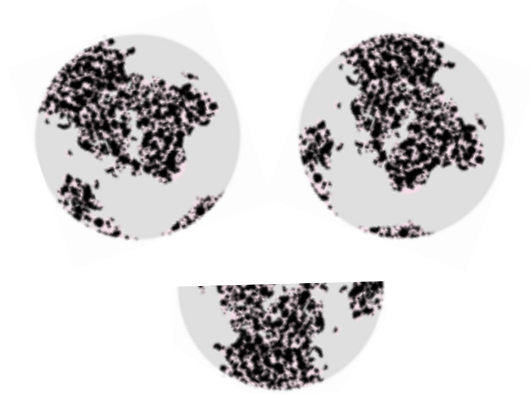
Natural resources and materials

Different roadmaps to 2050 concerning natural resources are becoming reality. There are strong incentives, fines, guidelines and regulations driving natural resource consumption. Little by little consumption is decreasing towards 5-8 tons per person instead of historical 29 tons. World is still not managing to produce what it needs within the resources of one planet, but finally growth is showing signs of slowing down and decreasing. This change is achieved through strong development on improving eco-efficiency of old and new materials. Like for example steel production is consuming half less energy than ten years earlier and same properties are achieved with half of the materials. Graphene has made wonders with many existing and new materials.

Because world is still consuming more than there is to take, many limitations on natural resources must be applied to change the direction to dematerialisation. In land and material use is priorised food and water production for people. Need for water, food and energy is exceeding supply.

Energy production is increasingly based on local, renewable production. Peak oil is just around the corner, but it is not important, because world is not dependended on oil anymore. Consumption of fossil fuels have dramatically dropped.

Regional closed loop systems have made concept of waste obsolete. Recycling systems are sophisticated, all waste is inventoried and accounting includes true value of materials. Everywhere is used local resources and materials are not transportated from another side of the world due to heavy restrictions.



Picture 97. Facade in Naga-Meguro, Tokyo.

Elevators are a service
KONE does not sell elevators. They are leased with long-lasting maintenance contracts. Advantages

- Better control over the elevator during its entire life cycle
- KONE can improve monitoring and maintenance of elevators
- Improved safety
- Elevators are always in excellent condition
- More power in decision-making, e.g., modernisation
- Improved end-of-life process
- Possibility to create 100% close loop system
- Voluntary producer responsiblity already before 2020.

See e.g., page 124.

Picture 98. The machine is large and heavy.

Biomimicry
Biomimicry is applied to different parts of the elevator, not just elevator cars. During 2015-2020 KONE will go through massive Biomimicry R&D project where it will seek better technology and renew products' structures. Project is done in collaboration with biomimicry experts like EliSE. The new structure in products will reduce their weight and they become more efficient in all phases of the lifecycle. See page 124.

Hollow sphere& foam structures
Hollow sphere & foam structures are used in heavy metal parts like machines. Hollow spheres are 40-70% lighter than solid ones (Peters 2011, 113). See page 121.

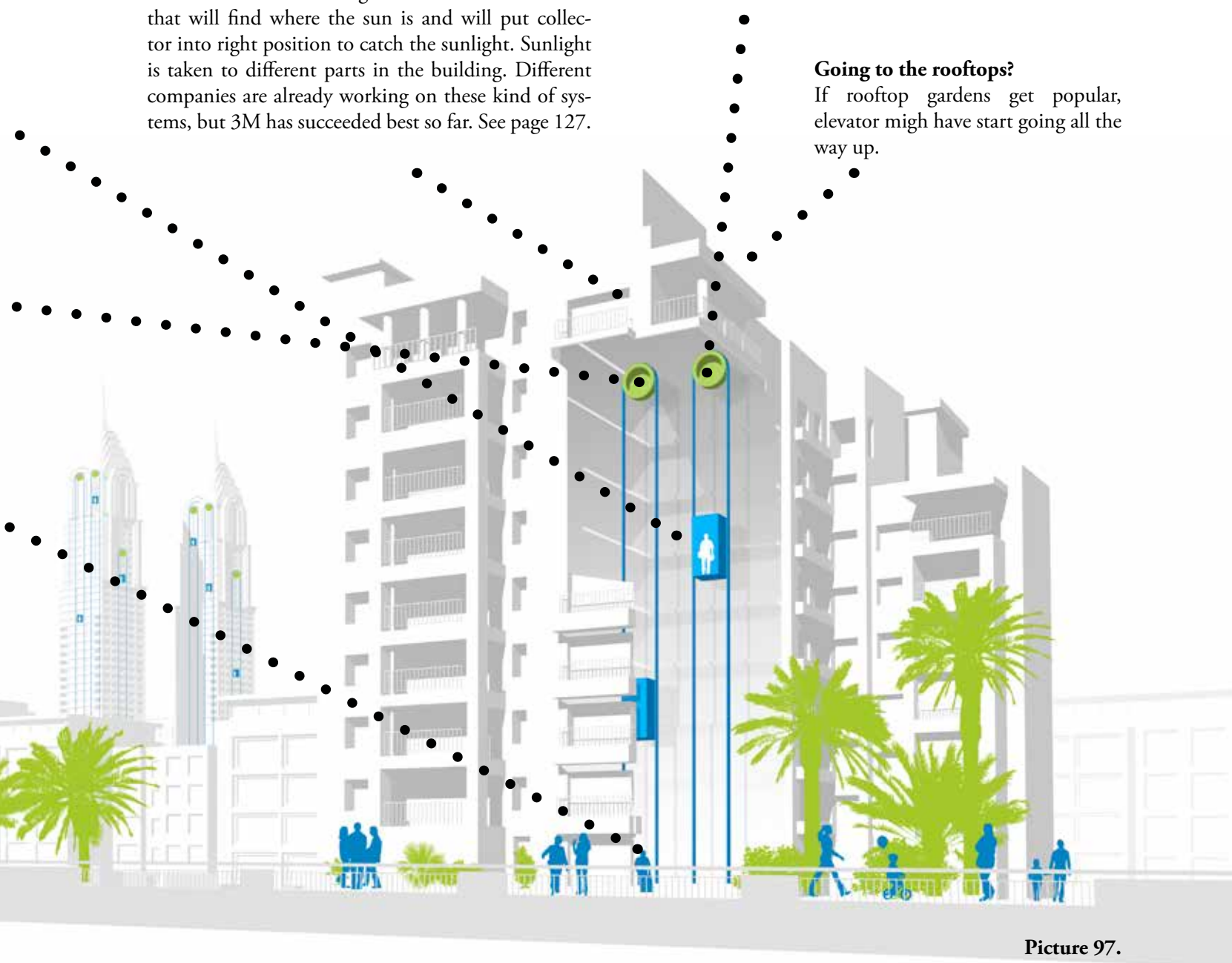
Syncronized with public transportation
Elevator could communicate with public transportation or PRT system. Elevator could be ordered beforehand so it is waiting when one arrives to lobby.

Open source concept
KONE launches an open source concept products to develop revolutionary elevator. Open source includes all parts of the R&D. Partners can test ideas related to technology, materials, eco-efficiency, usability and so on. The open source concept aim at boundary breaking thinking and accelerate the innovation process.

Natural lighting system to the shaft and elevator
Elevators have natural light even if they run in shaft without windows. This is possible by applying e.g., 3M's Sunlight Delivery System. (Anttonen 2013). There is a collector on roof, top of the elevator shaft, which will catch the sunlight. Collector has a detector that will find where the sun is and will put collector into right position to catch the sunlight. Sunlight is taken to different parts in the building. Different companies are already working on these kind of systems, but 3M has succeeded best so far. See page 127.

3D printing
At first 3D printing is applied to spare parts. It decreases material consumption and costs, transportation costs and environmental impacts. It also saves time, because service technicians can print spare parts close to site and there is no need for waiting spare parts from another country. See page 106, 126.

Going to the rooftops?
If rooftop gardens get popular, elevator migh have start going all the way up.



Picture 97.

Lights
Natural lighting system (pages 105, 127).
Light can be integrated anywhere and might be attached also elsewhere than in roof.

Coatings, functional materials
Different kind of coatings are applied to elevator surfaces.

- Self-cleaning coatings and materials are used in places where is much dirt and bacteria. E.g. accessories and flooring.
- Self-healing coatings are added to surfaces to increase longevity of materials and reduce need for maintenance.
- Functional materials can have other purposes too. For example purifying air or absorbing CO2 emissions.

See pages 112, 127.

Three dimensional wall panelling inside and outside
Even standard elevators will have unique design. 3D printing will provide new possibilites for car interior ambience. Architects and designers can 3D print elevator wall panelling close to site. Modularity of the walls can become unnessary. There is no long transportation distances. 3D printing can be applied to accessociers as well. See page 105, 126.

Antibacterial materials
It is already today that markets provide materials with antibacterial properties. Like GranitiFiandres floor tiles. Copper could be applied to handrails and buttons. See pages 76, 112, 127 and above.

Picture 100.

Biobased materials
Elevator car is made from biomaterials. Source for biomaterials come from waste and it is not from food crops. Entire elevator car is made from one material e.g., Zelfo, which comes in many forms and has many properties. Where metal part can not be replaced, it is used lightweigh metals e.g. Hybrix or metals with hollow sphere structures. See pages 71-74, 114, 132.

Renewable energy and zero energy
Energy is sourced frome everywhere: sprayable solar cells, energy harvesting from elevators acoustic noise, vibration and passenger movement. See page 125.

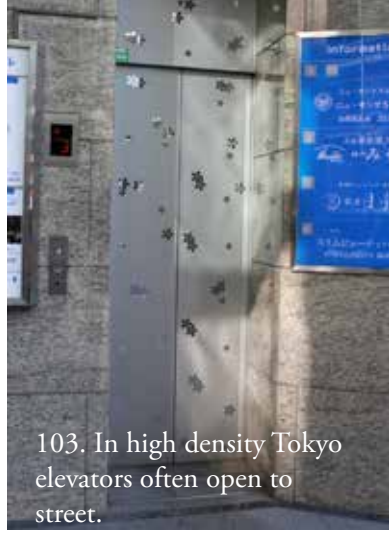
Extremely light materials
Extremely lightweight materials are achieved through biomimicry project. Elevator car with structures weight appromiximately half less than conventional steel box. See pages 104, 124.

Touchless, buttonless
There are no buttons. Users call for elevator and choose floors with hand movements without touching anywhere. Sensors could be placed to more than one spot in the elevator car so it is always close to user (improving e.g. accessibility). See pages 123,147. It is already today that elevators are called beforehand to go to exact floor.

Antibacterial materials
See previous page.

101. White elevator. Tokyo.


102. In high density Tokyo elevators often open to street.


103. In high density Tokyo elevators often open to street.


104. trollers in elevator.


104. Shopping center Shanghai.


105. Typical elevator in residential building, Shanghai.

106. Shopping center


107. Shopping center Shanghai.


108. Shopping center Shanghai.


109. Round elevator, Louisiana, Denmark.


110. Round elevator, Louisiana, Denmark.


111. An office? Shanghai.

SUPER

112. Japanese public elevators are always tidy.

113. Waiting for elevator at Stockmann.

114. "Personalized" elevator, Design Factory, Shanghai.

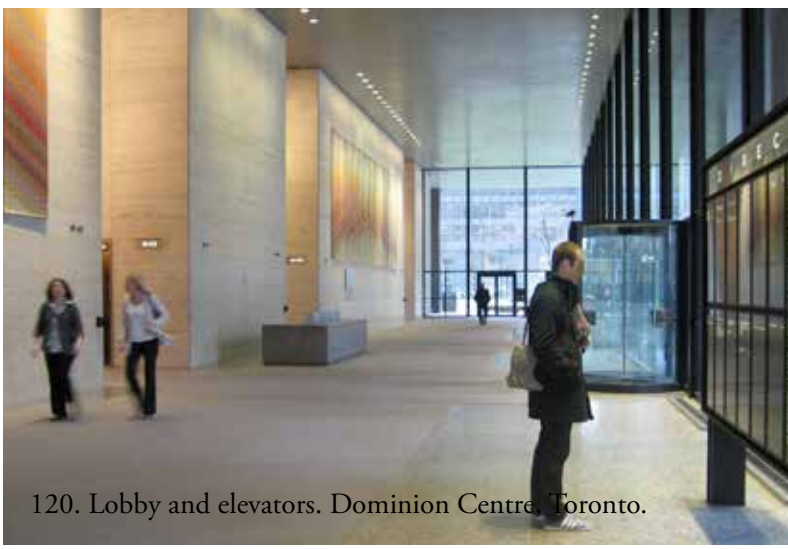
115. Toilet and elevator shaft. Mexico.

116. Black elevator, Shanghai.

117

118

119. Colors! Tokyo.



120. Lobby and elevators. Dominion Centre, Toronto.

7. Material research for LessElevator

7.1 Material selection strategy

Objective of the study was to find what kind of sustainable biomaterials there are in the markets or are coming to the market that have possibility to be suitable for elevator cars in near future. As elevator car materials were included car interior materials like floor, roof, wall panelling, accessories. Other parts (COP, doors and structural elements) were excluded. In material selection are followed Ashby's principals of materials selection.

Design requirements are based on information gathered in research phase and to discussions with KONE Design Team members in Finland, Italy and China, and environmental director Hanna Uusitalo. Since elevator material requirements are very strict and the conditions where elevators are quite harsh, list of constraints is very long. For these reason constraints were divided to three groups.

The three constraints are "Must Have", "Sustainabaility 2020" and "Desirable". "Must have" constraints must be met that the material has any potential to proceed. "Sustainability constraints" present the ideal sustainability values that every material should have. Sustainability constraints are crucial for ranking the materials. "Desirable" constraints are advantageous, but not crucial.

The identified requirements are described on next page.

7.2 Screening and ranking materials

Material screening was made by searching information from literature, online material libraries, blogs and webpages concentrating on materials and design. In the screening it was emphasized to find novelty materials, which are published but not yet mass-produced. These materials are in phase development, finding partnerships and have small production. It was not essential that material would 100% meet all constraints. More important was that it could meet the criteria in 2020 and shares the same idealogy with the LessElevator concept. Screening can be divided into two phases. Phase I was a general screening and building understanding of the markets. Most interesting findings from phase I were collected into a sustainable material library. During first phase it was also found new solutions, which are in such early stage that there is not samples or business yet. These are listed as phenomenoms to keep eye on as they could be very common in 2020s. In the phase II it was identified materials for ranking and having potential to become as future elevator car material.

Phase I: open-minded screening.
Materials that meet at least one of the criterias below

- Promising novelty that could be suitable for future elevator cars
- Present innovative approach and/or have wow-effect
- Sustainable materials that are suitable for industries with similar requirements, e.g. automotive, transportation, aviation and space industries
- Emphasizing biobased materials

Criteria to succeed to **phase II** and ranking

- Biobased material
- Novelty that presents the future
- Could be applied to elevators in near future through material development
- Have outstanding sustainable properties
- Meet "must have" -criteria
- Sample was received

Sustainability 2020 constraints

Raw material sources
- 100% sustainable source.
- Not from food crops.
- Preferably from waste materials – upcycling.

Production phase:
- Low energy consumption
- No waste or very little waste
- Water-efficient, close-loop water system

Usage phase
- Long-lasting material, at least 10 years or more
- Non-toxic/non-hazardous/no harmful to health
- Does not contain urea formaldehyde or other formaldehydes

Easy end-of-life treatment: Recyclable and/or renewable and/or compostable

Must have -constraints
- Suitable for public spaces
- High fire resistance.
- Minimum requirement European fire classification B.
- Lightweight material.
- High humidity resistance
- High stiffness.
- Material must meet the criteria set in Standard EN 81-1.

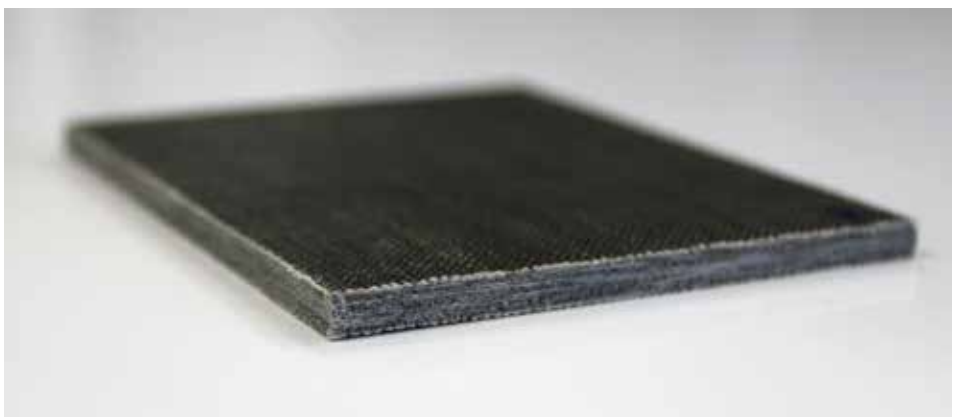
Desirable constraints
- Sheet or/and 3D form in sheet, preferably profiles and component if possible
- Thickness: as thin as possible.
- Weight: Preferably lighter than other similar materials and currently used materials.
- Noise dampening, acoustic
- Consider UV resistance, stain resistance, easy to clean, water, liquid, chemical resistance, scratch resistance, wear resistance, tear resistance, impact resistance
- Possibility to add self-healing or self-cleaning properties
- Material must have aesthetic look avoiding “eco-look”
- Material must be aesthetic on both sides
- It is preferable, if material is translucent
- Possibility to color material.
- Material has environmental label or certification
- Material supports LEED or BREEAM certification
- No drinking water used in production
- Material is easily available (e.g. for replacement)

7.2.1 Phase I: Intoroducing materials found in screening

Material name: BioVerbundwerkstoff
Company: Deutsches Zentrum fur Luft- und Raumfahrt e.V. (DLR)
Material for: Panelling, floor, roof

Description: Biocomposite material that is suitable for rigid panels and structural parts. Material is comprised of almost 100% of renewable resources. Material is always customissed and designed for the particular application in cooperation with the customer. So it would require a material development project. Fibers used are from flax, hemp, jute, ramie, kenaf and sisal and they are embedded in biopolymer matrixes. Material properties are similar to glass fiber, but it has significantly lower density and weight. Good fire resistance. Possible applications include interior lining in railway, automotive and potentially airplane. (MaterialConnexion 2012)

Picture 120 (right).
Sample with 14 layers of fabric.
Picture 121 (left). Structure on surface.



Material name: Active Clean Air & Antibacterial Ceramic™
Company: GranitiFiandre S.p.A.
Material for: Floor (outdoor & indoor)

Description: Active Clean Air & Antibacterial Ceramic™ tiles interacts with the environment by reducing pollutants such as nitrogen oxide and sulphur oxide up to 70%. These pollutants are generated from e.g., heating, air conditioning, odours, ammonia. Tiles eliminate bacterial strains that often damages surfaces and coverings. Tiles contain titanium dioxide (TiO2) that is baked in to material. Material is environmentally friendly - 1,000 m2 of ACTIVE slabs has the same beneficial effect of 300 trees and there is not need for detergents, because water is enough to clean the dirt. ACTIVE slabs are suitable and recommended for environments where cleanliness, sanitation and hygiene are important requirements e.g. hotels, restaurants, surgeries, laboratories and hospitals. Contributes LEED. (GranitiFiandre 2013). At least some of the tiles are very thin, 4,8 mm

Picture 122. Active Clean Air & Antibacterial Ceramic™ tiles have high recycled content and other advantagous properties

Material name: DuraPulp
Company: Södra
Material for: Panelling, accessories

Description: DuraPulp is a biocomposite mainly consisting of selected wood fibers and a bio-polymer called Polylactic Acid (PLA). The ingredients are from renewable, non-fossil based raw materials.

Dura Pulp is suitable for variety of products for different industrial applications. DuraPulp is used in two different ways – activated or inactivated. When activated, by heat and pressure, the material becomes very strong, rigid, dimensionally stable and has low water absorption. Activated DuraPulp is suitable for example for furniture. Inactivated DuraPulp is mainly of interest in the specialty paper. (Material 2012)

Picture 123 (above), 124 (middle).
Activated Durapulp provides many possibilities.

Material name: ForMi
Company: UPM
Material for: Accessories.

Description: UPM ForMi is new cellulose fiber reinforced plastic composite with high renewable material content. It is specially designed for injection moulding applications. Up to 50% of UPM ForMi's raw material is renewable. There three types of ForMi. ForMi GP is suitable for e.g. consumer goods, toys and dishes. ForMi SP is developed for special sufraces e.g. furniture. ForMi EFP is suitable for thin wall applications. (UPM 2012a & 2012b)

Picture 125. UPM Formi has unlimited color range.

Material name: Novofrux®
Company: Novoplastik Oy
Material for: Panelling, floor, ceiling

Description: Novofrux® is 100% biodegradable thermoplastic natural fiber composite, which does not contain any oil-based or inorganic materials. Like many biobased materials, it has excellent acoustic properties. Novofrux has good fire safety without any additives. Novofrux 2nd generation material is in development with improved qualities like inceased hydrofobicity and improved raw materials sourcing from wild and uncultivated sources. Current Novofrux® is made of food-crops sources (corn, hemp, cotton). (Novofrux 2012)

Picture 126. Piiroinen Oy produces COMPOS chair made of Novofrux. Design Samuli Naamanka.

Picture 127. Zelfo is an aesthetic sustainable material that comes is many forms.

Material name: Zelfo®
Company: Zelfo Technology GmbH
Material for: Panelling, floor, ceiling, accessories, cladding

Description: Zelfo Technology GmbH has develop patented technology that with company is able to turn 100% renewable or recycled cellulose fibres into self-binding Zelfo® materials. Possibilities of Zelfo® material are almost endless. On top of all, materials is extremely sustainable and has been awarded for its achievements. The technology behind Zelfo guarantees it does not need any additives. As raw materials can be used e.g. agricultural waste from non-food crops. Material can be localized. It means that same Zelfo material can be produced near the location where it is used from local waste materials that contain cellulose. Zelfo is economic, adaptable and sustainable alternative for many purposes. It is suitable for example product design, construction and interiors, furniture and for plastics as additive. Potential to contribute to LEED & BREEAM. (Zelfo Technology 2013a, 2013b)

Material name: MONIFLEX
Company: Isoflex AB
Material for: Insulation

Description: Cellulose-based material MONIFLEX has been in use for over 60 years. It is mainly used in vehicle industry and building industry as insulation. MONIFLEX has high fire resistance and resistance to humidity and vibrations. Material is very light in weight. MONIFLEX is biogradable and recyclable. (Isoflex 2013).

Picture 128. MONIFLEX is extremely light and transparent

Material name: Fibrolon®
Company: FKuR
Material for: Accessories, profiles

Description:
Fibrolon is an example of WPC. It is suitable for injection molding and can used for complex profiles, panels and hollow profiles. FIBROLON® is used in automotive interiors. FKur offers three kind of FIBROLON®. The main differences are the percentage of fibers contained in the compounds and therefore some mechanical features varies. Can be dyed.

Picture 129. FIBROLON®

Material name: Several fiber products for automotive industry
Company: Johson Controls
Material for: Accessories, profiles, panelling

Description:
Johson Controls has developed natural fiber products for over 50 years. With natural fiber products JC aims to improve CO2 balance, make a lightweight construction and improve recyclability. Company provides many natural fiber products e.g., Ecobond, EcoCor, Fibrowood, Fibrid, FaserTec, WoodStock. (Johson Controls 2013). Does not provide services for other than automotive industry.

Picture 130. Car parts made of EcoCor.

Material name: Cocodots and Palmwood
Company: Kokoshout
Material for: Flooring, panelling

Description: Cocodots and Palmwood are made of old palm trees, which have good wood quality. For coconut farmers new trees are more valuable, because they have better productivity. Palmwood is suitable for flooring. Cocodots is suits for flooring and also wall panellings. Both products have interesting, strong aesthetic look. (Materia 2012)

Picture 131 (above). Cocodots and Palmwood.
Picture 132 (below). Lightweight composite.

Material name: RE-Y-STONE®
Company: Resopal
Material for: Lamination

Description: RE-Y-STONE® is a sustainable lamination made from 100% recycled and renewable materials. It is emission and petrol free. Lamination consists of recycled core and decorative paper and a natural resin obtained from the waste from sugar production. RE-Y-STONE® is a hard, durable, mechanically very strong, dimensionally stable sheet with a highly resistant surface. Lamination has only dark brown and black colors and strong, raised patterns. (Resopal 2013)

Picture 134. RE-Y-STONE®

Material name: Different types of solutions of cork
Company: Amorim Cork Compositees
Material for: Flooring, panelling

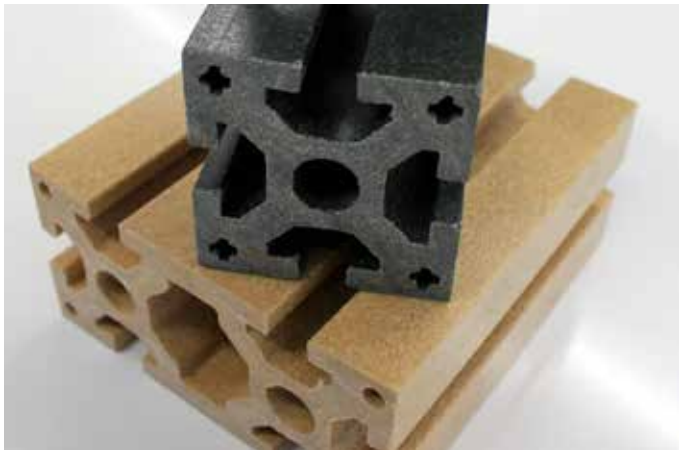
Description: Amorim Cork Composites makes cork composite solutions for many industries, e.g. aerospace, transmission & distribution, vibration control and corematerials. Company makes cork producst for usage purposes where acoustic, thermal and damping performance, lightweight, comfort and durability are important properties. Company has developed fire-resistant and water-proof solutions. Some products can contribute to LEED and BREEAM. (Amorim Core Composites 2013)

Picture 133 (right). Example of lightweight, acoustic panelling for transportation.

Picture 135. Six samples of "mushroom material"

Material name: "Mushroom materials"
Company: Ecovative Design
Material for: Core material for composites, packaging

Description: Ecovative Design is specialized in making different solutions out of mycelium. Mycelium is decribed as "roots" of mushroom. Mycelium products are not produced. They are grown in 5 – 7 days, in the dark, with no watering, and no petrochemical inputs. As its raw material is used agricultural byproducts. Besides being extremely sustainable material, mycelium has many other benefits too. It can bind itself to other materials, which eliminates need for hazardous glues in composite structures. In addition, mycelium is naturally fire-resistant and acoustic material. After usage, it can be composted safely. Truly a different material! Ecovative Design has achieved many awards and lots of media attention. (Ecovative Design 2013a).



Material name: NFC materials
Company: Hiendl NFC
Material for: Profiles, accessories

Description: Hiendl products are examples of NFC (Natural Fiber Composites). They consist of synthetic polymers and renewable raw materials. Products contain fibers from e.g., hemp, flax, and wood. Compared to other synthetic materials, Hiendl NFC materials have a very high solidity and rigidity. NFC materials are very lightweight. (Material 2012)

Picture 136. Hiendl NFC profiels.

Material name: FibriBoard, FibriMat, FibriCork, FibriCard
Company: EcoTechnilin
Material for: Panelling, floor, ceiling

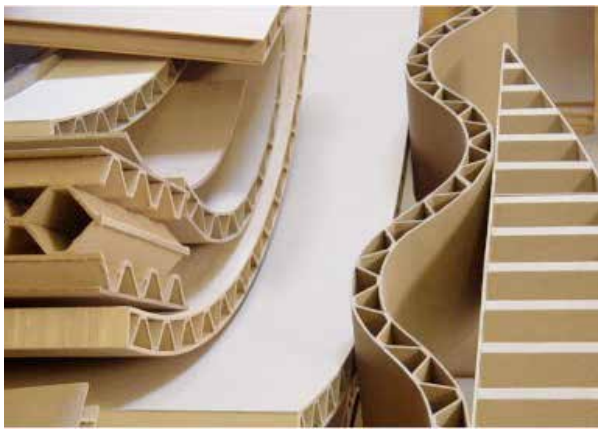
Description: EcoTechniling provides natural fiber solutions especially for automotive industry. Most of their products are used in different types of automotive interior parts like door panels. EcoTechnilin products are suitable also for other industries and for furniture.

Picture 137 (above). FibriCork
Picture 138 (below). EcoTechnilin nonwoven felts.

Material name: DurAlmond
Company: EcoTechnilin
Material for: Floor, ceiling, panelling

Description: Duralmond is a composite material made of crushed almond shells. The result is biodegradable and material, which is an alternative to wood. Like its name promises, DurAlmond is very durable. It is compostable, recyclable, UV, scratch and impact resistant, water and humidity proof as well as resistant to most household cleaning chemicals. It is also resistant to insects and other biotic agents, and has good thermal and acoustic characteristics. Sufficiently fireproof material. Versatile collection for many usage purposes, e.g., panelling, flooring and lattice. (Materia 2012, Material, Connexion 2012)

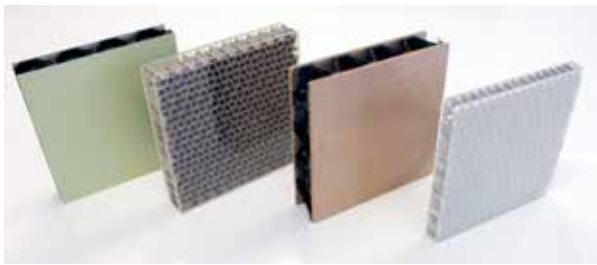
Picture 139. DurAlmond wall panelling.



Material name: ECOR®FlatCOR, ECOR®HoneyCOR, ECOR®WavCOR
Company: Ecor Global
Material for: Panelling

Description: ECOR® panels are made by molding cellulose fibers into high performance panels from recycled resources. ECOR® panels are strong, cost competitive compared to similar products, have design, fabrication & application flexibility. Products are non-toxic, recycled and recyclable. Applications from furniture to consumer goods. (Materia 2012)

Picture 140. ECOR® Products.



Material name: Bencore
Company: Bencore
Material for: Walls, decoration

Description: Bencore makes composite panels, often with honeycomb structure. Bencore panels contribute to the LEED points. Company has made Ecoben product, which cardboard core. Application suitable for interior design.

Picture 141. Bencore products create nice effect to interiors.

Material name: Fluidsolids ®
Company: Fluidsolids
Material for: Accessories, structural components

Description: Fluidsolids® is a new material entering the market. It states to be an alternative material for example for structural components and products that previously have been made of metal or plastic. It is a composite material consisting of renewable natural raw materials from industrial waste. Sustainability aspects of the materials are that no agricultural land is used for the production, material is free from odours and emissions, and is biologically degradable. FluidSolids® is individually programmable so it can be made to fit each specific usage purpose. (Fluidsolids 2013)

Picture 142. Stool made of FluidSolid®.

Material name: Tegris
Company: Milliken
Material for: creating composite structures

Description: Tegris a 100% PP thermoplastic composite. It was included to this research as it is fully recyclable and safer to handle than usual glass-filled composites. Material is ideal for panel and molded applications where is required high impact resistance, stiffness and low weight. (Milliken 2013)

Picture 143. Tegris is recyclable.

Material name: Trend green flooring materials
Company: Trend Group
Material for: Flooring

Description: Flooring tiles made of recycled materials in highly energy- and water-efficient manufacturing process. Trend group makes durable thin surfaces out of waste materials. Trend agglomerate use 60% less raw materials compared with traditional alternatives that perform the same fuction in the market. (Trend Group 2012)

Picture 144. Colorful flooring materials

Material name: Biotex
Company: Composites Evolution
Material for: Panelling

Description: Biotex are a series of natural fiber reinforcements and biocomposite materials, including yarns, tapes, fabrics, textiles and pre-consolidated sheets. The standard product range is based on flax fibers. Biotex materials are lightweight, noise and vibration damping, thermally insulating. Material is renewable, sustainable, recyclable, and in some cases biodegradable material. Suitable for automotive, furniture, consumer goods, construction and architecture, marine and transportation.

Picture145. Biotex textiles.

Material name: Organoid
Company: Organoids Technologies GmbH
Material for: Panelling, accessories

Description:
Organoid is 100% biodegradeable organic material, which can be sprayed and hardened in all kinds of moulds or on inflatables to produce everything from small trays to architecture. As raw materials is used different natural fibers like wood or bark. The material desnsity varies between 0,2-1,3kg/dm^3 depending on the raw materials and usage purpose. Organoid has a very good noise reduction (almost 100%) so currently company is developing an acoustic panel product. (Organoid 2013)

Picture 146. Furtniture made of Organoid

Material name: BioSurf
Company: Biosurf Solutions
Material for: Lamination

Description: BioSurf Laminates are made of soybean and corn. This new generation of laminates integrate state of the art "direct digital imaging" as to provide an endless array of designs. Biosurf does not contain formaldehyde and PVC, so it is an environmentally friendly alternative to standard HPL. In is lighter and performs better in some tests (e.g. scratches) than HPL. Contributes to LEED and LBC. (Biosurf Solutions 2013)

Picture 147. Biosufr lamination is durable and flexible

Material name: BioBased Tile
Company: Arsmstrong
Material for: Floor

Description: BioBased Tiles are made from rapidly renewable, U.S.-grown plant materials. Currently product is using corn as raw material, but company is constatly seeking for other options. BioBased Tile does not contain PVC or plasticisers, it has 10% of recycled content and has low VOC emisissions. Contributes to LEED.
(Armstrong 2012)

Picture 148. BioBased tiles in white. BioBased Tiles have wide colour range.

Material name: Naporo, several products
Company: Naporo
Material for: Insulation

Description: Naporo makes mainly insulation and acoustic boards of typha, which a fast-growing plant. Resource is worldwide as there are diverse typha species spread all over the world's climate zones. Special sustainability feature are that Typha binds large volumes of CO2 and simultaniously produces oxygen. Naporo states that its insulation can bind 9,000kg of CO2 and generate 5,500kg of oxygen with each building. A person can live on that volume of oxygen for ca. 15 years. Naporo can be composted or reused after usage.

Picture 149. Naporo in another form than insulation.

Material name: Foamet, Globomet
Company: Hollomet GmbH
Material for: reducing weight

Description: Foamet™ is an open-celled metal foam, combining the advantages of metals and light, permeable materials. Globomet is a metallic hollow sphere structured material allowing thin and evenwall thickness. These are included here, because they provide solutions to lower weight in heavy steel and iron parts. Other sustainability aspects they have are that they use lower quantities of valuable materials and is completely recyclable. These structures can be also made of ceramics. (Hollomet 2013)

Picture 150. Foamet (below), Globomet (above).

Picture 151. Duroplastic has cardboard honeycomb core.

Material name: Duroplastic
Company: Thüringisches Institut für Textil- und Kunststoff-Forschung e.V.v (TITK)
Material for: Panelling

Description: Duroplastic was developed by German TITK. Duroplast is a honeycomb cardboard laminated with matted fiber (flax, hemp, sisal, etc.). Surface has high density. Duroplastic is low weight, has high mechanical strength and stiffness. It is cheap to manufacture. And like many other natural fiber producst, it has good thermal insulation and material is acoustic. Duraplastic can be recycled. (Adream 2012)

Picture 152. Composite made of coconuts.

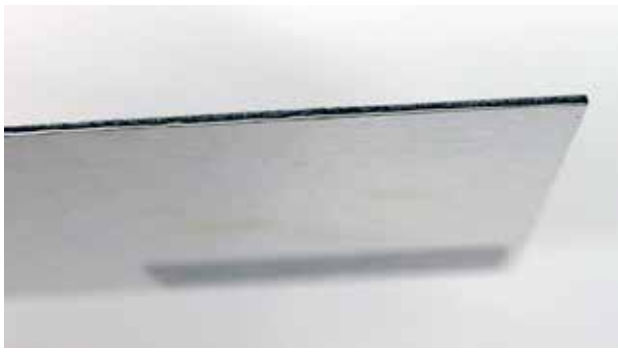
Material name: Natural Fiber Nonwoven composites
Company: Natural Composites Inc.
Material for: Accessories

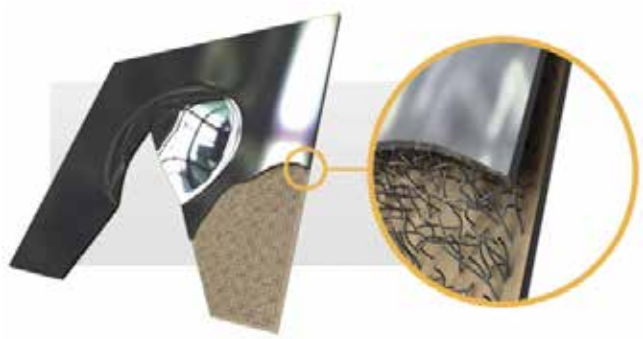
Description: Natural Composites' makes nonwoven composites and coconut shell plastics (CSP). Nonwovens are an alternative for traditional synthetic composites. Company's nonwoven coconut fiber felt can be custom-made to fit a wide variety of applications. By varying the material "recipe", composite can be tailored to different usage purposes. Material is suitable for example automotive industry transportation and building materials. Textile composites reinforced with coconut fiber offer several benefits including stiffness, impact strength, resistance to mold and odor, and natural burn resistance. CSP is made from coconut shell and has a wide variety of end-user market applications. (Natural Composites 2013)

Picture 153. Omarno's panels have strong aesthetic look.

Material name: Palm Panel Smooth, Palm Panel Flex
Company: Omarno
Material for: Panels, flooring

Description: Omarno uses industrial by-products for its panelling products. Products are made of exotic organic materials e.g., coconut shell and palm wood. Palm panel Flex is flexible surface material where Palm Panel Smooth is rigid and stiff (in picture). Company is launching floor material collection in near future. Contributes to LEED. (Omarno 2013)





Material name: Hybrix™
Company: Lamera
Material for: Panelling, replacing steel sheets

Description: Hybrix was developed by Volvo Technology. Inspiration for structure came from bird bones. Hybrix is 1-2 mm thin stainless steel micro-sandwich material. It has all the same looks, properties and behaviour as regular stainless steel, but it weights less than half as much as steel. Hybrix weights only 1,5-3,9 kg/m2. Hybrix core is hollow and consist of air and microscopic steel fibers that binds the surfaces together. Material is strong, rigid, and it can be shaped even to organic forms. Hybrix is available also in aluminium. (Lamera 2012). Material has many sustainability aspects. Hybrix production is more sustainable than conventional steel, it is lighter which reduces environmental impacts during the transportation and usage phase. Hybrix is recyclable. Hybrix was included to the study as it could be applied immediately to many KONE products.

Picture 154 (above). Hybrix is a very thin micro-sandwich material that could replace conventional steel.
Picture 155 (below). Microscopic steel fibers make Hybrix core hollow.

7.2.2 To keep eye on...

During the screening process were found few phenomenoms and innovations that are worthwhile to follow.

Touchless screen
Touchless screens are based on hand movements. For example Israelish company called XTR3D has developed a gesture recognition software that is able to read movement and then execute appropriate commands from the movements - without any need to press any buttons. Touch-free interface can be installed to any device having standard webcamera. These solutions are already applicaple in consumer good like televisions, computers and mobilephones. (XTR3D 2013). Solutions for touchless screens are developed also by other companies, for example Microsoft Kinect.

Picture 156. Surgeon using touchless screen technology based on Kinect.

Biomimicry

Biomimicry means imitating nature to solutions and innovations. It is based on thought that nature able to create complicated solutions without wasting natural resources and damaging environment. Nature has billions of years of evolution behind and has already got rid off design flaws. It uses energy efficiently from sustainable resources. (Ask Nature 2012). Biomimicry is seen as one solution for sustainable energy and sustainable materials.

Janine Benyus is most well known spokes(wo)man for biomimicry. She has written several books on biomimicry. In 1998 she founded an innovation consultancy agency Biomimicry Guild. She is also a founder of The Biomimicry Institute (TBI). TBI is a non-profit organization running e.g., www.AskNature.org webpage. (Biomimicry Guild 2012). It is a free of charge open-source database for everyone's use. Anyone who is seeking information on how to solve things by mimicing nature can search information through asking questions. ELiSE is a company providing "evolutionary light structure engineering" with help of biomimicry. ELiSe is a patented lightweight construction procedure. It takes advantage for example of shell structures from marine plankton organism - diatoms. These new structures provide basis for revolutionary lightweight products and composite materials with aesthetic look. ELiSE has made stuctures e.g., for automotive industry, ship building industry and windmills. (ELiSE 2013).

Voluntary take-back programmes and services increase

Companies have started to establishing voluntary take-back programmes. Late 2012 Ikea released its sustainability strategy for 2020. According to it, Ikea will soon start leasing low-cost kitchens for its customers. Company wants to encourage customers to return products at the end of their life to be reused. Ikea thinks that they can help to recycle things like furniture, kitchens and mattresses. Company calls for smart consumption and supposes that people less interested of ownership in future. (Milne 2012, Rajakallio 2013).

Another Swedish company H&M launched a global clothing take-back programme in February 2013. Customers can bring maximum 2 bags of clothes to stores per day and receive a discount voucher per bag. H&M accepts all clothes in any condition. Returned clothes are directed to second hand sales, recycling, reusing or energy production. H&M says that 95% of all clothes thrown away could be reused. Objective is to reduce environmental impact of fashion industry. (H&M 2013).

Growing materials and energy

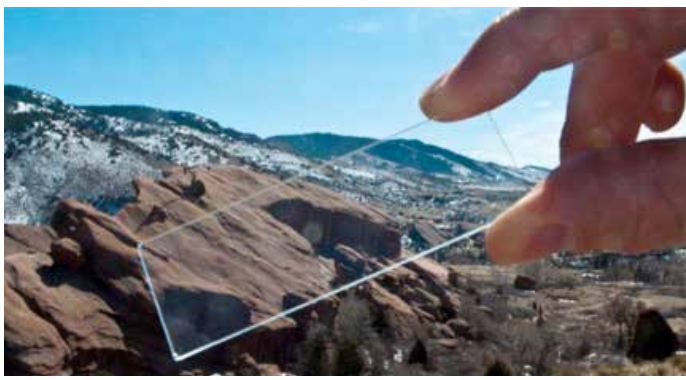
As mentioned before, in future materials might not be produced at all like today. They maybe very well just grown. Mushroom- and algae based materials are entering markets already (see pages 72-73, 117). Algaes can be used also for energy production. Arup presented the world's first building that is powered by algae in "bio-adaptive facade". The system is based on microalgae growing in glass louvres that are attached on buildings facade. (Dezeen 2013)

Picture 157 (right). A new pair of stockings honey? Or maybe a orthopedic cast based on diatom. 50% less weight to conventional cast.

Sustainable Energy from everywhere

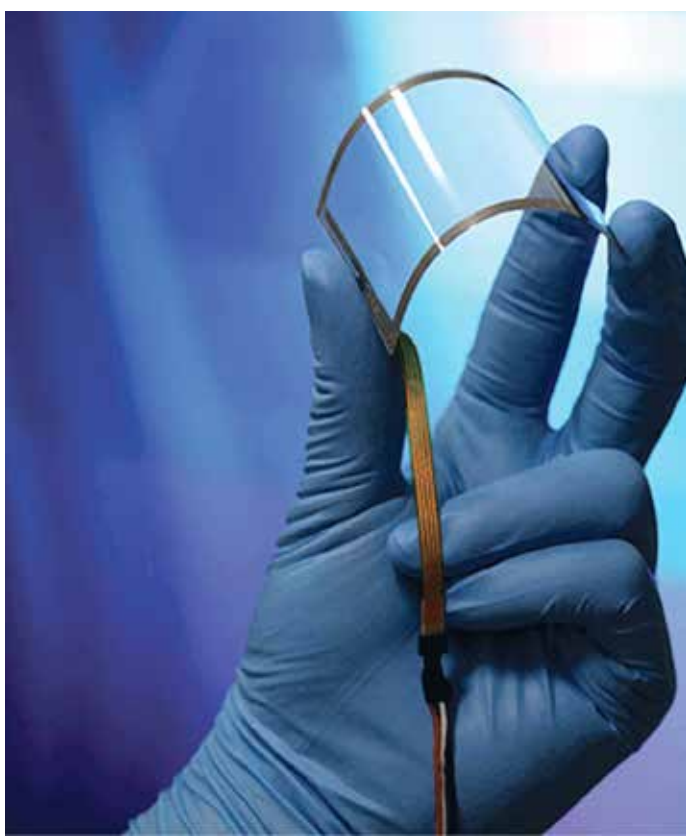
Energy harvested from small sources like foot steps, hand movement, kinetic energy or vibration could be very well something that turn on light to elevator call button in 2020.

USA based company New Energy Technology Inc. (NET) has succeeded to develop a sprayable solar cell coating that can make every window a source of solar power. Windows with NET's ecofriendly film and the coating keep windows clear and see-through. Besides sun, coating can produce electricity even from artificial light like fluorescent and LED lightings. Needles to say, coating works also in northern exposure with less light. Solution is based world's smallest functional organic solar cells, which size is less than grain of rice. Currently company provides six different solutions varying from small interior space dividers to larger commercial window installations. (NET 2013). NET estimates that when the coating is applied to entire facage of an large office building, it can generate 300% more energy than conventional solar panel on roof. Also their manufacturing process is more effiecient than competitors. (Dailey 2011)



Picture 158. Sample see-through glass with world's smallest solar cells.

Picture 159. Flexible smart window containing graphene.



Graphene

Graphene is most likely the supermaterials of the supermaterials. Graphene is world's thinnest material with thickness of a one single carbon atom. It is the first 2D material ever introduced. At the same time grapehene is lightest and strongest material ever known. It is harder than diamond and 300 times stronger than steel. Graphene conducts electricity much better than copper. It is also transparent material, bendable and can take any form. Graphene research and development projects have spread fast around the world, especially in fields of automotive, aerospace, energy storage, coatings and electronics. It has created a whole new range of materials that are now in development. So far graphene has been applied to for example flexible touch screens and rollable e-paper. Graphene has so many applications that it has possibility to change industries. Partly this is why European Commission recently founded a Graphene Flagship. EC has invested 1000 million euros on flagships. The mission of Graphene Flagship is "to take graphene and related layered materials from academic laboratories to society, revolutionize multiple industries and create economic growth and new jobs in Europe." (Graphene Flagship 2013).

Graphene was found by Andre Geim and Konstantin Novoselov in 2004. They received Nobel prize of their innovation in 2010. (Graphene Flagship 2013)

3D printing... and 4D printing?

Well, 3D printing is just around the corner and media is fussing about it. In April 2012 The Economist magazine published large special report on a third industrial revolution, where manufacturing is digitalized. 3D printing, also called as additive manufacturing, is making a break-through. (The Economist 2012, 3). Power of digitalisation of manufacturing should not be underestimated, but it could be also a hype. Still there are many great examples where digitalisation has changed remarkably business in fields that has had long traditions. Think about for example how Internet has changed music business, banking, newspaper and magazines or shopping consumer goods.

3D printing has been around for decades and so far it has been mainly used to rapid prototyping. Lately development of the printers and materials used in them has open new doors and ideas to revolutionise product design and manufacturing. There has been successfully printed for example medical implants, bicycles, eatable cupcakes, a racing-car and aeroplane parts and even a functional Stradivarious violin. Amsterdam-based DUS Architects are planning to 3D print entire canal home to Amsterdam in 2013 (The KamerMaker 2013). Terry Wohlers estimated that today more than 20% of 3D printed goods are actually final products and not prototypes. He says that 50% would be achieved already in 2016 and in year 2020 percentage rises to 80, but would never reach 100%. Currently materials used in printers are numerous plastics, metals, ceramics and rubber-like substances, even chocolate. Some printers are able to combine different materials. (The Economist 2012, 15)

3D printing has many benefits compared to traditional manufacturing. It

- can run unattended
- is not tied to location (almost anything, anywhere, anytime,
- allows customization in new level
- no retooling of production
- requires less assembly in ready-made objects or no assembly at all
- is faster
- has less risks
- produces no waste
- optimizes raw materials and consumes less materials
- allows to create new complex shapes, like organic shapes, which were not possible before
- allows new qualities that were not possible with earlier techniques
- usually reduces weight because of better material usage
- lower costs through material savings, less employees, less production phases, less space for production etc. (The Economist 2011, The economist 2012, 13)

Skylar Tibbits runs a Self-Assembly Lab at MIT. He is an architect, designer and computer scientists. Tibbits ambitions is "4D printing". By 4D printing he means objects that can self-assemble themselves after 3D printing without human interaction. All it needs is being subjected to an energy source for example, heat, sound, water or electricity. He aims to bring natural nanoscale structures into built environment as they are much more efficient than current manufacturing systems. As an example he presents that a skyscaper consist of 500 000-1000000 parts and takes few years to build, but in nature there are 2 million types of proteins per human and they "assemble" themselves in approximitely 10000 nanoseconds per protein. Could this structure and efficiency be applied to build environment through computing? Tibbits is already working with Stratasys (3D printing company) to experiment 4D printing by adding transformation as new capability to current 3D printing. He also works with autodesk to developed software that can simulate self-assembly behaviour in nanoscale and humanscale systems. (TED Talks 9/2011 & 4/2013)

3M Sunlighting Delivering System

3M launched Sunlighting Delivering System in 2011. It allows to harness sunlight and take it inside the building. 3M Sunlight Delivering System can carry light long way to even underground part of the building. This means pure daylight in windowless spaces. Sunlight is catched through a collectors on rooftops. Collectors can automatically move and find right angle and direction of sunlight. Advantages of the system is that

- natural light increases people's wellbeing and productivity.
- System decreases energy consumption and costs. Sunlight is free and renewable source.
- Sunlight is available daytime when there is peak hour in consumption of energy.

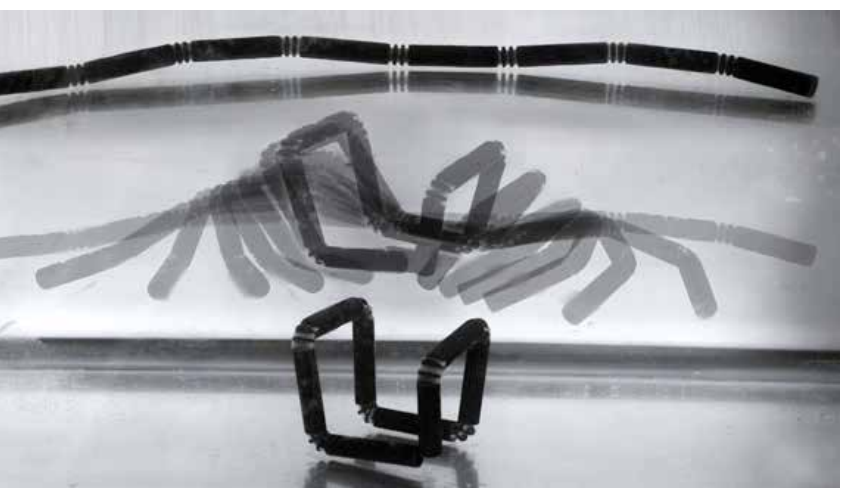
Sunlight Delivery Technology requires quite much space in building and from that perspective it is not yet suitable for elevators. But it is worthwhile to follow, because these kind of solutions are developing. (Anttonen 2013)

Picture 160. Sunlight Delivery System in use

Self-healing materials

Self-cleaning materials are already today. TiO2 applications are spreading from marine to building facades. Another growing area, which is closely related to biomimicry, is self-healing materials. Self-healing properties means that material is able to "heal" itself without human interaction when it is damaged, e.g., cut, torn or cracked. Self-healing properties will expand product lifetime, reduce need for raw materials and maintenance. (WEF 2012d). There are solutions already for self-healing cement based materials, polymers, bone substitutes. Self-healing properties can be added to steel for example in a coating.

Picture 161. Self-healing BioConcrete that contains bacteria. When concrete cracks, bacteria will heal the crack decreasing need for maintenance.



Picture 162. "4D printing", A self-folding strand that shapes into a cube after being exposed to water. First applications of these kind of structures could be seen in harsh construction environment like space or underwater constructions.

7.2.3 Phase II: Ranking sustainability constraints

Materials that meet phase II criteria were ranked through sustainability constraints. Unfortunately many of the materials had to be excluded here, because of their properties, e.g. inadequate fire resistance or poor humidity resistance. Many material producers also failed to provide samples even though they were contacted for many times.

Table 6 . presents compilation of the ranking. Zelfo and Mycelium stand out compared to others.

Sustainability properties / Material	Raw material source			Production phase				Usage phase				End-of-life treatment
	Sustainable source	non-food crop	waste materials/recycled material	Low energy consumption	No waste or little waste	water efficient	No drinking water used	Long-lasting material	Non-toxic/ non-hazardous/ non-harmful	No formaldehydes/urea-formaldehyde		Recyclable/ renewable/ reusable/biodegradable
ACM	+	+										+
Biobased tiles	+		+						+			+
Biosurf	+	+						+	+	+		+
Biotex	+	+						+				+
BioVerbundwerkstoff	+	+						+				+*
Cocodots & Palmwood	+	+										+
Durapulp	+	+										+
Active Clean Air & Antibacterial Ceramic™	+	+	+			+		+	+	+		+
Moniflex	+	+						+		+		
Mycelium	+	+	+	+	+	+		+	+	+		+
Naporo	+	+	+	+	+				+	+		+
Natural fiber non-vowen composites	+	+	+									+
Oranoid	+	+										+
Re-Y-Stone	+	+	+									+
Trend Group tiles	+	+	+									+
UPM ForMi	+	+	+									+
Zelfo	+	+	+	+	+	+	+	+	+	+		+

* can be recycled if resin is biobased.

7.3 Final selection

Selecting final materials for the concept car was based on following principals

- Does material reflect the future? If material is already on markets as mass-produced finished product, it is representing today.
- How well did material succeed in sustainability ranking?
- How well does the material support the concept? Could entire elevator car made of the material?

There are two materials that stand out in ranking. These materials are Zelfo by Zelfo Technology GmbH and Ecovative Design's mushroom materials. Both companies are strongly working on material development projects and building up collaboration with other companies. They are very sustainable materials compared to many others and present more future than present. Zelfo and mushroom material are good in sense that they could be used for many purposes. Most of the materials found in research can suit only for one purpose. For example lamination, flooring tiles or decorative panelling. Thesis is aiming to look "beyond the surface" and provide materials that can create also other type of advantages like reducing weight of the elevator car and this way reduce energy consumption. One of the objectives of the thesis was to find such sustainable material that entire elevator car could be made of it. Another important target was to find sustainable material that has good aesthetic properties. Chosen two materials can contribute to these objectives better than other found materials. Especially Zelfo provides great opportunities.

Aesthetic look of the material was emphasized. Many of the biomaterials still have an "eco-look" or very strong look that can be hard to apply to elevator car. Compare for example laminations like Re-y-stone and BioSurf lamination. Re-y-stone has very strong visual look with ready-made patterns only in dark colors and in aesthetic percpective probably would not be good elevator interior material. BioSurf lamination instead is refreshing example. It is made according to customers designs and that way is much more better option. Materials must appeal to many users. Too strong visual look, poor variation possibilities of the materials are unfortunately still common among biomaterials. Just by looking the material pictures, it is notable that many of them emphase maybe too much of materials "natural" origin. That theme is suitable only for one type of purpose, which has risk of image of green washing. At the same time leaves out many customers. On the otherhand many of the introduced materials are not meant to be surface materials or are made for completely different purpose so aesthetic is not needed.

One of the findings of the screening was that to find truly sustainable material for KONE products, a material development project is required. Many materials are promising, but there are hardly any biobased materials that could meet requirements of heavy industry. Positive thing is that there are bunch of materials that could be included to such project.

After selecting the materials, companies were contacted for further collaboration. In following chapter is described the chosen materials and how they were tested for the concept.

7.3.1 Growing elevators?

Ecovative Design is a small and a fairly young company, which had its start as university start-up. Company and its production plant is located in U.S.A. Ecovative Design has completely different approach to other biobased materials and definitely presents one of the most sustainable and innovative materials in the markets at the moment. Company has gained lots of attention in media and in forums concentrating to sustainable development. For example, it was part of World Economic Forum and Rio + 20 meeting voted as one of the top solutions to save the world in future.

Photo 163. Mushroom packaging.

Ecovative Design doe not manufacture its material. It grows the material. As said before, Company combines agricultural byproducts and mycelium, which is a "roots" of a mushroom. Mycelium is described as a natural, self - assembling glue, which binds the agricultural byproducts into a structural material. Materials properties like density, strength, appearance and texture can be varied to meet the usage purpose. Material can be made naturally fire-resistant without any additives. (Ecovative Design 2013a).

Company is strongly putting effort to bring mushroom material to packaging markets where it can replace EPS. They also do material development projects for companies. Their material could be applied to construction and consumer products, automotive industry, different types structural composites and next generation materials. (Ecovative Design 2013b).

Photo 164. Mushroom insulation.

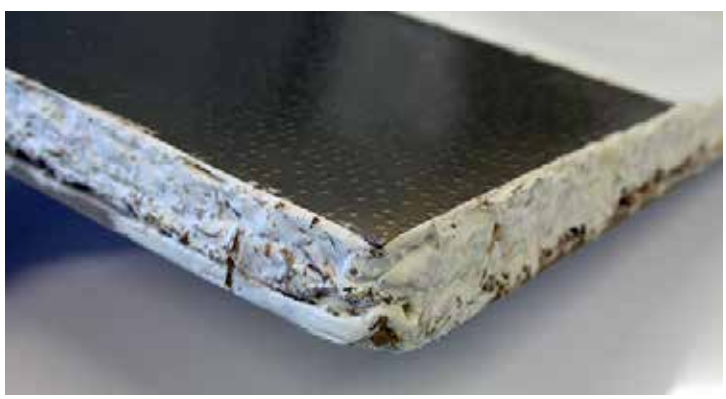
Ecovative Designs material is extremely sustainable. It is grown in dark, without water and hardly any energy in 5-7 days. Raw material is environmentally low-impact, 100% biogradable and renewable using only inedible crop waste. Material is biogradable, but company says there is a variation of end-of-life treatment. (Ecovative Design 2013c).

Wouldn't it be fantastic to grow wall panels straight to lamination almost without any energy and after its lifetime just compost it? For elevator cars this material would be suitable as a core in sandwich structured composite. Environmental advantages are that mushroom material reduces not just weight, but use of chemicals. Mycelium can grow on lamination and lamination does not need any glue. There is not need for chemicals to add fire-resistance either. Material is acoustic.

Photo 165. Mushroom packaging in production.

Core needs a surface and in thesis was tested how well mycelium grows on lamination. From the end result it was noticed that mycelium would need more stiff material as a surface and some of the thin lamination in samples were not stiff enough. It was also clear that as a material used in elevators, it would need much more development work than it was possible in the time frame of the thesis and its budget.

Picture 166. One of the test samples where mycelium was grown on lamination. More stiff the lamination, the better result.



Picture 167. Steel lamina and mycelium test is promising.

Picture 168. Stiff, porous material could be the solutions for elevator car wall panelling.

7.3.2 Entire car made of Zelfo?

Picture 169. Hemp guitar made of Zelfo.

Zelfo Technology GmbH produces material called Zelfo®. It is the most promising and potetial biomaterial found in research. For that reason most of the material testing was done in collaboration with Zelfo Technology.

Zelfo Technology is a European company with a pilot plant in Germany. It was founded by a team of experts with knowledge of bio-based materials, design and manufacturing. Today it has several patented systems and is focusing on development of engineered cellulose fibers for advancement of sustainable industry. (Zelfo Technology 2013a)

Zelfo is a high performance bio-based material made of cellulose fibers. Company has unique patented fiber technology called Cellulose Optimization Resource Efficient (CORE), which can transform 100% renewable or recycled cellulose fibers into self-binding Zelfo materials without additives or chemicals. Compared to many other sustainable materials, Zelfo is a truly sustainable material (e.g., most woodplastics still contain oil). It can be made of any plant or waste material containing cellulose, for example agricultural waste. Zelfo can be ”localized”. It means it is possible to make same Zelfo material locally from local resources. In Finland this could be from forest waste material, in Africa sugarcane waste. (Hurding 2012)

Due to CORE technology, production of Zelfo is extremely energy- and water-efficient. Zelfo is economic, adaptable and can even work as binder or matrix component in other bio-based material solutions. (Zelfo Technology 2013b)

Zelfo is suitable for

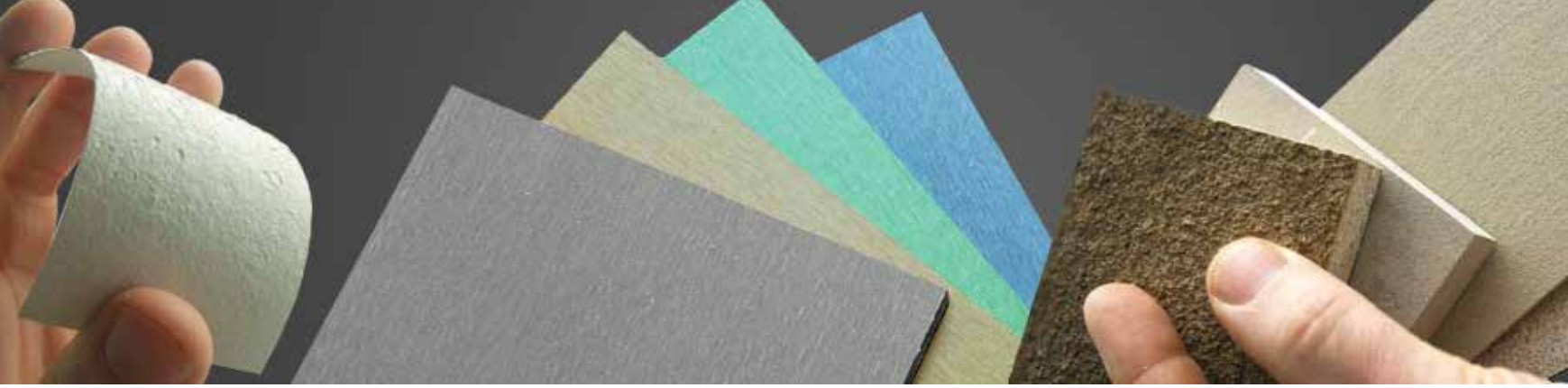
- Product Design and construction, e.g. consumer products, packaging, interior design solutions, housing, furniture, panelling, flooring.
- Pulp, paper and paper board where company has exclusive agreement with BASF.
- Plastics where Zelfo can operate as additive or matrix.

(Zelfo Technology 2013b)

Zelfo has many advantages why it should be tested for as potential elevator material

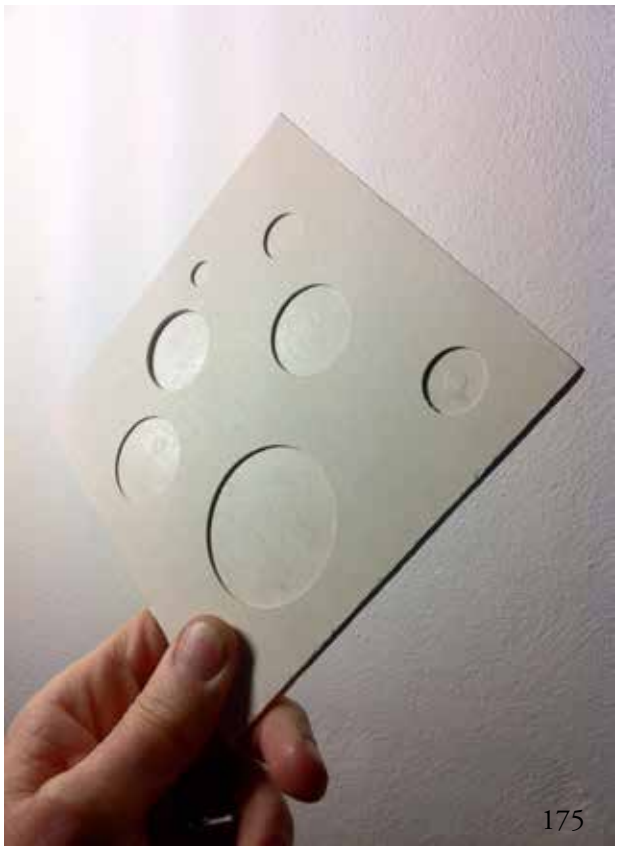
- Zelfo has great, verstatile properties. Zelfo can be made to match customers needs by modifying properties.
- Aesthetics. Material can be colored either through-body or just coloring the surface. Surface and texture can be flat, smooth, textured or mottled.
- Zelfo is one of the sustainable materials that actually looks good and is not just ”eco-looking”.
- Entire elevator car could be made of Zelfo. It suitable for wall panelling, flooring, roof and lamination. Company has already had collaboration in flooring business.
- Zelfo comes in many forms e.g. board and cladding.
- Suitable for wood working tools

Picture 170 (above), 171 (below).
Lamp and furniture made of Zelfo. Designer Elise Gabriel.



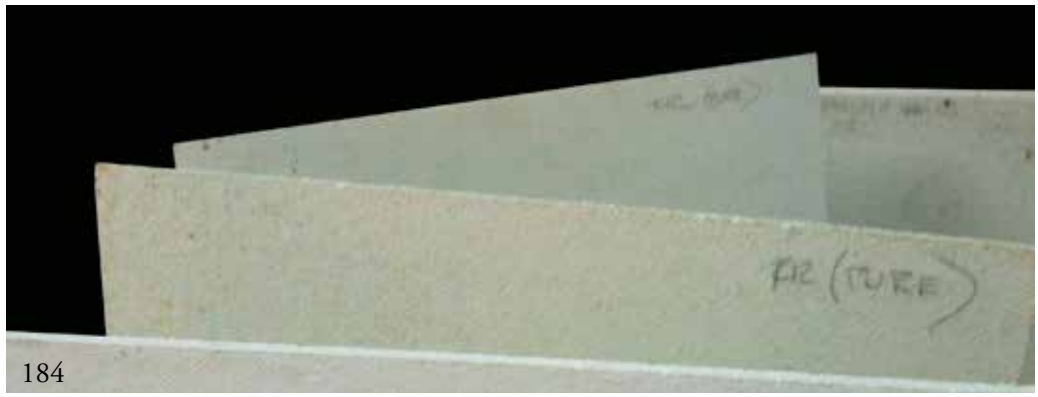
Picture 172. Samples of Zelfo.

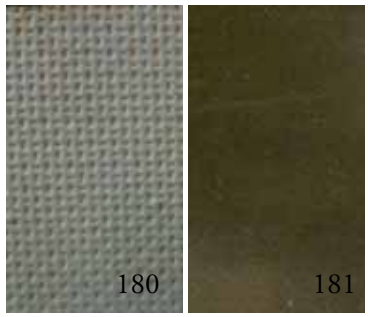
Best way to demonstrate how versatile one material can be, is to show many samples of it. To inspire KONE employees of this new material, several samples of Zelfo particularly designed for elevator purpose were ordered. These samples contain three different fibers: wood kraft, white recycled paper and bamboo. From each fiber, a standard non-treated sample, a sample mixed with mineral and a sample in laminate thickness were made. Other substances were mixed with fibers to test properties. Where advantageous, patterns were CNC milled on surface. Patterns are based on sketches presented later.

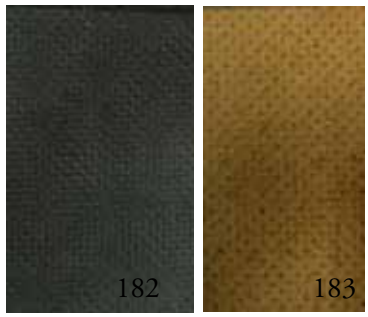


Picture 172-175. In the thesis project future elevator car ambience is pursuing translucent white material, which lets light shine through emphasising three-dimensional patterns. On left side are two pictures of tranlucent Zelfo in natural color that Zelfo Technology succeeded to achieve. On right is a white test sample with CNC milled patterns based on thesis writers sketches.

Picture 176. Zelfo Technology employee handing the bamboo used for samples.
Picture 177. Samples in colour white.
Pictures 178-179. First bamboo experiments.

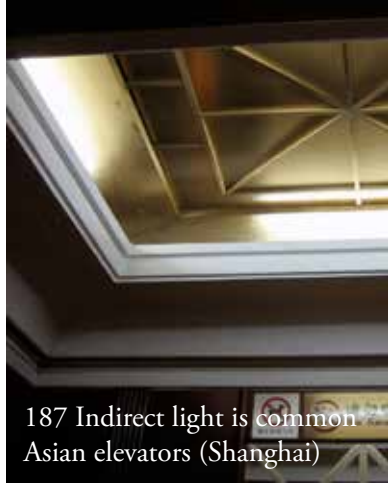






Pictures 180-183. Different surface structures.
Picture 184. Cut samples.
Picture 185. Samples ready to leave for finishing.

186. Color changing roof in elevator inTokyo.



187 Indirect light is common Asian elevators (Shanghai)

188. Signalization in shopping mall, Tokyo.

189. Signalization of Mori Tower,

190. Typical COP in Japan.

193. COP in new shopping mall, Shanghai

191. COP of Chinese residential building. Lots of floors with number 4 missing.

192. Very nice signalization, Tokyo.

194. Mori Tower elevator lobby, Tokyo.

195. Signalization in the shopping mall in Tokyo.


196. Mori Tower elevator doors, Tokyo.

197. Detail from Tongji university elevator lobby. Shanghai.

198. Elevator lobby of a shopping mall in Shanghai.

199. Typical COP in Japan.


200. Really shiny button in Arabia, Helsinki.


201. High-end elevator lobby of a residential building in Shanghai.

AMBIENCE

8. Future ambience

8.1 Sketching ambience

Pictures 202-214. At first there was several ideas from geometric patterns to tree themes. During the sketching, asymmetric patterns became more important.

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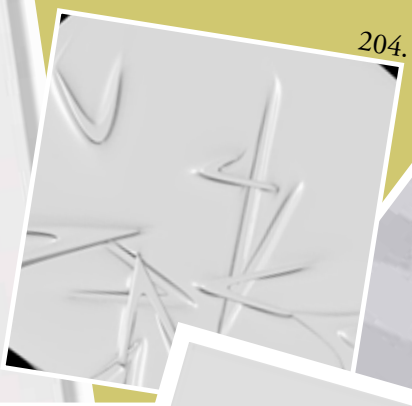

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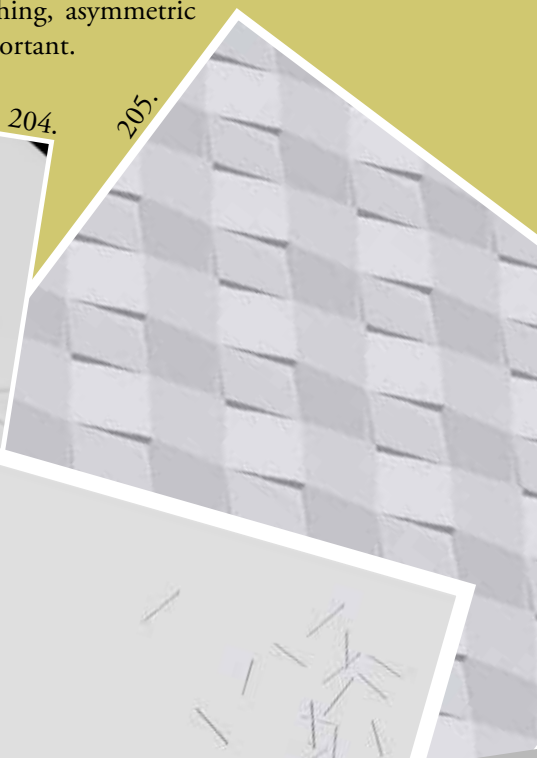

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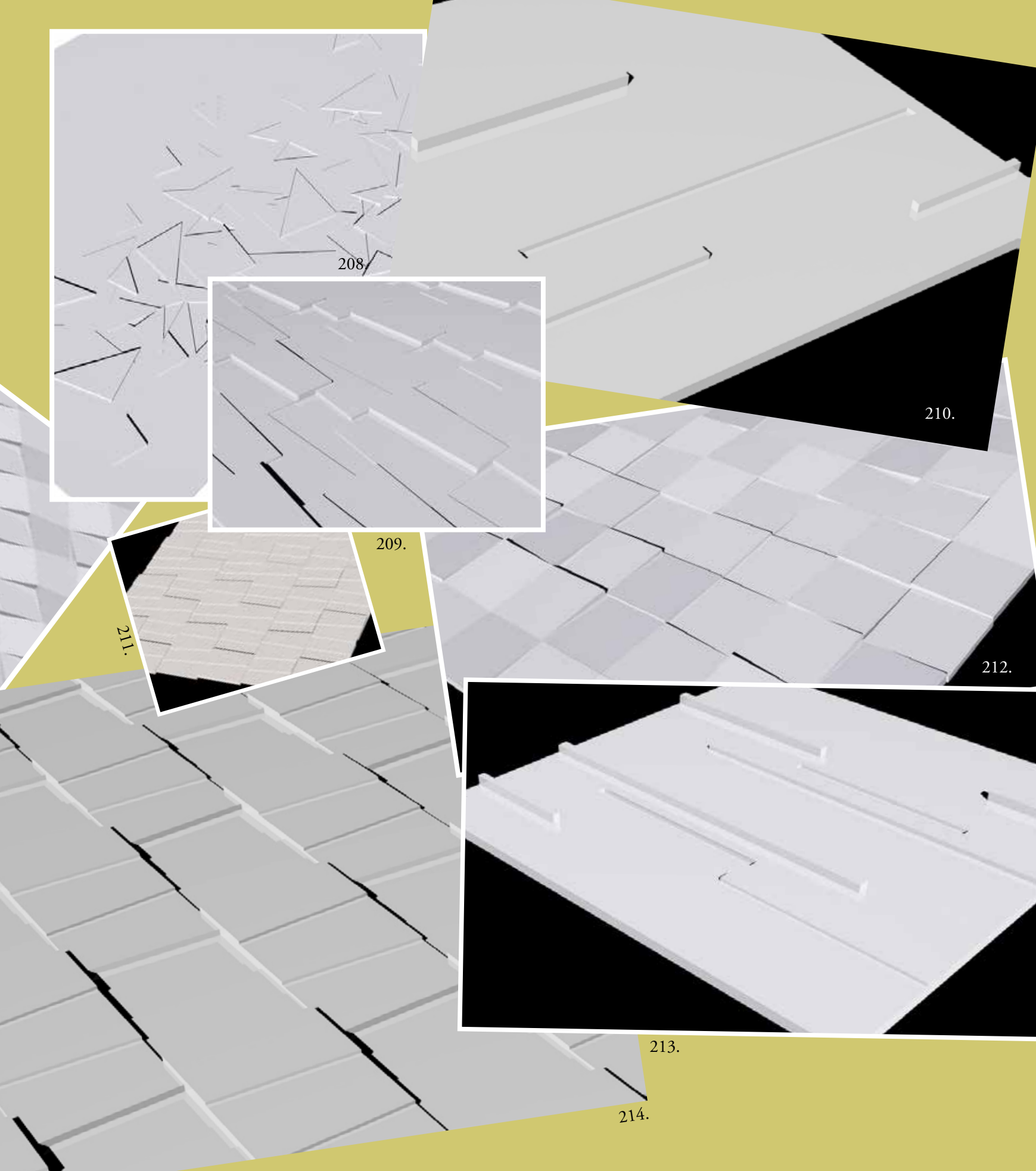
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Pictures 215-223. Testing proportions, angles and effects of light and shadow on geometrical patterns. Pattern size inside and outside the elevator car should be different, because inside the elevator car, pattern is seen from close and outside the car it is mainly seen from far. Also, there could be less patterns inside the car to create more peaceful feeling.

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Pictures 224-228. Early sketches of the design idea and feeling

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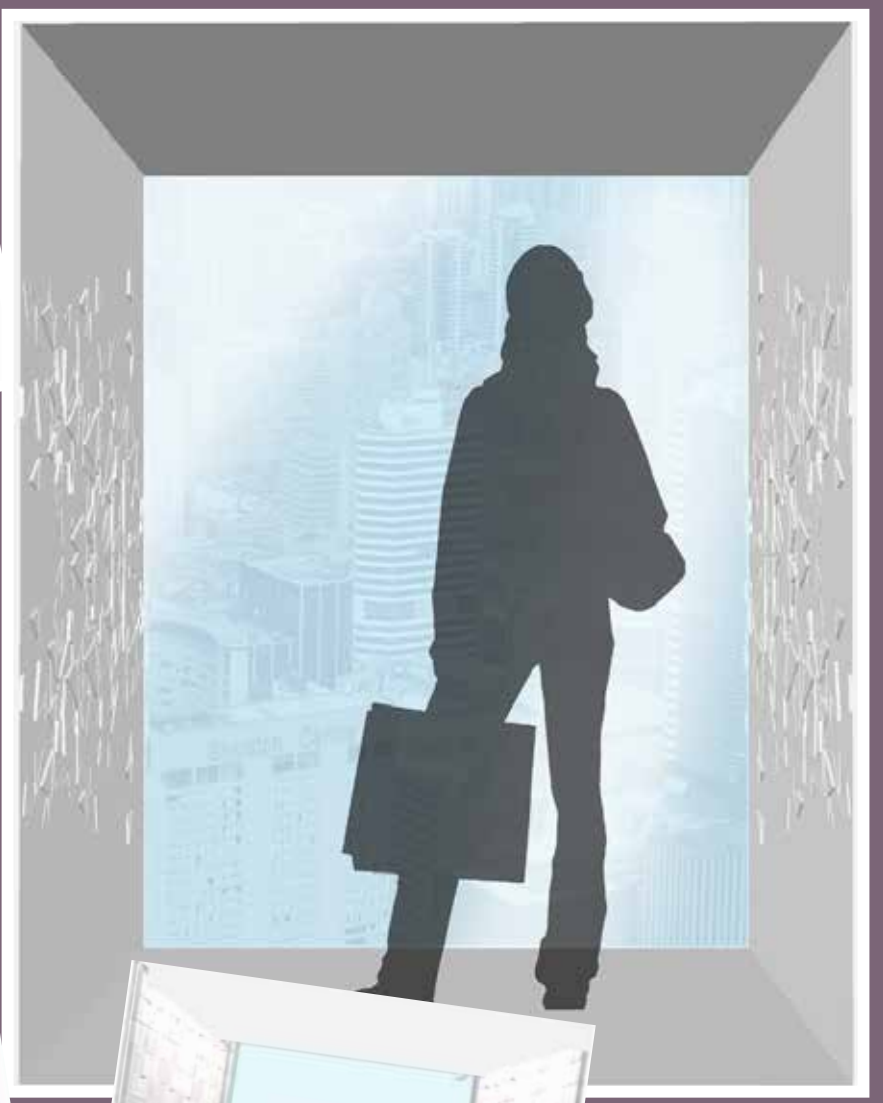

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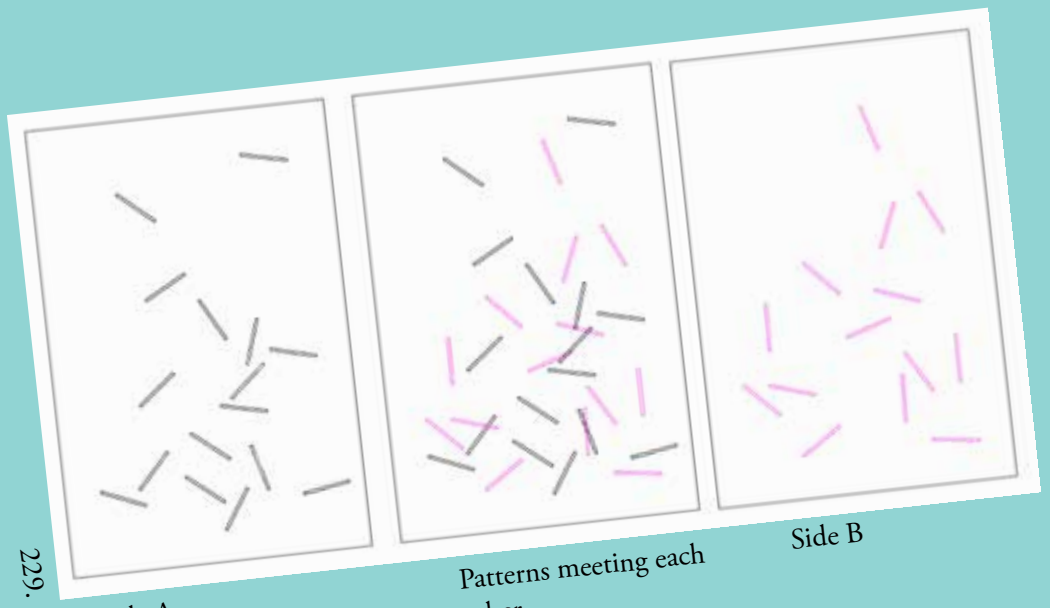

229.

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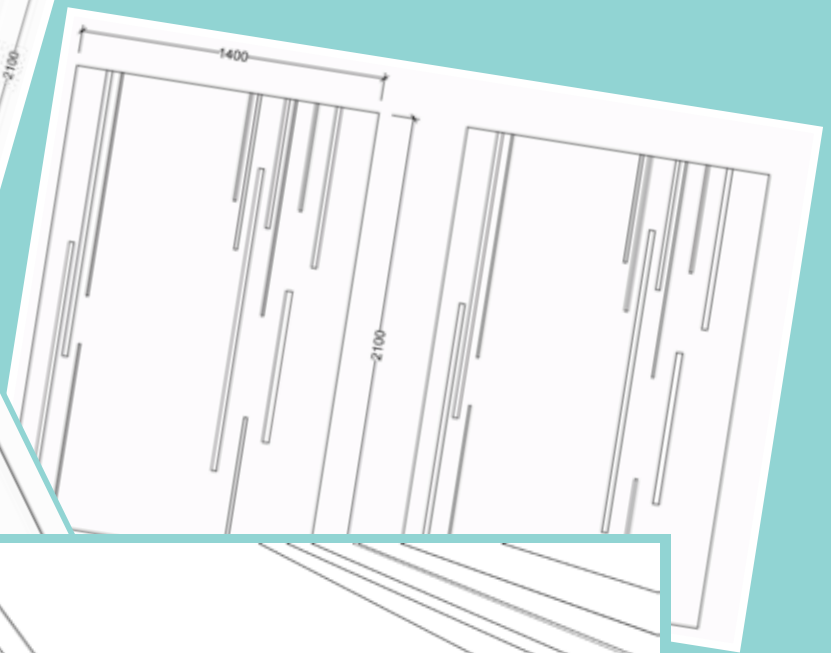
Pictures 229-233. What if future elevator car walls were 3D printed? It would be possible to have wall as one big module with patters on both sides of the wall. If the material is translucent, thinner parts would let light come through emphasizing movement and the pattern.



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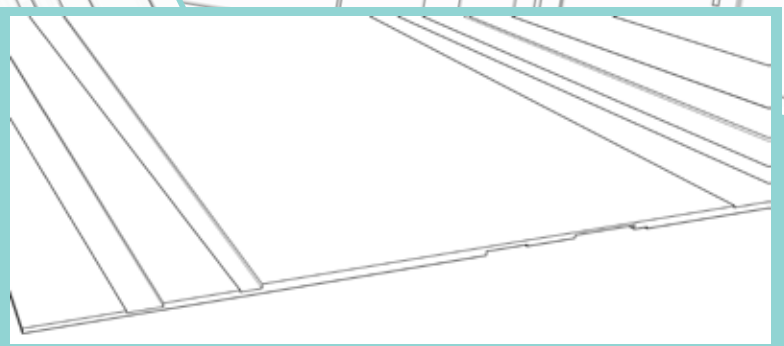

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234. 235. 236.

Pictures 234-237. Is it possible to make elevator car ambience more unique, artistic, humane and asymmetric to avoid feeling of an industrial product?

Final patterns were chosen from scanned sketches from a sketch-book. These dots could be different on each side of the board.

Inside there is less pattern and outside there could be more to raise attention. If material is translucent, it creates many possibilites to play with pattern shining through the material.

237.

Picture 240. Capture from technical drawing. Idea in these are that patterns could be identical on both sides of the wall panel or they could be different and light would shine through were patterns meet.

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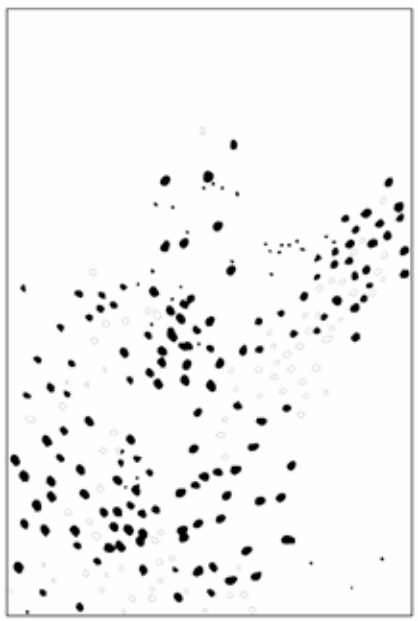
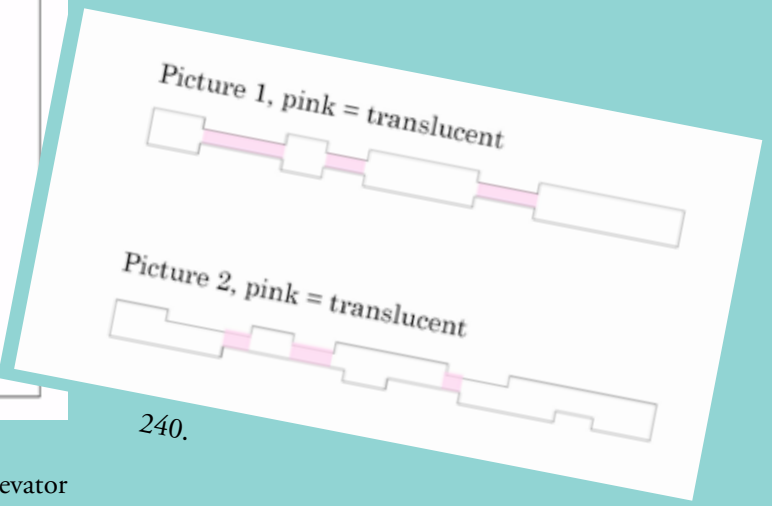


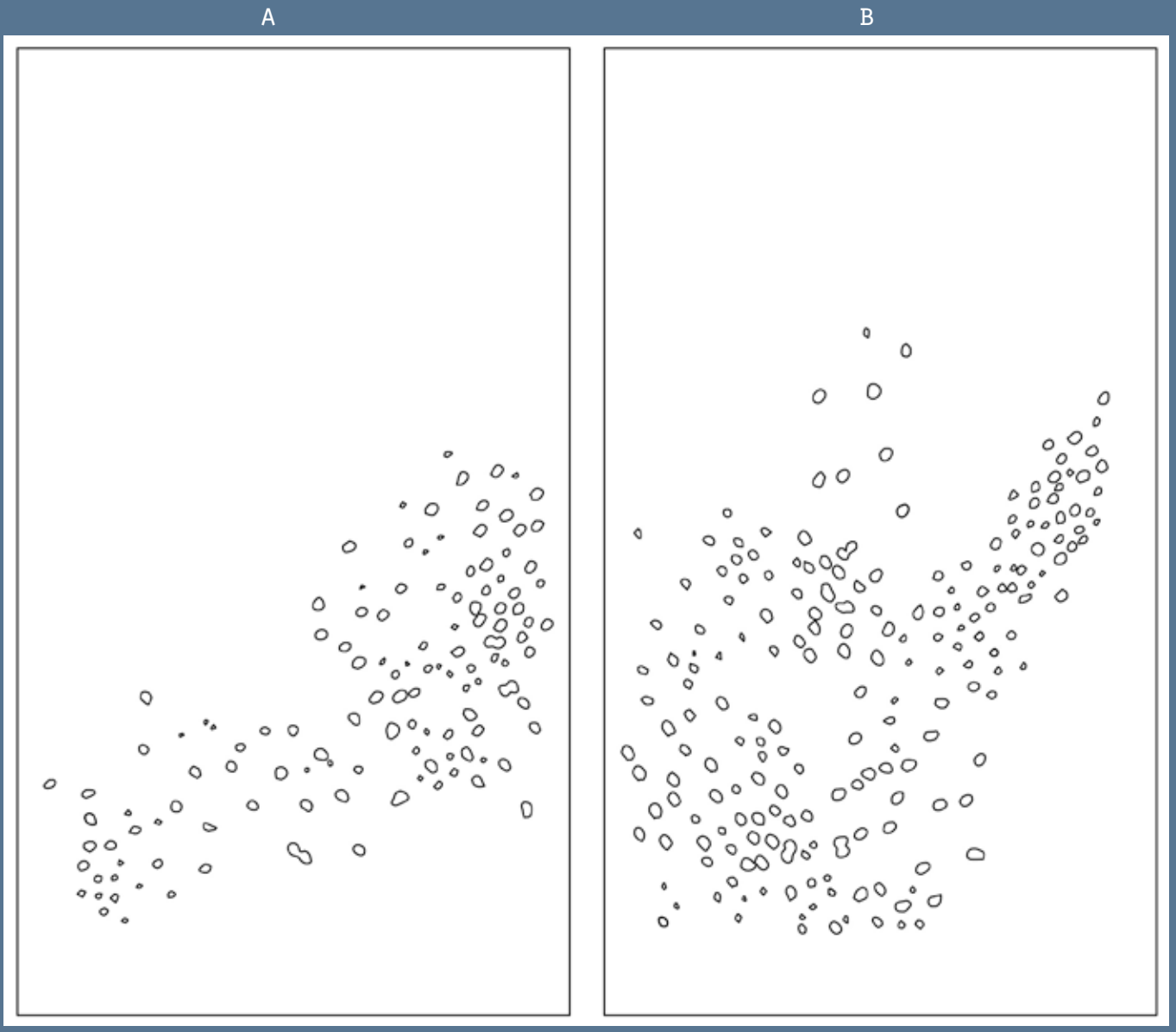
Pictures 238-239.
Testing the pattern on elevator car wall panel in size of (w*h) 1400*2100 mm.



240.

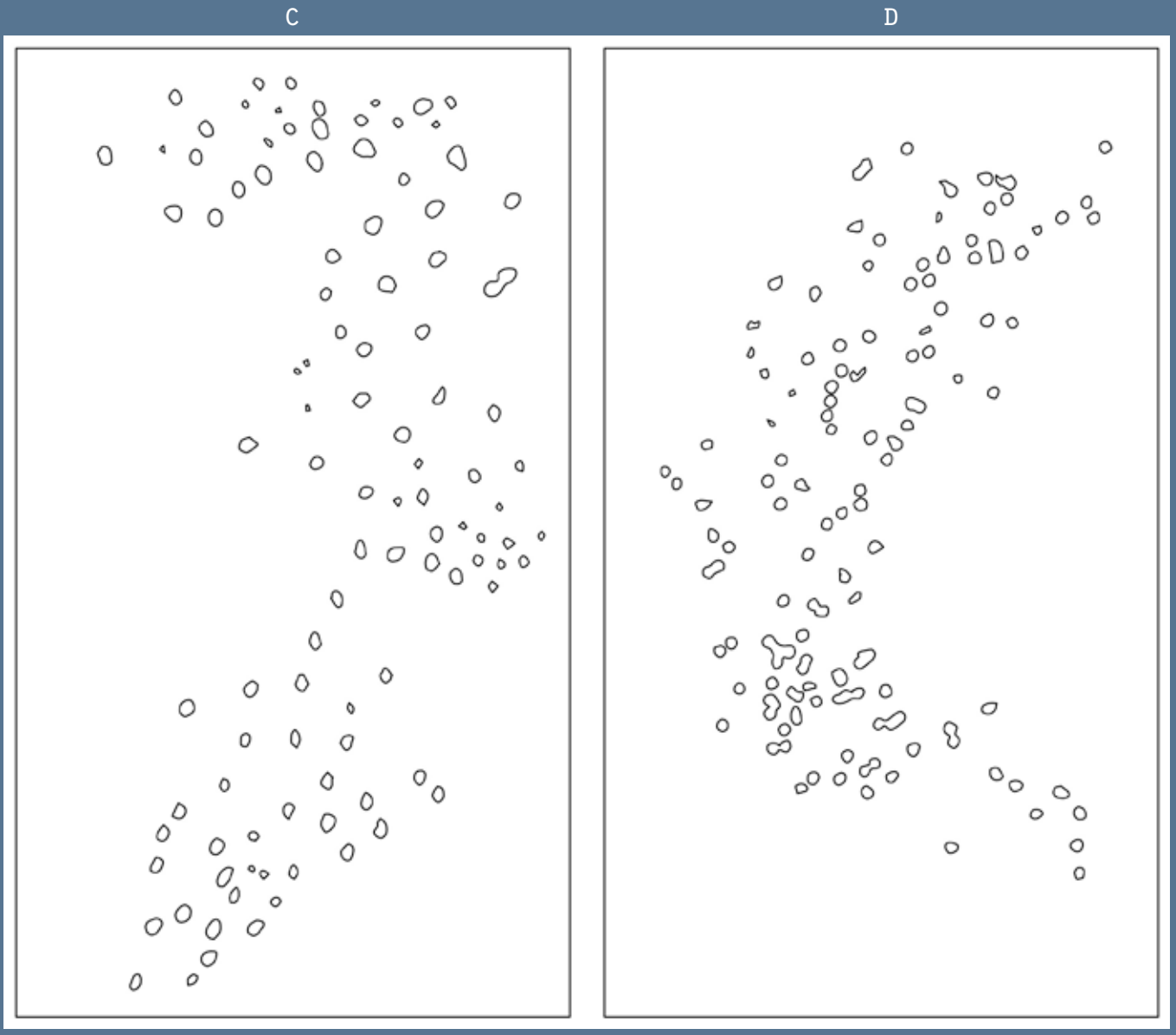
Final patterns for elevator

Picture 241. Sketches of panel in size (w*h) 1200*2100 mm.
A & B are patterns for inside the elevator car. C & D are patterns for outside the car.



CAR WALL PANELLINGS

Picture 242. In future each customer could design their own patterns and even standard elevator car interiors look



8.2 3D MODELLING THE AMBIENCE

The ambience of the future elevator car is personalized and unique. Architects and designers can easily modify existing models to match the building design or create completely new patterns. Ambience is designed for inside and outside of the elevator car. Unique designs make KONE elevators recognisable.

New techniques like 3D printing, allow panels in size of the entire wall. Modularity does not restrict pattern designs. Pattern sizes and quantity varies inside and outside. Three dimensional patterns create interesting shadows and atmoshpere to the elevator car. When material is translucent the patterns from the other side glow delicately through the panel emphasing e.g., movement.

In the car is used as little material as possible. Preferably it would be made out of one material.

Elevator lighting is based on combination of efficient OLED lights and sunlight delivery system, which is able to bring nautural light to windowless spaces. When ever possible, elevator uses natural light, which nearly energyless and renewable.

Buttonless and touchless elevator car is called and floors are chosen through motions. Cameras, as sensors on walls, are able to recognise movements and tell a difference, which move is for “pressing the button” and which is not.

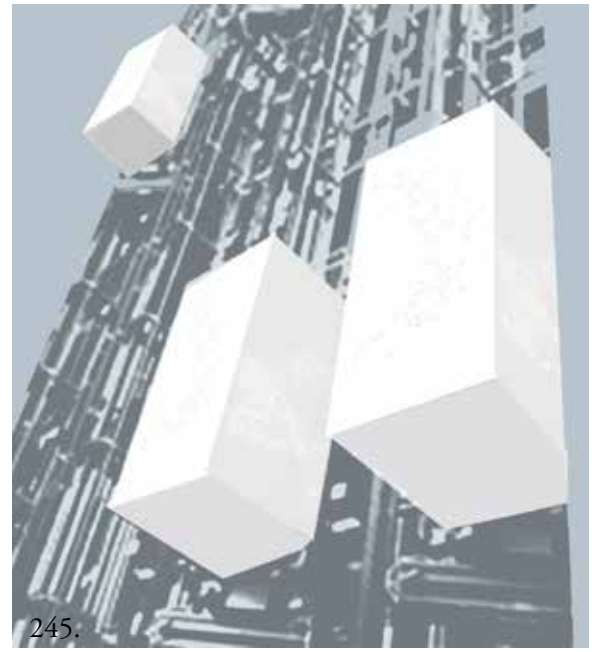
Picture 243. 3D modellings of the ambience.


244.

Pictures 244-245. Ambience is designed inside and outside.

Pictures 246-247. Buttonless & touchless elevator.

Pictures 248. Illustration of glowing patterns.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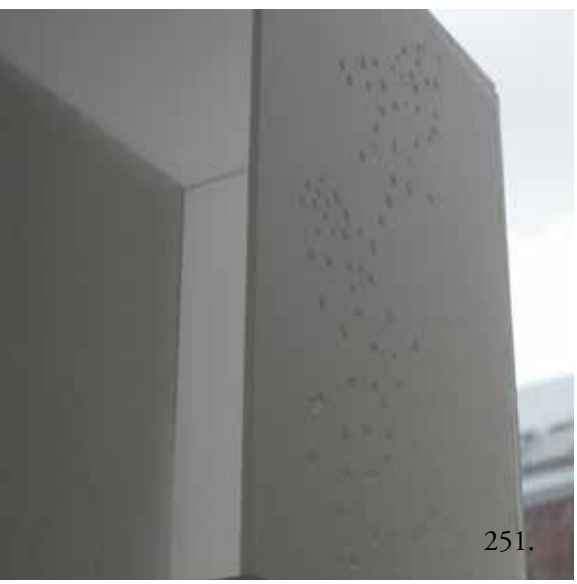

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Pictures 249-257. Ambience and patterns from the scale model.

256.

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9. Conclusions and recommendations for further research

Overall it is clear that sustainability in building industry is expanding fast. Green buildings are going to be new normal in near future. This means that customers acquiring KONE producst are going to ask more sustainable products. To maintain leadership position in most eco-efficient products requires innovations also in other fields than technological. This is where materials step in.

Key findings are that there are lots of potential biomaterials and some of them could be tested and applied immediately, if they are found suitable. As mentioned before, there are hardly any biomaterials that could meet the requirement of heavy industry as they are now. Results also show that most interesting and advantageous possibilites can be achieved through material development process. Even though KONE is not material producer, it is recommended to consider extensive material development project of biobased materials where materials are developed for exactly for its purpose. A material development project usually requires lot of funding. One option is to find funding outside the organisation for example TEKES' Green Growth program. Green Growth programme support projects that are focusing on energy and material efficiency of production and service chains during the entire lifecycle of the products. Programme is particularly supporting projects that looking for growth and renewal of the business through improved efficiency and are willing to break the boundaries of traditional industry sectors. This kind of collaborative project with other company or companies with similar material requirements could be considerable option to KONE. Another suggestion is to sign up to programs like EUs Graphene Flagship and find out if there are any development projects that could be suitable for KONE products.

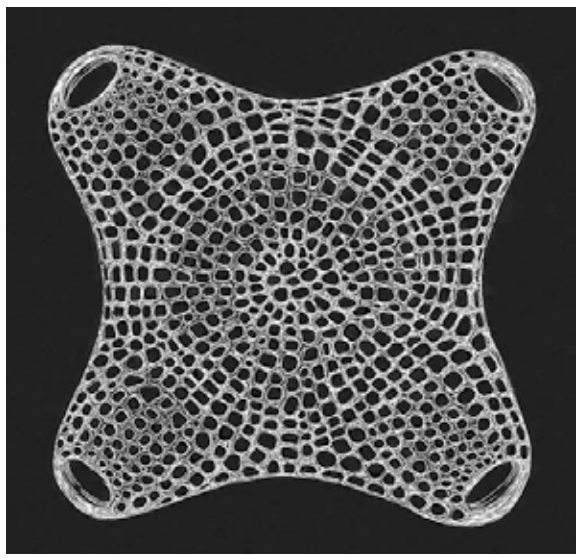
Elevators have not changed much during their history. In fact, maybe "the box" does not require reshaping. It seems bit artificial to provide curved walls made just for the sake of "new design" of the elevator car. However, it might be a time to revolutionize elevator industry by changing the structure of the elevator car to achieve more eco-efficient car. New structure could draw from biomimicry. Who knows, maybe elevator car has new shape and aesthetic look along such project. It might be worthwhile to check if this could belong to Green Growth's scope too.

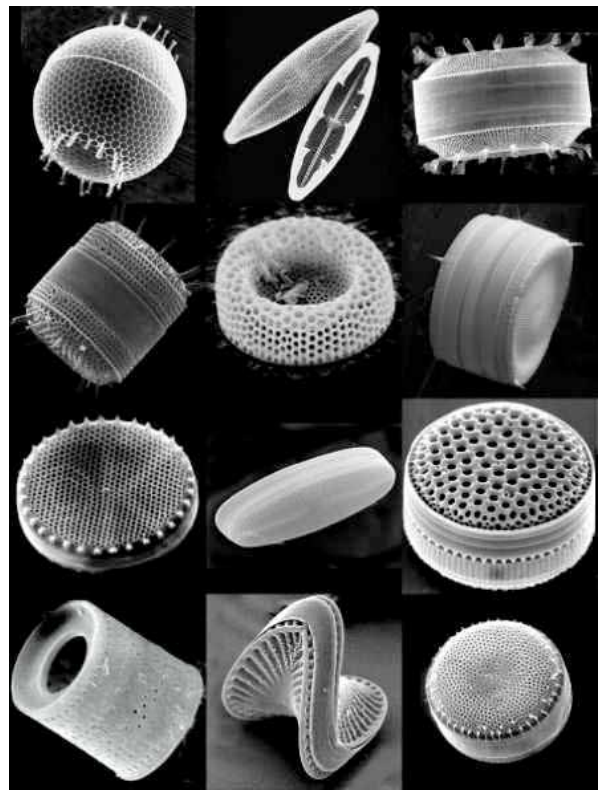
In the meanwhile, before the results of the projects mentioned above are known, KONE should consider to testing and applying following materials

- Replace steel sheets with Hybrix products to reduce product weight in entire of KONE portrolio. Entire lifecycle of Hybrix is more sustainable than convential steel's. Cost is higher, but energy savings during the use could create more value.
- Biosurf lamination. Only biobased lamination that can be modified to company's own designs. Biosurf Solutions states that its lamination has better properties than standard HPL. E.g. scratch resistance. Biosurf is compostable after use.
- Another biolaminate is Dekodur. Unfortunately, it arrived little late to be included to this thesis. But Re-Y-Stone is developed with Dekodur and basically it is same product. Dekodur has better collection.
- Research the possibility to replace heavy steel and cast iron parts with metal parts with foamed or hollow sphere structures.
- GranitiFiandre's Eco-Active materials.

Picture 258 (above). An tempting idea. Grow mycelium on Zelfo. Unfortunately time and budget were limiting. What other options for KONE Composite there are?

Picture 259 (right), 260 (left). Could these diatoms inspire the new elevator structure?





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