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ENHANCING AESTHETICS IN INDUSTRIAL ARCHITECTURE

Integrating 3D-Printed Facade Structures in the Design of an Incineration Plant in Tromsø

Laurea Magistrale In Architettura
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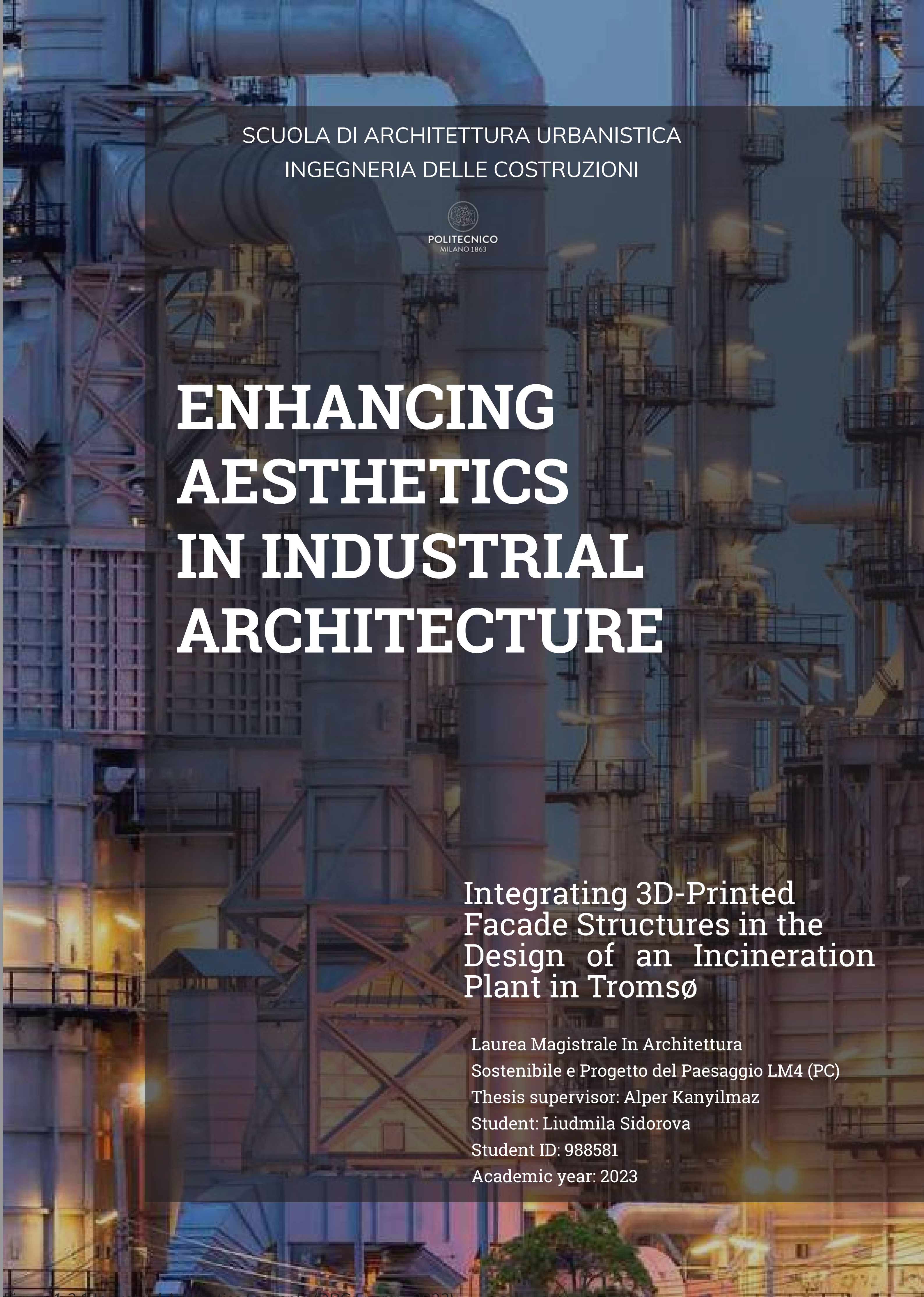

Figure 1-2: Industrial Aesthetics Example (BBC Energy, 2023)

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School of Architecture Urban Planning Construction Engineering
Master of Science in Sustainable Architecture and Landscape Design

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Abstract

Keywords: industrial architecture, additive manufacturing, facade nodes, free-form architecture aesthetics, incineration plant

Without industrial buildings, it is impossible to imagine modern life, although not so long ago they did not exist on earth at all. This thesis dissertation discussed the following questions: Is there a possible future in which industry will exist in harmony with nature and people? How to find a balance between strict functionality and organic architectural forms? One of the possible solutions to this problem could be a more accurate pre-project analysis of the site. In facade solutions, it becomes possible to use additive manufacturing as a more stable and aesthetically attractive design method. This master's thesis examines the origins of industrial aesthetics and suggests possible solutions to improve the aesthetic qualities of industrial architecture using 3D printing for facade fasteners. As an example of the study, a design project of an incineration plant in Tromsø was proposed.

Sommario

Keywords: architettura industriale, manifatura additiva, nodi di facciata, estetica dell'architettura a forma libera, impianto di incenerimento

Senza edifici industriali, è impossibile immaginare la vita moderna, anche se non molto tempo fa non esistevano affatto sulla terra. Questa tesi ha discusso le seguenti domande:C'è un futuro possibile in cui l'industria esisterà in armonia con la natura e le persone? Come trovare un equilibrio tra rigorosa funzionalità e forme architettoniche organiche? Una delle possibili soluzioni a questo problema potrebbe essere un'analisi pre-progetto più accurata del sito. Nelle soluzioni per facciate, diventa possibile utilizzare la produzione additiva come metodo di progettazione più stabile ed esteticamente attraente. Questa tesi di master esamina le origini dell'estetica industriale e discute idee per migliorare le qualità estetiche dell'architettura industriale utilizzando la stampa 3D per gli elementi di fissaggio per facciate. Come esempio dello studio, è stato proposto un progetto di progettazione di un impianto di incenerimento a Tromsø.

INDEX

01 INTRO

“All life is an urge towards harmony” - as Hannes Meyer stated in his work “The New World” [1]. I decided to start the thesis with this citation because we suppose it is very important for every human, especially an architect, to remember it and apply it to everything we create and do. The world has totally changed during the last centuries, mostly as the result of industrialization. “The picture the landscape presents to the eye is more diversified than ever before. This picture has the power to influence through the specific shapes, colours and lights of its modern elements.”[1] The totally new typology was born – industrial buildings. In this context people encountered a very controversial question we found interesting to think about: Do industrial buildings have or need a specific aesthetic? Should architects take a part in the designing process of totally engineering buildings? The thesis is based on curriculum and our own ideas about the importance of the Beauty component in modern sustainable industrial buildings. As a main focus, incineration plant was chosen as a continuation of our bachelor’s degree thesis. We would like to discover: Do we urgently need aesthetics for factories or is only function enough? And if we need it, which methods can be applied?

In the modern world, there are many stereotypes about industrial buildings that have firmly taken hold.[2] People often look down upon these giants made of concrete, metal, and glass. There are several understandable reasons for this, which we will explain further.

First and foremost, people tend to think that factories typically look repulsive.[3] They are either enormous, unimpressive boxes covered in plastic or other cheap materials, or the word “industry” conjures up frightening images of unfamiliar creatures made up of metal pipes and unconventional shapes that also emit columns of smoke.[4]

Moreover, it is widely believed that industry is something that inevitably harms the environment. The working machinery generates a lot of noise, emissions into the atmosphere pollute the air, and the massive concrete buildings themselves heat up the surrounding area, leading to the demise of numerous animal and plant species and negatively affecting human health.[4]

To reduce the visual and ecological impact of industrial buildings, historically, efforts have been made to relocate them to the outskirts of cities.[5] In urban planning, industry is always treated as a separate function that should not be combined with other urban spaces. Of course, these stereotypes did not develop by chance. Since the dawn of the industrial revolution, humanity has made many environmentally critical mistakes while trying to find ways to increase production of various goods.[4] With the rise of capitalism, the situation has exacerbated even further: there was a need to produce more, faster, and cheaper in order to sell at higher prices and continue this endless cycle.

Methods and Goals

This thesis is dedicated to the study of the aesthetics of industrial buildings and modern approaches to designing complex-shaped large objects. The author aims to prove the importance of the aesthetic aspect in industrial architecture, as equal to the practical and structural aspects. Theoretical and practical approaches are used as research tools.

The theoretical aspect delves into the evolution of industrial architecture over time, meticulously examining the development of modern factory structures. It scrutinizes methodologies, materials, and emerging technologies that form the foundation of these architectural giants. Beyond the tangible elements, this theoretical exploration emphasizes the intangible—the aesthetics, the subjective aspect that adds an unquantifiable dimension to these architectural marvels. Rooted in scholarly citations, this section addresses fundamental questions about the intersection of aesthetics and sustainability, especially in contemporary waste management. An intriguing aspect is the exploration of additive manufacturing as a catalyst, transforming industrial architecture and intertwining aesthetics with ecological sustainability. As the theoretical section unfolds, it weaves hypotheses, laying the groundwork for designing industrial structures that embody sustainability, ecological mindfulness, productivity, and undeniable aesthetic allure.

Moving to the practical front, the thesis transitions into the application phase—a realization of theoretical underpinnings in a preliminary design for a waste incineration plant in Tromsø, Norway. This design is not just a visual concept but a fusion of theory with real-world practice. Starting with a meticulously orchestrated preparatory phase, incorporating insights from scholarly works and on-site exploration, the project unveils intricate facade and structural solutions. What sets this endeavor apart is the harmonious blend of human ingenuity with cutting-edge technology—leveraging artificial intelligence and parametric design to sculpt a vision that transcends conventional paradigms.

Throughout the course of this diploma project, a comprehensive exploration of contemporary methods in building design rooted in the principles of sustainable development has been undertaken. A particular focus has been dedicated to delving into the aesthetic dimensions of architectural design for industrial structures. A thorough examination of both paper and online sources has provided valuable insights, serving as the foundation for conclusive observations.

The research extended beyond conventional avenues, involving a firsthand exploration of the terrain. A visit to the city of Tromsø in Norway was orchestrated, constituting a pivotal component of the investigation. This on-site endeavor facilitated a rich and contextually nuanced analysis, complemented by an insightful interview with a representative from Norway's preeminent waste processing company. The interaction not only gleaned pertinent information but also provided a real-world perspective, contributing significantly to the depth and authenticity of the study.

In synthesizing information from diverse sources, this research endeavors to illuminate the intricate interplay between sustainable design principles and the aesthetic facets inherent in the architectural configuration of industrial buildings. The empirical data gathered from the fieldwork in Tromsø supplements the theoretical foundations, fostering a comprehensive understanding that transcends the confines of conventional academic inquiry.

Thesis Structure

Considering the extensive scope of architectural sources and practices covered by this study, a deliberate decision has been undertaken to enhance the clarity and reader's accessibility by segmenting the text into distinct theoretical and practical sections. This strategic division aims to facilitate a more nuanced exploration of the intricate dynamics inherent in both the theoretical underpinnings and practical applications within the realm of architectural discourse. Such an approach not only acknowledges the multifaceted nature of the subject matter but also ensures a comprehensive and comprehensible presentation of the research findings. The theoretical section delves into the conceptual and philosophical foundations, drawing insights from a diverse array of architectural theories and principles related to sustainable development. On the other hand, the practical section grounds itself in tangible experiences and on-site investigations, translating theoretical knowledge into real-world applications. This division optimizes the reader's engagement, providing a structured and insightful journey through the multifarious dimensions of architectural exploration undertaken in this study.

In the theoretical part of this document, we will discuss the development of factory architecture in the modern world. The theoretical segment unfolds as a rich narrative, traversing the nuanced contours of the aesthetics of industrial buildings. Here, we peel back the layers of meaning within sustainable architecture, unraveling its profound implications for industrial structures. Concurrently, our exploration of aesthetics encompasses a historical odyssey, tracing the evolution of design paradigms through the annals of time. This historical contextualization provides a robust foundation for our examination of contemporary trends, where the interplay of functionality and visual allure defines the forefront of industrial architecture.

In the realm of additive manufacturing, we delve into the transformative potential of "free-form" shapes within architectural design, particularly emphasizing their benefits in industrial contexts. The discussion extends to the advantages of free-form façades, acting as a testament to the symbiotic relationship between aesthetics and technological innovation. Grounding these discussions are detailed introductions to additive manufacturing processes, supplemented by case studies that spotlight real-world applications, bringing theoretical concepts to life.

Transitioning seamlessly into the Norwegian context, our theoretical exploration aligns with practical considerations in the realm of waste management. The meticulous choice of Tromsø as the site for our investigation is articulated, setting the stage for a deep dive into the processes of waste management. An interview with Remiks Waste Management Company adds a pragmatic layer, infusing our theoretical understanding with real-world perspectives.

Culminating our theoretical journey are comprehensive suggestions for designing industrial buildings in Norway, where we grapple with the existential question of why these structures should be aesthetically pleasing. This segment provides nuanced insights into the intricacies of designing in harmony with the Norwegian landscape, climate, and cultural ethos.

The transition to the practical part of this research marks a shift from theoretical contemplation to grounded analysis. The practical section of this work is devoted to the preliminary design of a waste incineration plant in Tromsø, Norway. The design is based on the principles derived from the theoretical part and is an attempt to prove the importance of these methods. Our scrutiny is directed toward the specificities of Tromsø, encompassing its climate, landscape, and local materials. An in-depth analysis of local architecture and morphological features lays the groundwork for our subsequent exploration. A pivotal site visit is not merely an observation exercise but a sensory immersion, capturing the colors, textures, and natural landscapes of Tromsø, as well as the distinctive features of its buildings and industrial zones.

As we step into the architectural design project for a waste incineration plant in Tromsø, the practical becomes a canvas for the theoretical principles we've explored. Rigorous analysis of existing conditions is juxtaposed with proposed changes and additions, providing a dynamic narrative of transformation. Detailed descriptions of equipment and the innovative integration of 3D-printed facade nodes contribute to a narrative that fuses sustainability with aesthetic enhancement.

In the concluding chapter, we transcend mere summarization; we distill findings into meaningful insights and draw implications that reverberate across the spectrum of architectural discourse. Our recommendations for future practices serve as a roadmap for navigating the evolving landscape of industrial architecture, embracing sustainability, aesthetics, and technological innovation as guiding beacons. This research, poised at the intersection of theory and practice, resonates as a comprehensive exploration that invites reflection, innovation, and a reimagining of the aesthetics of industrial architecture.

02 THEORY

2.1 AESTHETICS OF INDUSTRIAL BUILDINGS

Sustainable Architecture

Sustainable architecture is an innovative design philosophy focused on creating structures that blend aesthetic appeal with environmental responsibility, resource efficiency, and resident well-being. The main idea is to design buildings that minimize external resource consumption and generate resources independently. For instance, a waste-to-energy plant could use the energy from burning waste to heat the building and provide hot water.

This practical approach aims to improve the ecological and human-friendly qualities of buildings. In practice, sustainable architecture involves aspects like smart energy use, conscious resource management, prioritizing user health and well-being, choosing eco-friendly materials, ensuring building durability, and environmentally friendly disposal of construction materials after use.[6]

From an economic perspective, sustainable architecture may initially cost more in construction, which can deter builders and clients. However, over a few years, it usually pays for itself several times over compared to a regular building. This results in significant cost savings through reduced or reused energy, water, and other resource consumption. Well-designed sustainable buildings also reduce maintenance costs and increase longevity, as environmentally friendly structures are built to last and require fewer repairs and replacements. The competitiveness of such structures increases with the growing demand for eco-friendly spaces. Financial incentives, such as tax benefits and discounts for incorporating sustainable design elements, further enhance economic attractiveness.[7]

Recently, special attention has been given to the well-being of users in modern buildings. Numerous studies have shown that people perform better at work, relax more, and experience fewer illnesses when the spaces they inhabit have ample sunlight, proper climate control, and aesthetically inspiring surroundings. Thus, aesthetics become an integral part of sustainable architecture, forming an inseparable component. It is clear that if people are satisfied with their life, they will protect not only themselves, but also the space around them. which means that sustainable buildings that increase the well-being of their users will last longer and more efficiently. [8]

Overall, understanding and implementing the principles of sustainable architecture empower professionals to create spaces that not only protect the environment but also make a feasible contribution to the economic and social well-being of the communities they serve.

Industrial Aesthetics: Meaning

In parallel to Böhme, from the early 2000s the architect and theorist Peter Zumthor has provided some essential yet key reflections on the role of emotions and feelings in built spaces[6]. In his view, the architect's work is deeply shaped by previous spatial experiences, feeding into the imaginative process by which buildings are designed and crafted. Despite the meticulous care in the material definition of his architectures, Zumthor considers experience as fundamentally oriented by atmospheres, evoked by means of light, sound, the radiance of material objects and a diffuse emotional content that can pervade space. He thus conceives of architectural design as a form of "emotional reconstruction", where feelings both present and past become embedded in the space the buildings institute. [7]

Seeing beauty in industrial buildings should be crucial for their designers. Years after functional or market changes have rendered these buildings obsolete, the simple, wide-open spaces of factories and warehouses with their clear use of building materials ignite the imagination of new generations who are saving these buildings.[3] But before being able to identify this beauty, it is essential to figure out what does "industrial aesthetics" term means.

According to The Great Soviet Encyclopedia (1979), Industrial Aesthetics states the practical steps to organize aesthetically the production environment. These steps include the architectural and artistic designing of interiors; the establishment of optimal light, color, and microclimatic conditions; the artistic designing of industrial equipment; the organization of workplaces and the means of visual communication; the planning of the ground. Another component part of these activities is aesthetic organization of the conditions and process of labor by means of rapidly changing environmental elements (variation in the light and colour climate and means of information, industrial music), works of art, indoor plantings, and so on. Industrial aesthetics ensures comfortable working conditions, which is one of the tasks of the scientific organization of labor. Its effectiveness is determined by the growth of labor productivity and improvement in the quality of output.[8]

The concept of "industrial aesthetics" encompasses the intentional revelation of structural and mechanical components, along with the adaptive reuse of manufacturing facilities. In industrial architecture and design, there is an emphasis on the efficient utilization of materials and construction techniques, often opting not to conceal or camouflage them. This ranges from the transparent exposition of reinforced concrete frameworks in daylight factories to the visible metal trusses found in steel mill buildings, early exhibition halls, and railway stations.[3]

Presently, this approach is employed for aesthetic purposes across various building typologies, extending beyond factories and warehouses. The explicit presentation of structural elements, as well as building systems like mechanical and electrical services, has evolved into a distinctive aesthetic.[3] This aesthetic is prominently showcased in examples such as the nonindustrial Centre Pompidou (R. Rogers & R. Piano, 1977) in Paris, France, where the deliberate exposure of these elements contributes to the overall architectural character.[9]

If we perceive and assess industrial and technical structures from an aesthetic-symbolic perspective, it is clear that the value of these works is not based only on their functional and technical components, but also derives from their specific poetry, monumentality and beauty.[5]

On another hand, nowadays industrial buildings are often could be related to neglected aesthetics because of the lack of attractivity as it is usually understood. But all that we need is to look deeper into the surrounding context, insignificant details that are a pieces of nature and time art. They could be successfully captured as meaningful but scattered places and moments in workers' ordinary life. [10]

We propose briefly reviewing the history of industrial buildings to understand where modern technologies have brought us and whether the field of industrial architecture is as hopeless as it may seem.

Industrial Aesthetics: Evolution

Industrial architecture pertains to the specialized field of architectural design dedicated to the construction of buildings within the industrial sector. These structures are strategically erected to facilitate the efficient and secure processing of raw materials into finished products. A diverse array of industrial buildings encompasses power plants, distilleries, breweries, manufacturing facilities, factories, grain silos, and refineries.
The design ethos of industrial buildings traditionally emphasizes functionality and worker safety, often prioritizing these aspects overelaborate interior aesthetics. However, a contemporary trend has emerged where interior designers are rejuvenating obsolete industrial structures by transforming them into multifunctional spaces. This innovative repurposing breathes new life into these facilities, converting them into modern office buildings, showrooms, apartment complexes, art galleries, and various other adaptive reuse projects. This transformation not only revitalizes the architectural landscape but also showcases the flexibility and adaptability of industrial spaces to meet diverse contemporary needs.
The development of industrial building aesthetics has mirrored the shifting attitudes towards industrialization and its societal implications throughout history. Industrial architecture has a rich historical trajectory dating back to the 1700s, and its influence resonates in the contemporary world.
In the early phases of industrialization in the 18th and 19th centuries, the primary emphasis was on the functionality and efficiency of factories, with aesthetics taking a backseat. For instance, during the First Industrial Revolution, spanning from 1760 to 1830 in England, industrial architecture emerged with the establishment of facilities processing materials like silk, cotton, and brass. Industrial structures were marked by utilitarian designs, constructed primarily from brick or timber, and featured large windows to optimize natural light for the workers within.[11] These early industrial structures were constructed with efficiency in mind, utilizing prevalent building materials of the time, namely lumber and masonry. During this time, society was primarily fascinated by the rapid advancements and economic growth brought about by the Industrial Revolution.[12]

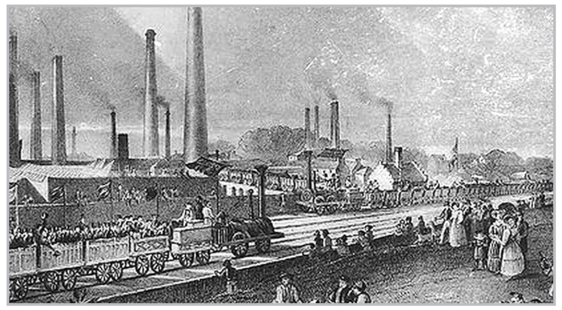

Figure 2-2.1 The Rise of Industrialization (Wajeehali, 2023)

The subsequent era, known as the Second Industrial Revolution, witnessed a significant evolution in industrial architecture. As the Victorian era unfolded in the mid-19th to early 20th centuries, a transition towards more ornamental industrial designs occurred. Inspired by Gothic Revival and Neo-Renaissance styles, industrial buildings started incorporating elaborate brickwork, decorative ironwork, and architectural embellishments. This change in aesthetic mirrored the growing emphasis on social decorum, appearance, and prosperity within an expanding middle class. This phase, characterized by the advent of new building materials like steel and concrete, ushered in advancements that transformed industrial facilities in the late nineteenth and early twentieth centuries. The incorporation of these materials not only enhanced efficiency but also bolstered worker safety.[13]

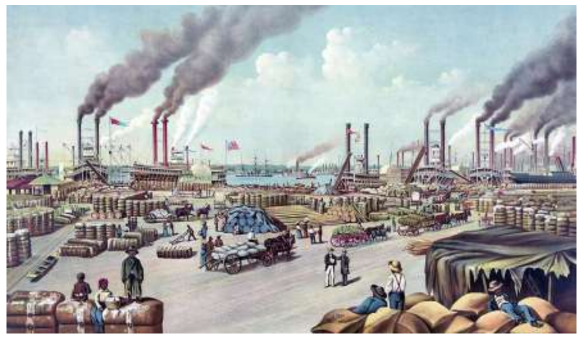

Figure 3-2.1 Industrial Revolution (Hrothsige Frithowulf, 2022)

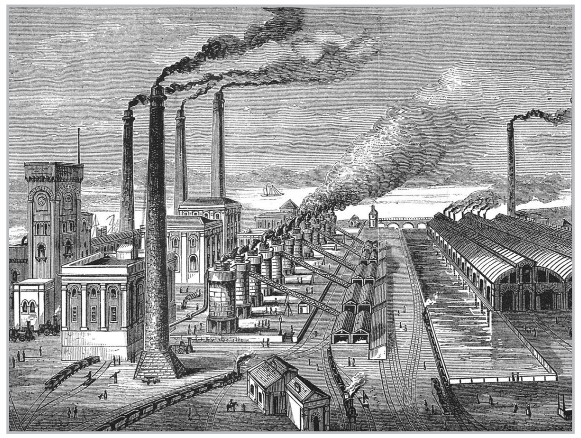

Figure 4-2.1 Industrial Buildings During the Second Industrial Revolution (The Industrial Emporium, 2023)

The early 20th century saw the influence of the Art Deco and Modernist movements on industrial building design. Art Deco introduced geometric patterns, bold colors, and streamlined designs, representing a sense of modernity and efficiency. The Modernist movement prioritized functionality, simplicity, and the use of innovative materials like concrete and steel. These design shifts reflected the era's enthusiasm for technological progress and a desire to break away from traditional styles.

Figure 5-2.1 Fagus Factory, Germany- Walter Gropius and Adolf Meyer (Sigfried Giedion 1922)

[3]
In the post-World War II and contemporary era, industrial aesthetics further evolved, encompassing the International Style and Brutalism. These styles emphasized clean lines, minimalism, and a focus on functionality and structural honesty. Industrial buildings of this era often showcased exposed materials and unadorned facades. [14]
As economies in Europe and the United States shifted towards a post-industrial model in the mid-twentieth century, many industrial facilities faced neglect and deterioration, no longer central to manufacturing jobs. However, a notable industrial revival commenced in the 1960s, notably in New York City, where architecture firms began repurposing obsolete industrial buildings into upscale apartments. This marked the onset of a wave of adaptive reuse projects, aiming to preserve the historical significance of industrial structures while rejuvenating abandoned spaces.
Additionally, the growing awareness of environmental impacts led to a contemporary emphasis on sustainability, energy efficiency, and green design in industrial architecture. In the modern context, industrial architects are responding to a global awareness of the environmental impact of industry.[15] Prioritizing sustainability and contemporary aesthetics, architects are shaping modern factories that not only meet industrial needs but also contribute positively to the surrounding environment. This reflects a broader commitment to marrying industrial functionality with environmentally conscious and visually

Figure 6-2.1 Post-World War II Industrial Buildings (Giuliana Mastri, 2023)

Figure 7-2.1 Incineration Line in Roskilde / Erick van Egeraat (Tim Van de Velde, 2014)

appealing design principles.[4]
In conclusion, the evolution of the aesthetics of industrial buildings reflects a dynamic interplay with shifting societal attitudes towards progress, technology, and environmental consciousness. This transformation spans across various epochs, tracing the trajectory from the initial phases of utilitarian design to the ornate structures of the Victorian era and eventually culminating in the embrace of modernist simplicity. In contemporary times, the aesthetics of industrial buildings continue to be dynamic, influenced by a heightened awareness of environmental concerns. Sustainability and eco-friendly design principles have become integral to the aesthetic discourse, manifesting in structures that not only prioritize functionality but also embody a commitment to minimizing environmental impact.
In essence, the aesthetics of industrial buildings serve as a visual chronicle of societal values, mirroring the prevailing sentiments of different eras. This evolutionary journey underscores the adaptability of architectural aesthetics in response to changing cultural, technological, and environmental contexts.

Contemporary Trends

Architecture is eternal research for harmony between building and its surrounding. The experience of architectural space is considered to be fundamentally atmospheric, a grounding perceptual condition that is direct and deambulatory, kinaesthetic and affectively engaging, synesthetic/polymodal. Buildings are thus no longer described as objects of visual art, but rather as affording possibilities of emotional involvement[16]. The designers' "aesthetic work" can configure the material support facilitating the supervenience of immaterial agents such as light, sound, air, haze and fog, etc., which will influence the subject's emotional response, thereby transversally tincturing space for all those who are perceptually present. According to Böhme, the effects of design are such that an atmosphere can be at least in part produced, albeit considering the architectural configuration as a "stage set" for the unfolding of variable and not fully determined situations. [7]

As we can gather from the history of industrial architecture, progress does not stand still. New technologies allow us to improve not only production volumes but also the quality and environmental aspects of modern buildings. In today's world, a factory is not just a massive machine for production or processing goods. Architects worldwide are constantly searching for ways to integrate industry into the urban fabric while minimizing its negative impact.[17]

For example, Schmidt Hammer Lassen's circular waste-to-energy plant in China. The project of architects Gottlieb Paludan Architects and Schmidt Hammer Lassen Architects have won an international competition to design the world's largest waste-to-energy plant.[18]

The new waste-to-energy plant, Shenzhen East, is designed to incinerate approximately one-third of the city's waste, amounting to around 5000 tons per day. The facility incorporates cutting-edge technologies for waste incineration and electricity generation. However, architects didn't solely focus on technical aspects but also considered the well-being of visitors. The waste-to-energy plant is intended to serve as an educational and informative center for the residents of Shenzhen. The entire plant, including auxiliary buildings, were combined into one round building, breaking the traditional rectangular layout of the technical rooms. Gratefully to the clear round shape, the footprint area is reduced. Moreover, the 66,000 m2 roof is designed in a specific way so it can be covered with solar panels of up to 44,000 m2, which gives the plant the opportunity to produce even more energy for the city. [18]

To demonstrate the production of energy from waste as an important technical process that solves the issues of increasing the amount of waste, as well as the problem of finding more environmentally friendly ways to generate energy, the exhibition path was designed.

Apart from excellent technical qualities, this incineration plant represents a good architect's work with surroundings. The sloped roof and round shape of the building correspond to the landscape with mountains and forests. There are several viewpoints on the top of the plant to let visitors enjoy the natural and urban views. Moreover, the facade design allows one to look through the glass walls to discover the working process inside so the huge walls do not seem so cold and emotionless. Two pipes made of contrast material play a role of architectural dominants to attract people's view from far away.

In the following section, we endeavor to provide a brief introduction to a selection of contemporary industrial buildings. These structures serve as compelling exemplars of the delicate equilibrium achieved between pragmatic utility and the appreciation of beauty in industrial design. Through these illustrative examples, we seek to highlight how modern industrial architecture has successfully integrated functional efficiency with a sense of aesthetic harmony, thus transcending the conventional boundaries of form and purpose.

Figure 8-2.1 The Shenzhen East Waste-to-Energy Plant, Shenzhen, China (Babcock & Wilcox Vølund, 2007)

Volkswagen's Transparent Factory, situated in Dresden, Germany, embodies a distinctive and captivating architectural concept. This manufacturing facility is deliberately designed to captivate attention, featuring an exterior predominantly crafted from transparent glass. This transparency extends beyond the mere visibility of the production process to symbolize Volkswagen's commitment to openness and clarity in its manufacturing operations. The name "Transparent Factory" carries a dual meaning, signifying not only the physical visibility of production activities but also the company's broader philosophy of transparency and willingness to engage openly with its processes and stakeholders.[19]

The BMW Central Building in Leipzig,

Figure 9-2.1 Volkswagen's Transparent Factory in Dresden (Volkswagen AG, 2011)

Germany, stands out within the context of modern industrial architecture. In contrast to the prevalent trend of integrating factory designs with natural landscapes or projecting into the future, BMW has chosen a distinctive path by preserving traditional elements. This approach involves the amalgamation of a conventional office structure with a traditional factory, resulting in a singular, cohesive complex that retains a connection to the industrial heritage of the past.[20]

The McLaren Technology Centre, located in Woking, UK, presents a unique architectural design as it gracefully borders the edge of a tranquil lake. The outer facade of

Figure 10-2.1 BMW Central Building in Leipzig (Werner Huthmacher, 2005)

the McLaren facility traces a lengthy, sinuous path, evoking the form of a continuous 'S.' Notably, the height of the structure has been meticulously constrained, a deliberate measure aimed at mitigating its visual footprint on the surrounding environment. This intentional limitation ensures that passersby retain the ability to observe the natural canopy of trees rising above the building, preserving the coexistence of modernity and nature.[21]

Figure 11-2.1 McLaren Technology Centre, Woking, UK (Foster and Partners, 2004)

The Vysota 239 Plant in Chelyabinsk, Russia, stands as an intriguing testament to innovative industrial design. Its walls are adorned with an array of brilliant and eye-catching colors, and the walkways and safety zones within the complex are elegantly appointed with wooden panel flooring that gleams reminiscent of a basketball court. This warehouse's aesthetic charm is so captivating that it could effortlessly be misconstrued as an integral part of an amusement park, masking its true identity as a pipe rolling factory.[22] This unconventional design not only defies traditional industrial norms but also reimagines the potential of industrial spaces, pushing the boundaries of creativity in the architectural realm.

Figure 12-2.1 The Vysota 239 Plant in Chelyabinsk (Indira Valeeva, 2011)

In Gaydon, Warwickshire, UK, the Aston Martin facility epitomizes a design philosophy rooted in understated elegance. The factory's unassuming exterior seeks to emulate the pristine, lustrous hoods of the luxury automobiles it produces. Just as the exterior belies the intricate power under the car's hood, this architectural approach conceals the complex and sophisticated processes that underpin the production of these exceptional vehicles. It is a testament to the seamless integration of form and function, reflecting the essence of the Aston Martin brand and the artistry behind its automotive creations.[23]

Figure 13-2.1 The Aston Martin Facility

The Flamingo Landfill Gas Power Plant, situated in Sweden, is a unique architectural endeavor where form harmoniously coexists with function. Positioned atop a landfill site, this power plant boasts an aesthetically striking green roof that seamlessly integrates with the natural surroundings. The design not only provides an innovative approach to environmental sustainability but also encapsulates the notion of unobtrusive, ecologically mindful industrial architecture.[24]

Figure 14-2.1 Värtaverket biomass power plant in Stockholm (Robin Hayes, 2018)

Figure 15-2.1 Copenhill, a waste-to-energy plant, Copenhagen, Denmark (Hufton + Crow, 2020)

The ARC Amager Bakke, commonly referred to as Copenhill, is a waste-to-energy plant located in Copenhagen, Denmark, that serves as a remarkable fusion of energy generation and community amenity. [25] This innovative architectural concept encompasses a distinctive design, characterized by the inclusion of a ski slope on its roof. This multifaceted approach not only provides a novel form of recreation for the local community but also concurrently harnesses clean energy from waste materials, thus redefining the role of industrial facilities in urban landscapes.

The Spittelau Waste Incineration Plant in Vienna, Austria, distinguished by its collaboration with celebrated artist Friedensreich Hundertwasser, emerges as a captivating architectural testament. Its notable features encompass a vibrant and artistic exterior, adorned with striking colors and distinct architectural elements. Beyond its visual impact, this plant plays a vital role in Vienna's district heating system, while also embracing cutting-edge air filtration technologies to ensure sustainable and environmentally conscious operations. [26] This integration of artistry and industrial functionality reflects a forward-thinking approach to architectural design and environmental responsibility.

Figure 16-2.1 Spittelau Waste Incineration Plant in Vienna (Victoria Mazurova, 2019)

Figure 17-2.1 BWM Welt Museum Munich, Germany (Galih Rama, 2023)

The BMW Welt in Munich, Germany, although not a conventional automobile manufacturing facility, fulfills a unique role as a vehicle delivery center and exhibition space. Its architectural concept transcends the ordinary, entwining aesthetics with a commitment to sustainability through the integration of solar panels, rainwater harvesting systems, and energy-efficient technologies. [27] This juxtaposition of form and function within the design of BMW Welt exemplifies a modern architectural approach that marries the allure of design with a conscientious dedication to environmental responsibility.

Therefore, by shifting our perspective to view industries not as financial liabilities affecting aspects ranging from construction to environmental considerations, but as entities replete with substantial potential, we have the capacity to enact profound qualitative transformations in the current situation. Such a shift in perception holds the promise of contributing to the incremental betterment of our world.[28]

2.2 ADDITIVE MANUFACTURING IN ARCHITECTURE

The realm of architecture has always been a canvas for innovation and creativity, and today, technology is broadening our horizons. This thesis encapsulates my journey into the world of steel 3D printing in architecture, with a particular emphasis on the development of connections for a distinctive freeform façade. First of all, I would like to discuss some essential topics related to additive manufacturing and its impact on design possibilities.

Figure 18-2.2 Free-Form Architecture Example - Harbin Opera House by MAD (Lidija Grozdanic, 2015)

The benefits of Free-form Shapes in Architecture

Place as a concept is relevant to research in aesthetics because an integral feature of specific places is their environmental atmosphere and "sense of place" marked by what the ancient Romans spoke of as genius loci—the specific character, ambience, and spirit of a place contributing to its effable and ineffable environmental uniqueness[29]. While specific environments may lend themselves to diverse modes of experiencing a place and shaping its atmosphere, the landscape of a site can sometimes possess a captivating charm, such as a breathtaking view of mountains. In such cases, free-form shapes can enhance the visual appeal and the unique sense of place, a quality challenging to achieve with straight lines. Furthermore, leveraging the natural landscape eliminates the necessity for designing exceptionally distinctive buildings; instead, one can harmonize with it, imitating mountain curves and adopting a natural color palette. Regarding the lived aesthetics of places, it becomes apparent that their atmospheres are elusive and mutable, defying complete understanding or description. These atmospheres extend beyond visual perception, encompassing various lived qualities like sound, smell, tactile sensations, emotional resonances, and the dynamic, indeterminate presence of elements, spaces, and environmental characteristics.[29]

Conversely, certain locations may exhibit a flat and uninspiring urban landscape dominated by mundane block-style apartments. In such instances, the introduction of free-form structures can rejuvenate the area, transforming it into a fresh and appealing focal point. Guggenheim Bilbao Museum is a representative example of how architecture can change the city life for better.[9] As the effort to shift Bilbao from an economy centered around industry to one focused on services persisted, news emerged that the Guggenheim Foundation aimed to expand its presence in Europe. In 1991, a pact was forged between the Basque government, regional authorities, and the foundation, outlining the construction of a new museum. Designed by Frank Gehry, this museum would showcase a portion of the Guggenheim's renowned art collection. Fast forward a quarter of a century, and the Guggenheim has become a radiant and integral element of the city, drawing

in nearly 25 million visitors since its inauguration and contributing an estimated €6.5 billion to the Basque country. Presently, industry is predominantly situated on the city's outskirts, while tourism constitutes 6.5% of Bilbao's GDP—a stark contrast to the era when few ventured to Bilbao unless for business or family visits.[28]
As a design approach rooted in algorithms that seamlessly blend design intent with actual outcomes, parametric design has sparked extensive discussions within the architectural community. Its ability to create intricate geometries and structures through the dynamic interplay of elements captivates widespread attention.[30] The rise of modern computer-aided tools has made intricate architectural shapes more accessible and popular in design and modeling. This development, however, prompts inquiries into the practical and cost-effective implementation of these designs. Employing genetic algorithms and parametric design proves highly effective in generating diverse solutions for complex problems. Nevertheless, the designer's role remains crucial in evaluating outcomes and selecting a design based on qualitative objectives. [31]
It is important to note that free-form architecture presents challenges in terms of geometry, structure, and construction. Addressing these challenges necessitates various optimization stages to achieve a viable and cost-effective solution. The advent of robust tools, including parametric and algorithmic design software, provides significant flexibility in shape design and effective control over extensive data management. These tools enable the integration of structural and construction considerations as guidelines for geometric generation and optimization, facilitating a more comprehensive and efficient design process.[32]

The Benefits of Free-form Façade for Industrial Buildings

As we delve into the realm of industrial architecture, the departure from traditional geometric constraints becomes evident in the prominence of free-form facades. Freeform façades, characterized by their deviation from traditional geometric constraints, have become a hallmark of modern architectural expression. These designs often take inspiration from nature, geological formations, or abstract concepts, resulting in intricate, organic forms. However, the intricacy of these designs has presented challenges when it comes to their construction and the creation of connections. However, the intricacy of these avant-garde designs presents unique challenges, particularly in construction and connection creation. Addressing these challenges, steel 3D printing emerges as a promising solution.
Reflecting on the historical evolution of construction types, we observe a shift from designs inspired by nature to more complex, scientifically influenced constructions. At the beginning, people were making buildings inspiring themselves

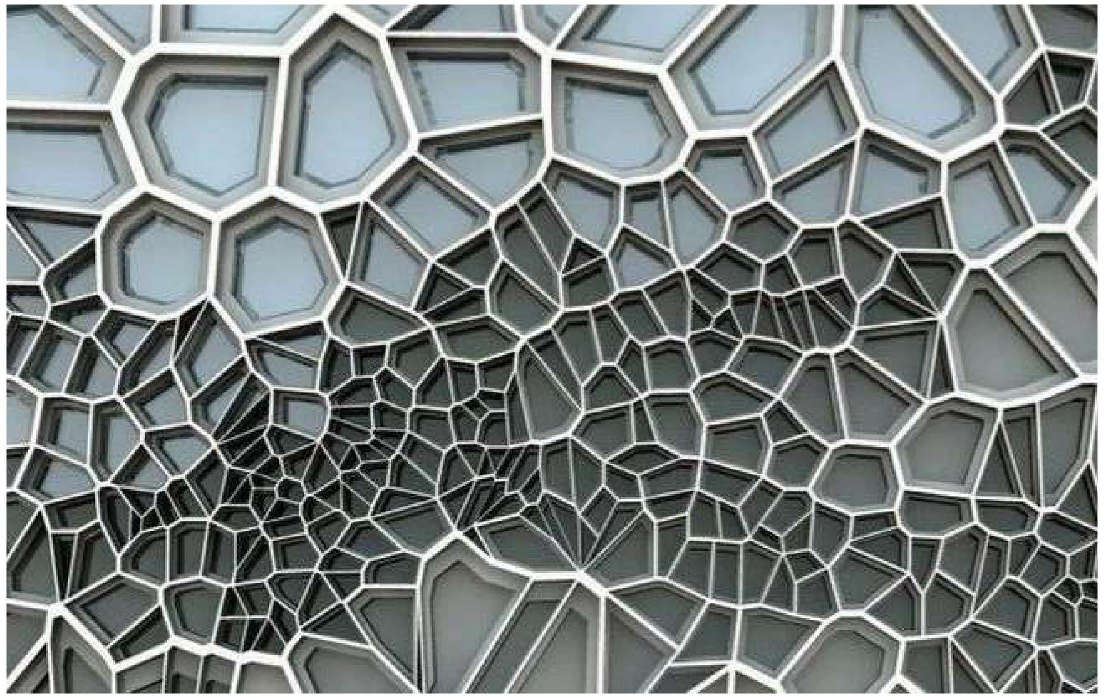

Figure 19-2.2 Free-Form Facade Example (Mucha Tse Ble, 2023)

from different shapes that existed in nature. As humankind made scientific discoveries, the types of constructions evolved. [17] In the realm of industrial buildings, the aesthetics of a structure can be greatly influenced by a free-form facade. Utilizing parametric design in this context proves not only aesthetically valuable but also highly practical. Geometric computing has recently expanded its applications into a new domain, addressing various geometric challenges inherent in the rationalization and construction-aware design processes associated with free-form architecture.[32] There are several benefits of this approach.

In the context of industrial buildings, the aesthetic impact of a structure is significantly shaped by the incorporation of free-form facades. Introducing parametric design proves to be not only aesthetically valuable but also highly practical. One of the primary features defining industrial buildings is their immense scale, often disproportionate to the human scale. The industrial site, opposed to the industrial area, arouses by "trailing" with all the sense awakened, similar in some way to wild animals that "feel" danger. This type of thinking is named by Martin Heidegger Besinnung "meditative thinking". [34] The space is a subtle quality of architecture that can be perceived only by physical elements which delimit it – walls, floors, volumes, etc. As the form has less significance and involves less interpretation liberty, the architecture is limiting towards the physical frame, becoming more of a machine, and approaching to "the descriptive art". It can have documentary historical value, but in order its significance not to stop here, it should aspire to the status of authentic art. But the aesthetical experience is conditioned by perception, by the world of senses. [34]

Drawing inspiration from nature, especially natural lines and shapes, proves to be a valuable element in creating facades that are not only visually appealing but also inviting to the human eye. We love views on mountains, water, or trees even though they are way bigger than our usual houses. Natural lines and shapes can make the façade seems more friendly and attractive to the human eye. Our evolution as human beings, either of material or spiritual nature, is based on the experiences we have in relation to outside world. In this interaction, the first element setting the connection between the two aspects is our capacity to conceive, through feelings, the conditions of outside environment. Without this perception, man cannot reason, cannot make valuable judgments, or cannot interpret a certain message – either of rough – physiological or subtle nature.[34]

Transitioning to the rehabilitation of industrial buildings, the process involves shattering the illusion of progress and reintegrating space into nature. This transformative approach views the building, after the cessation of its utilitarian function, as a natural form—a relief that delineates the building space. Therefore, the rehabilitation of an industrial building consists in fact of shattering the illusion of progress and reintegration of space in nature. The building becomes by itself after the extinct of its utilitarian function and of its initial logic, as a natural form, a relief form delimiting the building space. The abstracting of form and space can play a therapeutic role in the rehabilitation of architecture and society, because only through dematerialization of matter, in the sense of "spiritualization", one can find the fertile ground for evolution, without losing the contact with solid history. This is a challenge for the creative and artistic side of architect, who is called to "open" the rigid box and enable multiple interpretation of the object. [34]

Shifting focus to sustainability, the use of parametric design in creating factory-made free-form external envelopes emerges as a significant demand. Advances in digital fabrication offer opportunities for mass-producing these envelopes. Recent advances both in computer generated 3D forms and in digital fabrication offer a new opportunity of mass production free-form panels for architectural envelopes. One major issue when dealing with mass-production components for building construction is the usually short number of repetitive parts. Moreover, given that flexibility and customization are a desirable virtue of a good industrial process, methods that allow for single unit production are of great value. In this way digital processes could be the answer to the inherent architectural variation. [35]

Beyond construction costs, considering natural aspects of sustainability becomes imperative. Integrating factors like sunlight patterns in facade design not only enhances energy efficiency but also positively impacts health, mood, and overall productivity. Prefabricated free-form architectural envelopes are currently possible both using transparent or opaque materials. Digital control of forms plays a major role in the design stage. Nevertheless, seamless flow from digital design to digital fabrication has not yet been achieved. 3D software for creating solid forms are broadly available for architectural purposes, but panel division of big sized forms are not yet completely automated though several research attempts are on the way.[35] Buildings with architectural free forms are special buildings, momentous, that indicate a new stage in architecture. This was possible due to the vision of the architects who know how to use the most advanced and latest software for calculating installations and structures and manufacturing technologies in the world. Buildings meet the highest requirements of modern habitat, being equipped with the latest equipment to make it ecological in the process of exploitation, being called "green buildings". [17]As we can see, the mass production of free-form facades is already possible, even though it has its own pros and cons. Apart from the cost of construction, it is possible to achieve some natural aspects of sustainability. For example, if we take the sun pattern into consideration during façade design, it becomes possible to use the energy in a better way.[36] Apart from the energy savings achieved through better use of daylight in building design, researchers have also reported daylight's positive impacts on health, mood, productivity, and learning. From an energy perspective, daylight provides both light and heat. Even so, the outdoor climate and indoor temperature are seldom in balance, requiring the consumption of energy to provide a comfortable indoor climate. Astute use of the benefits of daylight can therefore be profitable for companies if it increases productivity and decreases absenteeism, offsetting any investment in optimizing daylight in the building. If the impact of daylight can be expressed in terms of financial benefits (related to, for example, sustainability or health), windows will be considered as an asset and not simply an expense. [37]

Expanding the ecological perspective, rainwater collection on free-form facades emerges as a practical and reasonable approach. This not only addresses water conservation but also offers substantial benefits, such as reducing the load on drainage systems and lessening the environmental impact. In this case, free forms are more reasonable rather than straight ones. The ecological benefits of recycling rainwater are potentially huge: toilet flushing, for example accounts for up to 35% of the average household's water usage.[38] Add in the amount of water we use for washing clothes or watering the garden and the possible savings begin to grow.

For businesses these figures are much higher, particularly for industries such as hotels that have many regular guests in one place. Using rainwater harvesting for jobs such as flushing the toilet eliminates the need to use fresh drinking water from the mains and offers a significant reduction in the total water usage. The main ecological benefit offered using rainwater collection systems is the reduction in this use of mains water which means that less water will need to be artificially drawn from the environment, a supply that is best used for drinking, bathing, and cooking.

One of the other ecological benefits of rainwater harvesting systems is that they can lessen the load placed upon drainage systems, reducing the effects of flooding by channeling the run-off water into tanks for recycling.[39]

The advent of additive manufacturing, better known as 3D printing, marked a new era in architectural design and construction. Especially, 3D printing of stainless steel has become popular due to its exceptional strength and versatility. This technology allows architects and designers to design and implement structures that were previously unavailable. It has redefined the way we approach architectural components, including connections, by offering a level of precision and complexity that was previously unattainable.[41]

Additive Manufacturing (AM) represents a cutting-edge technology wherein digital 3D design data serves as the blueprint for constructing components layer by layer through the deposition or growth of solid material. This process is entirely digital and necessitates the initiation from a 3D Computer-Aided Design (CAD) model. The model is then segmented into layers, each of which is transformed into a trajectory or path for the AM machine during the construction of the part.[42]

Introduction to Additive Manufacturing (AM) Processes

This disruptive technology provides tremendous advancements in how we can design and develop components to make them lighter and more efficient. When we pair the design technology with manufacturing advancements such as 3D printing, our approach is completely transformed and is fundamentally different to co-create with the computer in ways we simply couldn't have imagined before.[40]

— GM Vice President Ken Kelzer, Global Vehicle Components and Subsystems

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The conceptualization of AM dates back to the early 1900s, yet its full realization has materialized primarily in the last two decades due to advancements in contemporary technologies. Several factors have contributed to this development: enhanced cost-effectiveness attributed to improved equipment, widespread accessibility to computers and software, the ubiquity of the internet facilitating seamless data exchange, the availability of diverse material sources, and opportune timing for the concept. Rapid prototyping, an initial nomenclature for AM, encompassed die less, digital, additive production of prototypes, as well as rapid tooling involving easy material management and the additive production of moulds and tools.[43]

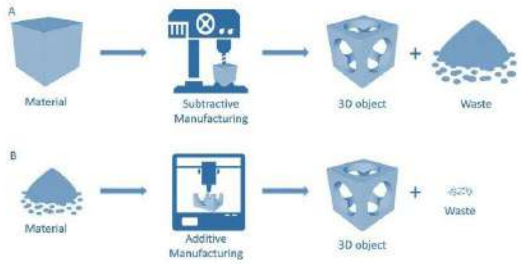


Figure 20-2.2 Substractive and Additive Manufacturing (Michael Berer, 2019)

However, AM has evolved to be more comprehensive than the term “3D printing” suggests, with the latter now specifically denoting the binder jetting technology at MIT. The original AM technology, Stereolithography (STL), marked the inception of this revolutionary approach. Presently, STL serves as a format for CAD featuring triangular surface patching after being sliced and converted into a process path through AM software. This shift signifies a transformation from traditional formula-based design to a wholly digital process utilizing computers to conceptualize complex geometries.[42]

AM process chains are integral components in modern manufacturing cycles, and its relevance is underscored by three key factors: being a completely digital technology, requiring no specialized tools, and enabling intricate geometrical complexity. It optimizes technologies such as undercuts and topological optimization, the latter involving weight, material use, and shape optimization, providing a novel perspective for design, and offering excellent prospects for space technology.

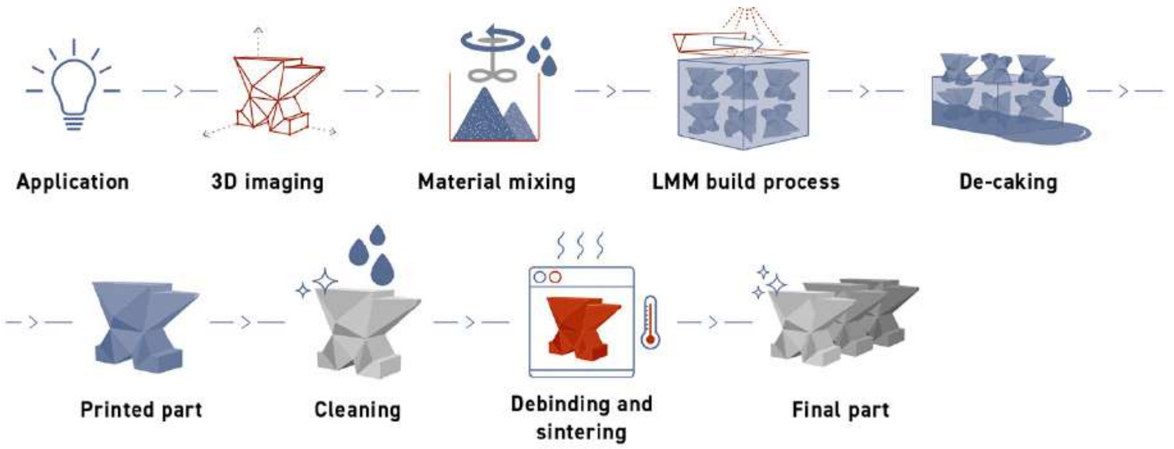


Figure 22-2.2 Vat Photopolymerization (Incus, 2019)

There exist seven primary additive manufacturing (AM) processes, each distinguished by unique attributes and applications. The first process is Vat Photopolymerization, specifically Stereolithography (SLA). In SLA, a vat of liquid photopolymer resin is employed, and the material is selectively solidified layer by layer using ultraviolet (UV) light. This process is commonly favored for generating detailed prototypes and intricate patterns, especially when a high surface finish is imperative.

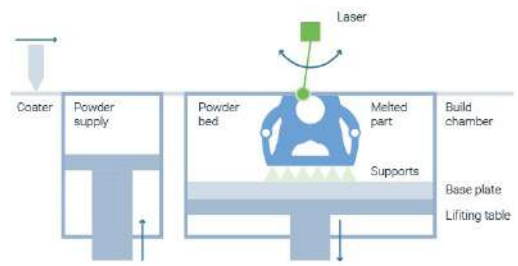


Figure 23-2.2 Selective Laser Melting (Ampower, 2023)

The second category is Powder Bed Fusion, which includes techniques such as Selective Laser Sintering (SLS), Selective Laser Melting (SLM), and Electron Beam Melting (EBM). These methods entail selectively melting or sintering powdered material layer by layer to construct the final 3D object. Powder Bed Fusion, particularly SLS, is often applied in scenarios requiring functional prototypes and end-use parts with complex geometries.

Material Extrusion, also recognized as Fused Deposition Modeling (FDM) or Fused Filament Fabrication (FFF), constitutes the third AM process. It involves heating and extruding a thermoplastic filament through a nozzle layer by layer to fabricate the desired object. This process is widely acknowledged for its versatility and accessibility, commonly used in rapid prototyping and concept modeling.

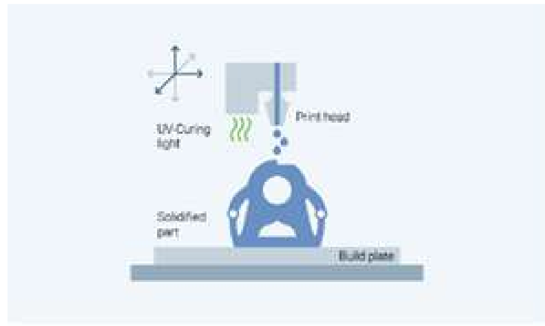


Figure 24-2.2 Material Jetting (Ampower, 2023)

The fourth process is Material Jetting, where droplets of liquid photopolymer are jetted onto a build platform and cured by UV light. Material Jetting allows for the simultaneous use of multiple materials and colors in a single build, making it suitable for creating highly detailed prototypes and multi-material parts.

Binder Jetting, the fifth process, operates by selectively depositing a liquid binder onto a powder bed to bind particles layer by layer. This technique finds application in producing metal, ceramic, and sand casting molds, as well as complex and large-scale parts, with additional post-processing often required.

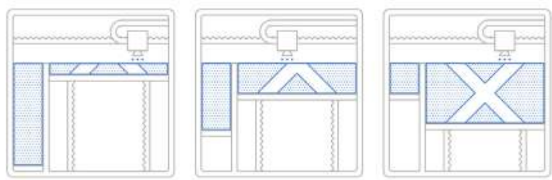


Figure 25-2.2 Schematic Binder Jetting Process (Cristina Fabuel Bartual, 2022)

Sheet Lamination, also known as Laminated Object Manufacturing (LOM), constitutes the sixth AM process. It involves layering and adhering sheets of material together, with each layer cut to the intended cross-sectional shape. LOM is particularly suitable for creating large prototypes, patterns, and molds, emphasizing cost-effectiveness and quick production.

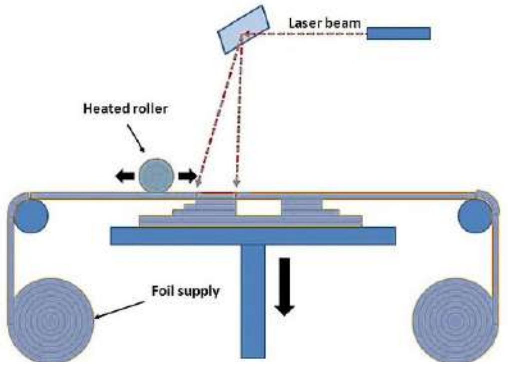


Figure 26-2.2 Sheet Lamination (Pinterest, 2023)

The seventh and final process is Directed Energy Deposition (DED). This method utilizes a focused energy source, such as a laser or electron beam, to melt material as it is deposited onto a substrate or existing structure. DED is commonly employed in repairing or adding material to existing components, as well as creating near-net-shape metal parts with complex geometries. Each of these AM processes contributes to the diverse landscape of additive manufacturing, offering a range of solutions for various industrial applications.
Among these, Wire and Arc Additive Manufacturing emerge as particularly pertinent for architectural applications due to its derivation from arc welding, presenting higher build rates and suitability for a variety of weldable materials.[44]
In conclusion, the diverse array of additive manufacturing (AM) processes opens new frontiers in the realm of industrial production and design. From Stereolithography's

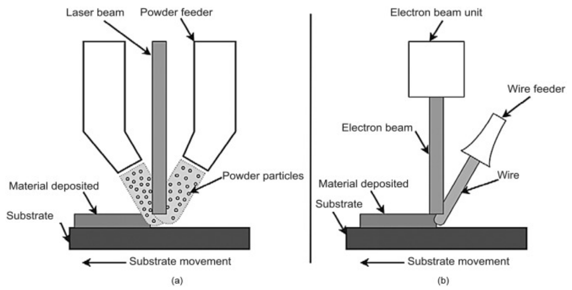


Figure 27-2.2 Directed Energy Deposition (Bansal, 2023)

precision in crafting intricate prototypes to Selective Laser Sintering's prowess in producing complex geometries, each technique caters to specific needs within the additive manufacturing spectrum. Material Extrusion, Material Jetting, Binder Jetting, Sheet Lamination, and Directed Energy Deposition further contribute to this landscape, offering versatility, multi-material capabilities, cost-effectiveness, and the ability to work with various materials, including metals and ceramics.[41]

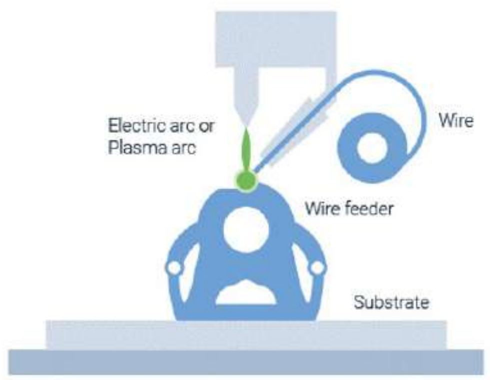


Figure 28-2.2 Wire and Arc Additive Manufacturing (Ampower, 2023)

As we delve into the subsequent chapter, we transition from the theoretical framework to real-world applications through insightful case studies. These case studies serve as exemplars, illustrating how different industries harness specific additive manufacturing processes to overcome challenges, streamline production, and unlock innovative possibilities. By examining practical implementations, we gain a deeper understanding of how AM transforms concepts into tangible results.
These case studies not only spotlight the strengths of individual AM processes but also underscore the importance of strategic selection based on project requirements.[44] Whether it be precision engineering, large-scale production, or the incorporation of multiple materials, the case studies elucidate the nuanced decision-making process that aligns technology with application.
Join us in the following chapter as we navigate through compelling real-world scenarios, exploring how additive manufacturing transcends theoretical frameworks to become an integral force in shaping the landscape of modern industry. Through these practical examples, we uncover the transformative power of AM in diverse sectors, providing valuable insights into its potential for revolutionizing the way we conceptualize, design, and fabricate objects in the industrial landscape.

Case Studies

To exemplify the applicability of AM in architecture and design, notable projects such as the MX3D Bridge in Amsterdam, the 3D-printed steel frame of the Arc Bicycle created by TU Delft students, MX3D and some other are showcased. These instances underscore the transformative potential of AM in the realm of architectural design and construction.

In a groundbreaking display of technological innovation, the creation of the Arc Bicycle stands as a remarkable testament to the fusion of 3D printing technology and the realm of industrial aesthetics. Designed by a student team at TU Delft and produced from 3D-printed steel by MX3D, this bicycle represents a pioneering venture that embodies the quest for aesthetically pleasing and functionally robust industrial structures.[45] Fabricated as part of the Advanced Prototyping course at TU Delft, the bicycle's frame is a remarkable lattice of steel, meticulously printed in layers by MX3D's cutting-edge technology. The unique construction technique employs six-axis robotic arms capable of printing metals and resins in mid-air, without the reliance on support structures. This methodology revolutionizes the production of medium- to large-scale metal objects, offering unprecedented design freedom.

Harry Anderson from the 3D Building FieldLab team at TU Delft highlighted the pivotal breakthrough that this 3D printing technique signifies. The ability to manufacture medium- to large-scale metal objects with considerable design flexibility marks a significant evolution in 3D printing technology, expanding the horizons of creative and functional possibilities. The team behind the Arc Bicycle asserts that it stands as the inaugural creation utilizing this innovative process. [45]Weighing similar to a standard steel bike, the bicycle's frame has exhibited resilience, enduring rides across challenging terrain such as cobbled streets. Team member Stef de Groot expressed the significance of choosing a bicycle as a test subject due to its exposure to complex forces, making it an ideal candidate for evaluating the technology's durability and functionality.

This particular case study serves as evidence of the continuous evolution of 3D printing technology within the domain of industrial aesthetics. The Arc Bicycle not just symbolizes the merging of technological expertise and creative ingenuity but also marks a fresh phase in the application of 3D-printed steel. It underscores the possibilities for industrial structures that are not only visually appealing but also robust in functionality.

Figure 29-2.2 Arc Bicycle (TU Delft students and MX3D, 2020)

Amsterdam, a city renowned for its serene canals, historical legacy, and innovative architectural ventures, witnessed a groundbreaking milestone bridging the chasm between its storied past and forward-looking future. In an extraordinary collaboration between MX3D, Joris Laarman Lab, and global engineering firm Arup, the world's first 3D-printed stainless steel bridge now graces one of the oldest canals in De Wallen, the city's famed red-light district.[46] Symbolizing a union of heritage and modernity, the bridge stands as an architectural marvel, stretching over twelve meters in length. MX3D, along with a consortium of designers and 3D printing specialists, employed sophisticated robotic technology empowered with custom tools and controlled by intricately crafted software developed over a two-year period. This fusion of traditional steelwork with cutting-edge computational design techniques encapsulates a significant architectural shift in Amsterdam's landscape.

Arup, as the lead structural engineer, utilized advanced parametric design modeling to refine the preliminary design process. MX3D articulates, "The unique approach allows us to 3D print strong, complex, and graceful structures out of metal.[47] The goal of the MX3D Bridge project is to showcase the potential applications of our multi-axis 3D printing technology."

Figure 30-2.2 MX3D Bridge in Amsterdam (Sawn McNulty-Kowal, 2021)

Recently unveiled to the public by Her Majesty Queen Máxima of the Netherlands, the bridge stands as a testament to the marriage between modern technology and a profound respect for the city's architectural heritage. Its presence signifies a bridge between Amsterdam's historical legacy and its futuristic aspirations, merging classical architecture with cutting-edge innovation.

The pioneering 3D-printed stainless steel bridge seamlessly navigated its way through Amsterdam's iconic canals, symbolizing a journey that intertwines the city's rich historical fabric with the dawn of technological advancement. [47] The project's debut, unveiled in homage to Amsterdam's cultural richness, marks a significant milestone in the city's architectural evolution, portraying the endless potential of 3D printing in the domain of industrial aesthetics and design.

Figure 31-2.2 Reade Street - Capitals (Michael Hanesmayer, 2016)

The renovation of the Reade Street building in Tribeca stands as a captivating case study in reinterpreting and reviving the cast-iron facade's column capitals, exemplifying the seamless integration of generative design algorithms and 3D printing technology within the realm of architectural aesthetics.[48]
The challenge posed by this project was the scarcity of comprehensive historical data regarding the original column capitals. Detailed drawings and records had succumbed to the passage of time. In this void of information, generative design algorithms emerged as a beacon of innovation, enabling the preservation and reimagining of these architectural features. What remained, albeit scant, was crucial: the proportions and key features of the capitals.
The generative design process harnessed the residual information to craft a departure point for the creation of novel capital designs. It leveraged the topographical properties of the surviving forms, ingeniously transforming these remnants into sculptural instructions.[49] Iteratively, this transformative process metamorphosed a simplistic form into an intricate tapestry of ornamental grandeur. The outcome was both an homage to history and an avant-garde expression of architectural creativity, seamlessly bridging the past and the future.

Figure 32-2.2 Pre-restoration Columns (Michael Hanesmayer, 2016)

The cast-iron facades of the 19th century epitomized the zenith of technical prowess and knowledge of their era. In the meticulous restoration of the column capitals, the utilization of generative design algorithms not only resurrected these historical treasures but also extended the tradition of engaging technology within architecture. This restoration project stood as a testament to the enduring beauty of historical context and ideals while embracing the transformative potential of contemporary design methodologies.[48]
The synthesis of tradition and technology was most palpable in the production phase. The molds for the column capitals were realized through 3D printing technology, a contemporary innovation that breathed life into these historical elements. Subsequently, the column capitals were cast in Glass Fiber Reinforced Concrete (GFRC) and iron, cementing the seamless integration of cutting-edge techniques with historical preservation.
This case study offers a compelling example of how advanced technology and design principles can revitalize the aesthetic essence of industrial architecture, creating a harmonious dialogue between the architectural heritage of the past and the innovation of the present.

Figure 33-2.2 Arup prototype 3D-printed steel construction joints (Anna Winston, 2014)

Recent advancements in engineering by Arup have introduced groundbreaking developments in the utilization of 3D-printed steel construction joints, sparking a paradigm shift in the construction and engineering sectors. The innovative production of prototype 3D-printed steel elements is set to revolutionize the creation of more efficient and aesthetically superior structures.[47] This pioneering development is a testament to Arup's novel design method for fabricating critical structural steel components, especially for tensile structures, signifying a profound leap in the use of additive manufacturing within the construction and engineering domains. By employing this cutting-edge technique, Arup aims to custom-produce structural pieces with higher efficiency, subsequently reducing waste and cutting costs significantly.
Salomé Galjaard, a senior designer and project leader at Arup, expressed the fun-

damental advantage of this approach, emphasizing its potential to enable sophisticated designs without the need for later simplification to curb costs. Each 14-centimeter-tall prototype, crafted from maraging steel, underwent rigorous material tests, highlighting the material's strength and suitability for construction applications.

Galjaard revealed that Arup aspires to utilize this technique in full-scale projects within a year, heralding a transformative shift in the industry's approach to construction and design methodologies. The company's foray into this innovative method was spurred by a desire to challenge conventional design paradigms, fostering a more open-minded and forward-thinking approach. [47]

The collaboration between Arup and specialists from CDRM, now a subsidiary of 3D Systems, along with WithinLab and EOS, facilitated the exploration and application of this groundbreaking technology. Initially designed for stainless steel, the decision to employ maraging steel was propelled by its ease of printing and exceptional strength, approximately four times stronger than conventional construction steel.

While the current 3D printing technology is constrained by size limitations, Galjaard foresees rapid advancements in printer capabilities, foreseeing larger and more complex construction elements becoming viable for production. The ongoing innovation and customization of materials for specific purposes are anticipated to further expand the application of 3D printing technology in the building industry, potentially optimizing the strength, size, and weight of future structural elements.[43]

This innovative leap echoes the broader trend of experimentation with 3D-printed metals in design spheres, emphasizing the potential for enhanced aesthetic and structural outcomes. As industry boundaries continue to be pushed, the potential for customized, efficient, and visually striking construction elements created through 3D printing technology heralds an exciting era of transformative architectural design.

Figure 34-2.2 3D-printed structural steel connector (Leonard Faustle, 2019)

In a pioneering collaboration, MX3D and the Japanese construction powerhouse Takenaka Corporation embarked on a transformative journey to design and construct a cutting-edge 3D-printed structural steel connector. This technological leap follows MX3D's previous success with the construction of a large-scale metal-printed bridge, highlighting the utilization of wire arc additive manufacturing (WAAM) and showcasing advancements in engineering customized and intricately designed steel joints.[50]

The joint development was a result of the combined efforts of MX3D and Takenaka, leveraging innovative topology optimization software. This software harnessed the mechanical properties of the printed material and design constraints to craft guidelines for the most efficient shape of the connector. The resulting hollow structure was later filled with concrete by Takenaka engineers, adhering to the CFST (concrete-filled steel tube) practice in civil engineering. This technique bolsters the steel's integrity by preventing local buckling while ensuring resilience against bending and tensile forces.[51]

The structural steel connector, crafted from duplex stainless steel, weighs 40kg, surging to 45kg post-filling with approximately 2.5 liters of mortar. Known for its exceptional mechanical properties and corrosion resistance, this alloy signifies an ideal material choice for structural designs. The success of this initial prototype has paved the way for envisioning and implementing larger-scale versions of these connectors in upcoming building projects.

A primary aim of the project is to automate the design and production of intricate joints in large structures within the construction industry. With the growing complexity of structures and a scarcity of skilled labor in aging populations, such innovation is paramount. Closing the digital design loop remains a pivotal focal point, enabling full digital control over design, production, timelines, and costs. This method demonstrates substantial logistic benefits and seamless integration with Building Information Modeling (BIM) applications.[52]

The manufacturing of the structural steel connector utilizes an advanced iteration of MX3D's proprietary technology. The recent launch of their MetalXL software paves the way for users to swiftly commence 3D printing of large-scale metal objects in their respective facilities. The ongoing testing of Beta 1.0 by selected users signals the evolution toward the anticipated Beta 2.0 version, available for pre-orders and anticipated for release in the first quarter of 2020.

Filippo Gilardi, lead R&D engineer at MX3D, expresses the growing interest from construction firms following the monumental MX3D bridge project. The joint creation with Takenaka underlines the readiness of WAAM technology to produce unique connectors for complex constructions, demonstrating that manufacturing constraints need not limit architectural creativity by tightening the digital design loop.

Takuya Kinoshita, project leader at Takenaka, emphasizes how this innovative manufacturing technology bridges the gap between design and physical realization, fostering quicker lead times, pushing design boundaries, and contributing to the creation of extraordinary architectural spaces. This synergy between MX3D and Takenaka epitomizes the fusion of visionary design and innovative manufacturing techniques, heralding a new era of possibilities in industrial aesthetics and architectural design.

The strides witnessed in the 3D printing of structural steel connectors, as exemplified by the collaborative efforts of MX3D and Takenaka Corporation, vividly depict the transformative potential of this technology within the realm of industrial aesthetics. The successful integration of wire arc additive manufacturing (WAAM) to create highly customized and engineered steel joints marks a significant advancement that holds promise for the fabrication of facade nodes in steel 3D printing.

The precision, adaptability, and strength demonstrated by this technology in crafting intricate structural connectors pave the way for its application in the creation of facade nodes. The ability to design, customize, and fabricate steel components with the intricate detail and strength required for architectural elements such as facade nodes is a testament to the evolving possibilities offered by 3D printing in steel construction.

The inherent advantages witnessed in the production of steel connectors, such as the ability to optimize designs, streamline manufacturing processes, and implement concrete filling for enhanced structural integrity, align with the requisites for manufacturing facade nodes in steel. The flexibility of the technology in creating complex structures with an amalgamation of design finesse and robustness bodes well for its application in enhancing the aesthetics and durability of facade nodes.[43]

The pioneering achievements in 3D-printed steel connectors, reflecting a synergy of design innovation and manufacturing prowess, serve as a beacon of promise for the implementation of this technology in the creation of facade nodes. As the technology continues to evolve, its potential to revolutionize the creation of facade nodes in steel, offering tailored design solutions, enhanced aesthetics, and structural integrity, remains an exciting prospect for the future of sustainable architecture and landscape design.

In this chapter, we embarked on an exploration of the transformative potential of Additive Manufacturing (AM) in the domain of industrial aesthetics, with a focus on architectural applications. Through a series of compelling case studies, we delved into the innovative convergence of 3D printing technology and architectural design, witnessing its profound impact on the creation of aesthetically pleasing and functionally robust industrial structures.

The showcased case studies serve as vivid illustrations of the revolutionary strides made in the field. The Arc Bicycle, a testament to the collaboration between TU Delft students and MX3D, stands as an iconic symbol of the fusion of creativity and cutting-edge technology. Its lattice-like 3D-printed steel frame, crafted with unparalleled precision, not only embodies a pioneering venture in industrial aesthetics but also serves as a testament to the endurance and resilience of 3D-printed structures.

The MX3D Bridge in Amsterdam, a collaboration between MX3D, Joris Laarman Lab, and Arup, further accentuates the transformative power of 3D printing in architecture. Stretching majestically over one of Amsterdam's historic canals, this 3D-printed stainless steel bridge symbolizes a harmonious blend of heritage and modernity, demonstrating the potential of advanced computational design techniques in reshaping architectural landscapes.

The renovation of the Reade Street building in Tribeca provides a captivating case study in seamlessly integrating generative design algorithms and 3D printing technology. The restoration of cast-iron facade column capitals, driven by generative design, not only revitalized historical elements but also showcased the dynamic interplay between tradition and technology.

Arup's groundbreaking advancements in 3D-printed steel construction joints usher in a new era of efficiency and aesthetic superiority in structural design. The prototype's success marks a paradigm shift in the engineering and construction sectors, offering a glimpse into the potential for custom-produced structural components that optimize strength, reduce waste, and cut costs.

The collaborative efforts of MX3D and Takenaka Corporation in designing a 3D-printed structural steel connector further underscore the transformative potential of this technology. The utilization of wire arc additive manufacturing (WAAM) and innovative topology optimization software presents a visionary approach to creating intricate and efficient steel joints, with implications for larger-scale applications in future building projects.

As we reflect on these case studies, it becomes evident that 3D printing technology is not merely a tool for construction but a catalyst for redefining the boundaries of architectural creativity.[53] The precision, adaptability, and strength demonstrated in these endeavours herald a new era where technology seamlessly integrates with architectural design, pushing the limits of what is achievable in terms of aesthetics, functionality, and sustainability.

The strides witnessed in the 3D printing of structural steel connectors, the creation of iconic bridges, and the restoration of historical architectural elements showcase a synergy of design innovation and manufacturing prowess. These achievements serve as beacons of promise, offering a glimpse into the exciting prospects that lie ahead for the future of sustainable architecture and landscape design. As we embrace the evolving possibilities presented by 3D printing technology, the journey towards redefining industrial aesthetics continues, opening doors to a realm of endless architectural possibilities.[15]

Benefits of AM Application

The integration of 3D printing technology in the creation of facade nodes within industrial architecture stands as a transformative advancement. This chapter will explore the myriad advantages offered by utilizing 3D printing specifically in the context of fabricating steel facade nodes. The main focus of this research is how exactly this innovative technology can contribute to improving not only the functional and constructive, but also the aesthetic properties of industrial structures. We will look at how the architecture of sustainable development can become more beautiful, thanks to the use of modern technologies.
3D printing can quickly make prototypes and real products, making it faster to introduce industrial structures to the market. In mass production, 3D printing has changed how things are made, making production faster and better. This expedites the production process and delivery, granting businesses a competitive edge by ensuring product availability in the market.[54]
The inherent flexibility of 3D printing within the production line provides manufacturers with a distinctive advantage. In the event of errors or design modifications, the technology allows for swift alterations in the production process. This feature is particularly significant in batch production as it enables the creation of prototypes for flaw detection, functional analysis, and alterations, thereby streamlining the design refinement process.
One of the paramount advantages of 3D printing lies in its capacity for customization. The technology offers unparalleled flexibility in adapting to specific orders and design alterations. Within the realm of industrial architecture, this customization ability becomes a crucial factor in meeting both functional and aesthetic requirements.[55] The diversity of available materials for 3D printing further amplifies the ease of customization, ensuring adaptability to varying design specifications and customer demands.
In the context of industrial architecture, the application of 3D printing in the fabrication of steel facade nodes introduces a paradigm shift. Not only does it offer the precision required for intricate designs, but it also enables the production of bespoke, aesthetically pleasing elements that significantly contribute to the visual appeal of industrial structures. Moreover, the use of 3D printing in steel nodes ensures a balance between functionality and aesthetics, fostering a sustainable yet visually captivating architectural landscape.[56]
Beyond the immediate architectural benefits, the adoption of 3D printing for steel facade nodes bears implications for sustainability and cost-effectiveness. The efficient use of materials and the reduction of waste in the production process aligns with sustainable architectural principles. Additionally, the technology's adaptability minimizes the costs associated with design alterations and iterations, contributing to both economic feasibility and environmental conservation.[43]
The advantages offered by 3D printing in the creation of steel facade nodes within industrial architecture extend far beyond mere production efficiency. The technology's ability to accelerate design processes, enhance customization, and contribute to both aesthetic appeal and functional integrity underscores its pivotal role in shaping the future of sustainable and visually appealing industrial structures. This chapter seeks to elucidate the significance of 3D printing in revolutionizing the creation of steel facade nodes, aligning with the pursuit of enhanced aesthetics and sustainable architectural design.
However, AM is not without its challenges and concerns. Porosities or voids between single roads, outer surface roughness, the necessity for post-processing (including heat treatment, Hot Isostatic Pressing (HIP), machining, and deburring/finishing), the staircase effect on the surface, macro-mechanical properties, geometrical tolerances, and cost considerations (wherein equipment costs are high, but per-part cost remains consistent and part complexity is superior compared to Injection Molding) necessitate careful consideration and innovative solutions in integrating AM into architectural practices.[50]
In conclusion, the integration of 3D printing technology in the creation of steel facade nodes represents a monumental leap in the evolution of industrial architecture. The discussed advancements in mass production, customization, aesthetic contribution, sustainability, and cost-effectiveness underscore the transformative potential of 3D printing. Despite the challenges and considerations, the benefits far outweigh the drawbacks, positioning 3D printing as a cornerstone for the future of sustainable, visually appealing, and functionally robust industrial structures. This chapter seeks to provide a comprehensive understanding of the significance of 3D printing in revolutionizing the creation of steel facade nodes, aligning with the pursuit of enhanced aesthetics and sustainable architectural design.

2.3 WASTE MANAGEMENT IN NORWAY

Site Choice

Tromsø, Norway, emerges as a promising locale for the realization of a sustainable industrial building project in the context of Northern Europe. This region, ensconced within the Arctic Circle, showcases an idyllic landscape characterized by majestic mountainous surroundings. In our exploration of Tromsø's attributes for a sustainable industrial edifice, several pertinent facets come to the fore.

First and foremost, Norway's staunch dedication to renewable energy sources becomes evident, a commitment from which Tromsø significantly benefits. [57] The geographic disposition of this location affords abundant opportunities for harnessing hydropower and wind energy, underpinning the viability of eco-friendly power solutions.

The climatic conditions of Tromsø, notably its frigid atmosphere, furnish an auspicious platform for the development of innovative energy-efficient systems designed to withstand the rigors of extreme weather. [58] The prospects for pioneering sustainable architectural solutions tailored to this unique environment are indeed enticing.

Tromsø's enviable proximity to nature, characterized by the mesmerizing mountains and enchanting fjords, offers an enchanting canvas for the realization of sustainable architectural designs. The potential harmonization of structures with the natural milieu not only augments the aesthetic appeal but also underscores the commitment to environmental harmony.[59]

The presence of research institutions and universities in Tromsø, dedicated to sustainable technologies and Arctic-related studies, adds another layer of attractiveness to the locale. These institutions serve as knowledge hubs, contributing invaluable expertise and potentially becoming collaborative partners for the envisioned industrial project. The fusion of academic excellence and practical application holds the promise of pushing the boundaries of sustainable design.[60]

Additionally, it's important to highlight the region's attractiveness as a tourist destination. The growing popularity of the region as a tourist hotspot is another aspect that should not be overlooked. The captivating natural beauty of Tromsø, with its mountains and fjords, acts as a magnet for tourists. [61] This presents the intriguing prospect of an industrial project that actively engages with ecotourism or showcases sustainable practices to visitors. This intersection of industry and tourism becomes a unique selling point for Tromsø, aligning economic development with environmental consciousness.

In addition, the immediate availability of local resources, such as natural materials and a skilled workforce, substantially facilitates the construction and operation of the envisaged industrial project.[62] The local ethos is intrinsically intertwined with the sustenance of the environment, aligning seamlessly with the overarching goals of our sustainable enterprise.

As a result of studying the current situation in the city of Tromsø, a waste recycling company Remiks was found, whose values coincide with the views on the concept of architecture of the author. In addition, an incineration plant is located on the territory of the facility, the project of which includes the expansion of the building area in order to increase the volume of incinerated garbage. [63]This means that now there is an opportunity to make a proposal to improve the aesthetic properties of the plant. This fact served as another argument in favor of choosing Tromsø as the location of the project.

In summation, Tromsø, Norway, emerges as an enticing canvas for the realization of a sustainable industrial building project, replete with attributes that bode well for environmental stewardship and architectural innovation. The confluence of renewable energy sources, a challenging climate ripe for inventive solutions, proximity to nature's bounty, a wealth of research and educational institutions, burgeoning tourism opportunities, and local resources collectively position Tromsø as an auspicious setting for our architectural aspirations. The selection of an incineration plant in Norway as our case study was deliberate. Its unconventional freeform façade design, influenced by the mineralites native to the region, offered a perfect platform to explore the viability of steel 3D printing for façade connections.

Waste Management Processes

Nowadays, our approach to waste management is evolving. No longer is the disposal of waste seen as a mere necessity, but as an opportunity to harness the potential of waste as a valuable resource. This shift of the common paradigm is redefining the way we perceive and treat waste, and it extends to the very infrastructure that manages this transformation.

One such infrastructure is the waste management plant, where waste is not only processed but where its latent potential is recognized and maximized. A key aspect of this transformation is that the waste management industrial building should be aesthetically attractive, symbolizing our commitment to environmental sustainability and the responsible management of resources.

Traditionally, waste management plants were often viewed as unsightly eyesores, tucked away from public view. However, we are now moving towards

Figure 35-2.3 Waste Distribution (Envac, 2023)

a more progressive mindset that recognizes waste as a potential resource. Advanced technologies and innovative practices have enabled us to extract energy, materials, and even nutrients from waste, contributing to a more sustainable and circular economy.

Waste-to-energy facilities, for instance, utilize organic waste to generate electricity and heat. Recycling centers sort and process materials, diverting them from landfills and returning them to the production cycle. Even organic waste, once considered a burden, can be transformed into valuable compost to enrich soils and support agriculture.

Tromsø's waste management system has been undergoing a transformation, evolving to embrace efficiency and sustainability while integrating advanced waste sorting methods. The primary focus lies in the redesign of the incineration plant and the enhancement of the aesthetic appeal of industrial architecture in the region.

This system integrates an advanced sorting mechanism and the Envac pneumatic waste collection system, utilizing color-coded sorting bags to simplify user engagement. By reducing transportation costs and emissions, this approach optimizes waste sorting and transportation to sorting plants.

Effective waste separation hinges on informative campaigns and user-friendly separation methods. Projects like the GrowSmarter initiative in Sweden have demonstrated a significant reduction in general waste, highlighting the impact of improved recycling methods on user behavior.

Incorporating optical sorting and AI within the waste management system has facilitated data collection and analysis. These technological features streamline waste sorting, optimizing system performance and influencing user behavior to increase recycling rates, thereby contributing to a smarter and more sustainable waste management system.

The adaptable nature of the waste sorting system allows it to cater to various recyclables, offering flexible solutions that can be tailored to different urban environments, regardless of city or municipality size.

This ongoing evolution of waste management in Tromsø isn't solely centered on functional efficiency; it also underscores the importance of integrating aesthetics into industrial architecture. The goal is to advance Tromsø's transition to a circular economy while simultaneously enhancing the visual appeal of its industrial infrastructures.

Interview Insights: Remiks Waste Management Company

The main purpose of the trip to Tromsø was to visit the territory of the Remiks waste processing plant. Fortunately, we managed to interview a representative of the company, Ivar Sture Handeland. With the permission of Petter Hofstad Strand, the company's leader, we are publishing some insights that opened up to us after visiting the facility.

Figure 36-2.3 Waste Management Companies Network in Norway (Remiks, 2023)

At the outset, the speaker explained that their company is actively involved in raising public awareness about waste sorting and recycling. They organize tours of the plant, host events to inform local residents about recycling possibilities and reuse, and welcome students, including those from the Changing Arctic program. They say: "We also have a Remiks day. Every second year we have an open day at Remix. Of course, people will see what is happening here. We show them what we are doing, and we also have theater, cafe - redesign all this kind of thing. So, it's very important." All these measures and ideas are aimed at raising awareness among people that garbage can be considered as a resource, and not just as unusable waste.

First and foremost, Ivar Sture Handeland emphasized the author's profession. He explained that architecture is as important to them as the functionality of the plant. Here's a quote from the interview: "Our building here is built in a way that shows that waste is not garbage, trash. So, the building is a picture in a way that this is a very important thing. This is not a shout, Square with the roof." This position once again confirms that the aesthetics of architecture are important to people, regardless of the building's purpose.

So, as you can see, this company occupies a really big area for Tromsø municipality

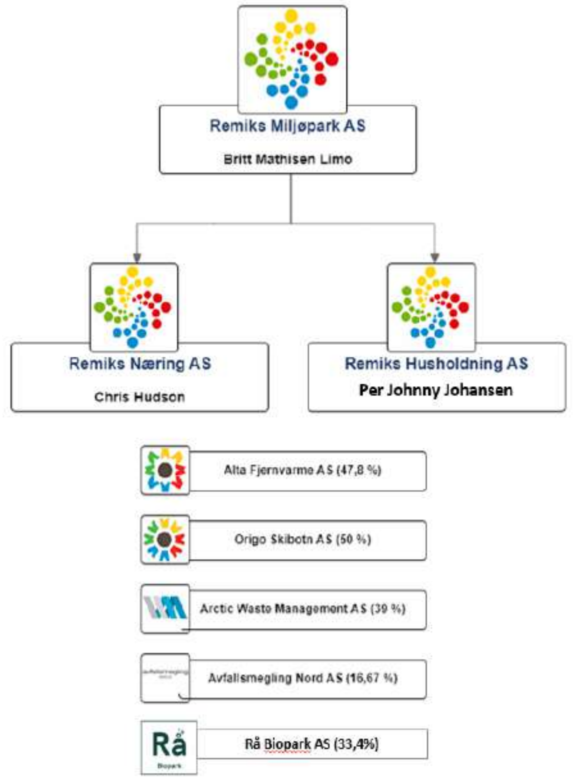


Figure 37-2.3 Remiks Companies Structure (Remiks, 2023)

and Norway. On a global scale, this may seem like a small portion, but the process itself leads to impressive proportions.

They are the biggest waste management tech company in Northern Norway. It needs to be mentioned that they have 130 employees and 400 million Norwegian croners the annual turnover. Remiks serves approximately 80,000 inhabitants. Around 77,000 - 79,000 tons of waste is processed in here annually, that mean 910 tons per hour. So, if the factory stops to collect or receive waste – there's a possibility that the municipality can collapse. A modern city will not function, so it's very important that they can receive waste all the time and if there is a problem, company have to have a plan B, C, D, E. As a result, they always have a possibility to receive waste in some way. They process 600 tons waste through a secondhand shop called Rebel. There are 1100 people every day buy secondhand stuff.

So far, they have a 94% of all waste is recycled, that means material recycling, also turning into new materials. It includes: 41% of household waste is turned into new materials, 45% of industrial waste is turned into new materials, 1% second hand – reuse, 42% material recycled, 51% waste to energy.

They are a large company with subsidiary companies known as Remiks Naering and Remiks Husholding. Remiks Husholding is responsible for the collection of household waste, funded through taxes in Norway, providing essential services. Individuals pay taxes to receive waste collection system services, contributing to the financial

Figure 38-2.3 Remiks Existing Site (Remiks, 2023)

support of these operations. In contrast, Remiks Naering operates as a business entity exempt from taxes, generating profits for the company. The profits primarily stem from Remix Naering, as Remix Hushold operates on a sunk cost basis, where profitability is restricted, and breaking even is imperative, overseen by Tromsø municipality.

They manage the incineration plant and waste-to-energy plant, along with machinery for bottle collection and composting of food waste. Additionally, they have biogas facilities. Looking ahead, Arctic Waste Management, set to commence operations in two years, will handle hazardous liquid waste, managing or trading waste on behalf of various waste treatment companies within the market-driven economic system.

Rå Biopark AS, another facility, focuses on biogas production, particularly as a Northern Norway project involving multiple municipalities and waste treatment companies owned by these municipalities. Remiks is jointly owned by Tromsø and Karlsøy municipalities, aligning with the prevalent ownership structure of waste treatment companies in Northern Norway, predominantly owned by public entities such as municipalities. While a few private companies exist, one of them is the largest in Norway. This collaborative effort among municipalities in Northern Norway is a remarkable project, aiming to establish a biogas facility for the entire region, with plans for a similar facility in Chiba, situated approximately an hour away.

In Norwegian waste policy and regulations, household waste management is considered a local government responsibility. Regardless of residents' locations, an equal cost is mandated for waste services. Waste collection and treatment are compulsory, representing both a duty and a right for individuals. To sustain these services, a special fee, distinct from ordinary taxation, is

imposed exclusively for waste management activities. It is crucial that this fee does not surpass the actual cost incurred, prohibiting profit generation (with adjustments made over a 5-year period).

Moreover, waste stemming from business activities, categorized as non-household waste, functions as a commodity or service within an open market framework. Since July 1, 2009, a landfill ban has been instituted for all degradable waste. Furthermore, the principles outlined in the Waste Hierarchy hold significance and are intended to govern all regulatory frameworks and business operations in the waste management sector.

We made inquiries to determine if the company required a new waste incineration plant. Their response revealed that an existing facility was already present on the premises, albeit under the ownership of a private company. However, the aesthetic properties of this current facility were noted to be less than satisfactory.

Adding an interesting historical dimension, it was shared that in the initial stages, waste disposal involved sending substantial amounts to Sweden—approximately 1500 trucks each year. However, significant changes have occurred since then. The current waste management infrastructure has evolved, and now there exists a practical 25-meter connection facilitated by conveyors linking the Remiks buildings to the incineration plant. This not only enhances operational efficiency but also represents a more sustainable and localized approach to waste disposal, compared to the previous cross-border transportation.

Certainly, the existing incineration plant is fully functional, although it may not boast the aesthetic appeal found in many renowned incineration plants worldwide, often likened to cathedrals. In terms of architecture, it serves its purpose well but falls short of being a visually striking structure. While it is not unattractive, its primary strength lies in functionality rather than aesthetics. Currently undergoing expansion, the construction process has introduced a bit of chaos to the surroundings.

Despite its utilitarian design, Tromsø Miljøpark was conceived with a vision: to showcase that it is not merely a waste facility but a resource center. The building is intentionally low, seamlessly integrating into the ground, resembling a kind of wave. This concept extends to both the administrative and process buildings. However, with the need for expansion, the company is in the process of constructing four additional boxes. This expansion is driven by considerations of functionality and urgency rather than financial constraints, making the endeavor challenging but necessary.

The initial two buildings were erected in 2008, with the process building number one predating them in 2006. Notably, the latter holds significance in the facility's infrastructure. While the current plant may not be architecturally remarkable, the company acknowledges the importance of aesthetics and is actively working towards incorporating a more visually appealing design into their expanded facilities.

Upon your visit, you'll notice that the storage facilities are composed of concrete boxes, resembling a structure akin to Lego blocks. Admittedly, it lacks visual appeal, especially when facing the main road. To address this, the company is contemplating an enhancement that involves transforming the entire wall into a canvas for creativity, considering options such as a graffiti mural or other artistic elements. The aim is to create a more aesthetically pleasing view, particularly for the numerous tourist ships that arrive, providing them with an engaging visual experience and prompting positive reactions.

In contemporary waste management policies in Norway, a pivotal shift mandates that all waste treatment activities must now be conducted indoors. The utilization of outdoor spaces for such processes is no longer permissible. This directive underscores a commitment to responsible waste handling, emphasizing the imperative to store and manage all waste within enclosed structures.

Figure 39-2.3 A View on the Site from the Road (Liudmila Sidorova, 2023)

While the regulation is relatively recent, it is not imposed as a mere suggestion; rather, it represents a clear directive that dictates the necessity of conducting every form of waste treatment indoors rather than outdoors. In adopting this policy, a shared responsibility emerges, aligning with overarching sustainability goals that are integral to every company's operational framework.

These environmental considerations are not only intrinsic to the corporate ethos but are also reflective of broader political initiatives and legislative frameworks in Northern Norway. The regulatory landscape stipulates a duty for individuals and entities in Norway to adhere to specified waste management practices. This fundamental principle involves the payment of taxes, and in return, individuals and businesses are entitled to certain services, albeit varying between municipalities.

In this context, municipalities in Norway may offer distinct services, each tailored to meet the unique needs of their communities. For instance, optical sorting is a prominent feature in their municipality's waste management system. Residents engage in source separation, sorting items into color-coded bags within their kitchens. The bins placed outside correspond to specific waste categories, with green dotted bags designated for food waste, blue dotted bags for paper, carton, and packaging, and purple dotted bags for plastic.

Upon collection, these diverse waste streams are deposited into the same facility, where advanced machinery equipped with optical sensors reads the colourof the bags and accurately directs them to their respective containers. This meticulous sorting process ensures efficient and environmentally conscious waste management practices, aligning with both municipal regulations and the broader commitment to sustainability goals.

Figure 40-2.3 Waste Management at Remiks (Remiks, 2023)

Certainly, the efficiency of their waste management system has garnered positive feedback from the residents of these municipalities. They appreciate the user-friendly approach, finding the system highly beneficial. Notably, they have designated bins for glass and metal packaging to further streamline waste sorting.

However, despite the success of the color-coded bag system, a significant challenge persists. A staggering 67% of all waste ends up in the residual waste category, representing items that could have been sorted through proper disposal. A breakdown reveals that 30% of this comprises food waste, erroneously placed in the residual waste instead of the designated green dotted bags. Additionally, 12% consists of plastic packaging, which should ideally be in the purple dotted bags but often finds its way into the residual waste.

The implications of this misclassification are substantial. If residents were to correctly sort their waste, the potential savings could reach 8-10 million Norwegian kroner annually. This, in turn, could contribute to reduced taxes for the community. Despite the straightforwardness of the sorting system, there seems to be a reluctance among some residents to engage in more meticulous waste separation. The reasons behind this apparent resistance remain unclear, as the system is both simple and effective.

While the current level of sorting is commendable, there is a call for increased participation and diligence in waste segregation. Addressing this issue could not only lead to significant financial savings but also contribute to a more sustainable and environmentally friendly waste management process for the benefit of the entire community.

The safety challenges faced by the Remiks company are particularly evident in the recurring issue of fires within the facility. Regrettably, instances of fire occur almost bi-weekly, posing a significant threat due to the potential difficulty in containing and extinguishing the flames. One notable incident occurred in 2014, necessitating the response of multiple fire brigades from Tromsø municipality and the airport fire brigade due to the inherent danger of toxic smoke emissions.


Figure 41-2.3 Safety Trainings at Remiks (Remiks, 2023)

Addressing this critical safety concern, Remiks has implemented comprehensive industrial protection measures under the Health, Safety, and Environment (HSE) protocols. These measures extend beyond mere response to proactive preparedness, encompassing a range of exercises and training programs.

To bolster readiness, individuals within the company, who may have primary roles unrelated to emergency response, undergo specialized training. When an alarm is activated, they transition into protective roles, equipped to handle various aspects of industrial protection such as first aid, fire protection, biochemical and chemical emergencies, as well as proficiency in the use of diving equipment for smoke and biochemical-related incidents.

Safety is a paramount concern at Remiks, where a range of comprehensive measures are in place to safeguard personnel and the environment. One critical aspect involves first aid training, ensuring that staff are equipped to respond promptly and effectively to medical emergencies. Strategically placed first aid stations and kits enhance accessibility throughout the facility.

Given the recurring nature of fire incidents, Remiks prioritizes fire protection. Regular training sessions cover fire prevention, evacuation procedures, and the proper use of firefighting equipment. Advanced fire suppression systems and equipment are strategically positioned to bolster response capabilities.

Environmental and chemical protection protocols address the risks associated with hazardous substances. Personnel undergo specialized training to manage chemical spills and environmental hazards safely. The use of personal protective equipment is mandatory in areas where exposure to chemicals or environmental risks is prevalent.

For tasks involving chemical diving, personnel undergo specialized training to navigate and address chemical-related incidents underwater. Proper use of diving equipment, including protective suits and breathing apparatus, ensures the safety of individuals engaged in chemical diving tasks.

Similarly, smoke diving operations receive dedicated training, considering the unique challenges of firefighting in smoke-filled environments. Techniques for navigation, communication, and effective firefighting under conditions of limited visibility are central components of this specialized training.

By prioritizing these safety measures, Remiks aims to establish a secure working environment, minimize the impact of incidents, and optimize the response capabilities of personnel across various emergency scenarios.

Importantly, the company's approach is not to directly combat fires but rather to establish a robust foundation for professional responders. This collaborative strategy ensures that the site is optimally prepared for the swift and effective intervention of the fire brigade, recognized as the experts in handling such emergencies. By streamlining response processes and creating an environment conducive to firefighting professionals, Remiks aims to enhance overall safety within the facility.

In our conversation, the Remiks representative highlighted the incineration plant owned by Kvitebjorn and acknowledged the environmental challenge of CO_2 emissions, noting its significance in Tromsø.

To address this concern, Kvitebjorn has initiated projects like carbon farms to clean CO_2 or trap carbon. Ongoing discussions surround this initiative, emphasizing the need for designated areas to accommodate necessary equipment and structures.

In addition to CO_2 emissions, Kvitebjorn has undertaken a noteworthy project involving the storage of heat in rocks. This environmentally conscious approach, inspired by techniques in the oil industry, involves drilling holes into the ground. It's worth noting that the representative expressed reservations about the underground heat storage during the summer, citing potential environmental drawbacks.

Despite this concern, the representative remained enthusiastic about other initiatives, emphasizing the practical benefits of utilizing excess heat for warming the ground and reducing dependence on other heating sources. These projects underscore Kvitebjorn's commitment to sustainability and innovative solutions in waste management and energy utilization.

2.4 SUGGESTIONS FOR DESIGNING INDUSTRIAL BUILDINGS IN NORWAY

Why This Building Should Be Beautiful?

In the realm of waste management, the design of industrial buildings takes on a new significance – one that signifies our unwavering commitment to sustainability. Central to this transformation is the incorporation of aesthetics into the design and construction of waste management facilities. When we speak of aesthetically attractive waste management plants, we're not merely referring to visual appeal but also the vital roles they play in our communities and the environment.
A waste management facility that is well-designed and visually appealing serves as a bridge to build community support. When these facilities seamlessly blend with their surroundings and contribute positively to the local landscape, they become an integrated part of the community. The once unpopular eyesore turns into a valued asset, harmonizing with the neighborhood and garnering acceptance.

Aesthetically pleasing waste management facilities convey a powerful message of environmental responsibility. They go beyond being centers for waste disposal; they stand as symbols of responsible resource management. Such symbolism can significantly influence public perception and help transition the concept of waste management into resource management. The facility's visual appeal becomes a visual statement of our commitment to the environment.
The positive impact of an attractive and well-designed working environment extends to the employees who operate the facility. Employee satisfaction and morale receive a boost in such settings, leading to more efficient operations and higher-quality waste processing. A harmonious, aesthetically pleasing workplace can inspire pride in the work and improve productivity.
Attractive waste management facilities can also function as educational tools. These places offer tours and educational programs, helping people understand the importance of recycling, sustainable waste management, and the valuable possibilities of waste as a resource. These facilities can be real-life examples of our dedication to being sustainable, spreading awareness and knowledge in the community.
The appeal of a waste management facility extends beyond aesthetics; it has tangible economic benefits. Such an attractive facility can attract businesses and visitors to the region, contributing to the local economy's growth. In doing so, it can create a positive image of the area, where sustainability and economic prosperity coexist.
In conclusion, the significance of aesthetics in the design of waste management facilities cannot be understated. It is not just about creating visually pleasing structures; it's about building community support, promoting environmental responsibility, boosting employee morale, educating the public, and driving economic growth. Aesthetically attractive waste management facilities are symbols of progress and our evolving commitment to a more sustainable and resource-efficient future. The project for the redesign of a waste-to-energy plant represents an enhanced version of the building located within the waste management complex in the city of Tromsø. It is important to note that the preliminary waste processing is carried out in the facilities of the Remix company. The thermal treatment is applied to pre-sorted waste that cannot be recycled or reused by other methods.

How to Design a Beautiful Industrial Building in Norway?

Designing a sustainable and aesthetically pleasing industrial building in Norway, especially in northern regions, requires careful consideration of various factors to address the challenges posed by the local environment and to ensure harmony with the surroundings. A comprehensive approach involves the utilization of local building materials, energy-efficient and sustainable design principles, optimal use of natural light, and integration with the local architectural and environmental context.

Conducting thorough research and a morphological analysis of the city or region is the initial step. This helps in understanding the local architectural styles, materials, and climatic conditions. Using this knowledge, the building can be designed to harmonize with the local aesthetic and effectively combat the harsh weather conditions.

Using locally sourced and sustainable building materials not only lessens environmental impact but also boosts insulation to combat cold weather and enhance energy efficiency. Apart from that, energy-efficient design features such as insulation, double-glazed windows, and renewable energy sources like solar panels normally play a crucial role in making the building more sustainable.

In regions with limited daylight hours during the winter, it is essential to design the building to maximize the sunlight presence in the rooms where people stay for a long time. Light-colored interior finishes and reflective surfaces can further enhance the distribution of natural light within the space, reducing the need for artificial lighting. Strategic lighting design with features like motion sensors and daylight harvesting, combined with energy-efficient LED fixtures, can optimize artificial lighting usage, and reduce energy consumption.

Weather resistance is the most important factor requiring the use of durable materials capable of withstanding extreme weather conditions. Proper drainage systems must also be installed to protect against rain and snowmelt, preventing water damage to the structure. Incorporating native plants and greenery in the design not only enhances aesthetics but also provides natural shade and contributes to a healthier environment. Outdoor spaces can be created for employees to enjoy during favorable weather, promoting a connection with nature.

Efficient space planning is vital to optimize usage while accommodating future expansions or modifications. Collaboration with local experts who have experience in designing sustainable and aesthetically pleasing buildings in the region is invaluable.

Continuous monitoring of energy usage, indoor environmental quality, and sustainability metrics allows for the assessment of the building's performance and necessary adjustments for optimal efficiency and comfort.

Engaging with the local community fosters support and understanding of the sustainable and aesthetic design principles employed in the industrial building, creating a sense of pride and responsibility within the community.

In conclusion, the design of a sustainable and aesthetically pleasing industrial building in Norway's northern regions is a multifaceted endeavor that combines local knowledge, sustainable practices, and architectural harmony to create a structure that thrives in its environment and enriches the surrounding landscape.

03 PRACTICE

3.1 ANALYSIS

Site Specifics of Tromsø: Climate

Tromsø, Norway, positioned north of the Arctic Circle, serves as an intriguing canvas for the realization of a sustainable industrial project. The Arctic region, known for its vast and pristine wilderness surrounding the North Pole, undergoes dynamic climatic changes throughout the year. In our exploration of Tromsø's attributes for a sustainable industrial edifice, several pertinent facets come to the fore. Geographically, Tromsø is situated 400km north of the Arctic Circle, embracing enchanting fjords and linked to the mainland by an arched bridge. This unique location not only offers an ideal setting for Arctic adventures but also presents an opportunity to integrate sustainable architectural solutions that align with its distinct climatic conditions.[64]

The extreme latitude of Tromsø results in distinct seasons—polar day in summer, marked by continuous daylight, and polar night in winter, when the sun remains below the horizon. In 2023, Tromsø experienced 2.3 months of constant daylight in summer and 1.6 months of continuous darkness in winter, creating a fascinating backdrop for architectural innovation.[58]

Despite its high latitude, Tromsø enjoys a milder climate than expected, courtesy of the Gulf Stream. Winters are relatively mild (average -3°C), while summers are moderate and cool (+15°C). This climatic balance, unique to Tromsø, provides a foundation for sustainable design principles that cater to both functional and aesthetic considerations.[58]

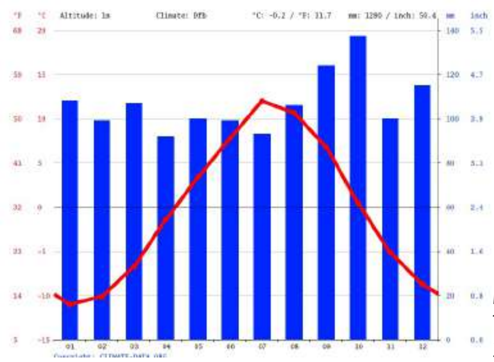


Figure 42-3.1 Climate of Tromsø (Climate-Data.org, 2022)

Tromsø's climate intricacies extend beyond temperature considerations. The city experiences a significant amount of precipitation, with October being the wettest and May and June as the driest months. This variation in precipitation levels highlights the need for adaptive design solutions that can withstand different climatic challenges throughout the year.

Summer in Tromsø spans from the end of June to September, offering temperatures peaking in July (around 12.0°C) and dropping to the lowest averages in January (-11.0°C). This seasonal temperature fluctuation underscores the importance of comprehensive climate analysis for architectural projects to ensure year-round functionality and comfort.[65]

Understanding Tromsø's distinct wet and dry seasons is essential for designing buildings that can withstand varying weather conditions. The wet season, extending from September to February, poses different challenges than the drier season from February to September. This knowledge informs architects about the need for adaptable and resilient structures.

Tromsø experiences significant seasonal fluctuations in cloud cover, with clearer periods lasting around 5.3 months, starting in April, and cloudier months beginning around late September, lasting 6.7 months. [65] These variations in cloud cover impact natural light conditions, necessitating thoughtful architectural considerations for optimal lighting and energy efficiency.

Humidity levels also vary in Tromsø, with the least humidity recorded in July (78.78%) and the highest in October (90.45%). These fluctuations in humidity add another layer of complexity to architectural considerations, highlighting the need for materials and designs that can withstand changes in moisture levels.

Tromsø witnesses extreme seasonal fluctuations in snowfall, with the snowy period lasting approximately 7.5 months, from September to May. This knowledge is crucial for architects considering the impact of snow accumulation on roofs and structures, emphasizing the need for durable and snow-resistant design elements.[58]

Water temperatures in Tromsø can warry in diapason from an average of 3.60°C in March to 10.90°C in August because of the Norwegian Sea influence. These water temperature variations, though not the primary focus for industrial buildings, underscore the importance of considering the broader environmental context for a holistic architectural approach.

Tromsø's reputation as a popular destination for witnessing the Northern Lights adds to its allure, attracting visitors between September and April. This unique feature creates opportunities for industrial projects that actively engage with ecotourism or showcase sustainable practices to visitors, further emphasizing the convergence of industry and tourism in Tromsø.[66]

In summation, Tromsø's climate intricacies make it an ideal gateway to the Arctic. Its popularity for witnessing the Northern Lights and its climatic distinctiveness present a unique backdrop for the realization of a sustainable industrial building project. Understanding these climatic nuances is crucial for designing a project that harmonizes with its environment and withstands the challenges posed by its unique climatic conditions.[65]

Site Specifics of Tromsø: Landscape

The multifaceted tapestry of Tromsø's landscape, situated beyond the Arctic Circle in northern Norway, unveils a captivating geological history and ecological richness. Nestled within the western, mountainous expanse of the Scandinavian Peninsula, Tromsø is part of a large block primarily composed of granites and gneiss, imparting a rugged relief that narrates the Earth's transformative forces.

This expansive block is asymmetrically raised, with the eastern slopes in Sweden exhibiting a more gentle and elongated profile, while the western slopes facing the Atlantic Ocean are steep and short. The southern region of Norway encompasses both slopes, housing an extensive highland. As one moves northward, the mountains' heights gradually increase, culminating in impressive peaks like Mount Gallheppigen (2469 m) and Mount Glittertinn (2452 m) in the Jutunheimen massif. Additional elevated areas, such as Dovrefjell, Ronnane, Hardangervidda, and Finnmarksvidda, contribute to the diverse topography, often characterized by bare rocks devoid of soil and vegetation.[67]

The legacy of the great Ice Age is evident in the glaciated mountains of Norway, where continental glaciations shaped the land. Although modern glaciers are relatively small, historical glaciation processes contributed to the development of U-shaped fjords, showcasing the profound impact of glacial erosion on ancient river valleys. The fjord shores, marked by their extraordinary picturesqueness, hold significant economic importance.[68]

Tromsø is historically located on two islands, Troms (Tromsøy) and Kval (Kvaløy), just west of the mainland, enjoys continuous sunlight from late May to late July due to its position well north of the Arctic Circle. The town shows how nature and people live together, and during the long summer months, the sun is always there.

Glacial and other forces have not only shaped the surface but also contributed to the formation of thick sandstone, conglomerate, and limestone deposits known as sparagmite. Extensive areas called peneplains, like the Hardanger Plateau and Finnmark Plateau, showcase the remnants of eroded relief. The geological timeline, stretching from the Cambrian through the Silurian period, narrates a tale of sea-level fluctuations and mountain-building processes, resulting in Norway's average elevation of 487.68 meters compared to Europe's 304.8 meters.[69]

The rivers, following fracture lines in the Earth's crust, carved deep gorges and canyons into the jagged coast during repeated glaciations. The Great Ice Age of the Quaternary Period left behind magnificent U-shaped drowned fjords that grace the western coast. Glacial action transported enormous masses of soil, gravel, and stone southward, exposing the bedrock in approximately 40 percent of the area.[70]

Norway is divided into four traditional regions, with Tromsø situated in the Arctic north. The topography around Tromsø exhibits significant elevation changes within varying radii. The diverse vegetation cover, ranging from trees and artificial surfaces to water, adds to the ecological complexity within these radii.

The geological story continues with the aftermath of ice ages, as large areas were flooded by the sea due to the weight of the ice depressing the land. Thick layers of clay, silt, and sand were deposited, creating rich soils in some regions. However, in forested areas, the main soil has been stripped of mineral content, resulting in poor agricultural land. [61]

The unique landscape of Tromso is an amazing coexistence of mountain ranges, an incredible variety of flora and fauna and structures erected by people — evidence of a complex symbiosis of nature and technology. Norway's rich flora includes about 2,000 species of plants, with thick forests of spruce and pine dominating glacial valleys. Wildlife, from reindeer and wolverines to seabirds and fish, contributes to the ecological vibrancy. The annual migration of salmon upstream through rapids and waterfalls is a natural spectacle, complementing the diverse bird species that migrate to Southern Africa for winter. [61]

Tromsø is located at 69.649° latitude, 18.955° longitude, and 14 meters above sea level. The area within 3 kilometers of Tromsø has varied terrain, with the highest point being 604 meters above sea level and an average height of 64 meters. The area within a radius of 3 kilometers from Tromsø is covered with trees (36%), artificial surfaces (36%) and water (17%), within a radius of 16 kilometers - trees (22%) and sparse vegetation (22%), and within a radius of

Figure 43-3.1 Topography of Tromso Region (Igor Voinov, 2006)

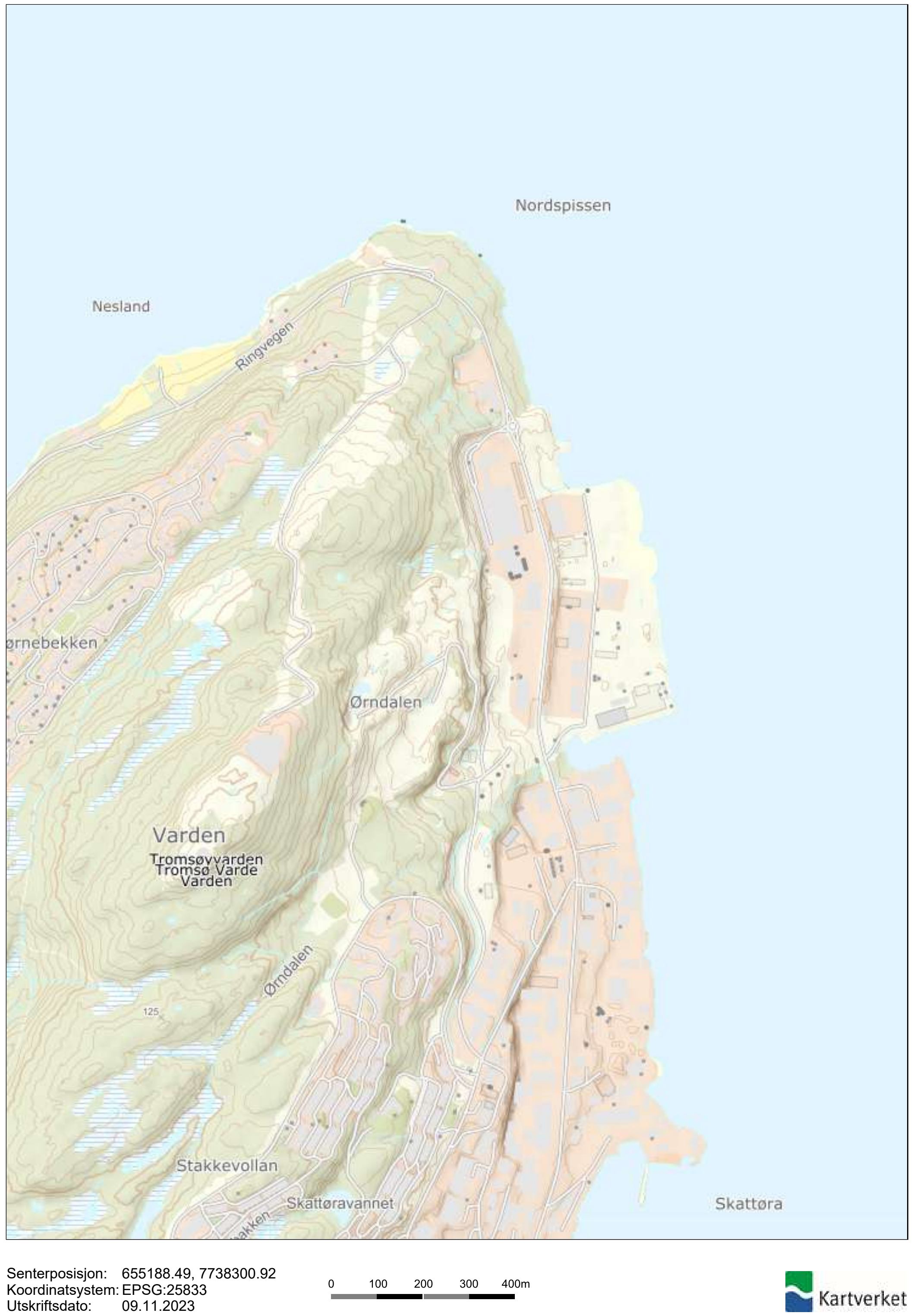


Figure 44-3.1 Topography on the Selected Site (Igor Voinov, 2006)

80 kilometers - water (43%) and trees (19 %).[58]

During the periods of ice age retreats, extensive regions in Norway experienced sea inundation due to the substantial land depression caused by the immense ice load. As a consequence, substantial layers of clay, silt, and sand were deposited along the present coastline, particularly in the Oslo and Trondheim regions, where elevations currently reach up to 650 feet (200 meters) above sea level. Rich soils formed beneath these ancient marine coastal areas, fostering varied vegetation.

In areas covered by expansive forests, the primary soil has been depleted of its mineral content, resulting in agriculturally poor land. In the Østlandet region's interior, farms are situated alongside broad valleys with soil deposits that have been extensively eroded. The Jæren Plain, benefiting from glacier-formed soils, mild winters, extended growing seasons, and ample precipitation, stands out as Norway's most productive agricultural area.

Norway boasts around 2,000 plant species, with a majority being mountain plants endemic to the region. Spruce and pine dominate the dense forests in the broad glacial valleys, reaching elevations of up to 850 meters in eastern Norway and 700 meters in the Trondheim region. Even in densely wooded areas, the ground is adorned with leafy mosses and heather, while deciduous trees such as birch, ash, rowan, and aspen thrive on the steepest hillsides. The birch zone spans from 900 to 1,200 meters above sea level, above which a willow belt, including dwarf birch, is found.

Western Norway boasts an equal abundance of conifers and broad-leaved trees. The largest forests in Norway stretch between the Swedish border and the Glåma River, east of Oslo. Approximately half of the Østlandet region is forested, accounting for about half of Norway's total forest resources and cultivated land area. Trøndelag, covering nearly one-third of its area, is also characterized by substantial forested land. North of the Arctic Circle, there is a scarcity of spruce, with pine predominantly growing in inland valleys amid unexpectedly rich vegetation. Wild berries, including blueberries, cranberries, and yellow cloudberries, flourish across all regions.

Norway is home to a diverse range of Arctic animals, including reindeer, wolverines, lemmings, and others, with their habitats extending throughout the country. Elk are prevalent in large coniferous forests, while red deer are numerous on the west coast. Large predators like bears, wolves, and lynxes were commonplace in Norway just 150 years ago but are now confined to a few northern areas. Foxes, otters, several marten species, badgers, and beavers are widespread in many regions.

The country's rivers and lakes host a variety of fish, particularly trout and salmon, with the latter thriving in at least 160 rivers, attracting anglers from around the world. Norway's diverse bird population includes species that migrate as far as Southern Africa for the winter. In the northern regions, millions of seabird eggs and down are collected, and cliff islands, even as far south as Ålesund, are often nearly covered by hundreds of thousands of nesting birds. Partridges and various grouse species are abundant in the mountains and forests, making them popular game birds.

The site-specific landscape of Tromsø is characterized by sharp elevation changes, with a maximum point at 158 meters descending to sea level over rocky terrain. Although the plant's territory lacks pronounced relief due to its history as a stone quarry, the surrounding background features a stepped rocky surface formed through natural stone mining operations. The adjacent sea's depth is sufficient to accommodate the movement and parking of cargo ships in the area.

Site Specifics of Tromsø: Local Materials

Nestled in the northern reaches of Norway, Tromsø presents a compelling canvas for architectural innovation, where the fusion of local materials and environmental responsiveness defines the essence of construction. This articulation is particularly evident in the strategic selection of building components tailored to endure the region's formidable climate.

Timber is a cornerstone of construction, with spruce and pine being especially favoured due to their abundance in the region. These woods offer not only structural strength but also excellent insulation properties, a key requirement for withstanding the cold climate. Wood, notably spruce and pine, stands as a cornerstone of construction, not merely for its structural prowess but also for its insulating virtues, a pivotal consideration in navigating the frigid extremities of Tromsø's weather.

Indigenous stones, including but not limited to granite and slate, meticulously extracted from quarries in close proximity, play a pivotal role in accentuating the architectural storyline, imparting not only a resilient groundwork but also an aesthetically refined touch. The incorporation of these local stones, celebrated for their exceptional durability, extends beyond mere utilitarian applications, finding purpose in foundational structures, walls, and landscaping endeavors.[61] Their multifaceted utilization not only reinforces the structural integrity of the buildings but also contributes significantly to the visual allure, seamlessly marrying strength with aesthetic finesse. Moreover, in the specific context of the designated site for the incineration plant project in Tromsø, the unique presence of migmatite, a distinctive metamorphic rock, further enriches the local material palette, offering an additional layer of geological intrigue and practical potential to the architectural narrative.

In the quest for maximizing natural light during the region's dark winter months, boasting exceptional insulation properties the prevalence of double-glazed or even triple-glazed glass emerges, seamlessly blending functionality with insulation capabilities to defy the cold. [70]

Metal, with a pronounced emphasis on materials like steel and aluminum, assumes a prominent role in the construction's structural components and roofing systems, thereby spotlighting its remarkable resilience when confronted with substantial snow loads.[65] The distinctive quality of these metals lies in their innate capacity to withstand the challenges posed by heavy accumulations of snow. In many instances, coated iterations of these metals are judiciously employed, not only as a means to fortify their durability but also to prolong their lifespan in the face of environmental elements. This strategic use of coated metal varieties stands as a testament to the meticulous consideration given to both the immediate and long-term structural integrity of the architectural elements.

The integration of earth and sod, manifested in traditional turf roofing, not only enhances insulation but also harmonizes structures with the surrounding natural tapestry. Sheep's wool insulation, locally sourced, epitomizes sustainability and eco-consciousness in the architectural lexicon of Tromsø.[71]

Sustainability finds resonance in the judicious use of recycled materials, breathing new life into salvaged wood from aged structures or driftwood from the coastal periphery.[72] Local concrete, particularly in its precast form, emerges as a choice that marries durability with thermal efficiency.

Figure 45-3.1 Migmatite
(Yuri Gritsenko, 2017)

By-products from local sawmills, such as wood shavings and sawdust, metamorphose into insulation materials, contributing not only to waste reduction but also to the broader ethos of sustainability.[72]

In the conceptualization of an industrial edifice within Tromsø's landscape, architects delicately curate this diverse palette of local materials, each chosen for its unique strengths and relevance to the envisioned purpose. This approach gives rise to structures that transcend mere functionality, embodying an aesthetic consonance with the natural milieu while steadfastly enduring the climatic rigors of the region.[73]

In my architectural inquiry, I intend to place a focused lens on the selection of facade materials for the forthcoming incineration plant project in Tromsø, with a keen interest in the distinctive presence of migmatite directly on the allocated site.

In the realm of geological formations, migmatite stands as a distinctive metamorphic rock, forged through the intricate processes of anatexis. Its inherent heterogeneity unveils a tapestry that bears witness to the nuanced interplay of partial melting, observable across both microscopic and macroscopic scales. Serving as a transformative link between metamorphic and igneous rocks within the broader geological narrative, migmatites epitomize the culmination of petrological and mechanical forces, orchestrating the creation and redistribution of anatectic melt amidst varying degrees of deformation.[73]

A fundamental categorization of migmatites rests on the pivotal parameter of melt fraction, with metatexites harboring modest melt fractions and diatexites embracing more substantial proportions. The phenomenon of partial melting, or anatexis, unfolds within the realm of upper-amphibolite to granulite-facies conditions, where melt emerges predominantly through incongruent hydrous mineral breakdown reactions. [73]Concurrently, hydrous fluids infiltrate comparatively arid rocks, instigating the genesis of melt. In the intricate dance of geological processes, many migmatites emerge as open systems, characterized by the dynamic exchange of produced, lost, and gained melt.

The holistic examination of whole-rock geochemistry emerges as a valuable tool, unraveling insights into the protoliths of migmatites, quantifying the magnitude of melt generated during metamorphism, and deciphering the intricate processes governing the separation of melt from residue in the profound depths of the Earth's crust. Geochronological analyses, delving into the timing and duration of melting, illuminate the temporal dimensions of migmatitic transformations.[74]

Beyond their geological significance, migmatites become hosts to mineral deposits, and the open-system dynamics associated with partial melting can either enrich or deplete elements of economic interest. Through the lens of migmatite studies, profound revelations emerge concerning the genesis of granitoids, prominent constituents of the continental crust. Moreover, these investigations shed light on the behavior of crust rendered susceptible by melt during deformation, offering insights into the enduring chemical evolution and stabilization of Earth's continents over the eons. [75]

Given the multifaceted attributes unveiled by migmatites, particularly their structural integrity and aesthetic allure, the incorporation of this metamorphic rock as a facade material for the incineration plant project in Tromsø is not only scientifically sound but promises to bestow a distinctive character to the architectural endeavor. The amalgamation of its geological history, coupled with the practical advantages it offers, positions migmatite as an optimal choice, harmonizing the scientific essence with the artistic vision of the architectural design.

Local Architecture Analysis

In the context of Norwegian architecture, this chapter delves into the profound relationship between architecture, society, culture, and the natural environment. Norway's unique ethos embodies the fusion of these elements, creating a seamless integration with nature that is a hallmark of Norwegian architectural philosophy. This philosophy is epitomized by the concept of 'Allemannsretten,' the right to roam, which is deeply ingrained in Norwegian society, signifying the accessibility of nature to all.

While traversing the landscapes of Norway, one encounters architectural gems that encapsulate this philosophy, serving as tangible expressions of equality and a harmonious connection with the environment. The Norwegian approach to nature is distinct; it is a shared inheritance rather than private possession. Although certain individuals may legally own specific tracts of land, the fundamental premise is that the land does not truly belong to any one person. This viewpoint underscores a profound appreciation of the Earth itself and the importance of its accessibility to all.

A quintessential example of this philosophy is exemplified by the Oslo Opera House. This architectural marvel embodies the principle that architecture should be inclusive and welcoming to everyone. The Opera House extends an open invitation for people to engage with it in a myriad of ways, from leisurely strolls and picnics to spontaneous activities like skating, irrespective of legal ownership. The intimacy experienced in the moment fosters a sense of ownership and connection to the structure and the culture it represents.

Historically, cultural experiences were often reserved for the elite, creating a divide between the public and the artistic world. However, the design of the Opera House, through its accessibility, eliminates this distinction. Visitors to the Opera House find themselves in proximity to the cultural offerings, even if they have not attended a performance. The roof of the Opera House epitomizes the concept of 'Allemannsretten,' as it provides a public space for free use and enjoyment, reinforcing the principles of openness and inclusivity.

In this context, the notion of ownership takes on a collective dimension. The larger public perceives a shared responsibility to protect and preserve spaces like the Opera House because, in a sense, they consider these spaces to be partially their own. In Norway, the ownership of nature is collective; upon entering the natural world, individuals shed the trappings of their societal roles, positions, possessions, and social status. Instead, they become equals, defined solely by their shared humanity.

The Norwegian architectural landscape thus serves as a reflection of the nation's unique perspective, where the natural environment is cherished, protected, and accessible to all. This inclusivity and deep connection with nature are central themes in the story of Norwegian architecture and the profound impact it has on society and culture.

Morphological Analysis

After establishing a general understanding of how architecture is perceived in Norway, we have delved deeper into the philosophy of the inseparable connection between nature and humanity. We now propose a more detailed examination of the morphology of buildings characteristic of Tromsø. This analysis is essential for comprehending the gradations of the city's architectural dominants.

Figure 46-3.1 Arctic University Museum of Norway (Kasper Kyndesen, 2020)

Kasper Kyndesen, Partner and lead of Henning Larsen's presence in the Norwegian market, offers insightful perspectives on the architectural vision for the Tromsø Museum. Located in the northern reaches of Norway, where extended periods of darkness are a hallmark of the region, the design approach sought to create a luminous focal point amidst the twilight. Kyndesen shares that the museum's distinctive feature will be its glass facades, designed to emit an inner light. During the nighttime, particularly in the winter months, the building will exude a soft, radiant white glow. This luminous concept draws inspiration from the celestial Northern Lights but also finds its roots in the warm, inviting glow of fire or lamps illuminating a tent, a nod to the area's Sámi heritage.[76] This radiant effect is not an anomaly in Tromsø; other significant buildings like the city library, swimming hall, and the Ishavskatedralen, which stands across the water, create a similar luminous impact on the cityscape. In this context, the Tromsø Museum is poised to become yet another guiding light in the city.

Kyndesen emphasizes that in this extraordinary environment, a building doesn't need to be towering in height to become a significant landmark. The museum will function as a beacon in the city's panorama, visible from the surrounding fjords. It serves as a guiding point, unchanging as you navigate through the adjacent landscape, always illuminated, always guiding your way.[77]

For Kyndesen, the practice of architecture is fundamentally rooted in empathy. It necessitates a profound understanding of the natural environment, the project's requirements, and the locally available materials; this understanding serves as the initial point of departure for any architectural endeavor. From this foundation, all other design elements take shape.

Kyndesen envisions an iconic building not as something that clamors for attention, but rather as an entity that initially piques curiosity and slowly unfolds its intricacies. Engagement with the structure allows for a deeper appreciation of the architectural details and the broader functionality of the space.[76] Importantly, in a setting as diverse as Tromsø, where the environment fluctuates between extremes, the building must remain versatile. In the darkness of winter, with a sparse landscape, the architecture stands out with clean, compact lines, resembling ice cubes on a dark canvas. Yet, during the vibrant summer months, when greenery flourishes and the waterfront comes alive, the museum seamlessly blends into its surroundings, appearing almost as a natural extension of the landscape. This adaptability ensures that the Tromsø Museum remains a compelling destination, luring people back time and again to appreciate its ever-changing character in a range of climates and settings.

Figure 47-3.1 Polaria (Jiri Havran, 2004)

In the architectural landscape of Tromsø, Polaria stands as a distinctive adventure and informational center, with its unique design encapsulating the essence of the circumpolar region.

Polaria, a prominent feature in Tromsø's landmarks, serves not only as an adventure destination but also as an educational hub offering insights into the intricacies of the circumpolar region. This iconic complex comprises two buildings, each carefully crafted to fulfill different functions, creating a visual narrative that enriches the city's architectural diversity.

The Polar Environment Centre, a striking seven-storied structure positioned transversely to the water's edge, embodies a sleek and upright quality. Its architectural grace is further emphasized by a gently curved roof, angled to catch the southern wind. This deliberate design choice not only adds to its visual appeal but also speaks to the functionality of the building in the face of the region's climatic challenges.

In contrast, Polaria, the second building in this architectural ensemble, exhibits a vastly sculptural quality. Drawing inspiration from the Arctic landscape, its design evokes the image of five sheets of "ice flow" converging towards land. This distinctive impression is not only a testament to Tromsø's unique geographical context but also an expression of architectural ingenuity. The use of glass between these "ice sheets" not only enhances the aesthetic appeal but also creates a sense of spaciousness, inviting visitors to immerse themselves in the surrounding environment.[78]

Moreover, the choice of materials adds depth to the architectural narrative. The entrance, clad with Siberian larch wood, not only introduces a natural and warm element to the structure but also establishes a tactile connection with the Arctic surroundings. This thoughtful integration of materials showcases an attention to detail that is characteristic of Tromsø's landmarks, where architecture becomes a means to harmoniously blend with, and even celebrate, the natural context.

Polaria, therefore, stands not just as a physical structure but as a testament to Tromsø's commitment to architectural innovation that respects, reflects, and interacts with the unique characteristics of the circumpolar region.[79] In our comprehensive analysis of Tromsø's landmarks, Polaria emerges as a symbol of architectural prowess and a harmonious integration of form and function in the northernmost reaches of Norway.

The Arctic Cathedral, officially named Tromsdalen Church, stands as a timeless testament to architectural brilliance and spiritual significance in the cityscape of Tromsø. Consecrated on November 19, 1965, this landmark, also affectionately known as Ishavskatedralen, captures the essence of both its era and the unique Arctic landscape that envelops it. The visionary architect, Jan Inge Hovig, orchestrated a masterpiece that transcends mere religious symbolism to become an iconic structure visible from the Tromsø Sound, the Tromsø Bridge, and even from the vantage point of incoming aircraft.[80]

Figure 48-3.1 Tromsdalen Church (Yngve Olsen, 2023)

The cathedral's distinctive form is articulated by 11 aluminium-coated concrete panels on each side of its roof, creating a captivating visual spectacle. As one approaches from the western side, the main entrance is framed by a vast glass façade, intricately adorned with a pronounced cross, setting the tone for the sacred space within. Adding to the cathedral's visual poetry, the eastern side boasts a breathtaking glass mosaic, a masterpiece crafted by the renowned artist Victor Sparre in 1972.[81]

This glass mosaic unfolds a narrative of profound symbolism, portraying God's hand from which emanate three rays of light, symbolizing the divine connection through Jesus, a woman, and a man. The mosaic, a focal point for visitors, becomes a source of contemplation and admiration, stirring curiosity and fascination with its intricate details.

Step inside, and the interior reveals a harmonious blend of severity and simplicity. Notable features include oak pews, large prism chandeliers, an altar rail, and a pulpit—all meticulously designed to resonate with the cathedral's architectural ethos. Each element contributes to the overall ambiance, creating a space for reflection and spiritual contemplation.

An integral part of the cathedral's auditory and visual experience is its organ, a masterpiece crafted in 2005 by Grönlunds Orgelbyggeri. With three manuals and pedal, boasting 42 stops, this organ is a testament to the French Romantic tradition. Ingeniously adapted to the cathedral's architecture, the organ becomes more than a musical instrument—it becomes a visual metaphor, evoking images of sails and ice floes. Comprising 2940 pipes, ranging from the towering 32 feet (9.6 m) to the minutest 5 mm, and featuring woodwork crafted from solid pine and bellows made of reindeer hide, this organ is a marvel in both craftsmanship and sonic resonance.[80]

As we delve into the analysis of Tromsø's landmarks, the Arctic Cathedral emerges not just as a religious edifice but as a cultural and architectural beacon, drawing visitors into its spiritual embrace and leaving an indelible mark on the city's skyline.

Nestled in the heart of Tromsø's city center, the main library building stands as a literary beacon within the vibrant Fokuskvartalet area. Located in close proximity to the bustling main street, "Storgata," and the Cultural Centre, the library shares its architectural space with the Town Hall and a cinema, forming a cultural nexus that radiates intellectual energy and community engagement.[82]

The library, spanning four floors and crowned by a top gallery, is not just a repository of books but a multifaceted hub of knowledge and cultural exploration.

Figure 49-3.1 Public Library and Archive (Liudmila Sidorova, 2023)

Adjacent to the City Archives, the building serves as a testament to Tromsø's commitment to preserving its historical narrative while fostering a contemporary space for intellectual pursuits. Its strategic location within 50 meters of key city landmarks, coupled with its striking architecture, has established the library as a natural meeting point for locals and an indispensable experience for tourists exploring Tromsø.

Beyond its physical presence, the library's vision extends beyond its walls. Aspiring to be a model library in the expansive region of northern Norway, it embodies a commitment to excellence in library services and community engagement.[82] This commitment garnered well-deserved recognition in 2006 when the library was honoured as the Best Service Enterprise in Tromsø, an accolade bestowed by the citizens of the city in acknowledgment of its exceptional contributions to the community.

The library's acclaim continued to soar, earning a nomination for the prestigious "Library of the Year" award in Norway in 2008. The following year, in 2009, a general poll resoundingly affirmed the library's standing as the best public library of the year, underscoring its pivotal role in shaping Tromsø's cultural and intellectual landscape.[82]

In the ongoing analysis of Tromsø's landmarks, the main library emerges not merely as a repository of books but as a dynamic cultural institution, a living testament to the city's dedication to knowledge, community, and the seamless integration of historical preservation with contemporary vibrancy.

In the culmination of the morphological analysis of Tromsø's main landmarks, the symbiotic relationship between architecture and nature in Norway emerges as a defining theme. Nature, an omnipresent force in the Norwegian landscape, asserts its influence on architectural endeavors, shaping structures that withstand the formidable forces of ice, snow, rain, sun, and wind, embodying the essence of robust and enduring design.[76]

Wood, a versatile and abundant building material, weaves through the historical tapestry of Norwegian architecture. From the iconic stave churches to the enduring shipbuilding traditions, wood stands as a testament to both the past and present in the construction industry, embodying a timeless connection to the country's architectural heritage.

The repertoire of materials extends beyond wood, encompassing stone, steel, and glass, each strategically employed to mirror the surrounding landscape in contemporary constructions. Some architectural marvels, such as Oslo's opera house, seemingly float like icebergs on the fjord, while others, like the Juvet Landscape Hotel, feature cabins meticulously crafted from wood, steel, and glass, seamlessly blending into the forest surroundings.[83]

The Norwegian ethos of an egalitarian society casts its influence on modern architecture, fostering a culture of inclusivity and sustainability. This ethos extends beyond climatic considerations to embrace social aspects, shaping buildings and environments that resonate with the principles of equity and harmonious coexistence.[84]

In the realm of successful projects, a common thread emerges—readable forms, a simple and judicious use of materials, and a resolute engagement with the landscape and social context. [77]These hallmarks characterize the most compelling architectural endeavors in Tromsø, reflecting not only a mastery of design principles but a profound respect for the dynamic interplay between architecture and the natural and social environments they inhabit.

3.2 SITE VISIT

Observations and Insights

Upon conducting preliminary analysis and meticulous online information gathering, a strategic decision was taken to elevate the level of project immersion by embarking on a comprehensive journey to the picturesque city of Tromsø in Norway. This strategic site visit, meticulously planned and executed from September 10th to September 13th, 2023, aimed to ensure the utmost precision in territory research and analysis, laying a robust foundation for the architectural exploration that would follow.

The overarching objectives of this transformative journey encompassed not only the fundamental study of architectural forms but also the nuanced morphological analysis of the cityscape. Additionally, the expedition sought to delve into the specifics of the terrain, unravel the intricacies of the landscape, and immerse deeply into the unique atmosphere that characterizes Tromsø. From the author's perspective, such an in-person visit to the chosen location is deemed crucial for any architect, especially when working on a project situated in a country as distinctive as Norway. Real-life experience, unparalleled in its authenticity, allows one to grasp the true aesthetics of the area — the genuine hues, the interplay of light on surfaces, and the scents that encapsulate the surroundings. This hands-on approach is instrumental in fostering a profound understanding of the inhabitants who navigate life in the challenging weather conditions within the polar circle. It recognizes that the aesthetics of architecture extend beyond functional aspects, delving into the emotional and visual components that are often overlooked in contemporary design. Immersion in the environment not only enhances the project's allure but also provides the architect with a heightened sense of comfort and understanding of the spatial context.

Beyond the broader impressions of the city, the expedition aimed to meticulously explore the designated project site. A key aspiration was to establish meaningful connections with local entities integral to the project's success. Notably, the author successfully engaged with Remiks, a leading waste management firm in Norway, providing an invaluable opportunity to glean insights directly from industry experts. A comprehensive summary of the enlightening interview with a representative from Remiks is thoughtfully presented at the conclusion of this thesis, contributing an enriched perspective to the overall discourse.

This chapter stands as a dedicated documentation and elucidation of the myriad observations and insights harvested during this transformative trip. The materials presented herein, spanning vivid descriptions of the surroundings, personal impressions, and a curated collection of photographs, distinctly represent the subjective perspective of the city of Tromsø, forming an integral part of the author's journey in crafting this master's thesis. The subsequent sections will meticulously unpack the multifaceted aspects of the site visit, categorized for the reader's convenience, providing a comprehensive exploration of the experiential richness garnered from this pivotal expedition.

Colors and Textures of Tromsø

To describe the colors and textures of the city of Tromsø, it is suggested to commence with an overall impression and then delve into a detailed analysis. At first glance of the city's panorama, the most striking elements are the mountainous landscapes adorned with emerald-green forested expanses. These are framed below by the bluish-hued expanse of the sea and from above by dusty, silvery clouds. Against the backdrop of the mountain ranges, the houses appear diminutive but remain distinctly visible owing to their vivid accent colors and shades, including hues of yellow, red, and blue. Moreover, a significant part of the city's palette is attributed to the cargo and passenger vessels arriving and departing, thereby enlivening the visual impression. The substantial masses of white, red, and blue contribute to the unique colourscheme of the locality, enhanced by the movement of the ships. This variety of clean, vibrant colors also operates effectively during the winter months when the city's palette transforms into various shades of snow.

Upon closer examination, it becomes possible to observe a multitude of hues and textures, created by the diversity of northern vegetation, particularly vivid in the autumn period. For instance, the Dahlia 'Bishop of Llandaff' flowers are characterized by a deep aubergine hue of the leaves, against which the red and yellow blossoms stand out vividly, resembling stars against a clear sky.

The analysis of colors and textures in Tromsø is a crucial element in understanding the visual and environmental aesthetics that shape the identity of the city, influencing architectural considerations and design principles. The interplay of these colors and textures not only creates a vivid urban landscape but also significantly impacts the seasonal transformations, portraying different moods and atmospheres throughout the year. This observation contributes to a deeper comprehension of the city's visual characteristics and aids in envisioning architectural interventions that harmonize with the natural environment and cultural context.

In the rich tapestry of Norwegian flora, a particularly splendid representative emerges in the form of Salvia Nemorosa 'Blaukonigin'. This botanical marvel, characterized by its delicately lilac-hued flowers and branches adorned with a subtle dusty turquoise hue, stands as a testament to nature's artistry, adding an exquisite touch to the urban landscapes it graces. The ethereal beauty of 'Blaukonigin' not only captivates the beholder with its nuanced color palette but also serves as a harmonious complement, seamlessly integrating into the intricate fabric of urban environments. This botanical gem, with its delicate yet resilient presence, becomes a living brushstroke in the canvas of city life, enhancing the aesthetic allure and embodying the symbiotic relationship between nature and the built environment.[85]

Figure 50-3.2 Red Bishop of Llandaff (Liudmila Sidorova, 2023)

In the rich tapestry of Norwegian flora, a particularly splendid representative emerges in the form of Salvia Nemorosa 'Blaukonigin'. This botanical marvel, characterized by its delicately lilac-hued flowers and branches adorned with a subtle dusty turquoise hue, stands as a testament to nature's artistry, adding an exquisite touch to the urban landscapes it graces. The ethereal beauty of 'Blaukonigin' not only captivates the beholder with its nuanced color palette but also serves as a harmonious complement, seamlessly integrating into the intricate fabric of urban environments. This botanical gem, with its delicate yet resilient presence, becomes a living brushstroke in the canvas of city life, enhancing the aesthetic allure and embodying the symbiotic relationship between nature and the built environment.[85]

Figure 51-3.2 Salvia Nemorosa (Liudmila Sidorova, 2023)

Nevertheless, it is crucial to clarify that the primary focus of this thesis does not extend to an exhaustive exploration of the local botany in Tromsø. Consequently, our approach will be to selectively showcase images of plants that left the most profound impressions on the author during the Tromsø field trip. The lively plant life certainly adds to the city's vibe, but the goal here is not to dive deep into botanical details. Instead, we aim to share some glimpses of the plant life that stood out to the author in Tromsø. These visuals aim to give an extra layer of understanding about the natural elements that make the city charming, adding glimpses of the plant variety that caught the observer's attention and admiration.

Figure 52-3.2 Flowers of Tromso
(Liudmila Sidorova, 2023)

From the analysis of the photographs, it can be inferred that the apparent sea of green surrounding the city conceals numerous incredible combinations of colors and shades, crafted by nature. Here, one needs to be more perceptive and atten-

Figure 54-3.2 Traditional colours of Tromso
(Liudmila Sidorova, 2023)

Figure 56-3.2 Pastel colours (Liudmila Sidorova, 2023)

tive to discern the extraordinary beauty of the northern plants, hidden from casual observers behind their seemingly monochrome appearance. A similar principle could be applied in future design—highlighting coloring small yet significant de-

Figure 53-3.2 Classicism colours of Tromso
(Liudmila Sidorova, 2023)

tails.
Of particular interest to the author, following an exploration of the history and culture of Tromsø, is the choice of shades for local buildings and structures. As the city suffered greatly during wartime, many ancient structures did not survive. This, on one hand, constitutes an incredible loss for historians and archae-

Figure 55-3.2 Contemporary colours
(Liudmila Sidorova, 2023)

ologists. On the other hand, it presents opportunities to more freely consider colourwithin the city fabric, allowing for experimentation and the introduction of new, unconventional elements not restricted by norms.
Consequently, alongside the traditional hues typical of Norwegian wooden architecture, such as Indian yellow and

Figure 57-3.2 Modern textures of Tromso
(Liudmila Sidorova, 2023)

red-brown, incredibly vibrant and bold colors like orange and bright blue are juxtaposed, alongside more serene minty and delicate blue tones. Additionally, the city hosts numerous buildings from the classicism era where various shades of white were extensively employed.
The city's palette represents a juxtaposition of historical context and the potential for innovative, unconventional applications. The coexistence of traditional and contemporary colour choices not only reflects the city's adaptive nature but also offers a unique canvas for architects and urban planners to draw inspiration from the cultural history and experiment with novel approaches, ultimately enriching the architectural landscape of Tromsø.

The Natural Landscape of Tromsø

In this dedicated section, our intention is to unfold unconventional observations that delve into the nuanced interactions between the natural landscape of Tromsø and its intricate relationship with the urban fabric. By steering away from conventional perspectives, we aim to shed light on aspects of the city's natural environment that may be overlooked in traditional analyses. This exploration seeks to capture the symbiotic dance between nature and urbanity, unraveling unique facets that contribute to the distinctive character of Tromsø. As we embark on this unconventional journey, we invite readers to join us in unveiling the less-explored dimensions of the city's natural tapestry and its intriguing interplay with the constructed environment.

For instance, in Tromsø, there is a small yet magnificent botanical garden, accessible to all around the clock. This underscores the Norwegians' regard for nature as a communal good, accessible to everyone. Within the botanical garden, plants from all corners of the world coexist harmoniously, arranged upon the rocky terrain characteristic of this region.

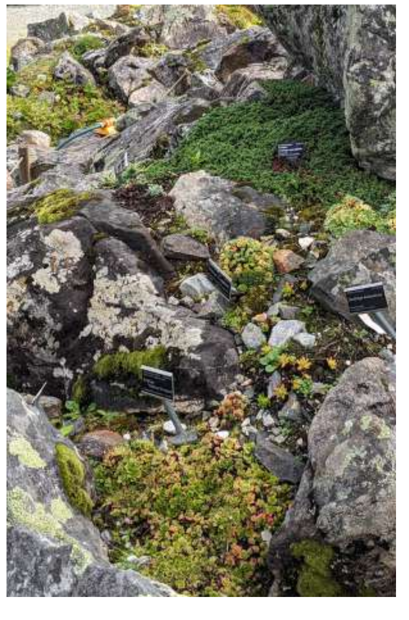


Figure 58-3.2 Botanical Garden in Tromso (Liudmila Sidorova, 2023)

This unique coexistence of flora from diverse geographical origins portrays a microcosm of global biodiversity, thriving in a carefully curated environment. The juxtaposition of various plant species against the backdrop of Tromsø's distinctive landscape creates an intriguing tapestry of natural beauty. Moreover, the garden's perpetual accessibility accentuates the Norwegian ethos of inclusivity, fostering a shared appreciation for the wonders of the natural world.

The symbiotic relationship between the urban space and the botanical garden highlights the city's dedication to integrating nature within its confines, fostering not just ecological preservation but also a holistic experience of coexisting with the natural environment. In this context, the botanical garden, with its diverse and well-maintained plant life, serves as a testament to Tromsø's unwavering commitment to preserving and showcasing the richness of global botanical heritage within a local setting.

Figure 59-3.2 Migmatite Presence at the Site (Liudmila Sidorova, 2023)

Among the various mountainous rock formations, a particular type stands out. The angular texture of migmatite has served as inspiration for the forthcoming waste-to-energy plant project. The contrasting beige-white veins against the dark-gray, nearly black stone mass create an impression of multiple connections among different components of a unified whole. These patterns can be endlessly contemplated, allowing for a deeper immersion into their essence, and each time, revealing new lines and motifs.

The intricate interplay of colors and textures within the migmatite ignites a sense of complexity and interconnectedness, which in turn has influenced the conceptualization of the waste-to-energy plant project. The marriage of light and dark hues in the rock formations mirrors the potential integration of various elements within the architectural design, symbolizing the unity and diversity coexisting within a single structure.

Figure 63-3.2 Tromso Landscapes Variety (Liudmila Sidorova, 2023)

The exploration and appreciation of these geological patterns not only contribute to the aesthetic development of the architectural project but also reflect the ethos of finding inspiration in the natural surroundings. The distinct textures and colors observed within the migmatite rock not only serve as an aesthetic muse but also carry the potential for a metaphorical narrative with-

Figure 60-3.2 Rainbow Over Industrial Zone (Liudmila Sidorova, 2023)

in the architectural language of the waste-to-energy plant, adding layers of meaning to the overall design concept.

Tromsø represents an incredible juxtaposition of seemingly incongruent elements at first glance. It is an endless expanse of water that is never entirely calm, perpetually traversed by vessels of various sizes and shapes. It is the stunning beauty of mountains emerging from the water, seemingly cradling the small houses at their feet, appearing minute against the backdrop of these colossal stone giants. However, it is within this combination of incongruities that Tromsø finds its essence.

The city, engulfed in darkness during winter, rewards those who endure it with unbelievable views during summer. The author was fortunate enough to witness several sunny hours amidst the rains and mists, witnessing a rainbow—a result of the collaboration of two opposing natural forces.

This juxtaposition of contrasting elements encapsulates the spirit of Tromsø. The coexistence of opposites—darkness and light, tranquility and movement, grandeur, and humility—defines the unique character of the city. The interplay between natural elements and the city's infrastructure creates an environment where the unexpected and the extraordinary converge, offering moments of awe and wonder to those who embrace its distinctive contrasts.

Figure 62-3.2 The Birch Trees (Liudmila Sidorova, 2023)

The birch trees, especially, present a captivating sight in Tromsø. They are not merely confined to the forests but seamlessly integrate into the urban landscape. The featured photographs were taken in close proximity to the city center.

In every corner of Tromsø, there is a palpable connection between humanity and nature. The careful regard Norwegians hold not only for their cultural heritage but also for the natural legacy of their country gives rise to spaces in which one would desire to live and work. Weather ceases to be an impediment if one can sense tranquility and serenity in any part of the city, merely a few steps away from the nearest green space or body of water. These spaces cannot even be aptly labeled as parks. Rather, they resemble living, invigorating streams permeating every cell of the city. The sensation created is ineffable. It is impossible to describe in words; one can only experience it by visiting Tromsø.

Figure 61-3.2 Botanical Garden Landscape (Liudmila Sidorova, 2023)

Distinctive Buildings of Tromsø

The true hallmark of Tromsø is unquestionably the Tromsdalen Church, also renowned as the Ishavskatedralen (The Arctic Cathedral). We have previously discussed it in preceding chapters; here, I aim to convey a fragment of personal impressions from the experience of seeing it.
The Arctic Cathedral stands as an iconic structure that etches itself into the memory of anyone who encounters its remarkable architecture. Its singular, striking design, the interplay of light and shadow upon its unconventional triangular structure, and the ethereal ambience it exudes, leave an indelible impression. The distinctive shape of the church against the Arctic sky forms an awe-inspiring silhouette, especially during the polar night or when bathed in the mesmerizing glow of the midnight sun. The way its form captures and reflects the ambient light, painting a different portrait in varying seasons and times of day, encapsulates a captivating allure that is both serene and compelling.

Figure 65-3.2 Panoramic View on Tromso (Liudmila Sidorova, 2023)

The personal encounter with the Arctic Cathedral transcends the mere observation of a building; it becomes an encounter with an architectural marvel that embodies the spirit of Tromsø, both in its unique form and the atmosphere it

Figure 64-3.2 The Arctic Cathedral Film Picture (Liudmila Sidorova, 2023)

creates. Its presence not only marks the city's skyline but also contributes to the cultural identity and visual narrative of Tromsø as a city uniquely entrenched in nature and architectural splendor.
The structure stands out vividly against its surroundings due to its significant dimensions and elevated position. Its form evokes images of snow-capped mountain peaks and the ice blocks of Arctic icebergs. The gabled roof with a steep incline crowns the surrounding landscape, marking an endpoint and completing the composition. It's evident that this cathedral has no peers in its immediate radius; new constructions ought to be of a lower height than The Arctic Cathedral and should not contrast as starkly with the building.

This building brilliantly showcases the potential of architectural thought, the boldness of its designer, and the audacity to construct something that has no rivals. It's important to mention that the building's architecture is carefully considered down to the smallest detail, supporting such a bold decision in this instance. People from around the world travel to Tromsø to witness this architectural marvel. After visiting the structure, the author observed that the planned waste-to-energy plant, despite being similar in size, should not overshadow the existing cultural heritage. Nevertheless, it's entirely plausible to create another attractive point on the opposite side of the island, thereby linking the industrial zone with public spaces and establishing new urban connections.
Another distinctive contemporary building in Tromsø is the library located in the Fokuskvartalet area in the city center. Its complex, curvilinear form conspicuously stands out among other structures on the street. Architects opted for neutral material shades to avoid overloading the city's visual background.
The modern public library in Tromsø stands as a testament to architectural ingenuity, where glass, steel, and reinforced concrete seamlessly weave into the city's urban fabric. This distinctive structure, while making a lasting impression, respectfully avoids competing with the Arctic Cathedral on the opposite shore. The architects behind this project demonstrated a sophisticated understanding of the delicate balance

Figure 66-3.2 Public Library Façade (Liudmila Sidorova, 2023)

between architectural prominence and harmonious coexistence with neighboring landmarks.

Glass panels, strategically integrated into the library's design, serve as both functional and aesthetic components. These structures enable natural light to flow through the building, producing a continually shifting interplay of light and shadows. This dynamic feature not only adds to the library's modern look but also boosts the overall visual charm of Tromsø's cityscape.

Steel elements, with their sleek and modern attributes, add a touch of sophistication to the library's exterior. Beyond their decorative role, these elements contribute to the structural integrity of the building, embodying a fusion of form and function. Reinforced concrete, chosen for its durability, provides a robust foundation for the library, ensuring its resilience in the face of the Arctic's challenging weather conditions.

In crafting this architectural marvel, the designers paid careful attention to the surrounding landscape, creating a structure that complements rather than

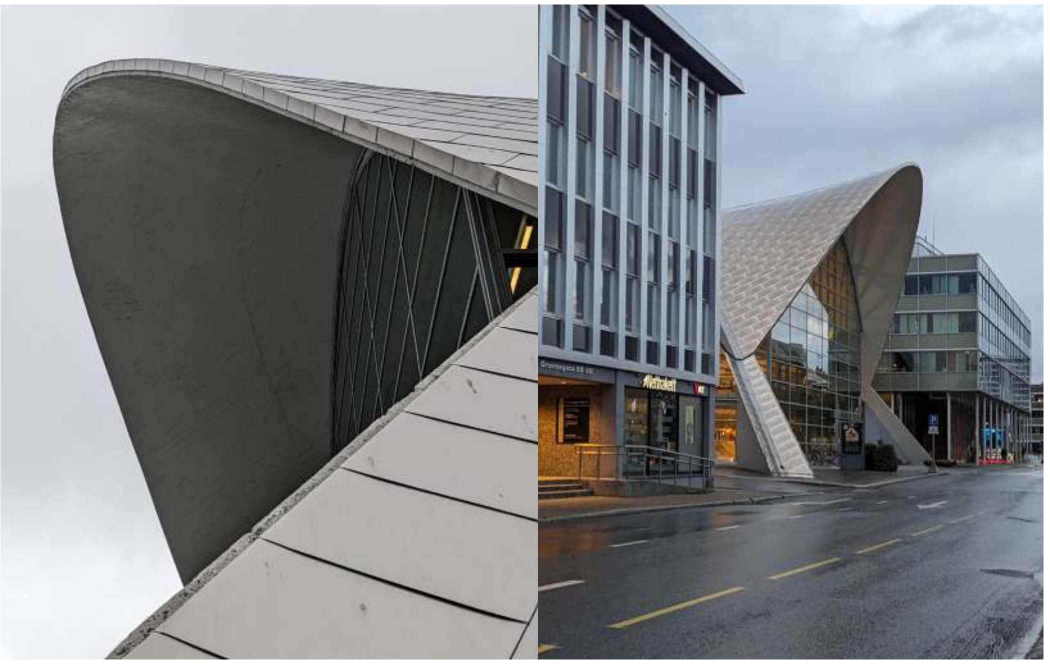


Figure 67-3.2 Textures of the Public Library (Liudmila Sidorova, 2023)

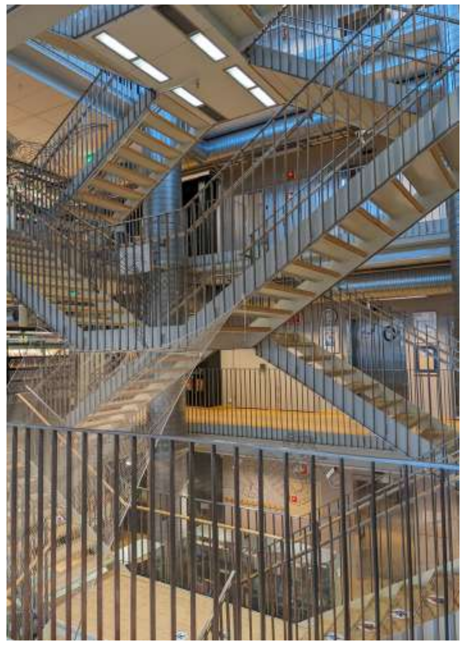


Figure 68-3.2 Staircase at the Public Library (Liudmila Sidorova, 2023)

competes with the iconic Arctic Cathedral. The library stands not only as a repository of knowledge but also as a visual testament to Tromsø's commitment to contemporary design and thoughtful urban integration.

The interior design of the building has proven to be a captivating aspect that has significantly intrigued the author throughout the exploration of the public library in Tromsø. A notable characteristic that stands out within the interior spaces is the pervasive use of industrial aesthetics, skillfully incorporated into various elements, most notably exemplified in the staircase structures and railings meticulously crafted from durable metals.

The deliberate choice of industrial motifs not only adds a distinctive and modern flair to the library's interiors but also serves as a nod to the city's industrial heritage. This thoughtful integration creates a visual narrative that transcends the mere functionality of the space, transforming it into an immersive experience that resonates with the city's cultural and historical context.

Furthermore, the implementation of panoramic glazing emerges as a strategic design element that goes beyond aesthetic considerations. The extensive use of glass not only enhances the overall openness of the space but also maximizes the inflow of natural daylight. This feature is of paramount importance, particularly in a library setting where ample illumination is crucial, especially for reading and other literary activities. The carefully orchestrated balance between industrial motifs and the strategic use of glass creates an environment that is not only visually stimulating but also functionally optimized for the intended purpose of the space.

Moreover, the intriguing visual relationship established between the library and Tromsø's primary landmark, the Arctic Cathedral, adds another layer of significance

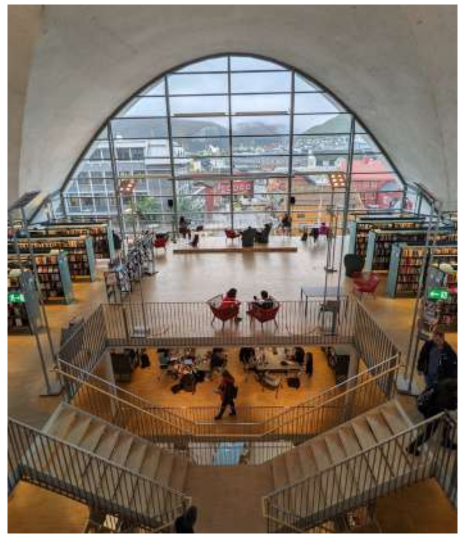


Figure 69-3.2 Interior of the Public Library (Liudmila Sidorova, 2023)

to the architectural composition. The cathedral, with its distinctive triangular form, becomes a captivating focal point visible from the upper floors of the library. The strategic placement of large windows perfectly frames the cathedral, offering a centered and panoramic view of this iconic structure within the city's skyline.
This visual connection between the library and the Arctic Cathedral creates an atmosphere of inspiration, fostering a sense of exploration and curiosity for those engaging with the library's spaces. The deliberate design choice to incorporate this landmark view adds an element of cultural and architectural context to the library experience, contributing to a dynamic and intellectually stimulating environment.
Within the library's interior, a multifaceted approach is evident, catering to diverse needs and activities. The design seamlessly integrates areas for relaxation, social interaction, and quiet reading. This thoughtful consideration of various functional spaces ensures that the library becomes not only a repository of knowledge but also a versatile and welcoming communal space for the city's residents and visitors.
Furthermore, when examining the broader cityscape, Tromsø's architectural identity often features sharply pointed rooftops, where triangles distinctly stand out against the backdrop of rectangular facades, serving as dominant architectural elements. This prevalent architectural form within the cityscape has not gone unnoticed in the planning of the forthcoming waste-to-energy plant's facade. The design concept draws inspiration from these triangular motifs, intending to harmonize the new industrial structure with the established visual language of the city.
To provide a visual representation of the conclusions drawn from these observations, a selection of additional photographs will be presented, offering a

Figure 70-3.2 Triangular Shapes in a city Fabric (Liudmila Sidorova, 2023)

more comprehensive insight into the visual dialogue between the library, the Arctic Cathedral, and the broader architectural identity of Tromsø.

The Industrial Zone of Tromsø

In order to design the new plant, it's necessary to study the specifics of the surrounding industrial zone, understand its general aesthetics, and identify the distinctive features of the area. To achieve this goal, it was decided to traverse the extensive territory on foot, to personally experience the sensations it evokes in visitors. The main impressions gathered from the experience are documented in this section.

Figure 76-3.2 Boat in Tromso (Liudmila Sidorova, 2023)

First and foremost, the striking mountainous landscape and the surrounding bodies of water stand out, providing an incredibly beautiful backdrop for the buildings located here. The area is predominantly characterized by serene, pastel tones, primarily shades of white and gray.
Nevertheless, the cityscape of Tromsø unfolds its surprises, revealing unconventional choices in materials that add a distinctive character to the urban fabric. One notable example is a Rockpanel Chameleon facade that departs from conventional norms. When bathed in sunlight, this avant-garde exterior transforms, casting enchanting pink reflections that playfully dance across the otherwise rectilinear surfaces.

Figure 72-3.2 Rockpanel Chameleon (Liudmila Sidorova, 2023)

This unexpected use of materials not only challenges the traditional architectural palette but also introduces an element of dynamic visual interest. The interplay of light and the metallic facade's reflective properties contribute to a lively and ever-changing streetscape. This daring choice demonstrates a willingness to experiment with design elements that defy expectations, injecting a sense of vibrancy and modernity into Tromsø's architectural narrative.

As we continue our exploration of Tromsø's urban landscape, these unique material choices become intriguing focal points, encouraging a deeper consideration of the intersection between architectural innovation and the city's evolving identity. The juxtaposition of traditional and contemporary elements fosters a dialogue that reflects the city's adaptability and openness to embracing diverse design expressions.


Figure 73-3.2 When Industry Meets the Nature (Liudmila Sidorova, 2023)

The striking contrast between the industrial, rigorously engineered structures and the breathtaking natural vistas evokes a sense of elation It's an amazing sight that honors both human creations and the breathtaking forces of nature. This mix forms a harmonious partnership, where technology and the untamed beauty of nature come together in a beautiful dance. It's a remarkable display of human innovation set against the backdrop of the majestic, untouched landscapes, a visual testament to the interplay between the controlled, man-made designs and the untamed, organic magnificence that surrounds them. This fusion of these seemingly disparate elements creates a narrative of mutual respect and mutual enhancement, demonstrating how the industrial landscape coexists and interacts with the awe-inspiring natural surroundings.

The presence of mountainous terrains and the abundance of greenery contribute to a less skeptical perception even of the most rudimentary industrial building forms. It was incredibly intriguing to observe the constant change in perspectives throughout the entire route, continually offering new vistas and angles.


Figure 73-3.2 When Industry Meets the Nature (Liudmila Sidorova, 2023)

Undoubtedly, the architecture of numerous industrial structures in this locale primarily prioritizes functional utility. These edifices often exude a practical, utilitarian design, crafted for specific industrial purposes. Yet, what is particularly fascinating is the Norwegian approach towards integrating these structures into the surrounding environment. The meticulous consideration and respect for the natural landscape tend to alleviate the stark contrast between the industrial structures and the surrounding natural beauty.


Figure 74-3.2 Industrial Landscapes of Tromso (Liudmila Sidorova, 2023)

The presence of these functional buildings against the backdrop of such stunning natural landscapes creates an intriguing interplay. While the industrial structures may stand out in their straightforward, functional design, they coexist within a setting of majestic mountains, lush greenery, and serene bodies of water. The Norwegian approach to architecture and land usage appears to be guided by a profound appreciation for nature's aesthetics. This ethos seems to soften the visual impact of the industrial elements within the broader natural canvas.

This careful integration prompts a harmony between man-made functionality and the organic, wild beauty of the region. Consequently, even structures designed solely for industrial use seem to embrace and harmonize with the broader natural environment due to the considered approach taken in their placement and design.


Figure 75-3.2 Eclectic Industry and Nature (Liudmila Sidorova, 2023)

The arrival of ships at the shore lends an extraordinary allure to the region, injecting a sense of liveliness and movement into the typically geometric and structured silhouettes of warehouses and industrial facilities. These vessels, with their varied sizes and shapes, create an intriguing contrast against the rigid, angular buildings that define the industrial landscape. They bring an organic and fluid aspect to the otherwise stark environment, broadening the scope of visual interest and enriching the overall scene with a multitude of textures, colors, and dynamic lines.

The presence of these ships not only introduces a distinct dynamism but also acts as a visual bridge between the static industrial structures and the fluidity of the surrounding water bodies. They become focal points that draw attention, breaking the uniformity of the industrial landscape and adding an element of movement and energy. This juxtaposition enhances the area, creating a fascinating interplay between the rigid, man-made structures and the natural ebb and flow of maritime traffic, resulting in a tapestry of visual interest and diversity within the industrial setting.

Remiks Site Visit

The final destination of the itinerary culminated in a visit to the largest waste management company in Norway. Representatives from Remiks were exceedingly accommodating, granting the author a comprehensive tour of the waste treatment plant, providing insights through an interview about the fundamental processes conducted on site. This segment will briefly outline the key highlights of the visit.

The initial standout observation was the company's commitment to the aesthetic appeal of their structures. From the interview, it was disclosed that one of Remiks' principles is that "Waste can also be beautiful." This philosophy underscores the idea that a waste processing facility need not appear unsightly. The acknowledgment that employees work in these surroundings emphasizes the psychological significance of maintaining an aesthetically appealing environment.

For instance, one of the initial structures encountered during the visit was the self-sorting area for waste not falling under the category of household waste. This section accepts items such as old furniture, household appliances, construction materials, and bulky waste. Particularly interesting was the two-tiered structure of the facility: large containers are situated at ground level, where trucks deliver and collect waste, while at the second level, accessible by a ramp, individuals can drive in to offload the brought materials.

Figure 77-3.2 Self-sorting Area (Liudmila Sidorova, 2023)

Figure 78-3.2 Construction Site (Liudmila Sidorova, 2023)

Next, we come across the construction site of the currently expanding waste incineration plant. Observing this site prompts thoughts about the potential for suggesting improvements in the aesthetic attributes of the plant. It is important to note that the selected site, although situated within the Remiks territory, pertains to a different company. The correlation between them will be explained in this section.

Following the enlightening lecture in the administrative building, the tour continued within the heart of the waste processing facility. The sprawling structure appeared to be a fusion of functionality and architectural aesthetics. Its rounded roofline and stepped facades exhibited an impressive, industrially-inspired design. The neutral palette of materials was a visual contrast against the machinery housed within, forming an interesting blend of form and function. These architectural nuances speak volumes about the institution's commitment to modernity and eco-friendly operations, highlighting its aim for a harmonious coexistence between cutting-edge technology and environmentally conscious waste management.

The futuristic essence of the structure was not just an architectural statement; it mirrored the plant's forward-thinking approach. It presented an intriguing juxtaposition—amid the challenging nature of the waste management process, the plant embraced a modern and inviting exterior. The façade design evoked an open and welcoming aspect to the otherwise complex and highly operational institution. This choice of architectural design represents the site's commitment to transparency and integration within the cityscape, fostering a positive relationship between the community and its waste management facility.

Figure 79-3.2 Administrative Building (Liudmila Sidorova, 2023)

As the waste processing processes have been previously described, in this chapter, we shall refrain from delving into technical needs, opting instead to illustrate the primary stages of the process with photographs in a chronological order.
The photograph presented here displays the area for independent waste sorting by private individuals. The operational principle remains identical to that of the initial site, with the sole distinction being the delivery of household segregated waste to this particular area.

Figure 80-3.2 Waste Sorting for Individuals (Liudmila Sidorova, 2023)

Following this, the waste is cleansed and directed to the sorting plant. At this juncture, a company representative stressed the pivotal significance of safety protocols and preventative measures. He articulated that the primary sorting phase frequently encounters a higher incidence of fires due to inadequate waste sorting by individuals. For example, disposal of fireworks or household appliances into mixed waste containers can pose potential fire hazards.

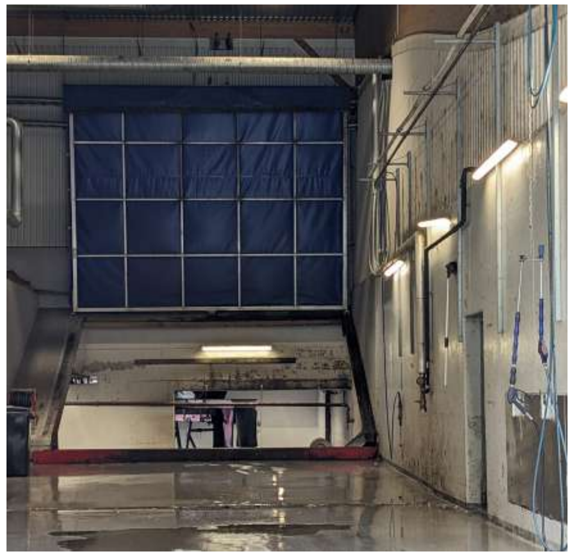


Figure 81-3.2 Cleaning Stage (Liudmila Sidorova, 2023)

During the waste sorting phase, a computer reads patterns on the trash bags and allocates each category to their respective compartments. The waste is then processed further through the conveyor belt.

Figure 82-3.2 Waste Sorting by Computer (Liudmila Sidorova, 2023)

The peculiar aesthetics of the equipment in this plant cannot go unnoticed. For instance, in this particular photograph, we observe industrial filters designed for dust collection. However, due to the choice of colors and intricate form, such a purely technological detail becomes more appealing to the human eye, resembling a piece of art.

Figure 83-3.2 Dust Filters (Liudmila Sidorova, 2023)

On the right-hand side of the photo, we can see a black-colored conveyor for non-recyclable waste. This is the final area in Remiks. Subsequently, the waste that cannot be recycled enters the waste-to-energy plant building, which is located nearby.

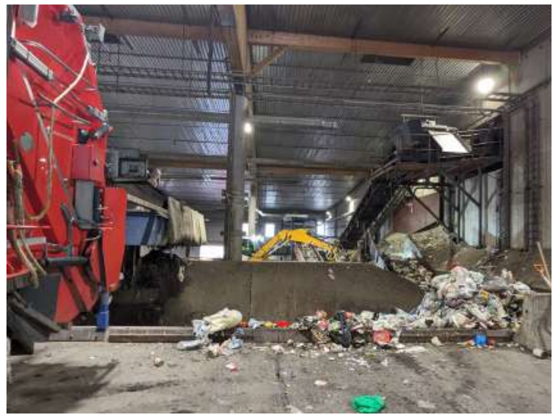


Figure 83-3.2 Dust Filters (Liudmila Sidorova, 2023)

Currently, the sole conveyor is connecting the structures. The developmental vision, akin to the proposal outlined in our project, involves the incorporation of another connecting belt. This planned extension is expected to enhance the logistical operations and facilitate the seamless movement of refuse between these pivotal facilities. The inclusion of an extra conveyor system anticipates a more streamlined waste management process, affirming an extended and advanced waste disposal and processing system for the foreseeable future.

Figure 85-3.2 Connection to the Incineration Plant (Liudmila Sidorova, 2023)

Additionally, we found interest in the setup for grinding wooden construction waste. On the premises, there is an area designated for discarded, non-usable structural wooden elements, such as columns, beams, window frames, and doors. Occasionally, film producers approach the company to use these materials in scenes depicting destruction, wartime scenarios, and the like.
The ground wood chips generated from this process can be used in numerous ways. However, this is not the main focus of this thesis.
The structure of the current waste incin-

Figure 86-3.2 Wood Recycling (Liudmila Sidorova, 2023)

eration plant, a massive cubic building, stands in stark contrast to the natural environment. Its colourpalette and design seem discordant and unsettling in the midst of an otherwise scenic landscape. The visual disharmony between the industrial facility and the serene surroundings raises questions about architectural integration and visual coherence within the landscape. The sheer scale and stark industrial nature of the plant stand out starkly in the surrounding scenery, emphasizing the need for further research and consideration of architectural aesthetics and the impact of such structures on their natural setting.

Figure 87-3.2 Incineration Plant Nowadays (Liudmila Sidorova, 2023)

Returning to the aesthetic properties of the buildings related to waste management, a representative of Remiks expressed plans for restructuring the storage area. They acknowledged that the concrete block walls induce aversion and obstruct the view of the beautiful landscapes of the area. The company intends to address this by reconfiguring the space, understanding the impact of visual obstructions on the scenic environment, and striving for more visually appealing architecture within the context.

Figure 88-3.2 Exterior Waste Storage (Liudmila Sidorova, 2023)

However, the expansive view is truly something one wouldn't want to obstruct with a concrete wall—there is much here to be inspired by.

The Tromsø landscape is a vivid tapestry, woven with dramatic contrasts and stunning backdrops that encompass its identity. Set amidst the majestic Northern fjords, this city embraces the embrace of the mountains, which rise majestically, seemingly cradling the quaint waterside dwellings. The backdrop of undulating mountains and the shimmering waterfront evokes an aura of tranquility and breathtaking natural beauty.

The gentle, undulating slopes of the mountains create an exquisite harmony with the tranquil, glassy waters of the fjords. This picturesque panorama unfolds a rich tapestry of visual delight, rendering the city an embodiment of serene beauty. The mountains, adorned with snow-capped peaks, serve as the city's remarkable natural wall, a grand display of nature's imposing beauty.

The juxtaposition of the stark, untamed majesty of the mountains against the peacefulness of the waterfront crafts a compelling narrative. It's as if these opposing elements have come together to compose a symphony that defines the aesthetic essence of Tromsø. The ever-changing canvas, from the tranquil fjords to the grandeur of the mountains, creates an inspiring blend that captivates the observer, inviting them to unravel the tale that lies within each element of this breathtaking landscape.

Figure 89-3.2 View from Remiks Site (Liudmila Sidorova, 2023)

3.3 ARCHITECTURE DESIGN PROJECT: INCINERATION PLANT IN TROMSØ

Existing Condition

Kvitebjørn Varme AS has been at the forefront of revolutionizing district heating in Tromsø, Norway, with a strong commitment to environmental responsibility. Established in 1989 as Troms Kraft Varme AS and now a subsidiary of SAREN Energy AS, the company has made substantial strides in transitioning towards renewable energy sources. While excelling in sustainable energy practices, there is a notable aspect that requires attention—the aesthetics of their buildings.
The ongoing expansion of the district heating network by Kvitebjørn Varme in Tromsø presents an opportunity to reconsider the design and aesthetic appeal of existing infrastructures. The primary motive behind this expansion is the inadequate heating capacity within the existing network, indicating the pressing need to meet the growing demand from customers.

Figure 90-3.3 Kvitebjørn Varme's Incineration Plant (Pål Julius Skogholt, 2021)

This development entails the extension of the district heating network across Tromsø Island, focusing on interlinking the current district heating networks. The strategic laying of routes aims to connect pre-existing buildings with their independent local heating systems and accommodate future structures.
As part of this extensive network development, plans entail the excavation of a 25 km trench to accommodate the piping network for transporting hot water to consumers. Such an extensive construction process, set to unfold over several years, is not only designed to expand heating capabilities but also poses challenges, particularly in managing traffic disruptions during construction.

This significant infrastructure undertaking provides a compelling juncture to not only address heating capacity issues but also to reconsider the aesthetic integration of these vital infrastructures within the cityscape. As the network expands and the physical footprint of the district heating infrastructure broadens, there exists an opportunity to fuse functional efficiency with architectural and visual appeal.

Addressing the expansion of the district heating network presents an opportune moment to reimagine and elevate the design aspects of these structures. By infusing architectural innovation and aesthetic considerations within the development plans, the aim is to transform these facilities into not just energy infrastructure but also visually appealing and harmonious elements within Tromsø's urban fabric.

Despite their paramount focus on sustainability, the visual appeal of Kvitebjørn Varme's infrastructures has been an area in need of enhancement. Many of the company's heating centers and related facilities, while instrumental in their energy production and distribution, lack an aesthetic charm. These structures, vital as they are for the community's energy needs, currently do not contribute to the visual allure of the areas they serve.

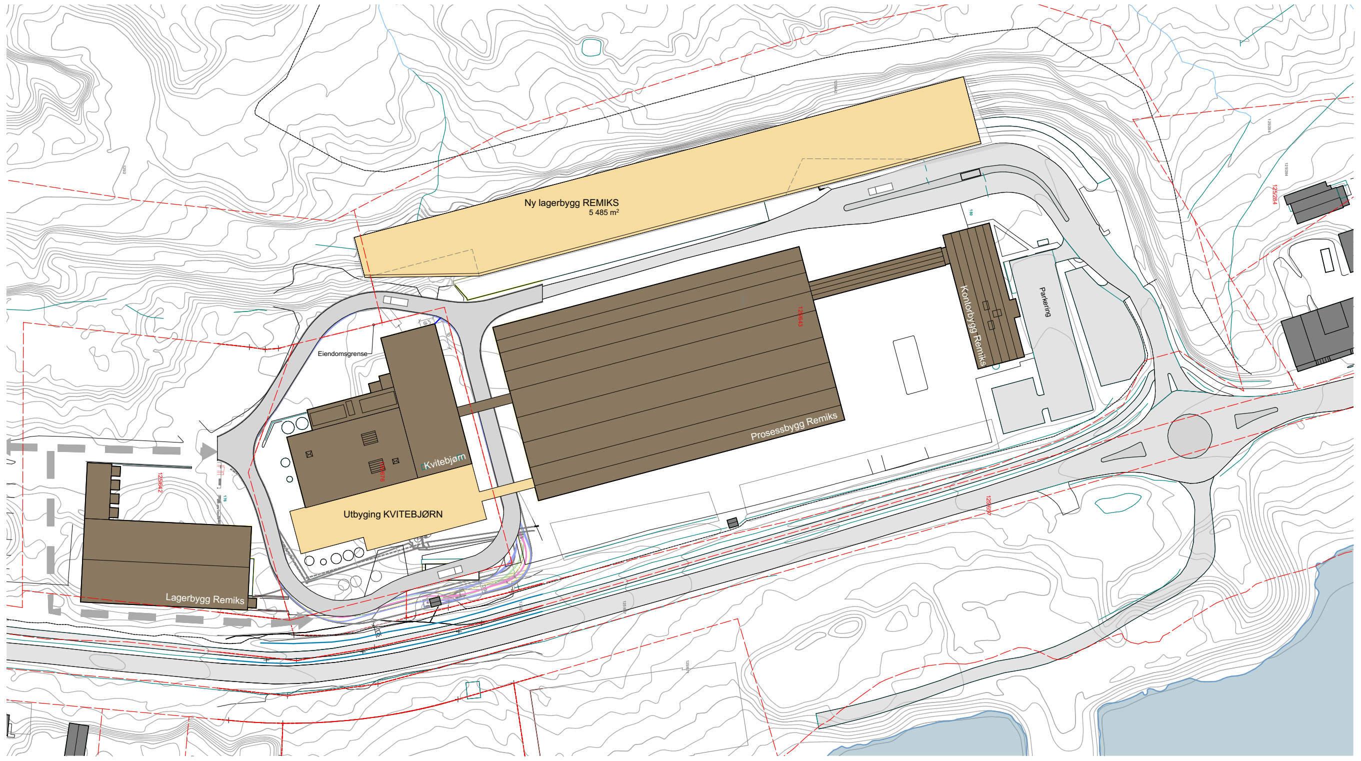


Figure 91-3.3 Site Plan Existing (Remiks Miljøpark AS, 2020)

In the context of my thesis work, I aim to address this issue by reimagining the design of these buildings. The objective is to merge the functionality and environmental efficiency that Kvitebjørn Varme prides itself on with an improved aesthetic appeal. By integrating sustainable design principles, architectural innovation, and artistic elements, the goal is to redefine the visual landscape of these facilities.

Through this redesign, I intend to propose architectural solutions that not only align with the company's ethos of sustainability but also elevate the visual harmony of these structures within the urban landscape. The aspiration is to create buildings that not only serve their functional purpose efficiently but also contribute positively to the aesthetics of Tromsø.

The transformation of these structures will not only enhance their appearance but also offer the local community a sense of pride in the infrastructure contributing to their well-being. The aim is to strike a balance between sustainability and visual appeal, ensuring that the buildings of Kvitebjørn Varme AS become integral components of a vibrant and visually appealing urban environment.

This proposed redesign seeks to accentuate the company's commitment to sustainability while embracing the significant role of aesthetics in fostering a cohesive and visually pleasing urban fabric. By merging sustainable principles with innovative architectural design, the intent is to redefine these structures as not just energy facilities but as visually attractive landmarks contributing to the city's aesthetic heritage.

Design Proposal

Our design proposal includes redesign of the existing incineration plant in order to improve its aesthertics and sustainable qualities and reduce the footprint as much as possible. The shape of the building is inspired by materials from the area and the local topography, like the migmatites found in this region.
The natural shape of the exterior avoids large, plain surfaces, improves the plant's appearance, and maximizes natural light in the areas people use. This gives the building a somewhat similar look to Tromsø's rocky landscapes.
The application of steel 3D printing for façade connections proved to be transformative. It allowed for the precise creation of intricate connection points, reducing the need for additional structural components. This innovation streamlined the construction process, leading to significant reductions in material use.

Figure 92-3.3 Designed Main Façade (Liudmila Sidorova, 2023)

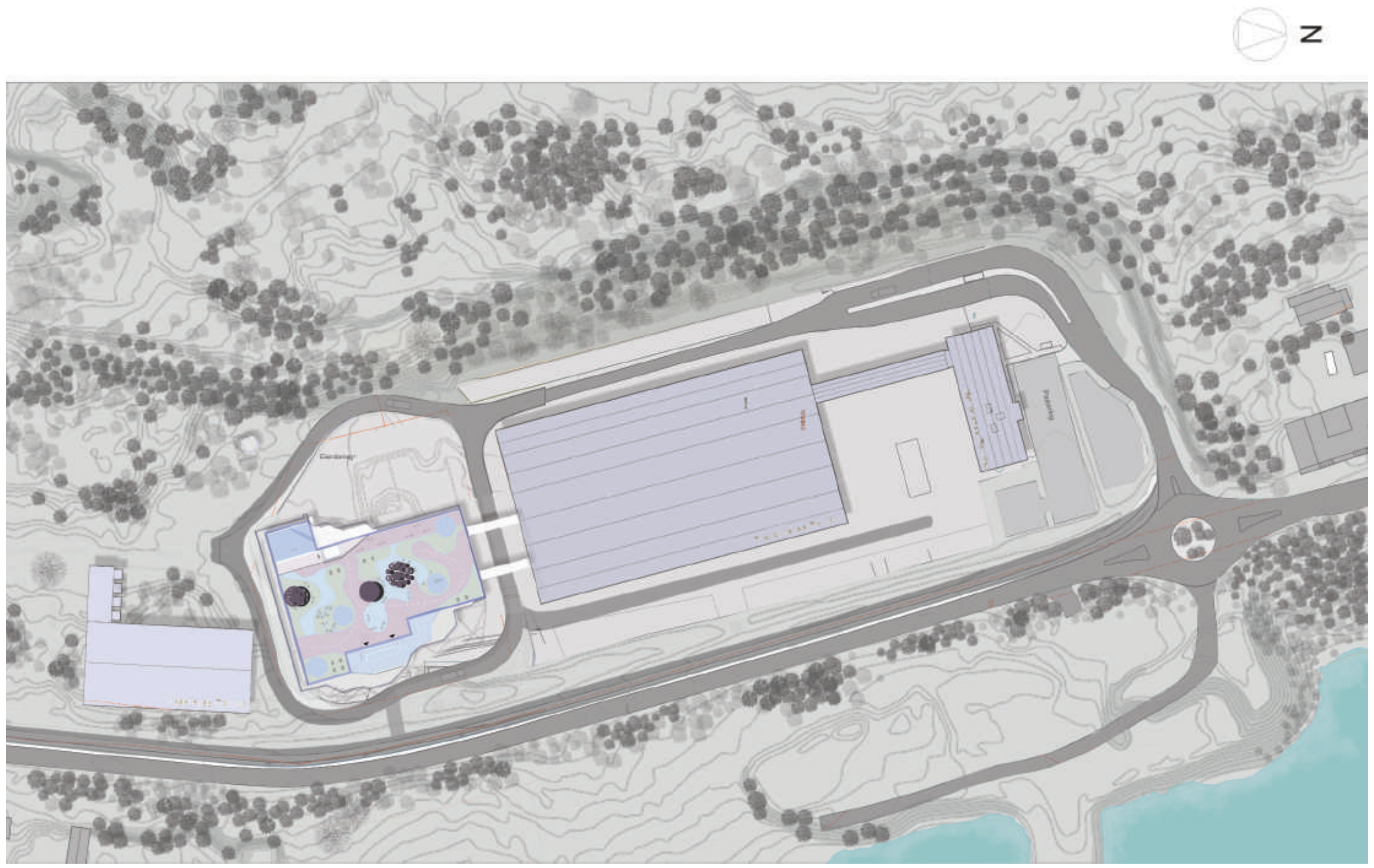


Figure 93-3.3 Masterplan (Liudmila Sidorova, 2023)

Figure 94-3.3 Designed Back Façade (Liudmila Sidorova, 2023)

The building itself can be broadly divided into three distinct zones based on function and user groups. Public spaces are situated at the front of the plant, closest to the accessible road, and are intended for use by visitors who do not work in the production but are interested in waste processing processes or visiting the waste-to-energy plant as a tourist attraction. The second set of spaces is designed for plant employees. This zone is kept separate from the public area, and only employees with the right credentials have access, mainly for security reasons. The design of these spaces considers the daily needs of the people using the building. The largest area by square footage is dedicated to the waste-to-energy equipment and is the most strictly secured zone.

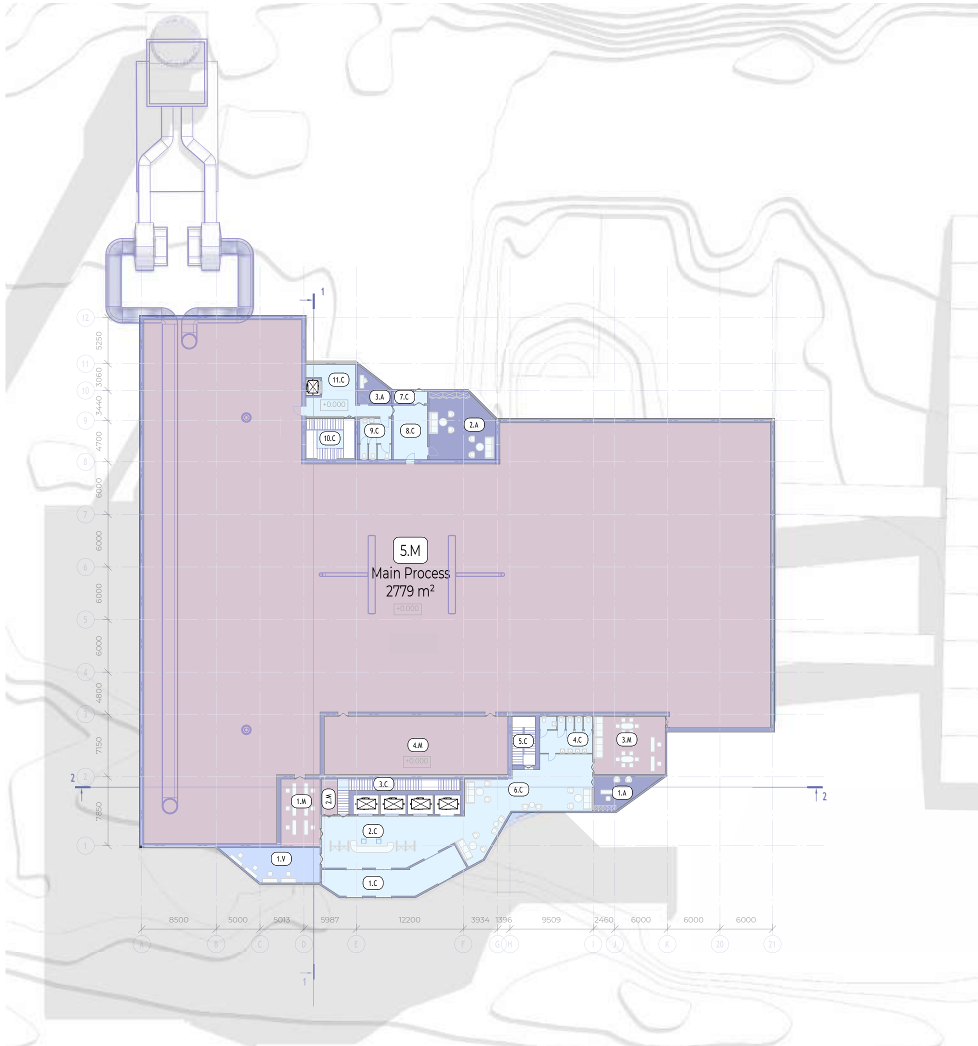
Let's examine the building's structure in more detail. The public area serves an educational and recreational function. Its primary goal is to break stereotypes that industrial buildings are off-limits to the general public. The layout of the spaces takes into account the maximum visitor load.

Thus, on the first floor, a spacious entrance area is organized with a waiting zone, a security checkpoint, and an information center. The staircase and elevator hall is directly connected to a cloakroom on one side and restrooms on the other. This space invites visitors and ensures comfortable mobility, regardless of each individual's physical abilities. Additionally, the first floor houses a workshop for repairing various items, increasing awareness in the use of everyday household items and reducing the disposal of objects.

Visitors can ascend several floors via the staircase and elevator hall, where everything is arranged for events. There's a roomy café with a terrace that gives you wide views of the stunning landscapes in Tromsø and the surrounding areas. Additionally, the sixth floor has offices and conference rooms for presentations, workshops, lectures, and events to raise public awareness.

The rooftop garden is the highlight, offering the most amazing views of cliffs going down into the sea, giving a special view of the city not available elsewhere. As a result, a visit to the waste-to-energy plant transforms into an unforgettable experience that will linger in the memories of visitors.

As mentioned earlier, the public area adjoins spaces designated for plant employees. The design of these areas ensures that uninitiated individuals cannot access potentially hazardous sections of the building. Moreover, most employees have a separate entrance on the northern side of the waste-to-energy plant.



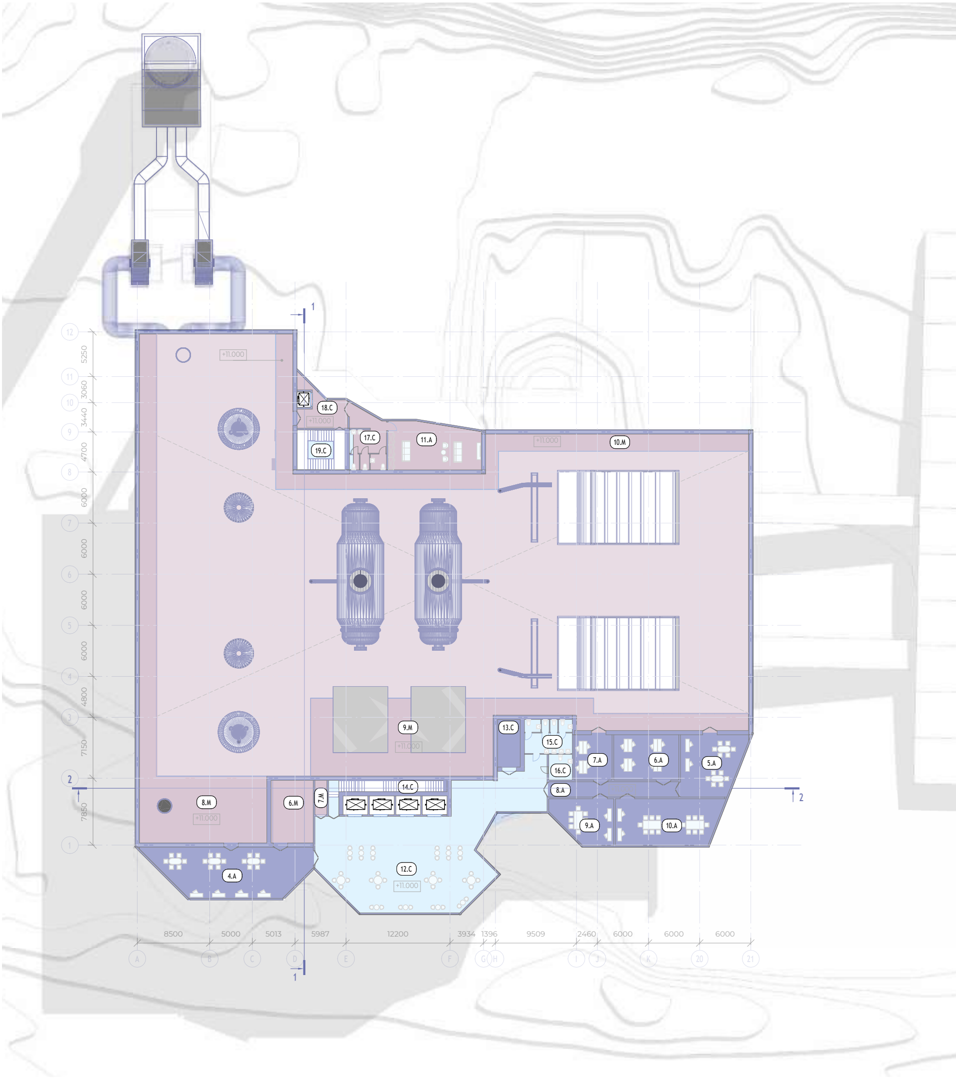
FUNCTIONAL PURPOSE

- A - administrative
- C - common zones and public spaces
- M - technitian and production process premises
- V - retail and lab rooms for visitors

TAG LABEL: 11.A — Functional purpose; Room number

1 Level Schedule		
№	Name	Area
A		
1.A	Cabinet	21 m²
2.A	Rest room	54 m²
3.A	Cabinet	12 m²
C		
1.C	Main Entrance	49 m²
2.C	Lobby + Reception	83 m²
3.C	Staircase	22 m²
4.C	WC	25 m²
5.C	Staircase	15 m²
6.C	Waiting area	98 m²
7.C	Entrance	5 m²
8.C	Checkroom	24 m²
9.C	WC	17 m²
10.C	Staircase	26 m²
11.C	Hall	35 m²
M		
1.M	Checkroom	34 m²
2.M	Cleaningroom	7 m²
3.M	Technician room	54 m²
4.M	Storage room	139 m²
5.M	Main Process	2779 m²
V		
1.V	Repair Store	37 m²

Figure 95-3.3 First Floor (Liudmila Sidorova, 2023)



3 Level Schedule		
№	Name	Area
A		
4.A	Stuff Room	99 m²
5.A	Room	50 m²
6.A	Cabinet	41 m²
7.A	Cabinet	24 m²
8.A	Room	27 m²
9.A	Conference Room	34 m²
10.A	Conference Room	66 m²
11.A	Rest room	58 m²
C		
12.C	Visitors area	264 m²
13.C	Staircase	15 m²
14.C	Staircase	22 m²
15.C	WC	22 m²
16.C	Mother and Child Room	8 m²
17.C	WC	28 m²
18.C	Hall	21 m²
19.C	Staircase	26 m²
M		
6.M	Technician room	36 m²
7.M	Cleaning room	6 m²
8.M	Room	229 m²
9.M	Room	262 m²
10.M	Lab Room	158 m²

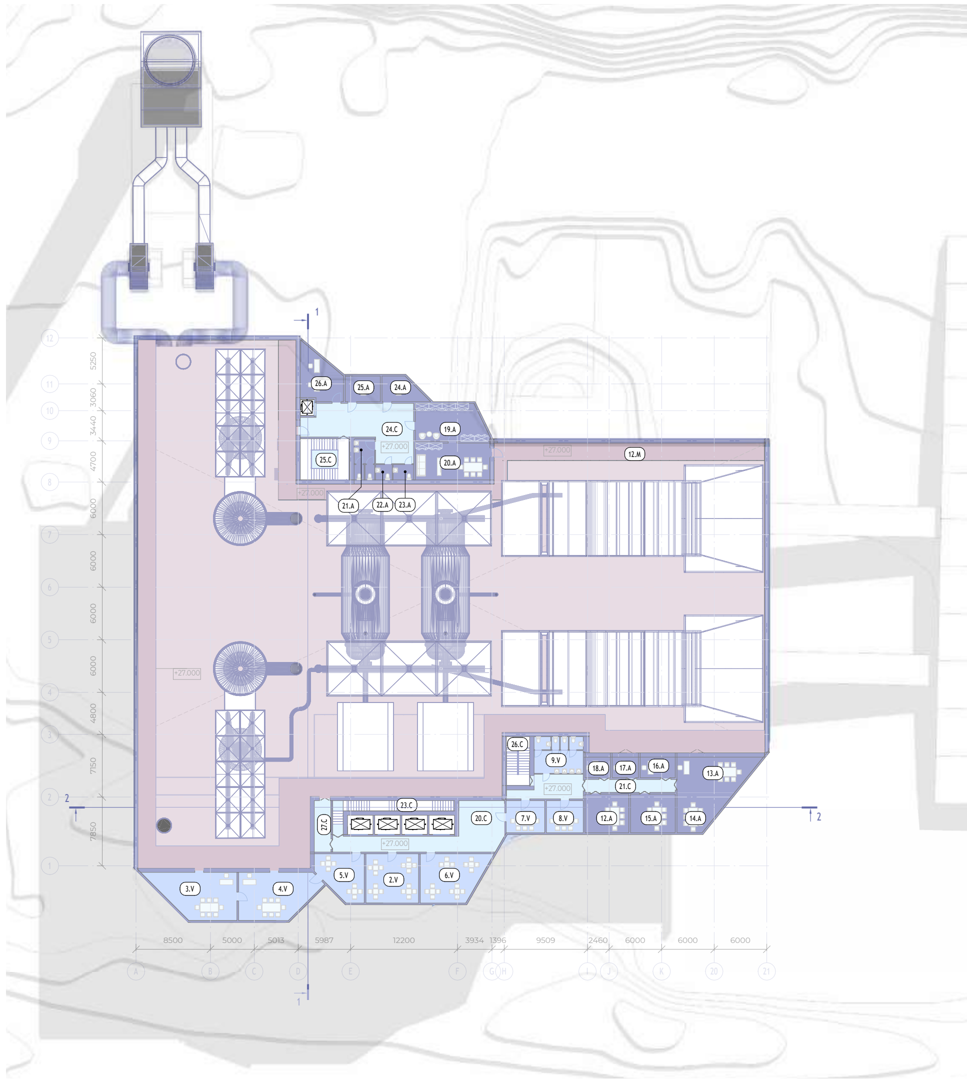
Figure 96-3.3 Third Floor (Liudmila Sidorova, 2023)

Now, let's explore the floor plans in more detail. First and foremost, dedicated stairwell and elevator halls for the staff are provided in the southern and northern sections of the building to ensure rapid and safe access to any part of the equipment on all floors, as well as to offer evacuation routes in case of emergencies. Restrooms are available on each level of the working area.

On the first floor within the staff zone, a separate entrance from the foyer is organized, complete with a security checkpoint – only company employees familiar with safety procedures and behavior on the premises have access. This area also includes a cloakroom for outerwear, toilets, and technical rooms. This part of the plant is dedicated to workers involved in physically demanding tasks related to the maintenance and control of all waste processing procedures.

On subsequent floors, the room layouts vary depending on the floor area. Among the spaces, shower and changing rooms for employees, relaxation areas, a kitchen, and a recreation room are essential. The spatial logic is geared toward ensuring not only the efficient functioning of equipment but also the well-being and comfortable working conditions of employees.

The public area in the southern part of the plant borders with the working areas in some places but is separated from them by corridors and doors that can only be opened with employee access cards. On the first floor, there is a shop where visitors can repair or purchase refurbished household items. On the higher floors, there are technical rooms, meeting rooms, and laboratories. This area is intended for personnel involved in more intellectual or computer-based tasks.



7 Level Schedule		
№	Name	Area
A		
12.A	Office Room	22 m²
13.A	Office Room	34 m²
14.A	Office Room	22 m²
15.A	Office Room	23 m²
16.A	Office Room	10 m²
17.A	Office Room	7 m²
18.A	Office Room	7 m²
19.A	Stuff Room	33 m²
20.A	Stuff Room	36 m²
21.A	Stuff Room	11 m²
22.A	Stuff Room	3 m²
23.A	Stuff Room	4 m²
24.A	Stuff Room	12 m²
25.A	Stuff Room	12 m²
26.A	Stuff Room	24 m²
C		
20.C	Room	56 m²
21.C	Room	16 m²
22.C	Room	19 m²
23.C	Room	19 m²
24.C	Room	60 m²
25.C	Room	26 m²
26.C	Room	15 m²
27.C	Room	11 m²
M		
11.M	Lab Room	328 m²
12.M	Lab Room	146 m²
V		
2.V	Lab Room	34 m²
3.V	Lab Room	45 m²
4.V	Lab Room	45 m²
5.V	Lab Room	25 m²
6.V	Lab Room	38 m²
7.V	Office Room	16 m²
8.V	Office Room	15 m²
9.V	WC	23 m²

Figure 97-3.3 Seventh Floor (Liudmila Sidorova, 2023)

Each staff room provides access to the main area where equipment is located, ensuring ease of evacuation and enhancing safety for visitors. In this area, open galleries are present on all floors, allowing for the efficient servicing of all internal processes and rapid response to emergencies, particularly fires.
The rooftop is a spacious open area accessible for all types of users to be exploited. People can reach this floor using both staircase and elevator. From here they can see a magnificent view on the fjord of Tromsø.

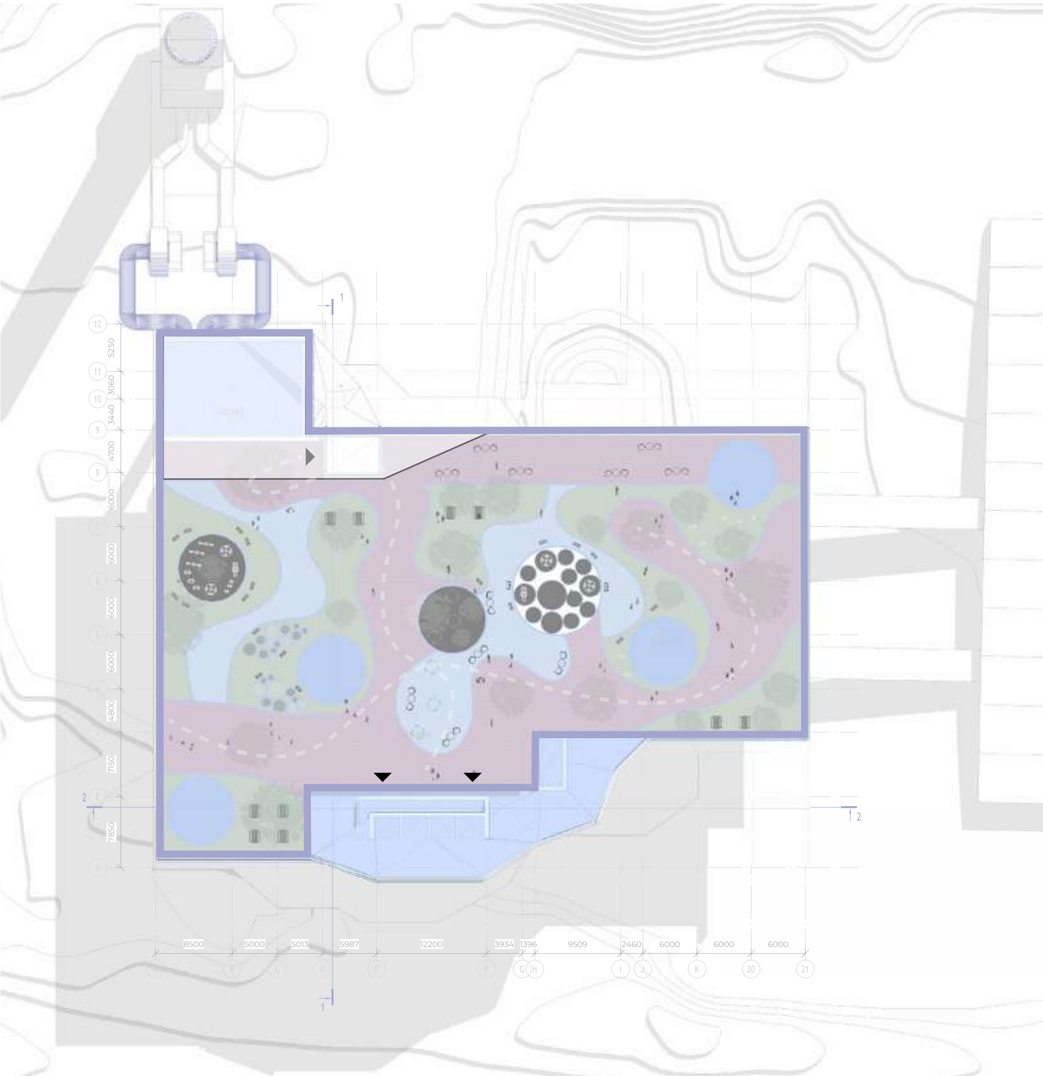


Figure 98-3.3 Rooftop (Liudmila Sidorova, 2023)

Equipment Description

In delving into the intricacies of the incineration plant's equipment, it is paramount to explore the thoughtful design elements that go beyond mere functionality. This chapter unravels the structural nuances and innovative features incorporated into the waste-to-energy plant, with a particular focus on the equipment zone. By examining the architectural considerations, reinforced protection measures, and the integration of advanced technologies like 3D printing, we gain a comprehensive understanding of how form and function harmonize to create an efficient and visually compelling industrial facility. Join us on this journey as we dissect the design choices and engineering solutions that shape the equipment zone of the incineration plant, transcending conventional standards to redefine the landscape of waste management infrastructure.
The predominant section of the structure will be a singular floor, primarily constituting a unified space. It will feature subdivisions along its western, northern, and eastern sides. Within the building, you will find the furnaces, post-combustion chamber, boilers, and gas cleaning equipment. Positioned along the western side, the ash bunker, ash handling areas, and ash silos dedicated to the moving grate furnace will be housed. The building's northern side will accommodate the boiler feed water treatment equipment, boiler feed water tank, transformers, and the high voltage switch room. Along the eastern side of the building, one can find the gypsum recovery equipment, solidification area, lime/limestone preparation area, and activated carbon area. The silos designed for the residues from the fluidized bed line will be situated along the southern side.
The architectural vision of the waste incineration plant in Tromsø is not just an aesthetic endeavor; it is intricately woven into the fabric of its technological processes. The core technology revolves around standardized procedures for the

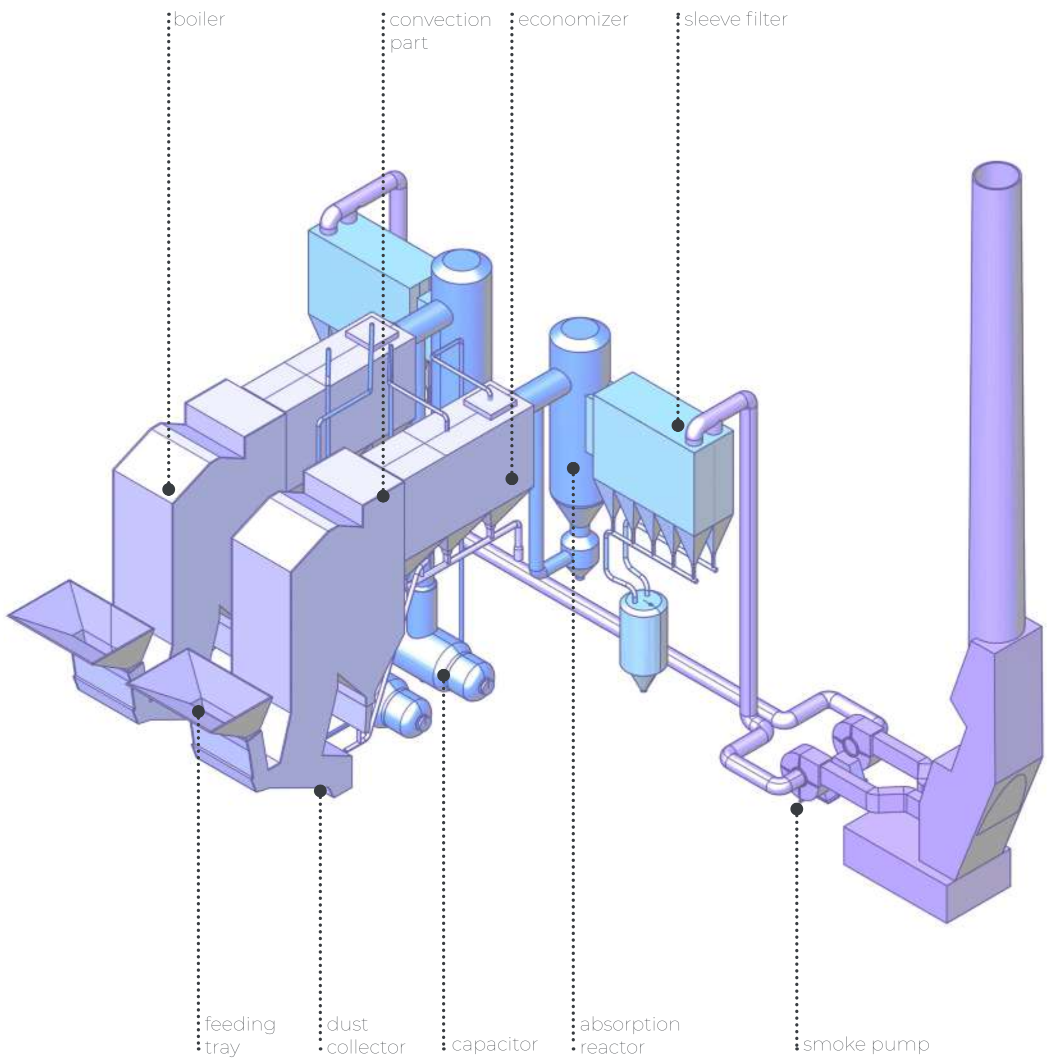


Figure 99-3.3 Incineration Plant Equipment Scheme (Liudmila Sidorova, 2023)

collection and incineration of solid household waste, accompanied by a distinctive flue gas purification system. In contrast to conventional methods, the facility adopts a dry system, distinguishing it from the prevalent wet cleaning systems used across many facilities in our country.

This innovative approach integrates primarily (pseudo) dry sorption methods, such as adsorption or chemisorption, to effectively eliminate sulfur from the exhaust gases generated during the incineration process. These methods are deployed in one- or two-stage configurations, increasingly employed for multifunctional separation, achieving optimal separation results or attaining minimal values.

Designed by TurbofiLter specifically for flue gas cleaning, a fabric filter with a

special deposition zone and high-quality bag filter materials is a key component of the waste incineration equipment. This filter reliably separates the predominant fine dust fractions in the emissions, ensuring that dust emissions remain well below the maximum permissible levels stipulated by regulations. Notably, this solution offers the additional advantage of significantly reducing the projected spatial requirements, leading to substantial cost savings in the overall construction process.

The proposed waste-to-energy plant in Tromsø thus aligns technological innovation with environmental responsibility, emphasizing a commitment to efficient resource utilization and adherence to stringent emission standards. The combination of advanced technologies and sustainable design principles makes this facility a groundbreaking example in waste management, setting a standard for future projects in the field. The incineration plant will be open all the time, with breaks for maintenance. You can drop off waste from 09:00 to 19:00 on weekdays and from 09:00 to 14:00 on Saturdays. The main steps in the process include accepting, storing, and handling waste, burning it, recovering energy, cooling and cleaning flue gas, and handling ash.

The proposal suggests integrating a small power plant into the basement of the central part of the building to harness the energy released during garbage incineration, thereby partially fulfilling the plant's electricity needs.

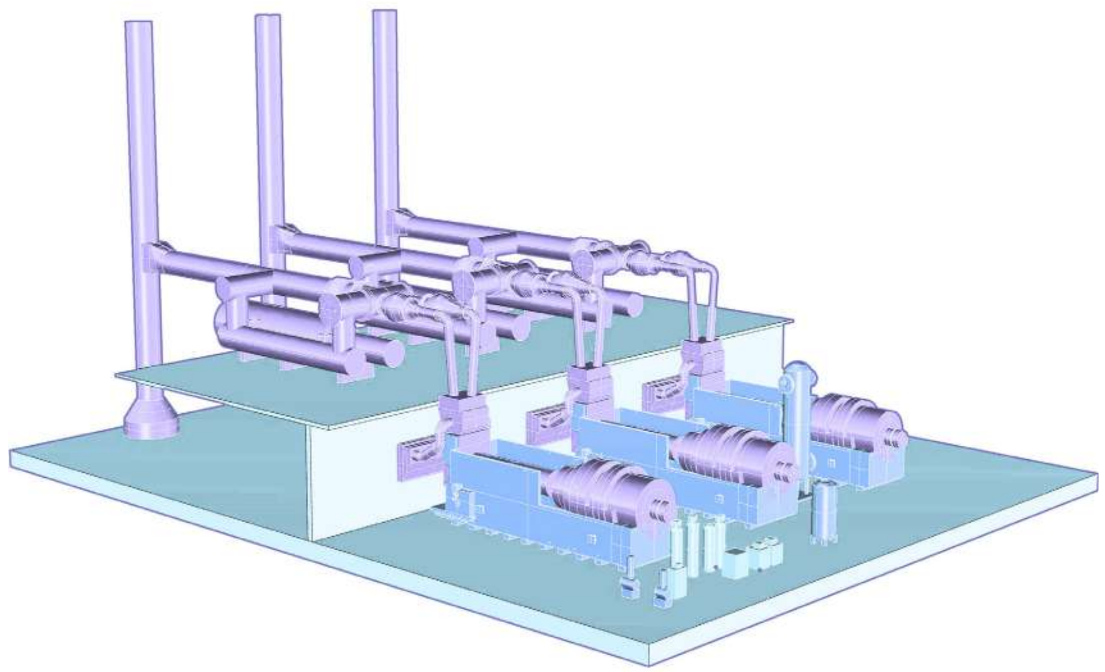


Figure 100-3.3 Power Plant Scheme (Liudmila Sidorova, 2023)

During combustion, the elevated temperatures (1000-1100 °C) are utilized to transfer thermal energy from the waste fuel to the water within the waste boiler's pipe system. The generated steam, under pressure, serves dual purposes - electricity and thermal energy production. The steam propels a turbine, initiating an alternating current generator for electricity generation.
The electric power generation efficiency ranges from 19 to 27%, slightly lower than fossil fuel power plants due to lower waste heat transfer (2200 kcal/kg).
The gas-piston power plant (GPP) emerges as a compact, autonomous, and efficient complex capable of producing both electric and thermal energy. Its primary role is to act as a backup energy source, ensuring uninterrupted operations in case of a main energy source malfunction, leading to significant cost savings during breakdowns. Additionally, the GPP operates in tandem with the primary energy source, enhancing overall efficiency.
The main components of the GPP include the MWM gas engine and alternator, along with related equipment and modules essential for operation. This installation can be permanently mounted within the building, such as on the basement floor of a waste recycling plant. Key advantages of the GPP include quick start-up, optimal installation costs, flexibility in power increase through additional modules, simplicity, and cost-effectiveness of on-site repairs.
The incorporation of this equipment ensures the sustainable development of the incineration complex by generating and absorbing its energy. The mini-CHP plant's selection as the primary energy source is justified by its high productivity, quality electricity production, and overall profitability. A single mini-CHP module comprises a gas piston, a diesel engine, an electric power generator, a heat exchanger for recovering heat from various sources, and a hot water boiler for peak-time heat load compensation. This approach avoids the need for expensive and risky power lines, reduces electricity losses, cuts the costs of connecting to centralized power networks, and ensures a steady supply of high-quality electricity. In simple terms, the mini-CHP is both cost-effective and sustainable for the waste incineration plant.
In conclusion, the exploration of the incineration plant's equipment delves beyond mere functionality, revealing a meticulous integration of thoughtful design elements that redefine the landscape of waste management infrastructure. This chapter has dissected the architectural considerations, reinforced protection measures, and advanced technologies like 3D printing, offering a comprehensive understanding of how form and function harmonize to create an efficient and visually compelling industrial facility.
The waste-to-energy plant's predominant section, primarily a singular floor with subdivisions, strategically houses furnaces, boilers, and gas cleaning equipment, ensuring optimal functionality. The proposed technological processes, such as a dry flue gas purification system and (pseudo) dry sorption methods, underscore the commitment to innovation and environmental responsibility.
The incorporation of a small power plant in the basement, leveraging energy from garbage incineration, demonstrates a holistic approach to energy sustainability. The proposed gas-piston power plant (GPP), with its compact design and efficient operation, acts as a backup energy source, ensuring uninterrupted operations and significant cost savings during breakdowns. The mini-CHP plant emerges as a cost-effective and sustainable solution, aligning with specified requirements and enhancing the waste-to-energy facility's overall efficiency.
This chapter unravels the intricacies of the waste incineration plant in Tromsø, emphasizing technological innovation, sustainable design principles, and adherence to stringent emission standards. As the facility operates continuously, with specific hours for waste acceptance, it sets a benchmark for future waste management endeavors. The proposed equipment not only aligns technological innovation with environmental responsibility but also positions the facility as a pioneering example in waste management, emphasizing efficient resource utilization and sustainability.

Integration of 3D-Printed Facade Nodes

In the realm of architectural innovation and construction technology, the utilization of Additive Manufacturing (AM), or 3D printing, has emerged as a compelling prospect for the construction of future buildings. This chapter delves into the intriguing world of 3D-printed façade nodes, where the fusion of advanced manufacturing techniques and architectural design yields promising results.
These additive manufacturing methods offer distinct advantages over traditional construction processes. They bestow unparalleled freedom in shaping intricate forms, accommodating complex geometries, scaling up to meet diverse needs, and optimizing material usage. Of particular note is the profound capability to customize inner geometries, enabling the integration of multi-functionalities within architectural components. This avenue of innovation not only promises multifaceted utility but also holds the potential for large-scale 3D printing, challenging the boundaries of architectural creation.
The façade, being one of the most challenging and aesthetically significant aspects of any building, stands at the forefront of these advancements. As such, an increasing interest is observed in the application of advanced building envelope solutions, manifesting both in the realm of research activities and industrial developments.
While existing research predominantly focuses on the mechanical properties of materials and their role within load-bearing and construction systems, this chapter takes a broader perspective This chapter talks about exploring how big we can 3D print façade parts and the challenges and possibilities of large-scale 3D printing. It introduces a research project to create 3D-printed façade nodes for a plant in Tromsø. The chapter explains the development process, considering what façade modules need and the complexities of printing, like materials, time, and scalability. The goal is to see how 3D-printed façade nodes can transform modern architecture.[54]

Initially, the project assumed the use of large-sized, 3D-printed facade panels. But after a more careful analysis of the territory and studying the specifics of aesthetics, it was decided to use local building materials. Thus, the exterior of the building is more in harmony with the environment, and the decision to use stone in the decoration contributes to more sustainable solutions in general.

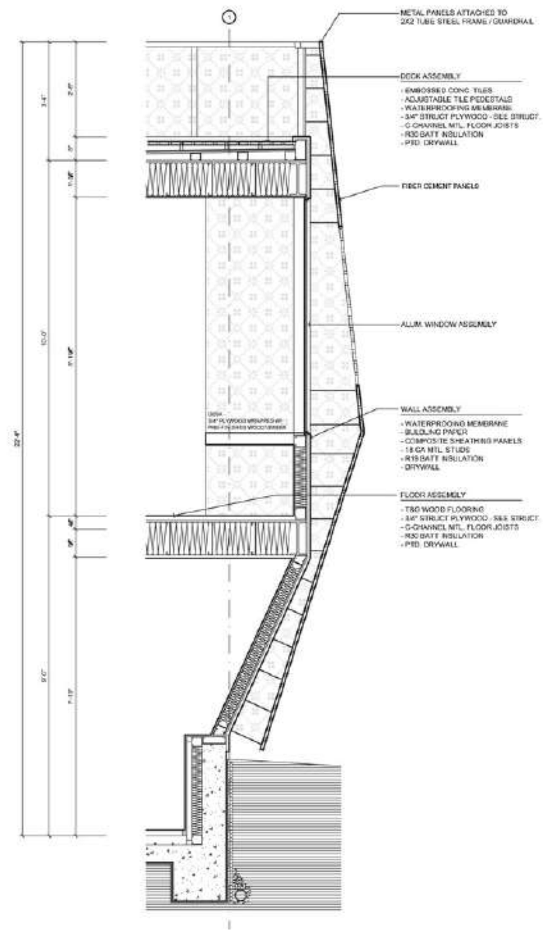


Figure 101-3.3 Principal Scheme of Facade Structure. Detail (XTEN Architecture, 2009)

The difficulty in this case was that the facade, which looks like a rock, assumes a complex design of fasteners of irregular shape and various sizes. Parametric design and additive manufacturing of facade fasteners helps to solve this issue.
The project was based on the fasteners discussed earlier in the chapter about Additive manufacturing. It should be noted that the author of this diploma is not a designer by education and the solutions proposed here are purely advisory in nature and require adjustments and consultations by engineers specializing in this industry.
Presently, metal additive manufacturing (AM) allows for the direct creation of personalized lightweight components featuring intricate geometries without the necessity of mold fabrication. Various methods within metal 3D printing are available. Nevertheless, each method exhibits significant drawbacks when considering their application within the field of architecture, particularly in the production of large-scale parts necessitating finely detailed surfaces.[50]
So, due to the fact that the facade material is natural stone, facade fasteners must withstand the load placed on them and have increased load–bearing properties. The hinged facade system is essentially an autonomous load-bearing structure, which assumes a variety of fasteners at different angles in different planes. The elements must be made of stainless steel and, thanks to 3D printing, reduce the number of necessary bolts to secure the structural parts to a minimum.
In the photo we see one of the possible solutions to the structural framework.
Within architectural contexts, cast metal serves as a suitable option wherever robust components featuring three-di-

Figure 102-3.3 Reference for Facade Structure (SignComp LLC, 2012)

mensional geometries are required. Casting involves the manipulation of molten metal to conform to desired shapes, enabling the creation of intricate, cohesive elements with design characteristics unattainable through alternative production techniques. These attributes include undercuts, overhangs, internal structures, and variations in part thickness. However, the extent of geometric complexity achievable in metal components remains restricted by our capacity to create the requisite molds, a process that conventionally demands substantial labor and time.[50]

In our research at DBT, we have addressed these challenges by implementing an innovative approach: utilizing Additive Manufacturing (AM) to 3D print sand-molds for metal casting rather than directly 3D printing the metal part. This strategic choice allows us to leverage the geometric flexibility offered by 3D printing and the versatility of metal casting. By combining 3D printed sand-molds with the process of metal casting, we can efficiently produce large, tailor-made architectural elements without being confined to specific metals or alloys – enabling the casting of virtually any type of metal.

The fabrication of sand-molds involves the use of binder-jetting technology, wherein a liquid binding agent is selectively applied to thin layers of sand. In the realm of architectural applications, binder-jetting technology presents a distinctive fusion of geometric freedom, intricate detailing, and the ability to operate on a large print-bed scale. These molds can be printed with precision within the range of one-tenth of a millimeter and in dimensions reaching up to 4 x 2 x 1 meters, offering a remarkable level of precision and scalability for

Figure 103-3.3 3D Print Sand-Molds for Metal Casting (Ma Xijie, 2018)

architectural purposes.

In our research, we develop computational methods to design and optimise bespoke metal elements which integrate the casting constraints. An important aspect is to facilitate the design of moulds and casting system for any given shape. We try to automatically integrate details such as the gating system which channels the molten metal to the mould cavity. Ideally, we can generate the required fabrication data for any geometry of a part at the push of a button and send it directly to the 3D printer. The casting process itself can follow the traditional setup and can be done within a short period of time.[50]

Next, we present possible options for the exterior appearance of facade fasteners for this project of an incineration plant in the city of Tromsø. Based on topological analysis and optimization methods, such a cable connection node design can be adopted, which is quite futuristic, and the material consumption is greatly reduced.[86]

Eliminating mass in parts where material is not required for performance combined with parts consolidation yields benefits for vehicle owners including the potential for more interior space and vehicle content, increased range, and enhanced vehicle performance. It also paves the way for new features for customers and provides vehicle designers a canvas on which to explore designs and shapes not seen today.[40]

Figure 104-3.3 Possible Design for Facade Connectors (Rich Pell, 2018)

The constraints of metal casting were encoded in the algorithm that generates the geometry of the nodes and their moulds, which then ensure cast-ability, dimensional-accuracy and good surface finish. AM allowed integration of a gating system for the liquid metal into the mould, thus considerably reduced tolerances and fabrication time.

By focussing design and fabrication primarily on the connecting node points,these smallest components of a framing system can be produced with relativelyexpensive digital fabrication techniques without resulting in much higher overallcost, as most volume and weight of the project remains composed of conventionalmaterials.[87]

Figure 105-3.3 3D Printed Stainless Steel Node, Prototyped (Manuel Muehlbauer, 2017)

As a result, the fabrication of all nodes took less than two weeks, which is considerably faster than casting with the traditional process of mould-making or direct 3D metal printing. With commercially available metal printers, large connections would even have to be split into smaller parts to fit into the build space.
Further optimisation of nodes will require more detailed information on the structural behaviour of 3D printed materials and further embedding of local structural engineering knowledge into the design team. However, designers will face significant challenges in assessing large quantities of such data and responding through design proposals. Heuristic and pragmatic responses are likely to be more readily adopted. [87]

Sustainable and Aesthetic Enhancements

The significance of sustainability in incineration plant design lies in the overarching philosophy of creating an integrated system capable of meeting long-term needs, such as energy and water, while simultaneously minimizing both financial and environmental costs. This holistic approach to design encompasses various factors, including social, economic, and environmental considerations.
Fundamentally, sustainable design principles for incineration plants are straightforward, emphasizing the imperative to use less energy, conserve water, and minimize the use of harmful chemicals. By adhering to these principles, the aim is to construct incineration plants that endure over time while requiring fewer resources from the outset.
To enhance energy efficiency in incineration plant design, it is crucial to assess current energy consumption comprehensively. Strategies include the incorporation of renewable energy sources, maximizing natural light, and employing efficient insulation to minimize heat loss through walls and windows. Energy-efficient appliances and the strategic use of motion sensors in appropriate areas further contribute to overall energy efficiency. In our project we propose optimal parametrical windows placement which provides the daylight where needed. According to the function of each zone of the incineration plant, we designed different sizes of openings. For example, the equipment zone does not have any windows on purpose of safety and also because people presence there is reduced to minimum. On the contrary, spaces for public caffe and laboratories are provided with glass walls to open the view on the fjord and allow as much daylight as possible in sake of people comfort.
Water conservation becomes paramount in incineration plant design, particularly given the increasing scarcity of water as a resource. The United Nations under-

scores the importance of water efficiency in regions facing challenges related to safe drinking water and sanitation. As the availability of fresh water is predicted to decrease further due to climate change and population growth, a focus on water conservation becomes crucial in minimizing environmental impact. Therefore, on the rooftop of the building we propose to use a raingarden system. This decision helps to collect and store rainwater during the rain season and reuse it for toilettes splashing and other needs.

The integration of sustainable building materials into incineration plant construction involves selecting materials that can be reused, recycled, or composted after use. These materials should be free from toxic chemicals, easily sourced and extracted from the earth, and ideally, renewable. Examples include clay bricks, concrete blocks, glass blocks, and granite slabs. Furthermore, the consideration of local materials aligns with sustainability goals, offering environmentally friendly alternatives. There is a magnificent stone carrier in the site which can be used for the main façade. It reduces the cost and CO2 emissions from transportation and fabrication of the material.

It is advisable to select materials that are easily repairable, less likely to require replacement, and boast greater durability, such as concrete. This consideration, along with the incorporation of recycled products or reclaimed materials in designs, aligns with sustainability goals, requiring less energy to produce and minimizing waste throughout their lifecycle. Since we are going to use additive manufacturing production of the façade nodes it should significantly reduce the usage of steel in the structure. Implementation of this technology allows us to reduce the building costs and make a more sustainable building.

In crafting the design for our incineration plant, we've embedded crucial tools that underscore our commitment to prioritizing the health and well-being of individuals. This approach resonates with the fundamental principles of sustainable architecture.

Central to our design philosophy is a focus on Indoor Environmental Quality (IEQ), ensuring that the plant's interior spaces contribute positively to the health and wellness of its occupants. We've strategically implemented various tools within the design. Our material selection process places a premium on substances with minimal volatile organic compounds (VOCs), actively working to improve indoor air quality and create a healthier working environment. Ventilation systems have been intricately integrated to guarantee a continuous influx of fresh air while effectively eliminating pollutants. This proactive measure ensures that the air within the plant remains conducive to the well-being of everyone present.

Recognizing the psychological benefits, our design emphasizes access to natural light and views. Beyond the aesthetic appeal, this feature contributes to a positive atmosphere, reducing reliance on artificial lighting and creating a visually pleasing and sustainable working environment. Spaces within the incineration plant are meticulously designed to provide thermal and acoustic comfort. This goes beyond merely creating a comfortable setting; it fosters an environment that supports the well-being and productivity of all occupants.

By seamlessly incorporating these tools into our incineration plant design, we aim to transcend conventional approaches and place a premium on the health and wellness of those operating within the facility. This dedication aligns with the core tenets of sustainable architecture, ensuring that our design not only functions efficiently but also enhances the overall quality of life for its users.

The benefits of sustainability in incineration plant design are multifaceted. As highlighted by the Natural Resources Defense Council, sustainable designs not only contribute to environmental preservation but also offer tangible advantages for businesses. Reduced operating costs due to lower energy, water, and material consumption are key financial benefits. Additionally, sustainable materials contribute to occupant health and safety while minimizing pollution.

In summary, sustainable incineration plant design represents a comprehensive and forward-thinking approach, with each aspect interconnected to create a system that is environmentally responsible, economically viable, and socially beneficial.

04 CONCLUSIONS

Summarizing Findings

As the concept of waste as a valuable resource continues to evolve, there is an increasing need to revolutionize our waste management industrial structures. The visual appeal of these facilities plays a crucial role in influencing public perception, fostering community acceptance, and advocating for responsible waste management. An aesthetically pleasing waste management plant not only aligns with our changing environmental values but also symbolizes progress toward a more sustainable and resource-efficient future.

This transformative journey delves into the realm of architectural innovation and construction technology, focusing on the promising opportunities provided by Additive Manufacturing (AM), commonly known as 3D printing, in the construction of future buildings. Specifically, this chapter explores the realm of 3D-printed façade nodes, where the fusion of advanced manufacturing techniques and architectural design yields promising outcomes.

The additive manufacturing methods examined in this chapter offer clear advantages over traditional construction processes. They provide unparalleled freedom in crafting intricate forms, accommodating complex geometries, scaling to diverse needs, and optimizing material usage. Notably, the ability to customize inner geometries facilitates the integration of multifunctionalities within architectural components. This avenue of innovation not only promises diverse utility but also holds the potential for large-scale 3D printing, pushing the boundaries of architectural creation. The façade, a challenging and aesthetically significant element of any building, stands at the forefront of these advancements. There is a growing interest in advanced building envelope solutions, evident in both research activities and industrial developments.

While much of the existing research focuses on the mechanical properties of materials and their role in load-bearing and construction systems, this chapter adopts a broader perspective. It acknowledges the necessity for further exploration into the maximum printable size of façade components and the complexities, challenges, and potentials associated with large-scale 3D printing.

This chapter unveils an ambitious research project centered on the development of 3D-printed façade nodes, seamlessly integrated into the architectural vision of an incineration plant in Tromsø. It provides a comprehensive overview of the development process, considering the multifaceted demands that façade modules must meet and the intricacies of the printing process, including material considerations, printing time, and scalability. Through this exploration, we embark on a journey to unlock the transformative potential of 3D-printed façade nodes in contemporary architecture.

The initial assumption of using large-sized, 3D-printed facade panels shifted after a careful analysis of the territory and consideration of aesthetics. The decision was made to employ local building materials, creating harmony with the environment. The use of natural stone in the decoration contributes to more sustainable solutions.

The challenge in this case lies in designing fasteners with irregular shapes and various sizes to mimic a rock-like facade. Parametric design and additive manufacturing of facade fasteners prove instrumental in overcoming this issue.

The project draws inspiration from fasteners discussed earlier in the chapter about Additive Manufacturing. It's crucial to note that the author, not a designer by education, provides advisory solutions requiring adjustments and consultations by engineers specializing in the industry.

Metal additive manufacturing (AM) offers the opportunity to create personalized lightweight components with intricate geometries without the need for mold fabrication. Despite various available methods in metal 3D printing, each exhibits drawbacks, especially for large-scale parts requiring finely detailed surfaces.

Considering the facade material as natural stone, the fasteners must withstand the load and possess increased load-bearing properties. The hinged facade system, essentially an autonomous load-bearing structure, assumes various fasteners at different angles and planes. Thanks to 3D printing, the number of necessary bolts to secure the structural parts is minimized.

Cast metal becomes a suitable option in architectural contexts where robust components with three-dimensional geometries are required. However, the extent of geometric complexity achievable in metal components is restricted by the conventional mold-making process, involving substantial labor and time.

In our research at DBT, challenges in metal casting were addressed through an

innovative approach: utilizing Additive Manufacturing (AM) to 3D print sand-molds for metal casting instead of directly 3D printing the metal part. This strategic choice leverages the geometric flexibility of 3D printing and the versatility of metal casting, enabling the casting of virtually any type of metal.
The fabrication of sand-molds involves the use of binder-jetting technology, where a liquid binding agent is selectively applied to thin layers of sand. This method presents a distinctive fusion of geometric freedom, intricate detailing, and the ability to operate on a large print-bed scale within architectural applications.
In our research, computational methods were developed to design and optimize bespoke metal elements that integrate casting constraints. The design of molds and casting systems for any given shape was facilitated, with details like the gating system integrated directly into the mold. This process allows for the generation of fabrication data for any part geometry at the push of a button, streamlining the casting process.
Possible options for the exterior appearance of facade fasteners for the incineration plant project in Tromsø are presented based on topological analysis and optimization methods. A cable connection node design, futuristic in appearance and significantly reducing material consumption, is proposed.
Eliminating mass in parts where material is not required for performance, combined with parts consolidation, yields benefit for efficiency, interior space, vehicle content, range, and vehicle performance. This approach opens doors for new features, providing a canvas for vehicle designers to explore innovative designs and shapes.
The constraints of metal casting were encoded in the algorithm that generates the geometry of the nodes and their molds, ensuring castability, dimensional accuracy, and good surface finish. AM allowed the integration of a gating system for the liquid metal into the mold, considerably reducing tolerances and fabrication time.
Focusing design and fabrication primarily on the connecting node points, the smallest components of a framing system can be produced with relatively expensive digital fabrication techniques without significantly increasing the overall cost. The fabrication of all nodes took less than two weeks, considerably faster than traditional mold-making or direct 3D metal printing.
Further optimization of nodes will require more detailed information on the structural behavior of 3D printed materials and the embedding of local structural engineering knowledge into the design team. Designers are likely to face challenges in assessing large quantities of such data, and heuristic and pragmatic responses may be more readily adopted.
In the course of this exploration, it is evident that steel 3D printing holds the potential to redefine architectural construction practices. The case study of connections for a freeform façade at the Norwegian incineration plant demonstrates the technology's capability to realize intricate designs inspired by nature, advancing sustainability and economic efficiency. As a burgeoning architect, steel 3D printing is seen as a beacon of hope for future environmentally conscious and innovative architectural endeavors, leaving a lasting impact on the field.

Recommendations for Future Practices

After conducting the research, several recommendations for designing modern sustainable industrial buildings in northern regions can be proposed. It's important to emphasize that these recommendations are purely advisory. Each project needs a detailed examination of the specific topic, and advice should be applied based on the collected data.
First and foremost, before commencing any project, a detailed analysis of the area should be conducted, identifying the advantages, disadvantages, and potential of the locality in each specific case. Similar to traditional architectural design, attention should be given to climate, terrain, social aspects, city transportation structure, and more.
Our suggestion is that during the pre-design analysis, not only generalized facts should be considered but also the city's colour palette. It is necessary to identify the peculiarities of local materials, examining not only the architecture but also the local nature. Inspiration can sometimes be found in small details, unnoticed without a personal visit to the design site. Textures and colors can reveal much about the people living there. Using these tools, it is possible to influence the well-being of the area, breaking stereotypes that industrial buildings are unsightly and dangerous to visit.
Additionally, it is highly recommended to study the social habits of the region where the building is being designed. Asking questions about the population's awareness of industrial building processes, understanding how interested people are in contributing to the project's development, and thinking about actions that can attract more attention to the existing problem and propose solutions are crucial.
Regarding the design of industrial buildings in northern countries, special attention should be paid to studying sunlight and its duration throughout the year. In places with polar nights, it is essential to consider not only the presence of a sufficient number of properly sized window openings but also the design of street lighting during dark hours. In the conditions of polar nights, electric light replaces the sun for people – its saturation level and colour temperature should be calculated considering this fact.
Due to the generally large dimensions of industrial buildings compared to humans, architects should explore the possibilities of parametric design. It is recommended to take into account forms and textures found in nature. For example, humans feel comfortable in surroundings like mountains or forests, which greatly exceed their own dimensions, as these views are historically familiar, evoke delight, and help relax. In the modern urban environment, we are often surrounded by monotonous flat concrete or glass walls, which frequently block visual access to the sky and sun. Buildings of organic form can mimic pleasing landscapes, thereby reducing anxiety, and enhancing aesthetic enjoyment.
As for the application of 3D printing, the decision remains with the architect. There are vast possibilities in this area, from printing small details to prefabricating structural elements and creating large parts of the building. In each specific case, it is necessary to weigh all the advantages and disadvantages, choosing the most suitable method. However, it significantly helps reduce material costs, thus lowering the overall building cost and preserving natural resources.
In conclusion, modern design should be based on the principles of sustainable development. In the case of industrial buildings, the selection of engineering equipment plays a significant role, reducing harmful emissions into the atmosphere to a minimum and reusing the generated energy to support the operation of its processes. As we can see, the collaborative work of various specialists from different fields can lead us to a slightly brighter future and contribute to solving many existing environmental problems.

05 BIBLIOGRAPHY

[1] Hannes Meyer, The New World. 1926.

[2] B. Goodey, “Interpretation of Industrial Buildings and Landscapes,” 1997.

[3] L. Jevremovic, M. Vasic, and M. Jordanovic, “Aesthetics of Industrial Architecture in the Context of Industrial Buildings Conversion,” 2012.

[4] Y. Wang and Z. Cao, “Industrial building environment: Old problem and new challenge,” Indoor and Built Environment, vol. 26, no. 8. SAGE Publications Ltd, pp. 1035–1039, Oct. 01, 2017. doi: 10.1177/1420326X17728788.

[5] J. Maskit, “‘Line of Wreckage’: Towards a Post-Industrial Environmental Aesthetics,” Ethics, Place, & Environment , vol. 323, no. 37, pp. 1–16, Oct. 2007.

[6] Zumthor Peter, Atmospheres. Architectural Environments. Surrounding Objects. Berlin: Bukhauser Verlag AG, 2006.

[7] F. De Matteis, “International Lexicon of Aesthetics: Atmosphere in Architecture,” 2020, doi: 10.7413/18258630074.

[8] Iu. , and B. S. Lapin, “Industrial Aesthetics,” The Great Soviet Encyclopedia, 3rd Edition. 1970.

[9] H. Iyengar, L. Novak, R. Sinn, and J. Zils, “Steel Flower,” Modern Steel Construction, Jun. 1998.

[10] Bin Jian, Landscape Empowerment. A Participatory Design Approach to Create Restorative Environments for Assembly Line Workers in the Foxconn Factory. Hong Kong: Springer Singapore, 2021. doi: 10.1007/978-981-15-2067-9.

[11] N. M. Kumar, “Design Approach for Industrial Architecture,” 2022. [Online]. Available: www.jetir.org

[12] Davies Veronica, “Basic Forms of Industrial Buildings,” The Art Book, vol. 12, no. 4, p. 56, Nov. 2005.

[13] Luce Barbisoni and Alessandro Zanoletti, “Industrial Memories. Le fill rouge between Urban and Social Regeneration,” Master Degree, Politecnico di Milano, Milan, 2016.

[14] Claire Zimmerman, “Albert Kahn in the Second Industrial Revolution,” London, 2017.

[15] H. Ahmad Nia, “Perception Based Method for Measuring the Aesthetic Quality of the Urban Environment: The Case of Famagusta,” 2017. [Online]. Available: https://www.researchgate.net/publication/312191981

[16] T. Griffero, “International Lexicon of Aesthetics: Atmosphere,” Mar. 2018, doi: 10.7413/18258630007.

[17] M. Mosoarca, A. Anastasiadis, and K. Apostolos, “Are Free Form Architectures Ecological Buildings?,” 2014. [Online]. Available: http://www.jepe-journal.info/vol15-no-1-2014

[18] Karissa Rosenfield, “Schmidt Hammer Lassen and Gottlieb Paludan to Design World’s Largest Waste-to-Energy Plant in Shenzhen,” https://www.archdaily.com/781588/schmidt-hammer-lassen-and-gottlieb-paludan-to-design-worlds-largest-waste-to-energy-plant-in-shenzhen.

[19] Jonas Wetzel, “Volkswagen Sachsen GmbH Gläserne Manufaktur (The Transparent Factory) Dresden | Volkswagen Newsroom” Accessed: Nov. 01, 2023. [Online]. Available: https://www.volkswagen-newsroom.com/en/volkswagen-sachsen-gmbh-glaeserne-manufaktur-the-transparent-factory-dresden-5906

[20] Zaha Hadid Architects, “BMW Central Building – Zaha Hadid Architects.” Accessed: Nov. 15, 2023. [Online]. Available: https://www.zaha-hadid.com/architecture/bmw-central-building/

[21] “McLaren Technology Centre | Projects.” Accessed: Nov. 11, 2023. [Online]. Available: https://www.fosterandpartners.com/projects/mclaren-technology-centre

[22] “SUSU Applicants Visit the Vysota 239 Production Facility - South Ural State University.” Accessed: Nov. 11, 2023. [Online]. Available: https://www.susu.ru/en/news/2018/07/30/applicants-visit-vysota-239-production-facility

[23] “Gaydon Headquarters | Locations | Aston Martin Lagonda.” Accessed: Nov. 11, 2023. [Online]. Available: https://www.astonmartinlagonda.com/about-us/locations/gaydon

[24] “Sweden’s Largest Biofuel Heat and Power Plant Is Fossil-Free Energy Hot Spot | Climate Technology Centre & Network | Wed, 04/14/2021.” Accessed: Nov. 11, 2023. [Online]. Available: https://www.ctc-n.org/products/sweden-s-largest-biofuel-heat-and-power-plant-fossil-free-energy-hot-spot

[25] Arc, “From Waste to Energy – The technology Inside Amager Bakke,” https://a-r-c.dk/english/from-waste-to-energy/.

[26] “Spittelau waste incineration plant | Wien Enerige Positionen.” Accessed: Nov. 11, 2023. [Online]. Available: https://positionen.wienenergie.at/en/projects/spittelau-waste-incineration-plant/

[27] “BMW Welt - BMW’s exhibition centre and showroom in Munich.” Accessed: Nov. 11, 2023. [Online]. Available: https://www.introducingmunich.com/bmw-welt

[28] Sam Jones, “Guggenheim effect: how the museum helped transform Bilbao,” The Guardian. Accessed: Nov. 06, 2023. [Online]. Available: https://www.theguardian.com/world/2022/oct/31/guggenheim-effect-how-the-museum-helped-transform-bilbao

[29] D. Seamon, “International Lexicon of Aesthetics: Place,” May 2020, doi: 10.7413/18258630087.

[30] “What is Parametric Design in Architecture?” Accessed: Nov. 01, 2023. [Online]. Available: https://parametric-architecture.com/what-is-parametric-design-in-architecture/

[31] M. L. Castro Pena, A. Carballal, N. Rodríguez-Fernández, I. Santos, and J. Romero, “Artificial Intelligence Applied to Conceptual Design. A Review of Its Use in Architecture,” Automation in Construction, vol. 124. Elsevier B.V., Apr. 01, 2021. doi: 10.1016/j.autcon.2021.103550.

[32] J. Wallner and H. Pottmann, “Geometric Computing for Freeform Architecture,” J Math Ind, vol. 1, no. 1, pp. 1–19, 2011, doi: 10.1186/2190-5983-1-4.

[33] “Parametric Design.” Accessed: Nov. 11, 2023. [Online]. Available: https://www.trendvisionforecasting.com/macrotrends-2018/sustainable-harmony/archive-2018/sustainable-harmony-the-digital-mod-

ernist/parametric-design
[34] R. Andrei, “Form And Space Abstraction in Architectural Rehabilitation of Industrial Buildings,” 2010.
[35] L. Alonso Pastor, B. Lauret Aguirregabiria, E. Castañeda Vergara, D. Domínguez García, and G. Ovando Vacarezza, “Free-Form Architectural Facade Panels: an Overview of Available Mass-Production Methods for Free-Form External Envelopes,” Valencia: Universitat Politècnica de València, Nov. 2012.
[36] The Daylight Academy, Changing perspectives on daylight: Science, technology, and culture. Washington: Science/AAAS Custom Publishing Office, 2017.
[38] P. Romagnoni, F. Peron, and F. Cappelletti, “Sustainability of Retrofit Actions in Industrial Buildings,” Venice, Oct. 2008.
[39] “Benefits of Rainwater .”
[40] Anonimous, “GM using Autodesk generative design software for lightweighting work,” https://www.greencarcongress.com/2018/05/20180503-gm.html.
[41] Dunyong. Deng, “Additively Manufactured Inconel 718 Microstructures and Mechanical Properties.,” 2018.
[42] Ali Gokhan Demir, Introduction to Additive Manufacturing (AM) Processes, (2022).
[43] Shenzhen Rapid Direct Co, “The Advantages of 3D Printing for Mass Production,” https://www.rapiddirect.com/blog/3d-printing-mass-production/.
[44] Ali Gokhan Demir, Introduction to Additive Manufacturing (AM) Processes, (2022).
[45] “Arc Bicycle has 3D-printed steel frame created by TU Delft.” Accessed: Nov. 11, 2023. [Online]. Available: https://www.dezeen.com/2016/02/04/arc-bicycle-3d-printed-steel-frame-amsterdam-tu-delft-mx3d/
[46] Gunseli Yalcinkaya, “World’s first 3D-printed steel bridge unveiled at Dutch Design Week,” https://www.dezeen.com/2018/10/22/worlds-first-3d-printed-steel-bridge-completed-mx3d-technology/.
[47] Anna Winston, “Arup unveils its first 3D-printed structural steel building components,” https://www.dezeen.com/2014/06/11/arup-3d-printed-structural-steel-building-components/.
[48] WorkAC, “Reade Street - Capitals,” https://www.michael-hansmeyer.com/reade-street.
[49] M. L. Castro Pena, A. Carballal, N. Rodríguez-Fernández, I. Santos, and J. Romero, “Artificial Intelligence Applied to Conceptual Design. A Review of Its Use in Architecture,” Automation in Construction, vol. 124. Elsevier B.V., Apr. 01, 2021. doi: 10.1016/j.autcon.2021.103550.
[50] Meibodi Mania Aghaei, “Digital Metal: Using 3D printing to cast metal parts in architecture,” https://www.tctmagazine.com/additive-manufacturing-3d-printing-industry-insights/digital-metal-3d-printing-casting-metal-architecture/.
[51] A. M. Early, M. E. Mohammadi, R. L. Wood, and K. D. Peterma, “Behavior of Cold-Formed Steel Metal Industrial Buildings,” St. Louis, Nov. 2018. [Online]. Available: https://digitalcommons.unl.edu/civilengfacpubhttps://digitalcommons.unl.edu/civilengfacpub/160
[52] Myers lynne, “MX3D + takenaka utilize robotic 3D printing to build a structural steel connector ,” https://www.designboom.com/architecture/mx3d-takenaka-3d-print-structural-steel-connector-12-12-2019/.
[53] J. Wallner and H. Pottmann, “Geometric Computing for Freeform Architecture,” J Math Ind, vol. 1, no. 1, pp. 1–19, 2011, doi: 10.1186/2190-5983-1-4.
[54] M. Sarakinioti, M. Turrin, T. Konstantinou, M. Tenpierik, and U. Knaack, “Developing an integrated 3D-printed façade with complex geometries for active temperature control,” Mater Today Commun, vol. 15, Nov. 2018, doi: 10.1016/j.mtcomm.2018.02.027.
[55] Luce Barbisoni and Alessandro Zanoletti, “Industrial Memories. Le fill rouge between Urban and Social Regeneration,” Master Degree, Politecnico di Milano, Milan, 2016.
[56] M. Sarakinioti, M. Turrin, T. Konstantinou, M. Tenpierik, and U. Knaack, “Developing an integrated 3D-printed façade with complex geometries for active temperature control,” Mater Today Commun, vol. 15, Nov. 2018, doi: 10.1016/j.mtcomm.2018.02.027.
[57] M. Becidan et al., “Norwegian Waste-to-Energy (WtE) in 2030: Challenges and opportunities,” Chem Eng Trans, vol. 43, pp. 2401–2406, 2015, doi: 10.3303/CET1543401.
[58] Inc. Cedar Lake Ventures, “Climate and Average Weather All Year Round in Tromso,” https://ru.weatherspark.com
[59] O. Øvrebø and E. Talleraas, “The Structural Geology of the Troms Area (Barents-Sea),” 1977. [Online]. Available: https://www.jstor.org/stable/41141967
[60] Johnsen Nils Arne, “Supporting development of Industry and Business in Arctic Norway,” https://nilsajohnsen.com/2018/09/14/supporting-development-of-industry-and-business-in-arctic-norway/.
[61] Gloria Lotha, Chelsey Parrott-Sheffer, Emily Rodriguez, Shiveta Singh, Amy Tikkanen, and Grace Young, “Tromsø,” Britannica, Jun. 2023.
[62] H. Design for the Living World, “Tromsø – A City as a Garden,” https://designforthelivingworld.com/2013/04/05/tromso-a-city-as-a-garden/.
[63] Benzin AS, “Remiks Official Page,” https://www.remiks.no/remiks-om-oss/omvisning-hos-remiks/.
[64] VisitNordic, “Arctic Circle Map,” https://www.visitnordic.com/en/article/arctic-circle-map.
[65] Climate-Data.org, “Climate of Tromso,” https://ru.climate-data.
[66] Kasper Kyndesen, “Above the Arctic Circle, We Find Inspiration in the Northern Lights,” https://henninglarsen.com/en/news/archive/2020/04/14-above-the-arctic-circle-we-find-inspiration-in-the-northern-lights.
[67] Gloria Lotha, Chelsey Parrott-Sheffer, Emily Rodriguez, Shiveta Singh, Amy Tikkanen, and Grace Young, “Tromsø,” Britannica, Jun. 2023.
[68] O. Øvrebø and E. Talleraas, “The Structural Geology of the Troms Area (Barents-Sea),” 1977. [Online]. Available: https://www.jstor.org/stable/41141967
[69] Voinov Igor, “Topography Map of Tromso,” https://kolamap.ru/topo/norge.htm.
[70] Kovaleva Irina, “Tromso – what is interesting about the northern city of Norway?,” https://kuku.travel/country/norvegiya/goroda-i-kurorty-norvegiya/tromsyo/tromsyo-chem-interesen-severnyj-gorod-norvegii/.
[71] Ingerid Helsing Almaas, “Norwegian Architecture Today,” https://doga.no/en/activities/de-

sign-and-architecture-in-norway/architecture/architecture-in-norway
[72] Schneider Electric, “The Principles of Sustainability in Building Design,” https://blog.se.com/sustainability/2023/03/13/the-principles-of-sustainability-in-building-design
[73] C. Yakymchuk, “Migmatites,” Encyclopedia of Geology: Volume 1-6, Second Edition, vol. 2, pp. 492–501, Jan. 2020, doi: 10.1016/B978-0-08-102908-4.00021-7.
[74] Voinov Igor, “Topography Map of Tromso,” https://kolamap.ru/topo/norge.htm.
[75] Tom Heldal and Peer Richard Neeb, “Natural stone in Norway: production, deposits and developments,” Trondheim, 2000.
[76] Kasper Kyndesen, “Above the Arctic Circle, We Find Inspiration in the Northern Lights,” https://henninglarsen.com/en/news/archive/2020/04/14-above-the-arctic-circle-we-find-inspiration-in-the-northern-lights.
[77] Johnsen Nils Arne, “Supporting development of Industry and Business in Arctic Norway,” https://nilsajohnsen.com/2018/09/14/supporting-development-of-industry-and-business-in-arctic-norway/.
[78] H. S. Monica Eileen Lian, “Polar Environment Centre and Polaria,” https://arkitekturguide.uit.no/items/show/795.
[79] Berloga workshop, “MS Polstjerna,” https://berloga-workshop.com/blog/559-ms-polstjerna.html.
[80] Visit Tromsø-Region, “The Arctic Cathedral,” https://www.visitnorway.it/listings/the-arctic-cathedral/127032/.
[81] Johnsen Nils Arne, “Supporting development of Industry and Business in Arctic Norway,” https://nilsajohnsen.com/2018/09/14/supporting-development-of-industry-and-business-in-arctic-norway/.
[82] librarybuildings.info, “Public Library and Archive, City of Tromsø,” https://librarybuildings.info/norway/public-library-and-archive-city-tromso.
[83] Ingerid Helsing Almaas, “Norwegian Architecture Today,” https://doga.no/en/activities/design-and-architecture-in-norway/architecture/architecture-in-norway/
[84] Willy Nikkers, Norway. Architecture, Society and Culture in Norway, (Nov. 14, 2019). Accessed: Nov. 06, 2023. [Online Video]. Available: https://www.youtube.com/watch?v=ZrY007_f5wU&ab_channel=VisitNorway
[86] PP, “Steel Structure·Technology. Comprehensive interpretation of the hinged connection of steel structures ,” https://www.sohu.com/a/233100912_278208.
[87] K. Crolla, N. Williams, M. Muehlbauer, and J. Burry, “Smart Nodes Paviloin. Towards Custom-optimized Nodes Applications in Construction,” 2017.

06 APPENDICES

List of Figures

Interview Transcript

Speaker: In changing Arctic there are 1-2 PhD from Russia, and one was from America, United States, Russia, Italy, Norway of course. They were foreign PhD students. But maybe a lot of information to help people - we must see waste as resources.
Mila: I'm totally agree with this point, I think we should let people know how to do it. So, they would also join the program. I found it really exciting.
Speaker: And you are studying architecture?
Mila: Yeah, I'm studying architecture now in Milan, in Italy. Also, I did an exchange in NTNU in Trondheim, last year. First Semester. Yes, I'm master's degree student.
Speaker: So, because I say architecture, that's because our building here is built in a way that show that waste is not garbage, trash. It's something else. So, the building is a picture in a way that the this is a very important thing. This is not a shout, Square with the roof. Yeah, this is something else.
Mila: This is exactly the topic of my thesis; I would like to... I'm writing about aesthetics of industrial architecture, and I would like to show that the industrial buildings - they also can be attractive, they also can be a part of the city and they can be even like attractive point, like Copenhill in Copenhaigen, for example. It's a wonderfull building.
Speaker: It's also normal thing that the waste treatment company is coming is inside the center at the Tromsø municipality, normally a garbage dump or something is outside of people. That's not anymore, because this is resources, this is something that we need to use. So yeah. We also have a Remiks day. Every second year we have open day at Remix. Of course, people will see what is happening here. We show them what we are doing, and we also have theatre, cafe - redesign all this kind of thing also. So, it's very important. So, this is from not this year. But last year, and...
Mila: And when is his day usually? You said every two years, do you have like a specific date for this day?
Speaker: Yeah. The first or second Saturday in September. We normally have it the first weekend in September. But sometimes we have to have the second week.
video playing
So, as you can see it's really big area for Tromsø municipality and Norway. But sounds in a world perspective is very little. But process a big. We are the biggest basically tech company in Northern Norway. I have to say we have 130 employees; we have 400 million the annual turnover, we sold approximately 80,000 inhabitants, we have approximately in the 77,000 - 79,000 tons of waste that processed in here annually, that mean 910 tons per hour. So, if we are stopping to collecting or receive waste is the perhaps - the municipality will collapse. I mean a modern city will not function, so it's very important that we can receive waste of course and if we have a problem here, we have to have a plan B, C, D, E. So, we always have a possibility to receive waste in some way. 300 tons waste out of a secondhand store - that is not true anymore because it's 600 tons, because we have moved a secondhand shop from here to what we call a Rebel. it's 1100 people every day do buy secondhand stuff. So on, we have a 94% of all waste is recycled, that means material recycling, also turning into new materials.
Okay, this is for household waste and solid material recycling. You see that the industrial waste has more degree of recycling that household, that's because they have a different kind of waste. That is much more and there's this very you can sort it out in that way. Second, 1% is secondhand, 42% is an average material recycled, 51% is waste to energy. That mean turning into hot water. You see we have radiators. There is warm water in there.
We are a big company. We have some daughters companies, that's called Remiks Naering and Remiks Husholding. Remix Husholding is collecting waste from household. That is why you have to pay taxes in Norway - and then it gets some services. And this service is waste collecting system services and they're paying taxes for that. And Remix Naering not paying tax, it doesn't have to pay, so that is the business. So, our profits every year - that is from Remix Naering. We can't have a profit in Remix Hushold because that is what you call a Sunk cost. That thing mean that you can't make profit, or you can even lose money. We have to break even always, and it's the responsibility of Tromsø municipality. We are doing the job on behalf of them. We also have all of our incineration plant waste to energy plant in we also have all the machine bottles collecting that is composting food waste for us. And also, we'll have a biogas facilities. 2 years from now, I think, we'll have Arctic waste management is collecting hazardous liquid waste offers mangling or trading waste on behalf of many waste treatment companies, because it's a market. It's a market economic system, according to waste also. And Rå Biopark AS is biogas facilities. This is Northern Norway project, many municipalities or waste treatment company that's owned by the municipalities. The Remix is owned by Tromsø and Karlsøy municipalities. Most of the waste treatment company in all Northern Norway are owned by the public that mean the municipalities in Norway. There are few private companies, and one of them are the biggest company in Norway. So, this is a cooperation between a lot of municipalities in Northern Norway - fantastic project - to cooperate with some that kind of project, one biogas for whole the Northern Norway. Fantastic. We will do have this facility in Chiba. A bit an 1 hour form here.
Mila: That's amazing. And how do you use biogas?
Speaker: We use it on vehicles, we use it on ship. Yeah. Also, it's very good thing to do. Because when you make biogas out of organic waste, that mean not food waste, but also suit, it is also fish, from fish industry, aqua industry, for instance. You can use all this to make biogas and then you also have a compost afterwards, after the process, but we don't use so much of fertilizing herring in Northern Norway because the agriculture is not so big in Northern Norway. Also, we do bio coal. And that is you have a much purer release and make it the kind of coal you can use it in food, you can use it as fertilizer, you can use it in many ways. And it's also storing carbon, storing co2. So, it's a very good thing. A bit new in process things as all. it's not the many who do make bio coal and that kind of stuff. But we can do it

and there's much more sounds to use it instead of making compost that no one will buy.
Mila: Yeah, About incineration plant, because I'm really interested in theat. Do you think it will be convenient to have one in Tromsø or it's enough that you have?
Speaker: We do have it in Tromsø, but that is a private. It's about 50 meters from here. We do have an incineration plant. So, we are using the waste that all burned locally. In early days we sent it to Sweden - 1500 tracks every year. Now we have 25 meters with conveyors from all buildings to the incineration plant.
Mila: That's great. My initial idea for the industrial building here was incineration plant. So, but now I know that you already have one. So, I was thinking of designing or redesign of that incineration plant, or maybe you need like, another building which will be more convenient nowadays, so I could state like, Okay, I chosen this site because it's a really needed building.
Speaker: Did I understand that? A whole rebuild the older architecture of this building? What you mean?
Mila: For my thesis, my first idea was when I found your company, I felt like: "Oh, that's a great company. Maybe I could build an incineration plant onto your site."
Speaker: Oh, yeah. Too late
Mila: Yeah
Laughting
Speaker: Yeah, yeah, we do have it and when you come to architecture, I know that incineration plants around the world are very fantastic buildings, cathedrals-like building something. This is not the cathedral at all. It's okay. It's more functional than a great thing to look at, in that sense, but it's not bad. Yeah, it's okay, but nowadays they have expanding there, so they are building now, so it's a bit mess now. So, yes, we do have it. And when we were building, Tromsø Miljøpark. We also said that the building should be showing that is not waste, we are doing there resources. And the other thing that's building is very low, that is building into the ground in kind of sense. And there's also a kind of wave, like buildings also and the process buildings also. But after this we have to expand also, and then we are building four boxes. It's not something about finance, that's something about functionality and something about to do take as fast as we can, so it's not that easy. But the first is two building from 2008, the process building number one is from 2006. This is a significant building.
Speaker: All that you have seen also when you come here - It's kind of storage facilities is made up of concrete boxes, like Lego. It's not so nice to see. We want to see the wall to the main road. We are thinking about to have a kind of graffiti for the whole wall or something artistic kind of thing. All these tourist ships are coming in and they can see and say like:"Oh!"
Mila: Yeah, it could be like nice attractive point.
Speaker: Yeah. Now it's only a wall, not treated at all. It's just concrete.
Mila: Yeah, cause when I see it, I was wondering like: "Is it temporary wall or...
Speaker: Yeah, this is temporary. It will not be that kind after some time. Yeah. These days all waste treatment shall be doing indoors; you can't use these things outdoors anymore. We have to stock it inside a building. You can't have anything outside. We do have a good department, would ship from world to ship that this is outside still, but all things are inside in some way.
Mila: It's like a new policy or...?
Speaker: It's relatively new. The are not demanded it, but they said you must do every kind of waste treatment indoors, and not outdoors. So, we take responsibility together, we have a lot of sustainability goal, of course - that's very important, every company must have that. We also have a somehow, we do it and so, this is of course politics according to regulations and legislation in Northern Norway. The people in Norway have a duty to do what we are saying. That basically meant to pay a taxes and then you get some services, it's differs between the municipalities. So, municipality can have that kind of services, we have another kind of services at the same, and more, and less, so on. So, we are slightly different things. We have also optical sorting in our municipality, that means we are sorting in bags in the kitchen and all they have bins outside, five bins - one for paper, for one for food... We have what we call bags, and we had food in green dotted bags, we have paper, carton and raking packaging in blue dotted bag, in purple dotted bag we have plastic. So, they go into the same bin into the facility here and they are sorting by machinery that is reading the colourof the bags and putting it into the right containers.
Mila: This is very convenient.
Speaker: Yes, it's probably a more efficient than that sounds and should be very liked by the inhabitants of these municipalities. They liked it, this thing is very good. We also have one bin for glass and metal packaging. But the problem is 67% of all waste in residual waste, rest waste after your sorting out 67% in that bag could have been sorted. That mean a 30% is food waste that is putting into residual waste instead of the green doted bag. 12% is plastic packaging that should have been in purple dotted bag that is in the residual bags instead. So, if they have sorted it out correctly, we had saved 8-10 million crones every year. And that mean lower taxes. But for some reason, they are sorting it in this colourbags pretty good. Fantastic. But they are sorting too little. They should do something much-much more. And we don't know why this simple system creates a kind of laziness, that they put it in residual instead of doing a bit more job to put it into right bags.
Mila: You should sort only clean packages into these bins, as I know, yeah? Like, for example if I eat yogurt, I should clean and then waste. I think like half of this garbage is not cleaned.
Speaker: Yeah, I know that. The rate of cleaning. Yes, yes. It shouldn't be totally clean. No, it's not. You just eat your yogurt. And clean it under the water flow. Yeah, there's always something left. But empty. And if you do that, it's no problem. But we have a campaign now that trying to have a social light on this issue. We also have university and so on. And they have to be learned how to do this, they learn a prior.
As a company we also have a problem according to safety. We have fire, but it doesn't have an open flame every second week in this facility. It's very dangerous because if we started to burn really, it is very difficult to put out the fire. We had a fire here in 2014. Then most of the fire brigades in Tronso municipality and also the airport fire brigade came here to put out the

fire, because it's very dangerous, it's toxic smoke. It's not good at all. We saved the building and it cost us 14 million crones and so on. Therefore, we also have industrial protection what we call HSE. And we have exercises and people who have another job in this company but when the alarm is going to put on a new uniform, and they are into protection. Situation, first aid, fire protection, biochemical, chemical diving equipment, smoke diving. So, we are not putting out fires and so on, we are making it ready for the professionals, and professionals is the fire brigade. And so, they are the professionals, but we are making everything as ready as we can for them just come and started.
Speaker: This is garbage truck
Mila: It was here??
Speaker: No, this is from Bergen. This is not today kind of garbage truck. I have worked in when I was studying in Bergen. I have my summer job in Bergen Renholdsverret waste treatment company in Bergen, and on that kind of car, that was only for two years. But the thing is what you call that in Bergen 'slankeboken' field plus, and in 1960s they closed it down. But in these days, they are digging it up again. Because after they close it down, they made a football arena on this field and that was too polluting this garbage dump, polluting everything. And municipality say, the council say: "we have to dig it up", so they know in 2022-2023 they are digging up the garbage dump and then they are putting it together, to take away the garbage, sorting in it and fill it again and become a new football arena. But they had to do it. It's extremely costly, it cost a lot of money to do it. But therefore, this building is where I played a lot of football games. When I was younger than today. We have more than, of course, modern equipment in our waste treatment. We don't have so many ordinary garbage trucks anymore. We do have a another kind of product, that mean, we have one main vehicle, we have a hydraulic arm aside and it's collecting waste, is more efficient than ordinary garbage truck. We do have a loader, we have underground city - underground collecting system that means that we have these here, they put chip in it and the hatches opening, and then you put the waste in and down into this container is underground. With sensors we are measuring the height of the waste and it tell us when we had to come to update. When they unkey to they just lift the whole system and emptying it into the top lowering board and emptying it in this container, for the site. It's very efficient for small dense living area, for bigger dense living area, where many people are living together in a closed area, we do have a vacuum sucking system, that means that inside the living area, it's this kind of inlets. It's pipeline, it's let you just put the garbage into and it's going down into a container, it's connected together with pipelines, and the pipeline is ending outside the living area. This vehicle is not entering the living area at all. It's very safe, children friendly and all this kind of thing, and then it's like a vacuum cleaner - sucking the waste from the containers. We also have a stationary that the waste is coming through pipeline directly to our facilities. There are no vehicles that collecting in this living area at all - sucking directly into it.
Mila: But I think that the last system you cannot use like for far away, for example, you cannot put the pipes into another part of the city, you can use just like 2-3 kilometers...
Speaker: We can't use it in a long distance because when garbage coming through the pipeline - is friction and so on can destroy the bags of course. So, it's normally to have relative short distance. This is a mobile variant, and we have one stationary also, but this is a very efficient. It's not as cheap as ordinary waste electric system, but it's very eco-friendly and there is no vehicles inside the living area at all.
Mila: It's very sustainable.
Speaker: And the design. According to design - it's very little pollution around these containers either, because it's from an ordinary container. This ordinary container is very easy for someone to just take, but when you have these kinds of things, just stand there a pipeline kind - it's much more nicer to look at. You don't feel it's something about garbage kind of thing.
Mila: Yeah, it's more attractive. Aesthetically good.
Speaker: Yeah. And then we are receiving waste into these facilities after conveyers where the bags coming one after another. Then we have a computer, the machinery that is reading the color.
Mila: Huh? So, it's not people reading the color? It's machine?
Speaker: Yes. From the kitchen to the factory. There is no human interference at all. It's machinery to do the rest.
Mila: It's sounds like future for me.
Speaker: Yeah, but it's more part of it. Of course, there have to be some people in facility because you have to do something, but this very automated. We have of course for business community and business industry, we do have a lot of vehicles, different kinds of vehicles. This is the next step, it's "HIGHWAY TO EL" - electric vehicles. We are now receiving the three first major vehicles that mean trucks, we do have some recourse on electricity, but garbage truck - we don't have it yet. That means that this is feeling good for city transporting and collecting, but for long distance in Finnmark county. And so, on it's too long distance. It's have no function, but here in Finnmark at longer distance vehicle on gas can be a very good thing. Yeah, we also have to automate the collecting system. But we do have the working for area, that this a chip that we are putting on the cover of the bin. And then when every time we are emptying the bin, it say that we have emptying it. Also, they can take a call that they're waiting, and you can do a lot of things because we've had that kind of chip it's also says where this bin is located, it's GPS located also, so you can see where it is. It's not surveillance in that sense, but you can do also when one inhabited is calling that is not have been emptying for instance, then we can directly say if it had been or not. We also have an expansion kind of thing.
This is administration billing, this is a recycling station for businesses. We do have one for household, private household they are here, much bigger. This is for companies and so on that want to deliver to base themselves. They can come here and deliver. This is awaited, that is waiting all kind of waste is coming in. This is process building number one. This part is for the hazardous waste. This is optical sorting system. This is for the paper cardboards, plastic and so on, here we are collecting it and recycling, and this part is where there is

grinder, that is crushing the rest waste, burnable rest waste, crush it and then it goes through conveyors in create to be on government that is private company incineration plants. They are now expanding this way. And then this twice amount they can receive, then earlier. Earlier they have 60,000 tons, now they are in 120000-150000 or something tons of waste. We are trying to reduce residual waste. They want a lot of residual waste.
Mila: It's kind of competition
Speaker: Yeah, it can be, but not really, because it's more than enough residual waste. They have, of course, to receive it from someone else. We are the major company that deliver waste. All map of course this is where we are treating wood, that mean have been painted or something, and non-treated wood, that is composting and use in that process and also gardening waste - trees, brushes and grass and all the leaves. It's also here from the recycling station for the household.
And we also have a big area here that we had to use to something, but these two buildings - are made very fantastic. And then this is also building, here we have some concrete blocks. Here we have a box, that have some paints on the side.
Mila: maybe I could create redesign offers for this site. Like in my thesis I could make a proposal how we could change the facade of this buildings to make it more attractive. I also can see that this is a screenshot from SAD file. Yeah, like from SketchUp?
Speaker: Yes, this is from design architect. This is on the other side of main road into the sea. Yeah, that we have a harbor. So, we are competing with our major competitor, but here we are together, we are doing together. Because we see the benefits for both of us to have these facilities. We can transport with by ship out of the area. The wood chip, for instance, is sending to Poland and make plates and furniture. It's recycling and it's transport by ship.
Mila: Oh, yeah, for my bachelor's degree project, I designed incineration plan, which was also on a seaside and like half of it was transported by cars, like from the city, and another part was connected to the whole cities in the area by the sea. So, this was like really cool.
Speaker: Yeah. Because you do have this incineration plant, they also have, they tried to have the beach area, because they have one of the major, what we can say, environmentally bad thing that the incineration plant is CO2. Four outlines here - this is the most emission of co2 in Tromsø, it's not in general but for the company itself - this is the biggest emission, and so to contribution to the emission of co2 in Tromsø. So, they have the cleaning co2 kind of carbon farms, we call it trapping carbon. There is lot of discussion around it. And when they will do that, they also have area because we have to have a lot of equipment, or buildings, or kind of things to make this happening in that sense. So, they are doing a lot of. And I wasn't doing an order expels since you are talking about incineration plant. They also have a project that is to store the warm in the rock. They drilled a lot of holes in the ground down to 300 meters from - it's an oil industry, that have been here. They were doing a fracking system. But this is about environmentally kind of fracking because then they are sending down in the summer. They are sending down hot water, that they can't deliver, because it's summer. They don't need to warm up houses in the summer so much. So, they are warming up the ground. They're used instead burning for the crops, you can use it warm up the ground under half, in two years' time.

In the winter you can take down the water - down into the ground and warming it up, and down standing it out into the areas. Fantastic. So instead of not using it at all, you can use it to just be warming up ground itself.
This is a lot of municipalities of waste treatment company, that is coming together and saying you want one biogas facility in China. I love that kind of presentation because I always look at the board of itself. How bad it is. Climate change - someone is still saying that it's not happening. Kind of asshole. But we do have sustainability goal, we do have two major types of problem that is climate change and marine pollution. We do have food problem, we have over 8 billion people some month ago. We need a lot of food, but a lot of food is just wasting and this all not only food waste, it also what you call it food loss. I mean food that could have been eat. It's not that. We see it here in Norway. We see it at our groceries and so on is coming delivering things that could have been eaten. We have dumpster diving; our people are collecting food loss waste in the containers from the groceries and living. It's not bad at all. Of course, they have to know what is bad and what is not.
Mila: Yeah, for me there is an app called 2Good2Go. They are fighting with a food waste. I really liked the idea that you can just go and get food which is not expired yet.
Speaker: We also have a dumpster diving all this kind of thing and we have to do something to reduce that kind of because we have so much to say instead of making more and more agricultural land. We get rid of forest, burning it down. All this kind of thing is not sustainable. That's the problem. Air pollution is a big-big problem. That means that people are dying in the cities because of bad air. I have a site from Beijing. It's equipment that is measuring the air pollution it's micro cubic meter of air especially. When I have a presentation, I always ask how much air pollution do you think it is in Beijing? No. Because I said between 15 and 35. Just think on a picture I say, don't hold measuring. Doesn't matter. That's 15-35 okay air over of 50 you show up the outdoor, because it's car gases. When you come to Beijing now you can have 20 and you can have 40. And then I ask how you think it is in Tromsø. It's worse in Tromsø, because, when you are measuring these air pollution this one of the most polluted areas in Tromsø, that is Hansjordnesbukta It's a tunnel also coming out, and this a lot of coal traffic around this area, but in the spring it's very problematic because then you have the winter, winter's away, it's very dry and then it's raining and so on. It can be extremely polluted. Beijing had done something, it's not a democracy at all but they understand that it could be a hot measuring 600-900 loss. So, the amount of diversity in animal population have decreased, lot insects also very problematic and the worst thing is lack of drinking water. There was a person, who said "I think we will die of lack of drinking water before the climate change starts", and that was not to say that climate change was bad, not at all, he just said we have the problem of get enough drinking water. It polluted so much. We can go in a tap water. We also have some days that we have to solve municipality problem in water, but this an incident. It's not the major kind of thing. But you don't need to go so long out of Norway before they have to have bottled water.

It’s not so hard. That’s the problem because our shortage of drinking water in area that is raining a lot. We also started to pollute space, with particles from satellites and so on. They are 7-10 billion tons of waste are produced per year, 2,5-3 billion tones are also waste. The most is industrial waste. 80% approximately are industrial waste. We do have here a waste pyramid. That’s say how we should treat waste. Of course, prevent waste, packaging kind of thing. Reuse just to let a thing last longer, repair things, buy secondhand instead of new things. And so, obvious kind of thing that make it more thing last much longer. And then you have recycling - material recycling. The other things you can make recovery on the almost the bottom this pyramid. Of course, landfill and so on, dispose landfill. That is the last thing, last we should do. We do have this kind of thing - ultimate sorting, we also have a campaign - the communication area is called “me and also me.

Rebel is secondhand sustainability center, it’s not only a secondhand shop, but also a presentation kind of thing. You have a repair. You can come and repair things. if you want. We have the equipment. And you can come and repair or redesign. So, this is incineration plant of course. The biggest part of an incineration plant is the cleaning facility, because this mission - regulation according to emissions very hard. This is clean air out of this pipe. This chimney done air around here. That doesn’t mean that this zero. So, you can’t use it in some way, but the clean extremely well and you have burned it in 900 degrees in two or three seconds, then you are destroying almost everything, but then you have to clean it with omnium kind of thing, active coal and also bicarbonate. It’s kind of stuff that is taking off to difficult thing and therefore receive where the waste is coming in. Here is and oven, and all this is a cleaning facilities. This is different kinds of incineration plant technology, this is flatbed, but the waste is very important that there is no air is coming in outside. Everything must be very controllable. So, it’s very closed kind of thing. So, therefore, you also have this kind of thing - waste is coming up to way inside this and this tumbling down and burned all the way down. And then you have two kinds of waste after the burning process. 15% of the waste after burning is bottom ashes and then you have flying ashes. Bottom ashes - you can depose it into landfill, you can also use it - we have project to use it for some way. But the flying ashes is very dangerous waste, so they are sending to move it into concrete and store into the cave. We have a recycling station.

Mila: I have seen how it works today. It’s interesting how track comes and put the big container there and just normal people goes up by car and they just wasted.

Speaker: This kind of thing is also built very modular. Also, these concrete blocks. So, we can move it very easily. But now we have a roof also. So, it’s not that easy anymore, but still possible. We also have a MiniRetur, that mean we have a mobile recycling station is working for the suburban area.

Everything is free, all the stuff it can deliver this MiniRetur is free from recycling station also you can deliver the residual waste as all and then we have a service that car can deliver six times a year things that we normally have to pay for. They can use it for free. After the six turn you have to pay. And that only for residual waste. All the things are free. We also have a cleaning ocean. We also do cleaning beaches and so on. This is refugees - 150 people - we invite them to clean the beaches.

And it was fantastic. They were so glad. But then we have the ordinary also. We also have Fishing for Litter that mean a fishing boat - is a project from the Environmental Agency. Fishing boat fishing fish and fishing garbage. And they are taking back fishes and a garbage into container. And we are collecting these containers. We also have analyzed what is coming in. We calling it fishing, but there’s no one who’s collecting the fish. Therefore, we call it ghost net. So, we are collecting as much we can. It’s fantastic. It is very popular, and all efficient work from Tromsø, and all the municipalities in the coast, that are part of it also and they are fishing boat from Homison is coming in to Homison, fishing from Tromsø is coming from Tromsø. So, it’s fantastic and we have a management company that is making analyzes and so, we also have according to construction materials, also reuse of construction materials, doors, windows, construction goods, making buildings. And so instead of throwing it away, we use it. When they are tearing down the buildings, tearing apart the building and do some renovation.

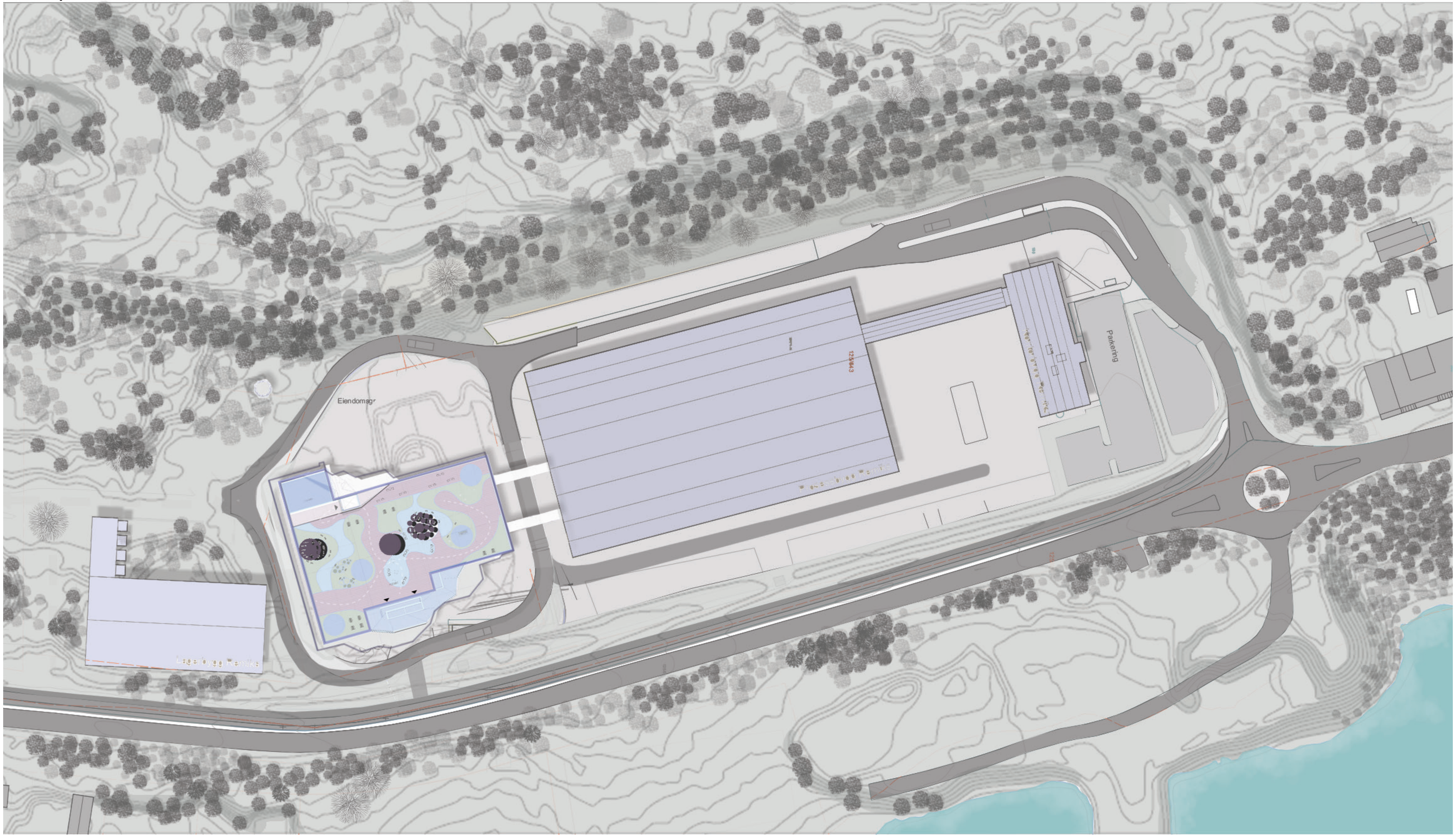
Mila: When we were in Oslo we had like a tour into the building in the city center of Oslo - there is a buildings, that used to be like industrial building and now they turned it in the offices, but they use recycled materials.

Speaker: But the problem to have efficient and so on is that when construction firm - the company are trying to build something they don’t want two doors, they want 10-20 doors, and it’s important that you have a storage capacity to store as much and done someday the companies coming, I need 20 - 50 doors. So, it’s a storage, what you call, intensive kind of business. This is architect firm - the construction company. This is new dice organization that is have something about architecture and these kinds of things. This is high school, who are learning people construction. This is environmental organization. We have to learn this to see these kinds of things can be used to something in industry, in building, construction.

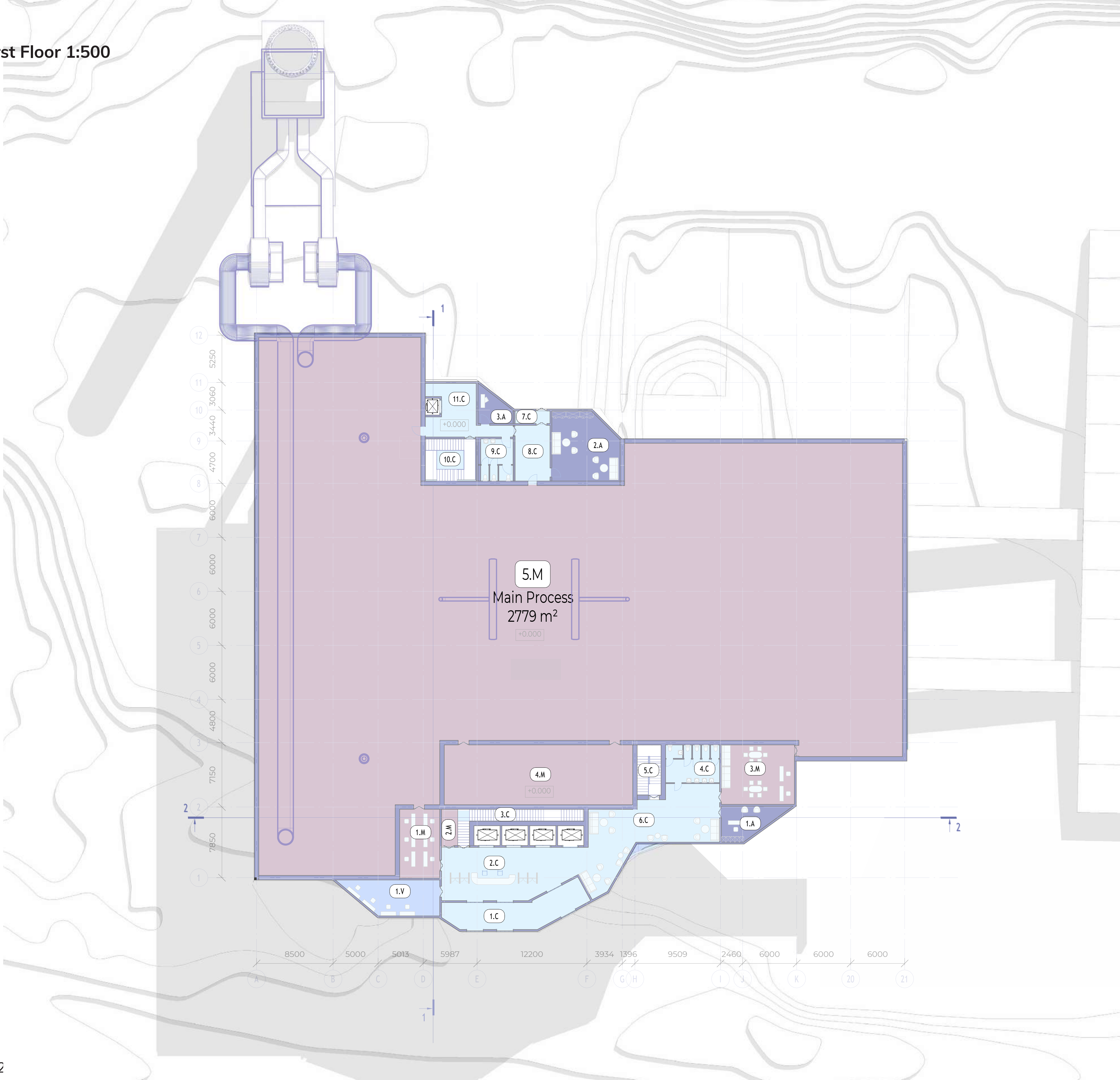
Additional Supplementary Material

N

Masterplan 1:1000



First Floor 1:500



FUNCTIONAL PURPOSE

- A - administrative
- C - common zones and public spaces
- M - technitian and production process premises
- V - retail and lab rooms for visitors

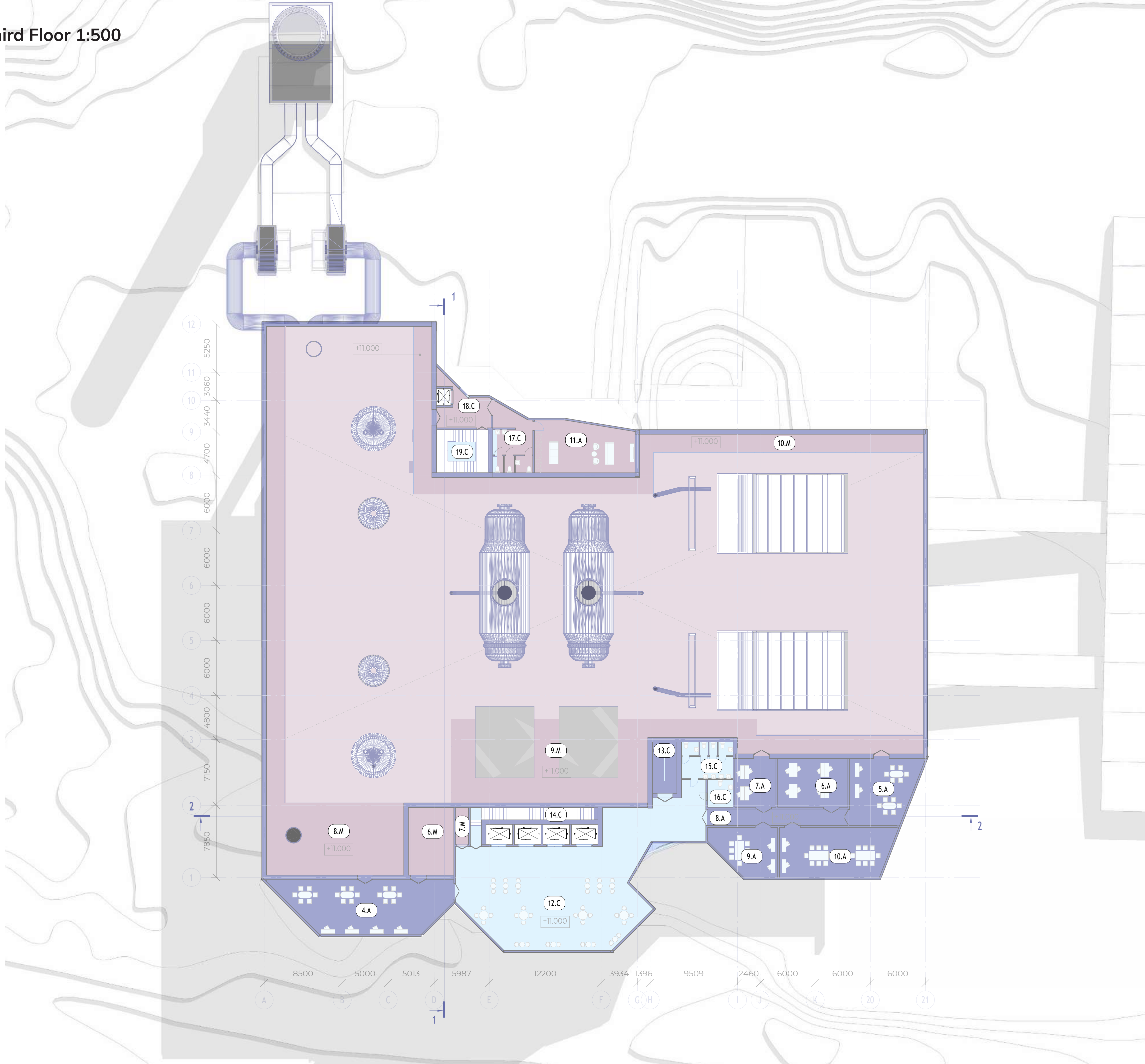
TAG LABEL

11.A — Functional purpose, Room number

1 Level Schedule

№	Name	Area
A		
1.A	Cabinet	21 m²
2.A	Rest room	54 m²
3.A	Cabinet	12 m²
C		
1.C	Main Entrance	49 m²
2.C	Lobby + Reception	83 m²
3.C	Staircase	22 m²
4.C	WC	25 m²
5.C	Staircase	15 m²
6.C	Waiting area	98 m²
7.C	Entrance	5 m²
8.C	Checkroom	24 m²
9.C	WC	17 m²
10.C	Staircase	26 m²
11.C	Hall	35 m²
M		
1.M	Checkroom	34 m²
2.M	Cleaningroom	7 m²
3.M	Technician room	54 m²
4.M	Storage room	139 m²
5.M	Main Process	2779 m²
V		
1.V	Repair Store	37 m²

Third Floor 1:500



FUNCTIONAL PURPOSE

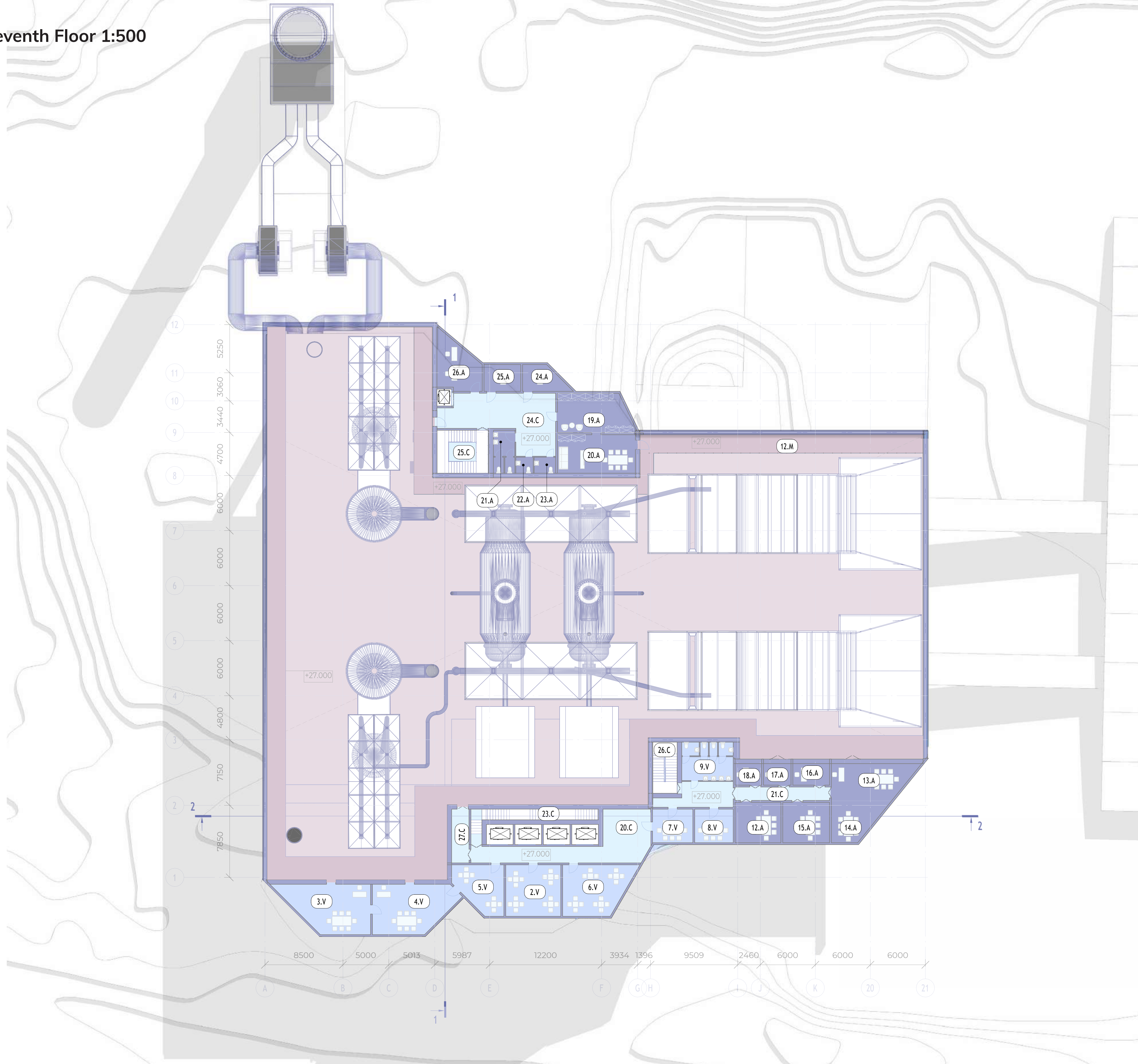
- A - administrative
- C - common zones and public spaces
- M - technitian and production process premises
- V - retail and lab rooms for visitors

TAG LABEL

11.A — Functional purpose; Room number

3 Level Schedule		
№	Name	Area
A		
4.A	Stuff Room	99 m²
5.A	Room	50 m²
6.A	Cabinet	41 m²
7.A	Cabinet	24 m²
8.A	Room	27 m²
9.A	Conference Room	34 m²
10.A	Conference Room	66 m²
11.A	Rest room	58 m²
C		
12.C	Visitors area	264 m²
13.C	Staircase	15 m²
14.C	Staircase	22 m²
15.C	WC	22 m²
16.C	Mother and Child Room	8 m²
17.C	WC	28 m²
18.C	Hall	21 m²
19.C	Staircase	26 m²
M		
6.M	Technician room	36 m²
7.M	Cleaning room	6 m²
8.M	Room	229 m²
9.M	Room	262 m²
10.M	Lab Room	158 m²

Seventh Floor 1:500



FUNCTIONAL PURPOSE

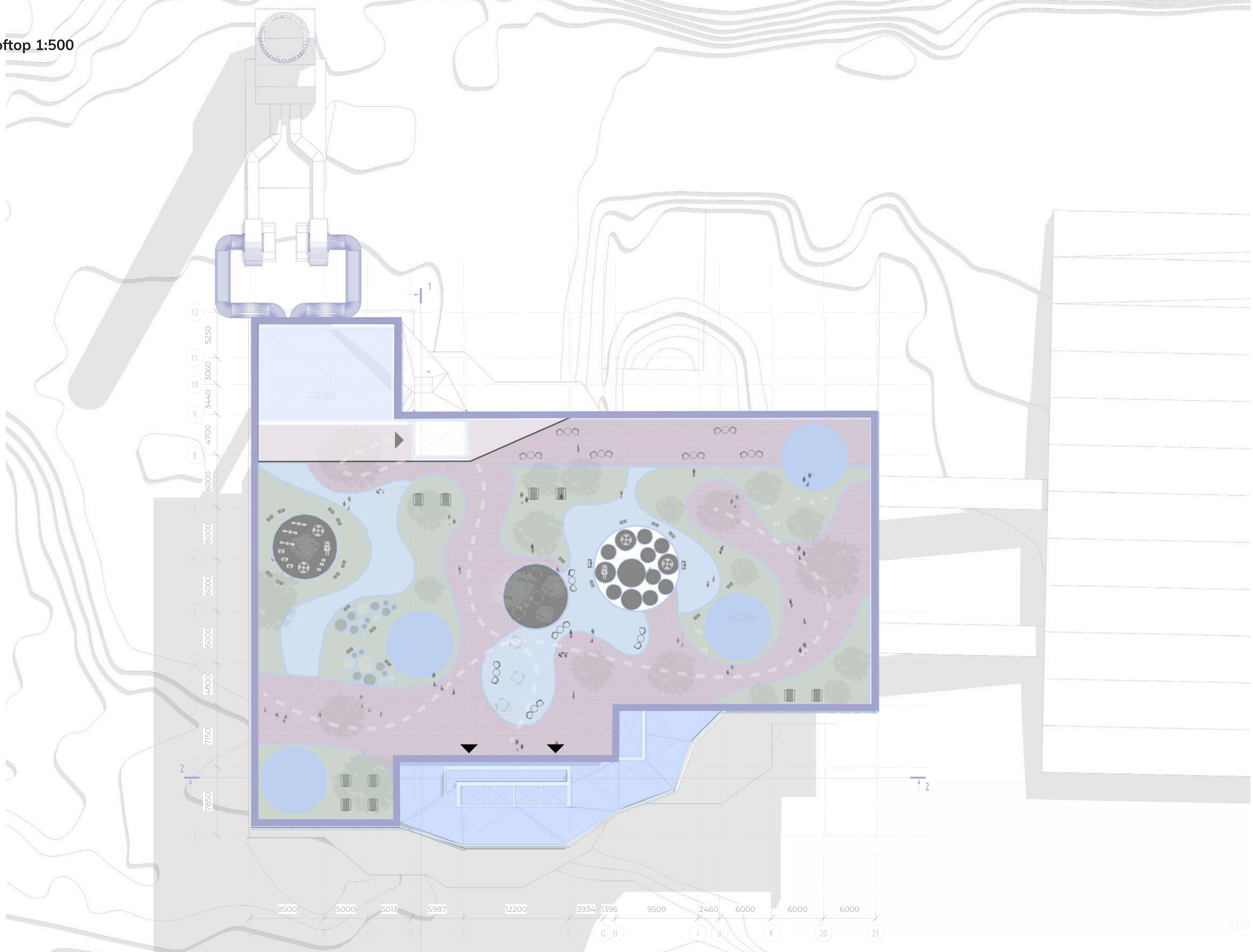
- A - administrative
- C - common zones and public spaces
- M - technitian and production process premises
- V - retail and lab rooms for visitors

TAG LABEL

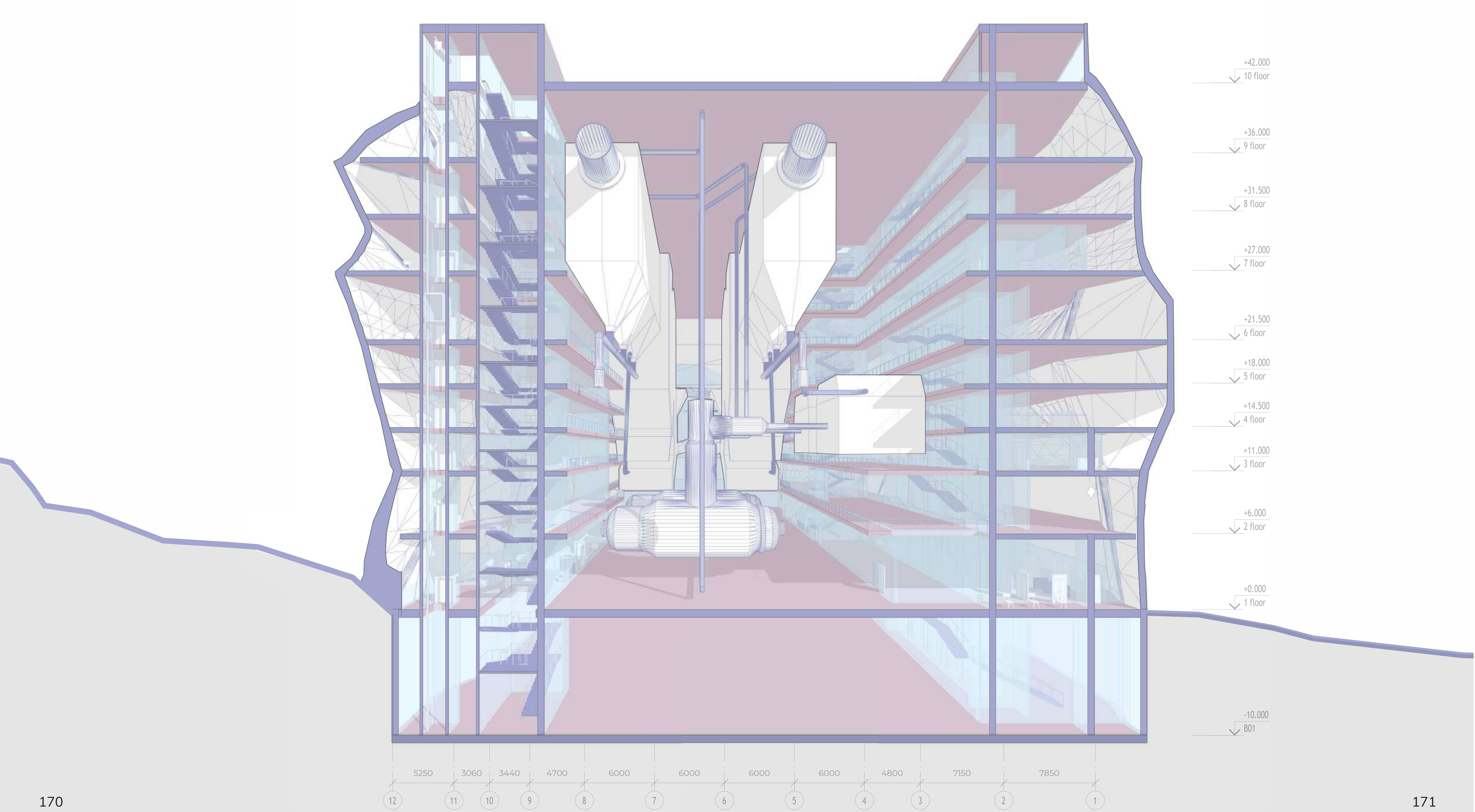
11.A — Functional purpose — Room number

7 Level Schedule		
№	Name	Area
A		
12.A	Office Room	22 m²
13.A	Office Room	34 m²
14.A	Office Room	22 m²
15.A	Office Room	23 m²
16.A	Office Room	10 m²
17.A	Office Room	7 m²
18.A	Office Room	7 m²
19.A	Stuff Room	33 m²
20.A	Stuff Room	36 m²
21.A	Stuff Room	11 m²
22.A	Stuff Room	3 m²
23.A	Stuff Room	4 m²
24.A	Stuff Room	12 m²
25.A	Stuff Room	12 m²
26.A	Stuff Room	24 m²
C		
20.C	Room	56 m²
21.C	Room	16 m²
22.C	Room	19 m²
23.C	Room	19 m²
24.C	Room	60 m²
25.C	Room	26 m²
26.C	Room	15 m²
27.C	Room	11 m²
M		
11.M	Lab Room	328 m²
12.M	Lab Room	146 m²
V		
2.V	Lab Room	34 m²
3.V	Lab Room	45 m²
4.V	Lab Room	45 m²
5.V	Lab Room	25 m²
6.V	Lab Room	38 m²
7.V	Office Room	16 m²
8.V	Office Room	15 m²
9.V	WC	23 m²

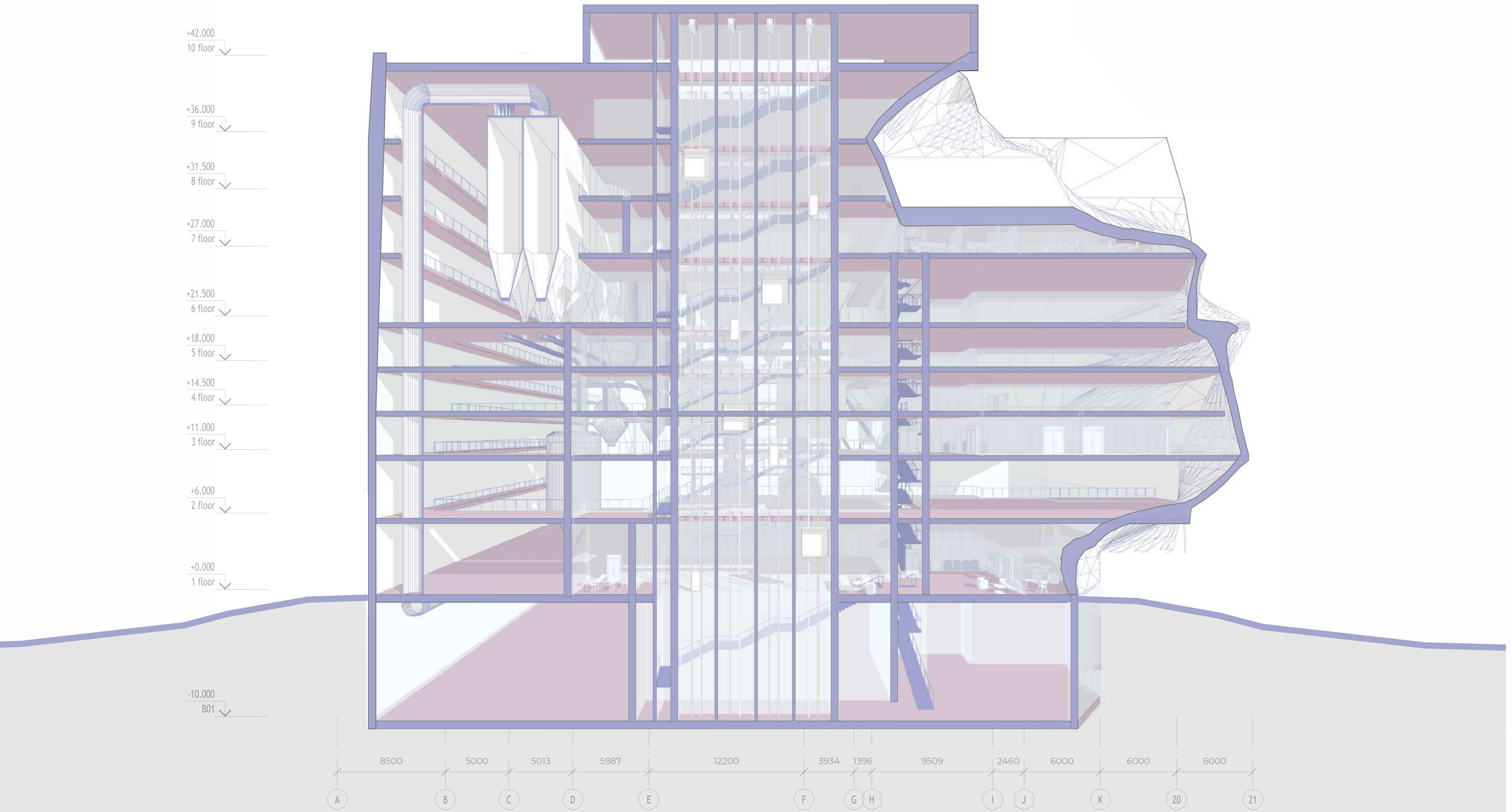
Rooftop 1:500



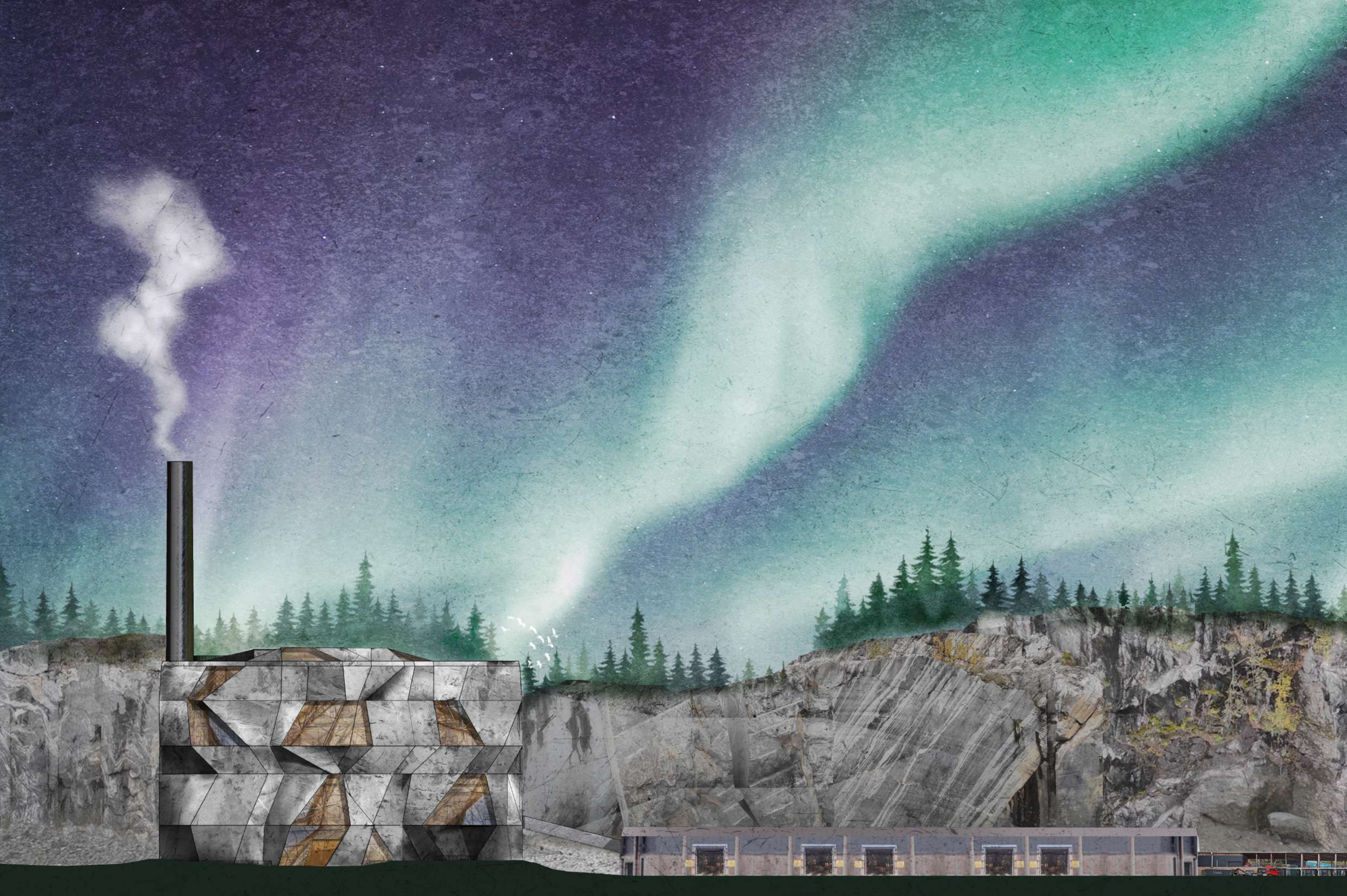
Section 1-1 1:500



Section 2-2 1:500



Main Facade 1:500



Back Facade 1:500