IN VITRO

by Jonatan Angell-Ramberg

RESEARCH & PROCESS

In Norse mythology, Sæhrímnir is the creature killed and eaten every night by the Æsir and einherjar. The cook of the gods, Andhrímnir, is responsible for the slaughter of Sæhrímnir and its preparation in the cauldron Eldhrímnir. After Sæhrímnir is eaten, the beast is brought back to life again to provide sustenance for the following day.

Sæhrímnir is attested in the Poetic Edda, compiled in the 13th century from earlier traditional material, and the Prose Edda, written in the 13th century by Snorri Sturluson.

RESEARCH

The research during the semester has consisted of a visit to NOFIMA, The Norwegian Institute for Food Research at Ås, where they are currently doing research on producing In Vitro meat, interviewing a scientist to understand how the production line works and discuss how it can be done on industrial scale.

This was followed by further reading of what written sources that was to be found, collecting statistics, history and facts about the technology as well as traditional production of meat and finally sketches of initial production line diagrams that the building was planned around.

Todays slaughterhouses are usually inaccessible to the public, offering little insight into what goes on inside their walls. This is both because of hygienic concerns and because of the mechanical process the industry has adopted as demands for mass-production of meat have risen.

The production facilities are classified as Laboratory level 2, meaning possible public contamination is not hazardous to humans, but should be avoided. The parts of the building housing the line of production should be kept separate and clean. These parts also have high demands on climate, temperature control and human access.

Growing meat in a controlled environment will allow the public to observe, experience and learn from the production process, all the while avoiding the existing problems of animal welfare in the traditional industry. Instead of closed slaughterhouses, in vitro meat production can offer the gleaming stainless-steel surfaces of a brewing facility, with cells happily growing in vats in clean labs, operated by scientists in white coats. All the while providing a sustainable source of food production.

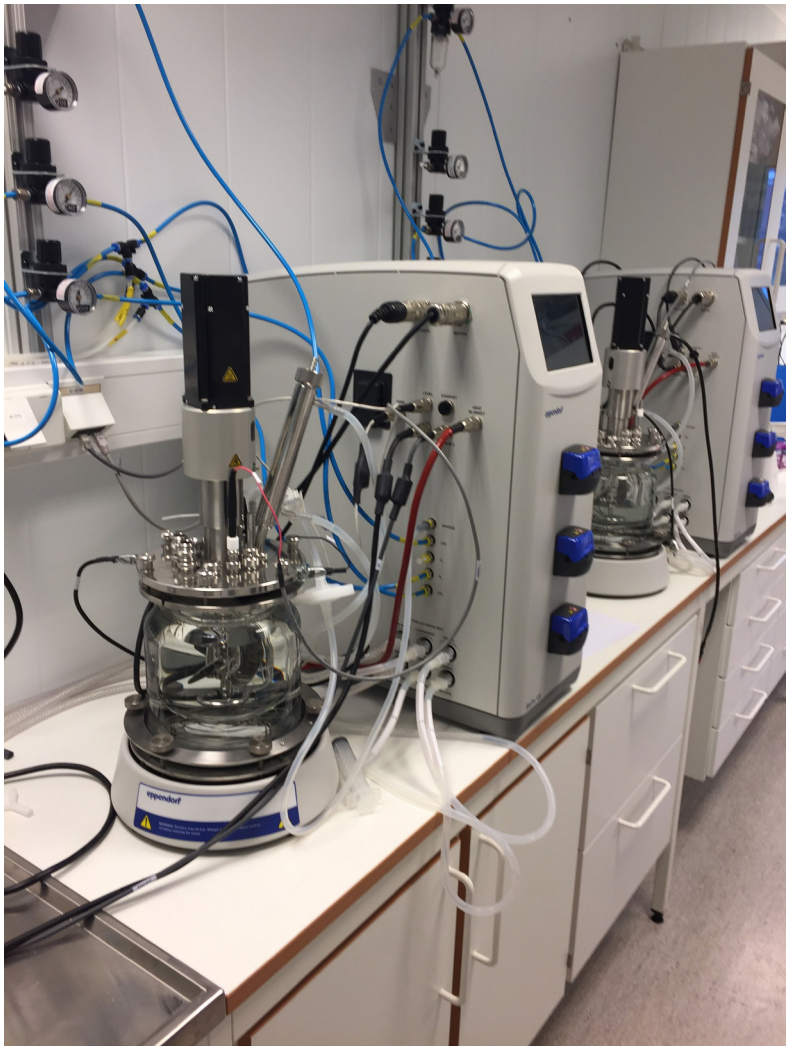
In recent years, the industry of breeding agricultural livestock for food produce has developed into a non-sustainable solution for future generations. An expanding global middle class has created an ever-increasing demand for higher yields of food produce, propelling traditional farming of livestock into the industrialized world. By 2100, the earth's population could reach 9.6 billion people, and traditional production of meat would have to nearly double to keep up with today's consumption rates.

Out of a projected record production of 262.8 million metric tons of meat globally in 2017, Norway is responsible for 350 000 metric tons, equaling roughly 67 kilograms of industrially produced meat (bred from livestock) per inhabitant in the country every year. This constitutes a growth of 34% in total meat production since 2000. In addition, Norway imported meat products worth 1.2 billion NOK, resulting in a total consumption of 76 kilograms per inhabitant. We are literally eating our own weight worth every year.

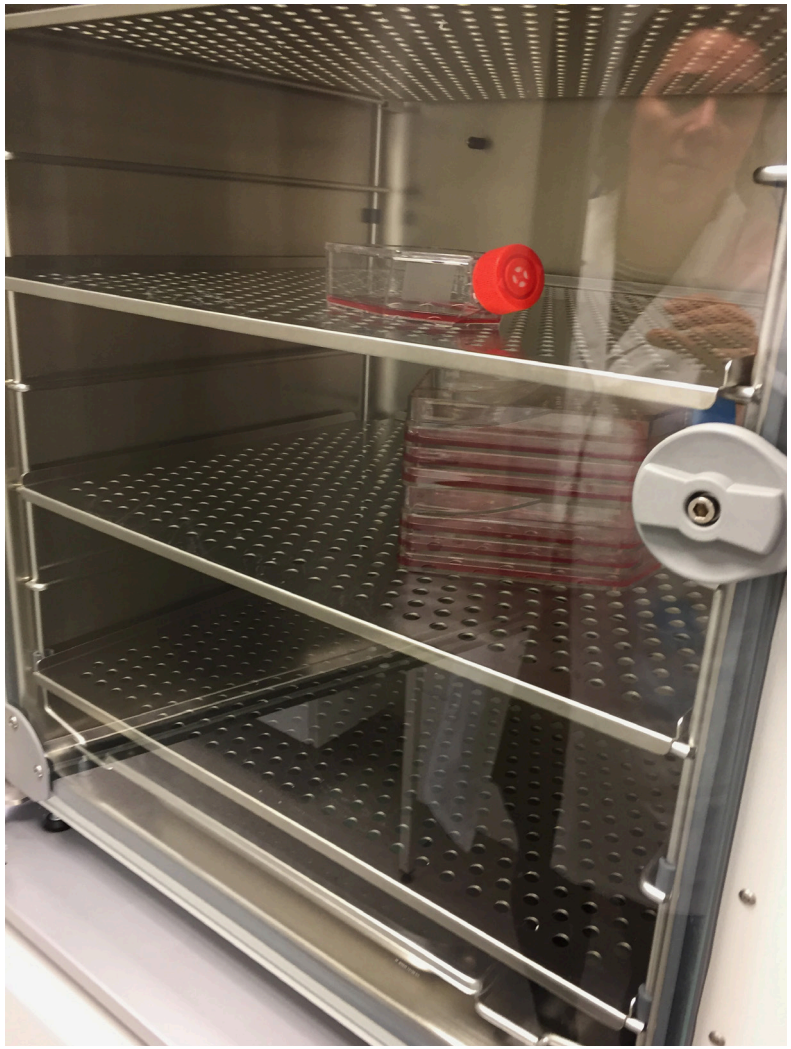
1000 to 1500 liters of water and 10 kilograms of feed concentrate is required to produce 1 kilogram of prime beef by traditional breeding, in addition to 30 m2 of land for grazing and growing feed crops. In 2017, the Norwegian livestock and fish farming industry consumed 1 990 415 tons of feed, out of which 794 171 tons were imported from developing countries.

According to the UNs Intergovernmental Panel on Climate Change, the carbon dioxide and methane emissions stemming from the livestock breeding industry alone are equivalent to the total emissions of all automotive activity (transport of people and goods) in our society. But they are still nothing compared to emissions from the industrial production of feed.

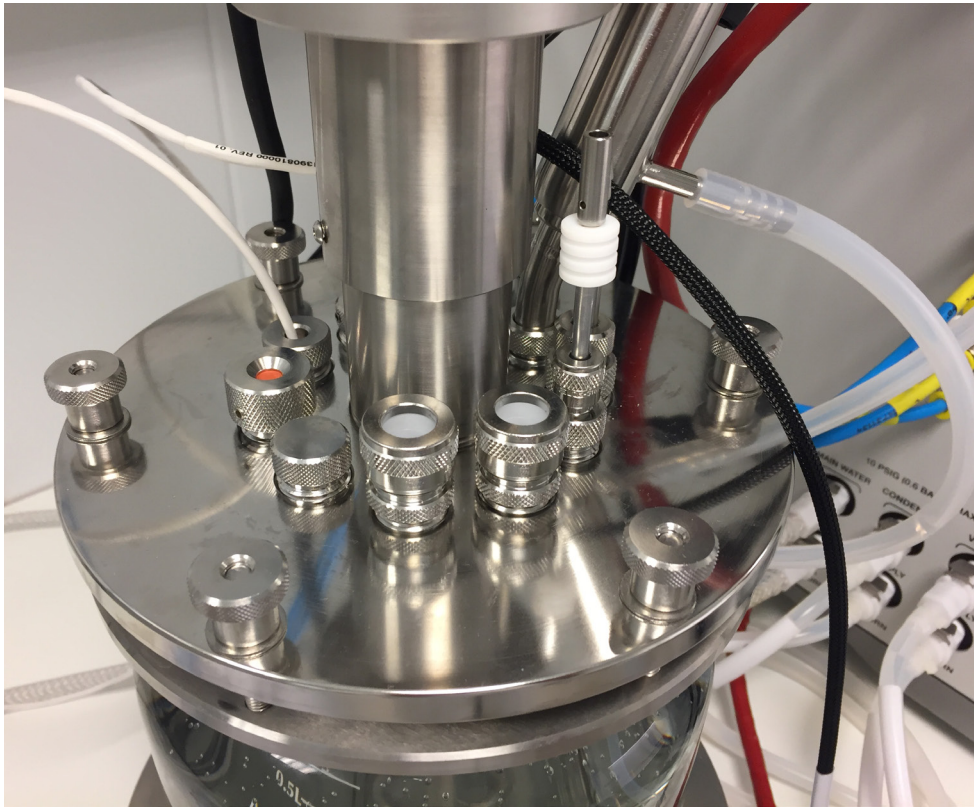
See end of document for references.

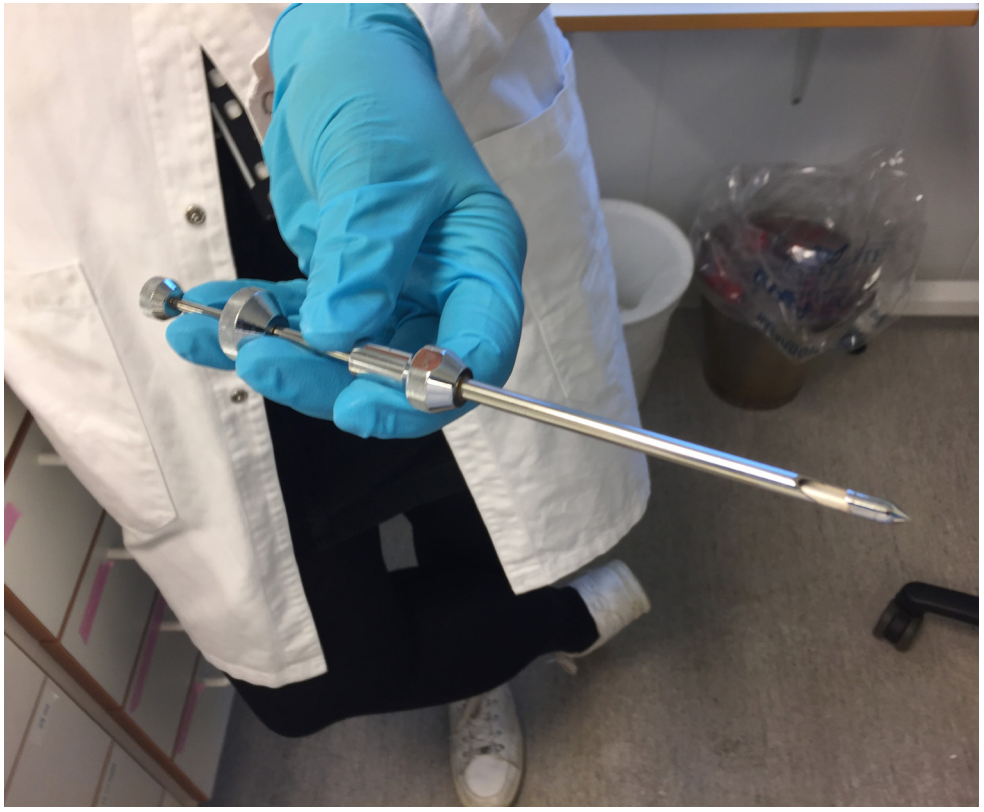


Small bioreactor for cell cultivation

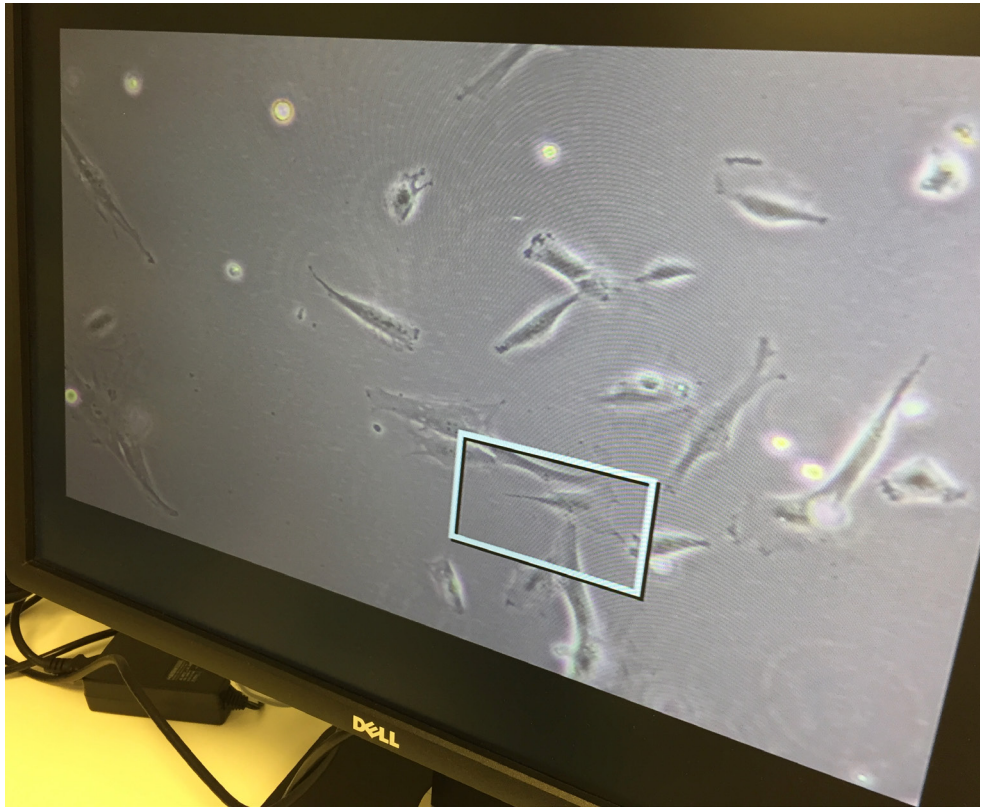

Small growth chamber for cell cultivation

Controls for gas intake

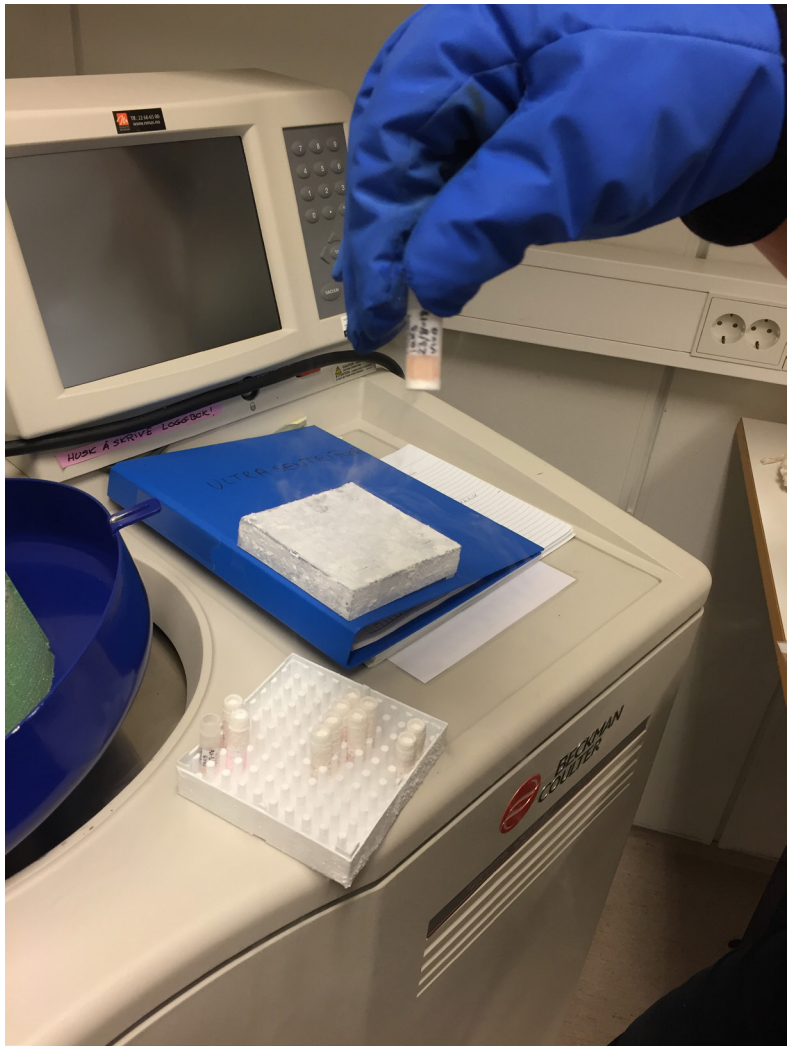

Detail of small bioreactor for cell cultivation



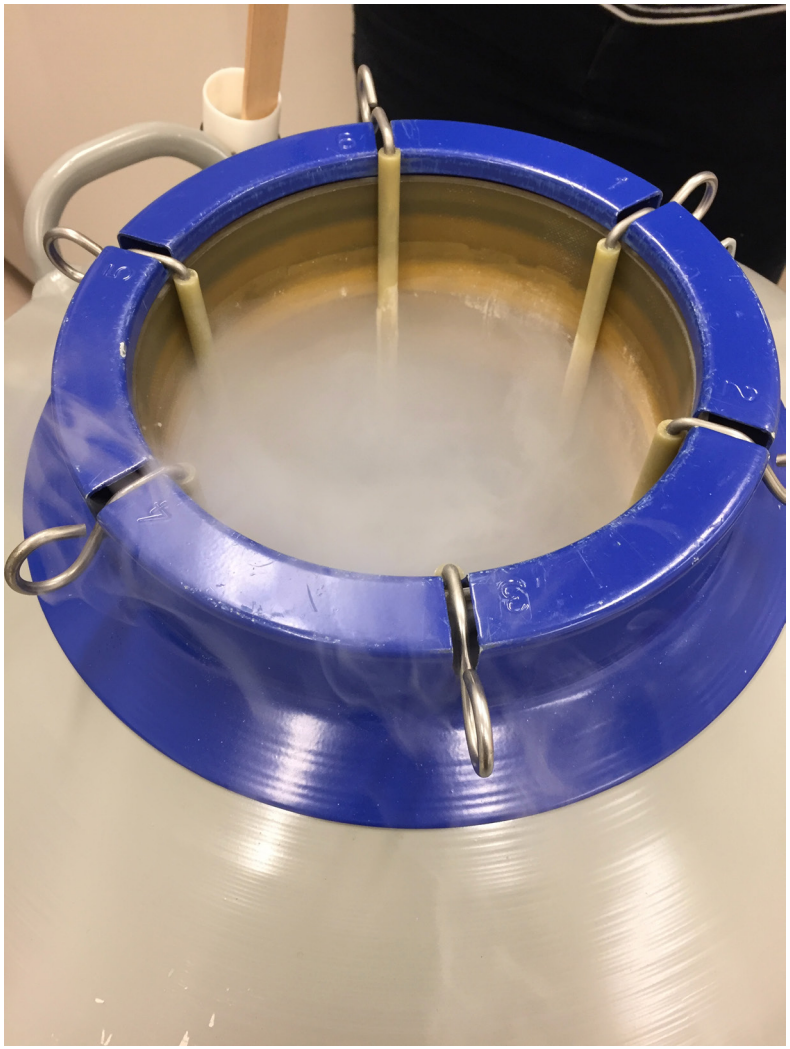
Tool for obtaining cell samples



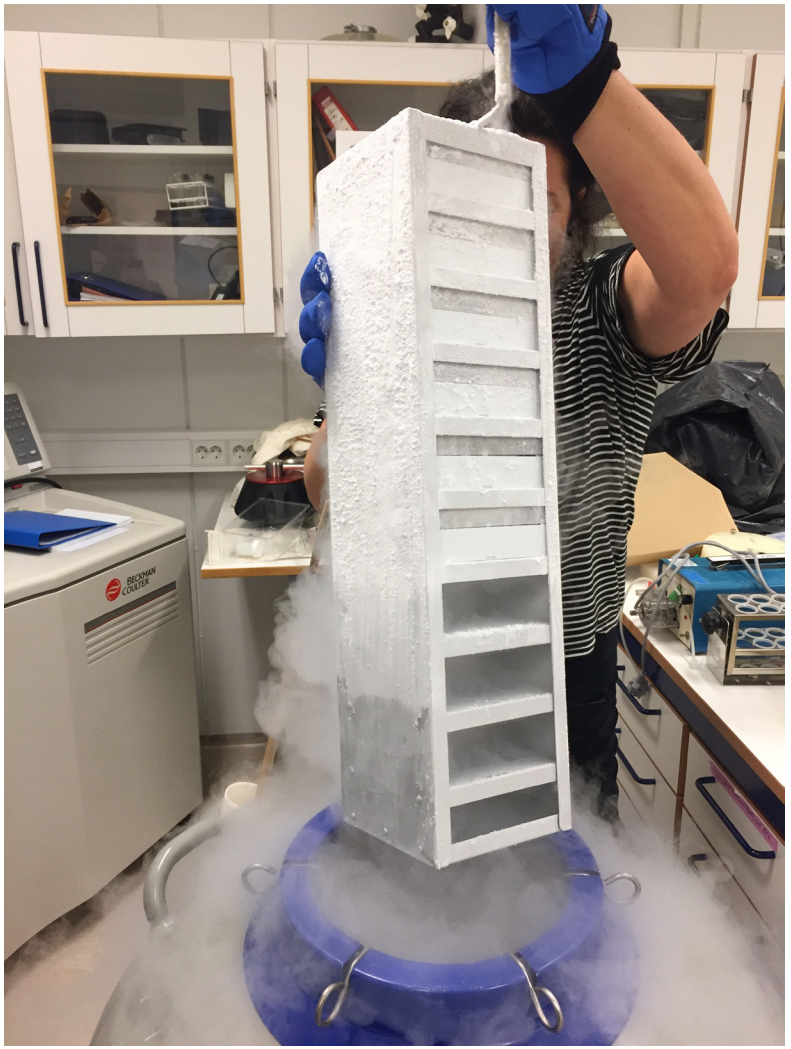
MIcroscopic view of cell proliferation



Cell sample used for starting the cultivation process



Liquid nitrogen tank for sample storage



Scaffolding holding the stored cell samples

MEAT THE FACTS

TO MAKE A HAMBURGER OF 200 GRAM YOU NEED:

3 kilograms of grain and forage, 200 liters of water for the irrigation of land and for cattle to drink, 7 m^2 for grazing and growing feed crops and 1,093 kJ of fossil energy to grow and transport feed; enough to power your microwave for 18 minutes.

MEAT CONSUMPTION

The global average for meat consumption is 42 kilograms. People in the developing world eat an average of 32 kilos of meat each year, compared to 80 kilos of meat in industrialized countries. Below the meat consumption in per capita in the year 2009, according to the United Nations:

USA: 125 KG
Kuwait: 119 KG
Spain: 97 KG
The Netherlands: 85.5 KG
China: 58.2 KG
Rwanda: 6.5 KG
India: 4.4 KG

GAS EMISSIONS

The United Nations estimates that the global greenhouse gas emissions from the total supply chain of producing livestock for meat range from 15% to 18% per year. A more in-depth report from the WorldWatch Institute indicates that this number is actually closer to 51%.

FOOD WASTE

30 to 50% of all food produced globally is never eaten, due to supply chain in efficiencies, crops left to rot in fields, consumers rejecting 'imperfect' foods or throwing away food after purchase.

ANIMALS KILLED IN THE USA

Cattle: 35,507,500
Pigs: 116,558,900
Chickens: 9,075,261,000
Layer hens: 69,683,000
Broiler chickens: 9,005,578,000
Turkeys: 271,245,000

Source: USDA statistics 2008

WATER USE

Water use for in vitro meat would be 82 to 96% lower than for conventional meat*. It takes 20 to 50 times the amount of water to produce one kilo of meat than one kilo of vegetables. It takes 20 to 50 times the amount of water to produce one kilo of meat than one kilo of vegetables.

ECOLOGICAL FOOTPRINT

Between now and 2050 global livestock production is predicated to nearly double. Studies indicate that in vitro meat would require far less energy input than beef, pork or mutton, but that it would require more energy than poultry such as ducks or chickens*. Compared to conventional meat, greenhouse gas emissions for in vitro meat would be up to 96% lower*.

* These numbers assume that cyanobacteria will be the feedstock for in vitro meat, which is not yet possible.

LAND USE

66% of agricultural land is used to grow animal feed; only 8% of agricultural land goes to food that we directly consume. 30% of ice-free land on earth is used for livestock raised for meat. In vitro meat could require only 1 to 2% of the land area used to produce the same amount of conventional meat.

CALORIE SUPPLY

The Netherlands: 1,151.4 Kcal/person/day
Kuwait: 524.6 Kcal/person/day
Spain: 936.6 Kcal/person/day
China: 618 Kcal/person/day
Rwanda: 60.5 Kcal/person/day
India: 198.4 Kcal/person/day

Source: Chartsbin.com

IN THE YEAR 2030

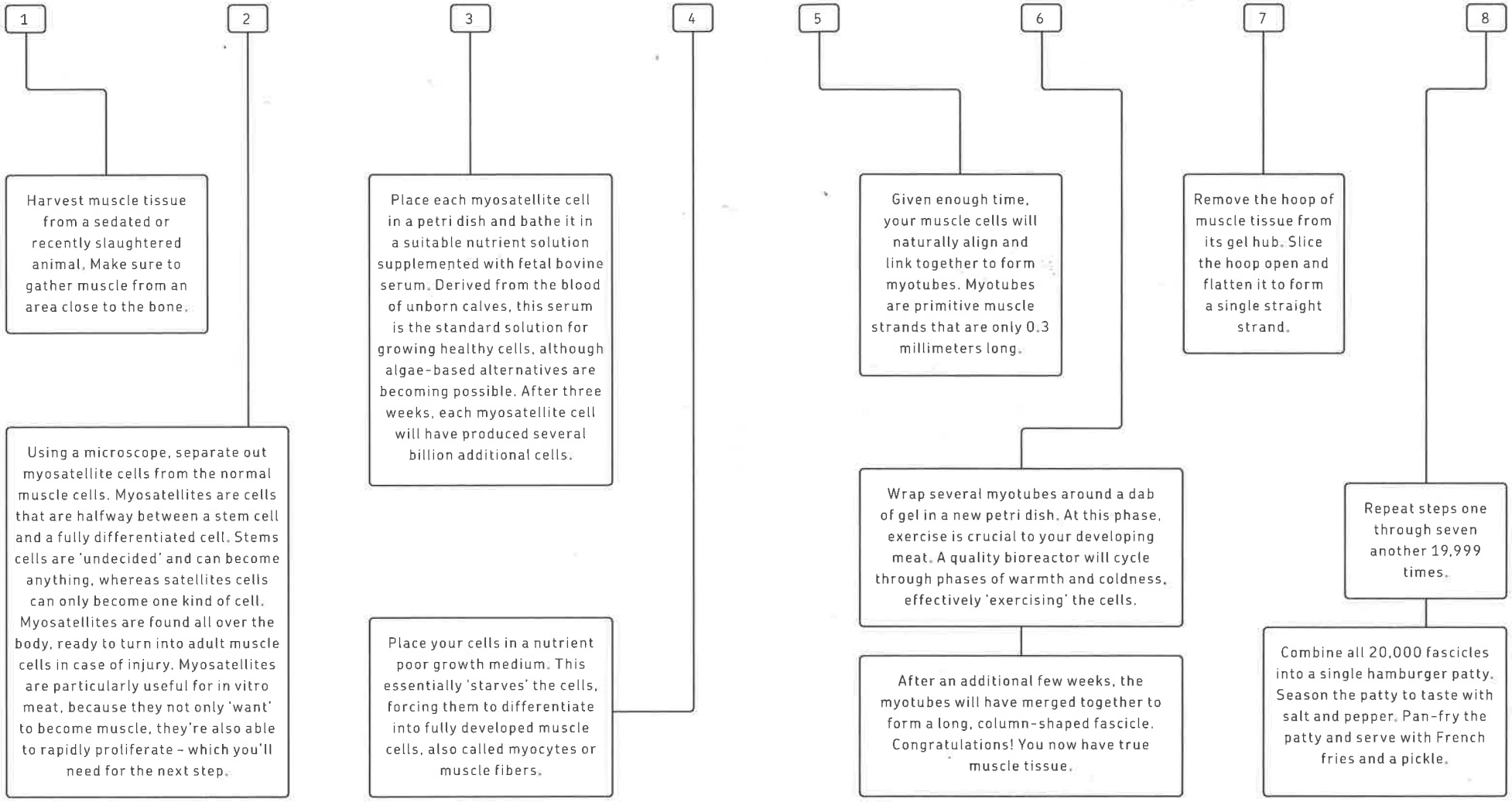
The global middle class will balloon from 1.8 billion today to a staggering 4.4 billion by 2030. In fact, we're almost talking about a tripling of the meat-eating class.

IN THE YEAR 2050

The world's population will be 9.6 billion people by 2050, compared to 7.1 billion people as of 2013. Global meat consumption may have doubled by that time, mostly as a consequence of increasing world population, but also because of increased per capita meat consumption from 2000 to 2050.

Source: The In Vitro Meat Cookbook, ISBN 978-90-6369-358-9

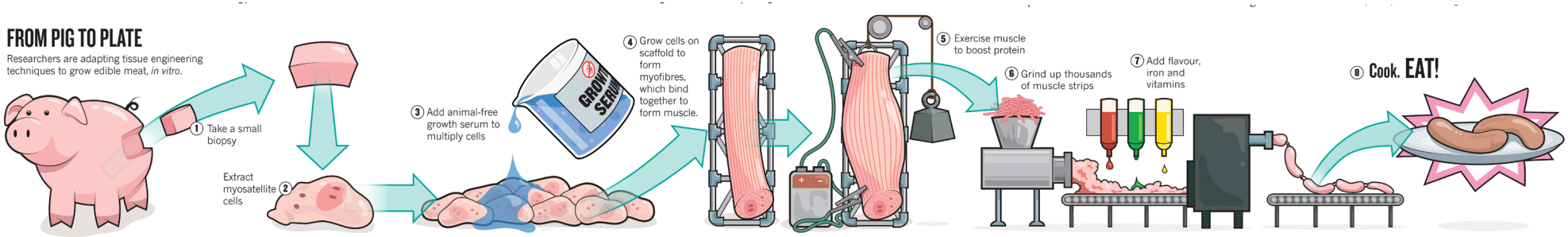
HOW TO MAKE AN IN VITRO BURGER?



Source: The In Vitro Meat Cookbook, ISBN 978-90-6369-358-9

A HISTORY OF MEAT—EATING

Source: The In Vitro Meat Cookbook, ISBN 978-90-6369-358-9



9 DECEMBER 2010 | VOL 468 | NATURE | 753

Simplified diagram of production process

Source: Nature, Issue 468, Macmillan Publishers Limited

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In-vitro meat: A solution for problems of meat production and meat consumption?[1]

Silvia Woll, Inge Böhm

Abstract

In 2013, Mark Post and his colleagues at the University of Maastricht presented the first cultured meat (in-vitro-meat) burger made from bovine stem cells. The technological innovation is intended to offer a possibility of reducing or even eliminating the negative effects of current meat production and meat consumption on humans, animals, and the environment. Large scale production, however, is not yet possible, and the question remains whether cultured meat will be able to keep what the developers promise.

The following article deals with this question, addressing the results of expert and stakeholder interviews as well as participative processes that were carried out in a project at the *Institut für Technikfolgenabschätzung und Systemanalyse* (Institute for Technology Assessment and Systems Analysis = ITAS). Among other aspects, the manufacturing process, possible impact on the environment, animals and humans, consumer acceptance, as well as the subsidy of research and development of cultured meat will be discussed.

Cultured meat presents an interesting alternative to conventional meat production, although many questions are as yet unanswered, particularly with regard to technical feasibility and ethical as well as social aspects. More research is essential; the search for a sustainable alternative to current meat production should, however, also involve other approaches such as ecological agriculture.

Keywords: cultured meat, meat consumption, food technology, world nutrition, animal ethics, sustainable nutrition

Introduction

The question of future nutrition is the focus of public discourse, particularly with regard to the prognosis of a growing world population [1]. The discussion is about how we can make our current diet sustainable. Considerations of the topic of "meat" are inevitable in this context. It is evident that today's meat production and meat consumption are having a negative impact on the environment, human health, and animal welfare, and are exacerbating the issue of world hunger. For instance, worldwide livestock farming is contributing 18% of anthropogenic emissions of greenhouse gases, mainly through CO_2 from slash-and-burn clearing of (tropical) forests for feed cultivation and grazing land, nitrous oxide from fertilizers used for feed cultivation, and methane from the digestive tracts of ruminants [2]. If global trends in the consumption of animal products continue, the global mean temperature will rise by more than 2 °C, even if emissions from non-agricultural sectors are drastically reduced [3].

A sustainable conversion of the current mass production system is not possible [2, 4–6]. It is therefore essential to consider possible alternatives to common meat production and meat consumption.

One possible technological solution could be cultured meat (in-vitro-meat) [7]. The meat we consume consists largely of animal muscle fiber. The basic idea behind cultured meat is to grow this muscle fiber in cell cultures based on muscle stem cells. This would eliminate the necessity of using enormous amounts of resources to raise animals for the purpose of producing meat (◆ Figure 1). In August 2013, the first cell-cultured hamburger made of bovine stem cells was presented at a press conference in London [8]. The burger patty had been produced by Mark Post and his colleagues at the Dutch University of Maastricht. In principle, then, the production of cultured meat for human consumption is possible.

Cultured meat is presented as an environmentally-friendly, animal-friendly, and healthier alternative to conventional meat, and thus as a plausible technological solution to the problems of current meat production and meat consumption [9, 10].

This article deals with this vision and addresses the results of expert and stakeholder interviews that were conducted as part of the project. It examines various aspects of cultured meat: the production process, the innovators' vision, the question of impact on the environment, animals, and humans, and the subsidy of research and development of cultured meat.

Citations from expert interviews are identified as such. The interviews were abbreviated with the letters A–L, the following number refers to the line number in the transcript.

Interview A: Representative of an ecological agriculture association, June 13, 2016
Interview B: Representative of an animal rights organization, June 15, 2016
Interview C: Cultured meat researcher, innovator, June 15, 2016
Interview D: Representative of agricultural policy, June 16, 2016
Interview E: Representative of an environmental protection organization, June 22, 2016
Interview G: Representative of the food industry, July 13, 2016
Interview H: Food technician, June 28, 2016
Interview I: Cultured meat researcher, June 28, 2016
Interview J: Researcher in the field of tissue engineering, June 30, 2016
Interview K: Representative of a conventional grower's association, July 13, 2016
Interview L: Representatives of system catering, July 19, 2016

Box 1: **Expert interviews**

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Project *"Visionen von In-vitro-Fleisch"* (visions of cultured meat)

The project titled *"Visionen von In-vitro-Fleisch (VIF) – Analyse der technischen und gesamtgesellschaftlichen Aspekte und Visionen von In-vitro-Fleisch"* (visions of cultured meat (VIF) – analysis of technical and social aspects and visions of cultured meat) has been ongoing since October 2015 at the *Institut für Technikfolgenabschätzung und Systemanalyse* (Institute for Technology Assessment and Systems Analysis = ITAS) at the *Karlsruhe*

[1] The article is based on a talk given at the *"LGL Gespräche zu Lebensmittelsicherheit und Verbraucherschutz"* (LGL meeting on food safety and consumer protection) on July 10, 2017 at the *Bayerische Landesamt für Gesundheit und Lebensmittelsicherheit* (Bavarian State Office for Health and Food Safety) in Oberschleißheim/Germany.

Institut für Technologie (KIT) and subsidized by the German *Bundesministerium für Bildung und Forschung* (Federal Ministry of Education and Research = BMBF).

The project is dedicated to answering the scientific, technological, social, cultural, and political questions regarding the guiding principles and visions of current research into cultured meat. The results are intended to provide guidance for research policy and governance[2].

Various methods were used to examine the research question: a literature analysis was used to determine the current state of research, as well as opportunities, risks, and challenges. These results along with further information were published on a German-language home page, which is to serve as an information platform for citizens. Also, twelve expert and stakeholder interviews as well as participative processes with citizens were conducted (◆ Box 1), in order to probe their ideas about cultured meat. This is followed by an analysis of the ethical aspects of the guiding principles and visions of cultured meat based on the previous tasks. At the end of the project, some research policy options for national research policy are presented. The results of the empirical research elements are discussed in section ▮▮▶ "Visions of cultured meat".

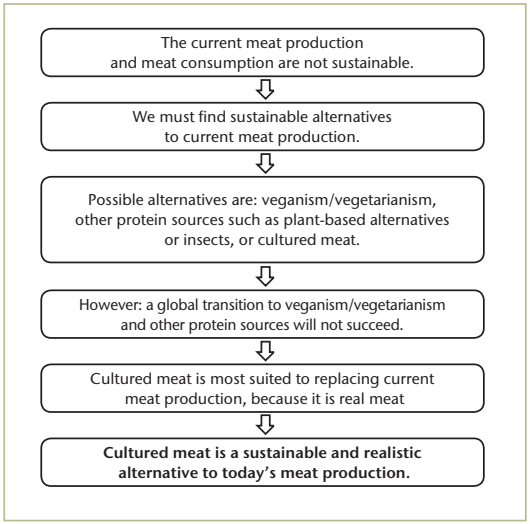

Fig. 2: **Reconstruction of innovators' argumentation** [own illustration]

Method

Over the course of the project, expert and stakeholder interviews were conducted, as well as focus groups and a Citizens' Jury[3]. This article is based on the results of the expert and stakeholder interviews.

After some research in publications and on relevant web sites, a selection was made of five experts from the fields of tissue engineering (medical application), cultured meat research and food and environmental sciences, as well as seven stakeholders from the realms of environmental and animal protection, politics, conventional meat production, ecological associations, and system catering (◆ Box 1). Qualitative, semi-standardized individual interviews (45–75 min.) were conducted from June to July 2016. For each interview partner, personalized questions were added to a standardized guideline, the experts were asked five additional questions on technical aspects. The questions referred to the previously prepared innovators' visions regarding cultured meat, to opportunities, risks, and challenges, to the future of a world with cultured meat for animals, agriculture, and society, to environmental impact, the cultural significance of meat, to changes in the relationship between humans and animals potentially caused by cultured meat, and to the (financial and ideological) support of cultured meat research. The responses were evaluated using a computer software.

Visions of the innovators

„If you want to solve the meat problem, you need to be able to produce meat." [C369f.]

The innovators, meaning those who are researching cultured meat or support such research, focus on the claim that cultured meat is a plau-

[2] Governance describes the control or regulation of processes, in this particular case of cultured meat the way policy makers handle the new technology, particularly with regard to research (subsidy), possible market entry, etc.

[3] The Citizens' Jury is a participative process. Citizens are invited to discuss the topic at hand with experts. At the end of a Citizens' Jury, a citizen's report or position paper is prepared. The Citizens' Jury in the project was conducted with participants (aged 18–25 years), in order to focus on the attitudes of the generation that will potentially be most affected by the impact of cultured meat.

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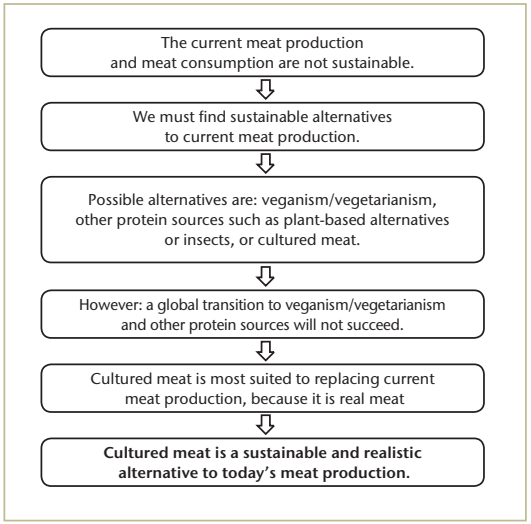

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sible technological solution to the current problems of today's meat production and meat consumption [9, 10]. The innovators' argumentation can be reconstructed as shown in ◆ Figure 2.

This shows clearly that the innovators consider cultured meat to be a feasible and sustainable solution to the current problems of today's meat production. They claim that cultured meat is more environmentally and animal friendly, healthier, and safer (◆ Figure 2). Some of these aspects will be addressed in the following.

Environmental friendliness

The innovators present cultured meat as an environmentally friendly alternative. Their statements are mainly supported by a life cycle analysis, which arrives at the supposed result that the production of cultured meat would consume less land and water and emit fewer greenhouse gases and pollutants than conventional meat production [17]. However, there are other life cycle analyses that qualify those results [18]. This is mostly because the studies are premised on different basic assumptions, for example regarding the resources used. These different assumptions and results are owed to the fact that there is as yet no large-scale production system for cultured meat which the analyses could reference, so they describe not so much the actual status as possible future scenarios [18].
One of the interview partners expresses criticism and emphasizes that he sees cultured meat as a potential solution for more sustainability and environmental friendliness, but that he cannot make any certain statements in this regard as long as there is not yet a marketable product [I317, 322]. Another interview partner, on the other hand, ensures that the impact on land, water, and climate change will be virtually eliminated compared to conventional meat production, and that energy consumption as well would not be higher than it is currently [C460]. Another interview partner says he cannot imagine that cultured meat could result in sustainable nutrition or that it would be more resource-friendly [J251, 293].
Beyond that, the ecological advantages vary greatly depending on the type of meat. The existing studies merely allow for the conclusion that cultured meat from bovine cells *could* present an environmentally-friendly alternative to beef. It cannot be concluded from the studies that cultured meat is more environmentally friendly than perhaps poultry or pork. The statement that cultured meat is more environmentally-friendly than conventional meet can thus not safely be made based on the available studies. The anticipatory studies could, however, serve as indications of what aspects will be essential in the development of cultured meat in order to in fact create a more environmentally-friendly product.

Animal welfare

The advantages of cultured meat in terms of animal ethics include the reduction of the number of animals needed for meat production. The literature on the subject formulates the vision that a single animal might be enough to satisfy the worldwide need for meat [9]. Though this might be an exaggeration, it is conceivable that the reduced number of animals could make factory farming obsolete, resulting in better living conditions for the few animals still needed.
Another argument is the fact that no animals have to be killed to obtain stem cells. It is not clear, however, how painful a muscle biopsy is and whether animals would stay alive but be subjected permanently to cruelty. The prophesied "liberation of animals" is also not yet feasible because of the use of other animal products, mainly the fetal calf serum used as a growth medium. Other components of the production process also contain animal products, such as growth factors and the materials for the matrices [I, J]. The innovators are striving to replace particularly the fetal calf serum with alternatives (e.g. algae, yeast) [C, H].

Representatives from the field of critical animal studies express concerns that cultured meat will serve to further cement the central role of meat in human nutrition. The meat paradigm, the social matter-of-causes and normality of consuming meat would remain. Veganism as an attitude opposes the meat paradigm and is an expression of unease about eating animal products – an unease that can be the driver for a radical change. Cultured meat would alleviate this feeling of unease: animals would continue to exist only as a means to an end [19, 20]. One of the interviewed stakeholders takes a similar view, stating that "*cultured meat production would further accelerate the already progressing estrangement of consumers from animal production*" [E69].

Health and safety

Cultured meat is also presented as being healthier, because it is produced in the laboratory under controlled conditions. There is no factory farming and no necessity for antibiotics [21]. Yet, antibiotics were used during the production of the first cultured burger, because cell cultures do not have an immune system [21]. Post assumes that antibiotics will no longer be needed once large-scale production in sterile systems has become possible [14, 21]. It remains unclear, however, if and to what degree antibiotics are necessary for cell cultures. This is corroborated by the assessment of another interviewed expert: "*[…] it is already safe, with the right cells and the right quality standards. And it will probably be healthy as well, as we will generally know what is really in it.*" [J269, see also H543]
Since the production of cultured meat requires little or no contact with animals, the risk of zoonosis is reduced. Zoonosis is the spread of diseases that can be passed from animal to human and from human to animal. However, fetal calf serum and other animal components can harbor communicable diseases [22]. A non-animal alternative is therefore the desirable solution.
Many studies confirm the connection between excessive meat consumption and obesity, cardio-vascular disease, hypertension, and type 2 diabetes mellitus [23]. Here as well, it is not clear if and to what degree such health risks would also result from excessive consumption of cultured meat.
Furthermore, cultured meat could become a functional food, meaning a food that is enriched with nutrients like vitamins or n-3 fatty acids in order to achieve a positive effect on human health [21]. However, the health effects ascribed to functional foods are not widely scientifically proven [24].

Visions of cultured meat

Cultured meat as a technology is still in its infancy, because large-scale production is not yet possible. At the moment, cultured meat lives on promises and future projections, also called visions. Visions play an important role in the examination of the interaction of social and technological change. This is why the project "*Visionen von In-vitro-Fleisch*" (visions of cultured meat) deals with these visions. The following is an introduction of some of the visions found in the literature and derived from the expert and stakeholder interviews. They are not necessarily only visions of cultured meat per se, but also visions of the future of meat or the future of nutrition in general.
Interviews were conducted with experts and stakeholders primarily from the German-speaking region with different professional backgrounds who are involved in the innovation of cultured meat or will probably have some contact with it in the future. The interview partners (◆ Box 1) from the realms of science, society, and politics were confronted with the innovators' argumentation.

The innovators' vision of a better world with cultured meat was shared by some of the interview partners. Some think that cultured meat could be an improvement on the original without the negative effects. Others believe that cultured meat could be a step toward a society without animal exploitation, because it stimulates reflection on meat consumption. Cultured meat should thus be supported for pragmatic reasons: "*I think cultured meat will be an interim solution. Consumers have to ask themselves: do I really have to kill animals to be able to eat meat? The answer is no. The task of cultured meat will be to achieve this and thereby reduce the consumption of conventional meat. People will then realize that plant-based alternatives are better than cultured meat.*" [B196]
This view is also found with Van Der Weele and Driessen: Cultured meat could be an instrument of "*techno-moral change*", "*a chance to change our thinking*" [25].
There could also be a restructuring of agriculture that would lead to more appreciation for farmers and animals and thereby drive back factory farming. To make that happen, it is crucial to start a dialogue with farmers about cultured meat and make them familiar with this innovation. Cultured meat could, according to the statement of one interview partner, be a support to farmers who do not engage in organic animal farming for economic reasons. Cultured meat could enable them to compete with factory farming [I254].

Other interview partners questioned the vision of cultured meat. They present a different, preferable solution for the problems of current meat production and meat consumption, an approach that they also consider more realistic: the reduction of meat consumption by half, and organic animal farming (▮▮▶ following section). Cultured meat, by contrast, would further advance the estrangement of consumers from animal products. Meat production would become even more industrialized and thus continue to increase meat consumption. Respect for meat and animals could be lost even more than it has been already. The removal of animal farming from agriculture would also destroy the natural cycle that is essential for sustainable agriculture [A, B, D, E, K].
Some interview partners do not see meat production and consumption as a problem, but still think cultured meat could be a product for people who still eat meat, but have a guilty conscience about it:
"*Ultimately, cultured meat is normal meat without the animal welfare discussion*" [K42].

Future of agriculture: Organic animal farming

Representatives of environmental organizations and organic farming associations as well as politics present an alternative approach to solving the problems of current meat production and meat consumption: the reduction of meat consumption by half and meat produced through organic animal farming are seen as the most obvious and most realistic solution for the current problems of meat production [A, D, E]. This solution is supported in the climate protection plan 2050 of the German civil society as part of the climate

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To date, there is no process for proliferating not just muscle cells but also fat cells, which are particularly relevant for taste. It is also not yet possible to produce larger pieces of meat such as steaks.

conference in Paris in 2015 by numerous non-government organizations [26].
This approach contradicts the innovators' argumentation which assumes that meat consumption will continue to rise and a reduction of it will not be realistically feasible, because people like to eat meat too much. The only thing to replace meat, they say, is "real meat" – so cultured meat is the only realistic solution [C].

Acceptance and potential consumers

According to one of the innovators and a spokesperson of an animal rights organization, cultured meat must be perceived as being original, not just a copy, in order to succeed [B140, C231]. Cultured meat may under no circumstances be associated with genetically modified foods or foods from the USA, as these are viewed with skepticism by German consumers [B139]. Proponents should focus on the advantages to human health and food safety, e.g. better nutritional composition, as one animal rights representative and one food scientist suggest [B47, H296, H317]. The innovator assumes that cultured meat could alleviate consumer concern about meat contamination, for instance with zoonosis like BSE [C193, C297]. However, the long-term health effects of cultured meat have not yet been sufficiently studied and present an ethical-moral problem, according to a politician and a spokesperson of a conventional farming association [D20, K237].
Several studies emphasize the relevance of more research, both for acceptance of cultured meat as well as acceptance of aspects that are important to consumers like safety, health, and environmental impact [27, 28]. Acceptance cannot generally be taken for granted, particularly due to consumer insecurity about risks, the assumption of unnaturalness, and long-term effects (concerning a lasting and comprehensive transition from conventional meat production and consumption to cultured meat) [29]. Hocquette et al. [30] go so far as to conclude that cultured meat will not be accepted by the majority of consumers.

Cultured meat as an everyday product

On the one hand, cultured meat could become a product for indifferent, uninformed consumers, who do not care about enjoyment and culture [A300], the origin of the animals, and "agrarian culture" [E260]. This is closely connected with the question of naturalness and artificiality of cultured meat (▮▮▮ section "Naturalness and artificiality").
On the other hand, cultured meat could become a product for ethically aware, educated wealthy people and those interested in innovative products [B150]. It should therefore first be an exclusive product for an elite group of persons [H102, H487], before it can become an affordable mass product in the long term. The innovator also assumes that cultured meat will initially be a premium product [C514, C546] before gaining a significant market share as an everyday product: a product for *"mass consumption"* [C242, G95, I172].
If, however, cultured meat remained an exclusive product for the rich or turned out to not taste good, it would not solve the meat problem [C317, I] – particularly since a study has shown that consumers are not willing to accept inferior taste in exchange for a healthier product [31]. It is therefore crucial that cultured meat will be able to compete with conventional meat in terms of price and taste [H110, H92, H546]. This view is also reflected in various studies: cultured meat will have to satisfy consumer expectations, especially taste and price will have to be comparable with those of conventional meat, but aspects of food safety are also emphasized [27–29, 32].
The representative of an environmental protection organization describes two possible economic scenarios: when cultured meat hits the market, it could either result in reduced animal farming and "real" meat would become a premium product, or it could spark a price war between factory farming and cultured meat [E126]. In both cases, cultured meat will be viewed as a product for everyday consumption.
The basic assumption of a representative of the food industry is that conventional meat will become significantly more expensive in the future and therefore become something special [G337]. In this case, cultured meat would be the more affordable alternative [G44, G47]. Conventional meat would then be a premium product – which would be a positive development in the view of a cultured meat researcher, because it would then once again be appreciated [I170].

Naturalness and artificiality

"Is cultured meat equal to meat or rather something artificial?" [G64]
The representatives of an organic and a conventional growers' association are of the opinion that the production of cultured meat is not a natural, normal process. It is viewed as *"small-scale cloning"* [A326, K62]. In their view, the enjoyment of eating different meat types (e.g. from different species of cattle) cannot be imitated with artificial meat [D41, A301, K317]. Also, the artificial product cultured meat does not appear to be quite suitable for the archaic charcoal grills, says the representative of the food industry [G95]. Conventional meat is thus implicitly perceived as a natural product, whereas cultured meat is rejected as an artificial product.
The literature also reveals that the perceived unnaturalness of cultured meat deters potential consumers [29, 32]. A food scientist remarks, however, that current meat production is a long way from being natural [H298]. If people eat meat from factory farming, then cultured meat doesn't appear all that bad, says a cultured meat researcher [I286].
"If you put it on the table in front of me and I had no information about it, I would not eat it" [K297ff].
The representative of a conventional grower's association and a politician emphasize the importance of safety and transparency. Consumer safety must be proven in long-term studies. Consumers must be informed about what cultured meat is. Before it can be accepted, a lot of educating must be done. The demand for more (long term) studies also appears in the literature (▮▮▮ section "Animal welfare").
The representative of the food industry believes that consumers have reservations about artificial foods: *"Eating is one of the most natural things in the world. The trend goes first towards naturalness"* [G261].
To successfully establish cultured meat on the market, then, the innovators must resolve the conflict between artificiality and naturalness [G140]. Communication is essential: the consumer must be convinced of the additional advantages of the new product. As long as conventional meat is still affordable, it will be difficult to justify the necessity for cultured meat [G151]. Cultured meat should therefore be positioned as a product that is artificial, but has an ethical-moral added value because it is more sustainable. This would be a novelty and would stimulate sales [G267], as a study shows that consumers are increasingly willing to spend more money for products made with acceptable processes such as better treatment of farm animals [33]. Another novelty would be to change the composition of the product and to produce for instance crocodile-kangaroo meat [H56, H105] or meat of extinct animals [B46]. Ultimately, however, the representative of the food industry believes, taste will be more important than health or ethical considerations: *"I think the most important thing is that consumers recognize a benefit: why should they buy this and not something else? This benefit must be more than just a lower price. And an absolutely necessary condition is convincing consumers in terms of taste. They will only reach for an alternative if that alternative is better or at least offers a different benefit than the previous product was able to offer"* [G323].

Transparent subsidy and development

For the formulation of research policy options for the BMBF, it is particularly relevant if and how the research and development of cultured meat should be subsidized by the state. Some of the interview partners agree that cultured meat research and production should be subsidized by the state [B, C, I].
"Although the subsidy should focus more on plant-based alternatives, society has a duty to support cultured meat, because it is more sustainable, because normal meat is already heavily subsidized even though it is less sustainable, more costly to produce, and more harmful to the animals. I would support this for economic as well as ethical reasons." [B35]
Subsidies should be granted, because the basic problem is a social one and the government could influence the consumer [C40]. The neutral position that would go hand in hand with state subsidy is also emphasized:
"I think that particularly the government and industry should subsidize this. I don't think it's the place of NGOs, because that would again give the whole thing an ideological character, which it should not have" [L36].

Some interview partners do oppose state subsidy: *"The question is whether the state should spend its money on this. I would be very cautious about that. This must develop out of the economy or the participants; I am skeptical about the state getting*

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involved" [K29]. This rejection is justified by the fact that other areas need subsidies much more urgently: *"It cannot be accepted to spend funds on such a future technology when we need more funds for solving current problems"* [E23].

Conclusion

Cultured meat appears to be an interesting alternative to conventional meat production. There are, however, many open questions, both regarding technical feasibility and ethical and social aspects – whether cultured meat can keep its promises remains doubtful. More basic research is necessary, not only of the production system, but also with regard to potentials and risks. Involvement of societal players and citizens will be absolutely necessary to create acceptance through transparency.

In principle, the search for a sustainable alternative to meat production should focus not only on the technological innovation of cultured meat, but should also pursue other approaches, such as the reduction of meat consumption, abolishment of factory farming and the ecological conversion of agriculture, the support of plant-based alternatives and other protein sources (e.g. insects, algae) etc. The great challenge of a sustainable future food supply can only be met by pursuing various sustainable solutions that become truly effective only when combined. Cultured meat represents one of many possibilities for solving these problems.

Conflict of Interest
The authors declare no conflict of interest.

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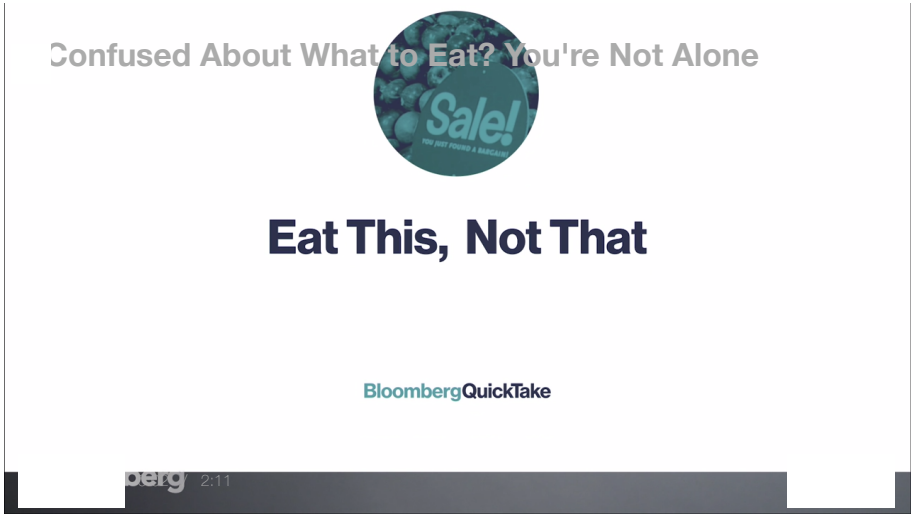
Food

Meat Has a Replacement But No One Knows What to Call It

Battle lines blur over labeling lab-grown substitutes as Big Meat invests in the startups making them.

By Deena Shanker, Lydia Mulvany, and Teaganne Finn
8 November 2018, 10:00 CET



Confused About What to Eat? You're Not Alone

Lab-grown. Cell-based. Clean. In vitro. Cultured. Fake. Artificial. Synthetic. Meat 2.0. These are all terms that refer to the same kind of food, one that's not even on the market yet.

But the companies making it have already raised hundreds of millions of dollars worth of investor cash and earned the close attention of U.S. regulators. Rather than methodically slaughtering animals, this industry uses science to grow what it claims is essentially the same thing as traditional meat. Given the planetary damage wrought by mass-market animal husbandry, such cellular agriculture is seen as the future of meat.

But what to name it, and getting people to eat it, is another matter altogether.

Crucial to public acceptance of any consumer product, of course, is branding. But no one can agree what to call this stuff. Originally, there was a push for the label "clean meat." This was seen as a better alternative to the more clinical "lab-grown meat," said Bruce Friedrich, co-founder and executive director of the Good Food Institute, which lobbies for these new products.

But then the traditional meat industry weighed in, saying the cellular version shouldn't be called meat at all. "We're using the term 'lab-produced cultured protein,'" said Dan Kovich, deputy director of science and technology at the National Pork Producers Council. Other groups representing meat producers, including the North American Meat Institute, the National Cattlemen's Beef Association and the National Chicken Council, also objected to the "clean meat" label.

Photographer: Victor Moriyama/Bloomberg

The U.S. meat industry represents almost $200 billion in sales, according to one industry estimate, and spends millions of dollars annually to keep Washington in its corner. Investing in this new sector could be giving it more leverage in the debate over what to call the product and how it should be labeled for consumers.

Now, other terms seem to be gaining traction, both in the U.S. and abroad. Mark Post, co-founder of Dutch company Mosa Meats, told *AgFunder* in July that he doesn't use the "clean meat" label. "It can't translate into Dutch, French or German, and it kind of suggests that current meat is dirty," he said. A spokeswoman for the company told Bloomberg the term is "too antagonistic to industry."

Meat producers have said "clean meat" is offensive, said Sarah Lucas, head of strategy & communications for Mosa Meat. Investors, meanwhile, "haven't particularly said that they

would like us to use one term over another," she said.

In August, cellular agriculture company Memphis Meats (which counts among its financial backers meat giants Cargill and Tyson) used the term "cell-based" in a letter sent to the White House. The co-signer of the letter was none other the Meat Institute, the meat industry's main lobbying arm.

"We thought it was reasonable and far better than 'clean meat,' which is inappropriate and inaccurate," Eric Mittenthal of the Meat Institute told Bloomberg. Cell-based is "clear, factual and inclusive," Eric Schulze, vice president of product and regulation at Memphis Meats, told federal regulators last month during a two-day meeting in Washington. "It is distinct from plant-based proteins and animal-based meats. It differentiates our products while also clearly conveying that cell-based meat is, in fact, real meat."

JUST Inc., which said it may make its first commercial sale of a cultured chicken product this year, is in the "cultured" camp when it comes to names. Labels should include "a statement of identity which indicates that the product is cultured, as well as the species from which the product is derived," Peter Licari, chief technology officer, said at the meeting.

JUST "Chicken Bites." *Source: JUST*

Friedrich's opposition notwithstanding, Good Food Institute Policy Director Jessica Almy told Bloomberg her organization has rethought its position on how to talk about the products, too.

"It feels like 'clean meat' doesn't resonate with everybody right now," she said. Others see this budding consensus in a more cynical light.

"I think the meat industry has done something very clever," said Sarah Sorscher, deputy director of regulatory affairs at the Center for Science in the Public Interest (CSPI), a consumer advocacy group. By investing in companies such as Memphis Meats, it now has a voice from within its own aspiring competition. "They're not up against the meat industry," she said of meat substitute companies. "They are the meat industry.

At the meeting last month, officials of the Food and Drug Administration and the U.S. Department of Agriculture listened as industry representatives chewed over the labeling issue. It's important to protect consumers with transparent labeling, Almy testified, adding that there should be some flexibility in labeling requirements. Meanwhile, Danni Beer of the U.S. Cattlemen's Association said new processes should be spelled out explicitly.

Brian Spears of New Age Meats argued that it would be dishonest to label meat substitutes as anything other than meat, since it's really the same thing.

"This conversation is feeling more and more premature," said Tyler Lobdell, a food-law fellow at the Animal Legal Defense Fund, who told Bloomberg the group seeks to ensure that the meat industry doesn't hamper consumer options. "We just don't know what the product looks like, so it's hard to say what's misleading when there are no products available."

Barbara Kowalcyk, a professor in the department of food science and technology at Ohio State University, said there are still too many unknowns about the products and how they're made–including food safety risks–for regulators to make any decisions.

"When I asked questions, there weren't good responses, and that suggests we're not ready for prime time," she said. "Before we put it in the marketplace, we need to know the answers."

Photographer: Dhiraj Singh/Bloomberg

One look at the American food landscape reveals that organic sales are outpacing everything else at the grocery store. Restaurant menus are highlighting the locality and diet of the animals they serve. Consumers are hungry for more natural foods and willing to pay more for them.

Key to the success of any new “meat” product, however, is overcoming what’s colloquially called the “ick” factor, and labeling is a big part of that. Almy contends that consumers aren’t overly concerned with the provenance of their meat (or its substitute). “I don’t think most consumers care how their meat is produced,” she said. “There’s a strong desire to not have requirements about distinguishing the origin of these products.”

Sorscher of CSPI called this approach a “horrible mistake.” Using the example of widespread consumer mistrust of genetically modified organisms in food, she predicted “there would be such a backlash from consumers, it would ultimately undermine these products.” Indeed, only 5 percent of Americans think such meat substitutes should be labeled as “meat” without further explanation, according to a survey conducted by Consumers Union, which has also called for more transparency.

Photographer: Daniel Acker/Bloomberg

“The labeling issue surrounding products of cellular agriculture is fundamentally a public policy question,” said Robert Hibbert, a partner at law firm Morgan Lewis who focuses on food and agriculture regulations. Because the FDA has allowed food companies wiggle room around identity standards (think “soy milk”) while also bringing enforcement actions when it sees potential for confusion, Hibbert said, it’s hard to predict how these labels will be treated.

Even those rooting for meat substitutes said consumers deserve to know what they’re getting. Jessica Resler is creative director at Participation Agency, an experiential marketing firm. A vegan who wants to see all slaughterhouses closed, she said a failure to disclose the meat’s origins will anger consumers.

Still, Resler said. “It has to be described on labels, for sure.”

Eventually, consumers will develop their own shorthand for meat substitutes, for good or for ill. “The mass-adopted term is going to be decided by the public.” Nik Contis, a branding expert at PS212, said.

In this article

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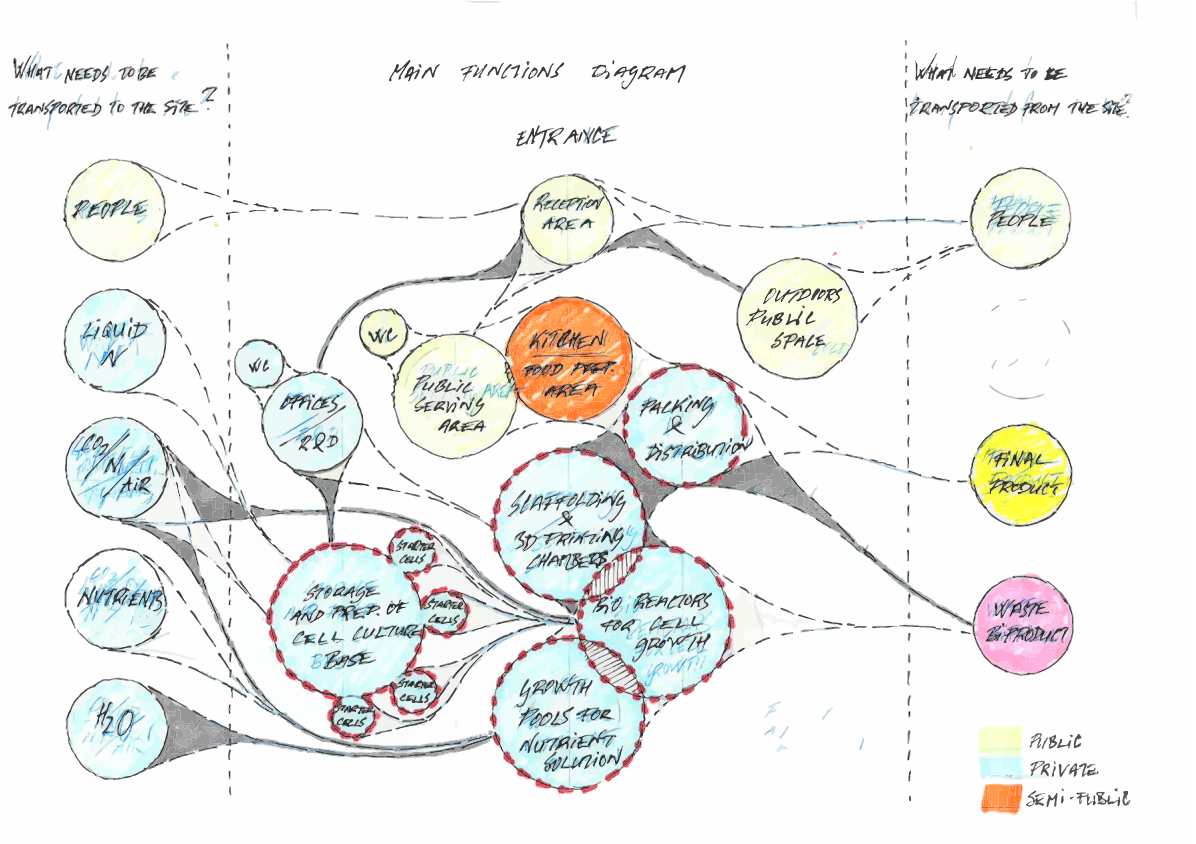
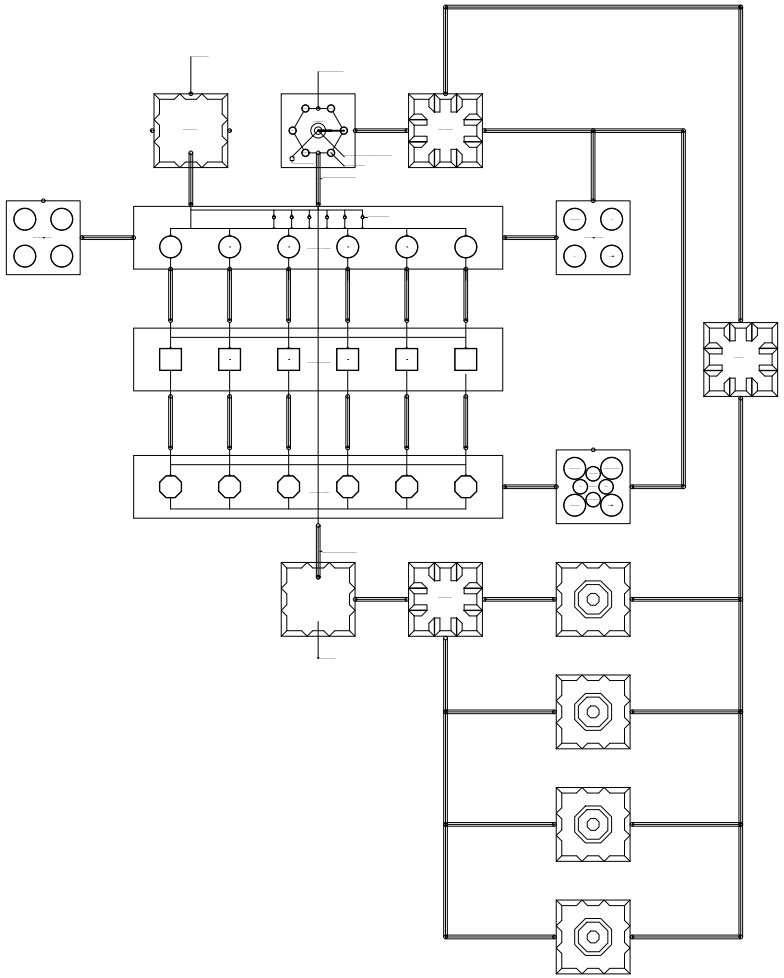
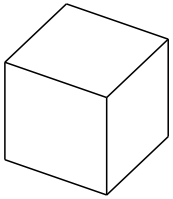
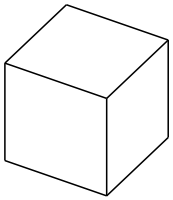


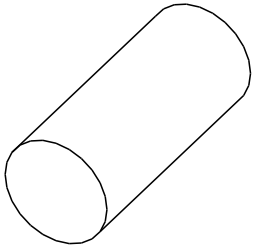


Sketch diagrams of functions and theoretical production lines as part of my research

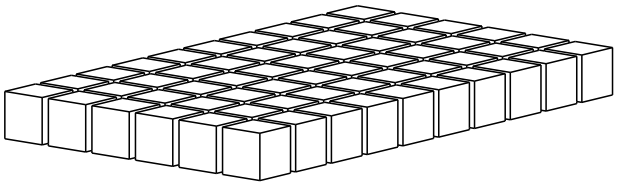


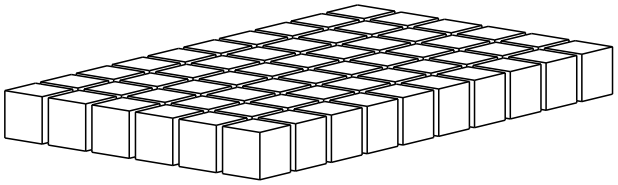


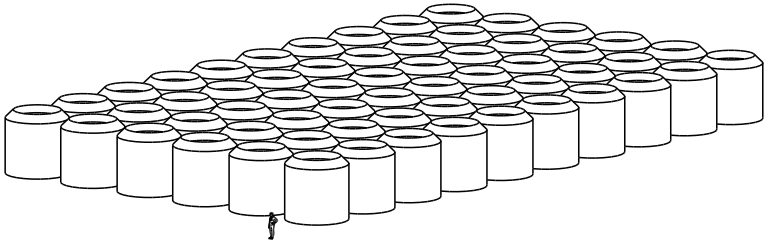
The diagrams show how big a theoretical production line would have to be to produce roughly 50 kg of meat produce for 10 0000 or 600 000 (approx. population of Oslo) in a year.

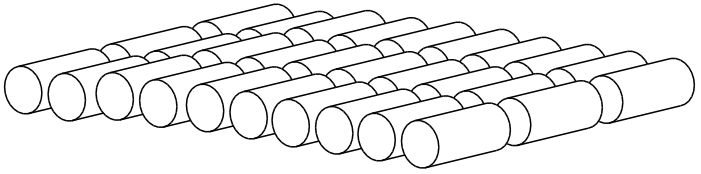


10 000 people









600 000 people

Size study of theoretical production line volume as part of my research

PROCESS

66% of all agricultural land in the world is used to grow animal feed, only 8% of agricultural land goes to food that we directly consume. 30% of ice-free land on earth is used for livestock raised for meat. In vitro meat could require only 1 to 2% of the land area used to produce the same amount of conventional meat.

The traditional approach to animal breeding and meat refinement requires vast amounts of space and transportation of both feed and livestock, making production of meat produce in the city close to impossible. Growing of cultured meat will allow for locating the production facilities in urban areas, given its low demand for physical area and transportation. To exemplify the possibility of locally grown produce, the project is located in the context of the city of Oslo.

I spent a day walking along Akerselva in Oslo, searching for possible sites for the project. Most industrial buildings still existing there today have been reprogrammed and reused with programs fit for the needs of modern times.

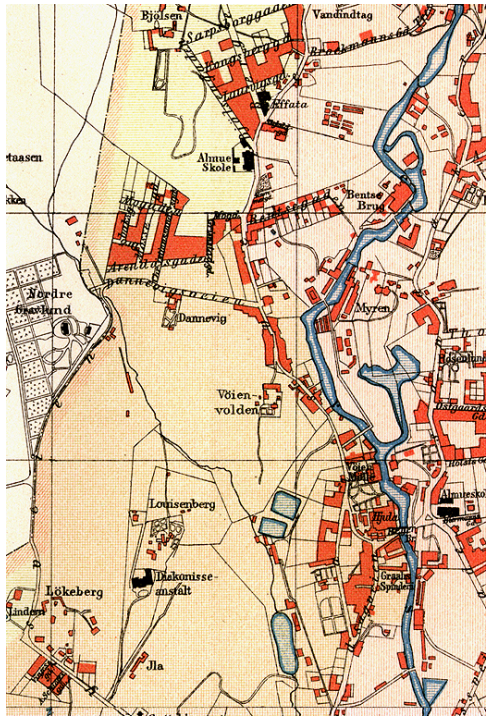
As I approched Sagene, about 25 minuttes walk north of AHO, I came across the old tattered Lilleborg warehouse building in Treschows gate 16, and immidiately recognized the sites potential for accomodating my project. It also became clear that the structure currently occupying the site is not fit for preservation.

Investigating further, it became apparent that the building was no longer in use, and had been standing empty for the past ten years. The current owner of the site, Orkla, wanted to build residental housing on the site (as most of the surroundig buildings are), but this was finally turned down by the municipality of Oslo in 2018, and there are no current plans for development.

The process continued by studying the sites long industrial history, conducting volume studies, sketching and finally determining the scale and placement of my structure before beginning the design process of the final project proposal.

Today, the site is completely closed off to public access by fences and what could potentially be green areas is covered by asphalt.

I decided to remove the structure currently occupying the site, constructing a new building with a scale relating to the buildings surrounding it and and to open most of the site to the public, while introducing green areas reconnecting the parks along Akerselva.



Map of Sagene from 1897 with Bentse brug marked.
Source: Oslo Historical Museum.

Treschows gate 16s history

Bentse Brug was an industrial facility situated by the Akers River in Oslo, between todays Bentsen Bridge and Lilleborg, from 1696 until 1898/99. Other names used for the facility throughout history were; Bentse Papirmøller, Øvre Mølle, Øvre Papirmølle, Drewsen & Søn, Akerselvens Papirfabriker and Akerselven-Embretsfos.
Bentse Brug was originally a papermill founded by Ole Bentsen after receiving a royal decree from Christian V to build a papermill in Christiania. It was the first of its kind in Norway and would develop into a pioneering facility for the Norwegian paper industry.

With various owners and names, the facility was in operation until 1889 when it finally became bankrupt. The factory was bought out and modernized several times until its closing, at which time it was named Akerselvens Papirfabriker. In 1912, the factory buildings were acquired by Myrens Verksted and repurposed as a machine workshop. Parts of the original buildings survived until the 1950s. The site was then purchased DeNofa Lilleborg, and the old brick building that was once the main facility of Bentse Brug was demolished between 1956 – 59, most probably at the request of Lilleborg factories.

Ole Bentsen grew up in Christiania where his grandfather and father was involved in the operations of a sawmill by the Akers River. After inheriting them in 1683 a cousin in law became owner of half of Nedre Vøyen saw mill and Bentsen got Øvre Vøyen saw mill. The water conditions were not the best at Bentsens property and this can have been motivating to him to search for other means of production than a saw mill.

Bentsen travelled to Holland in 1684. He stayed for months and thoroughly educated himself on how to build paper mills and produce paper. At the time, paper was produced by so called cloth mass, textile fibers from linen, hemp or cotton. On his return to Norway, he approached the king to request the sole right to produce paper, and in 1686 he received the royal privilege of producing paper in Norway for the following 15 years.

1696 Ole Bentsen establishes Bentse Paper Mills, Norways first paper mill.

1863 Norway's first production facility for wood pulp is established. It is given the name Bentse Brug.

1889 Bentse Brug declares bankruptcy. Akerselvens paper factories continues the operation.

1912 Myrens Workshop buys the disused factory buildings. Produces metal objects.

1952 Denofa Lilleborg buys the site and buildings. Produces soap.

1956 The main building is demolished.

1973 The remaining building is demolished and a new building with approx. the same footprint is built.

1976 The building that is still on the site today is finished. Used as storage facility.

1978 New fence around the site is built, closing it off from public access.

1985 Offices are added to the building in a connecting wing.

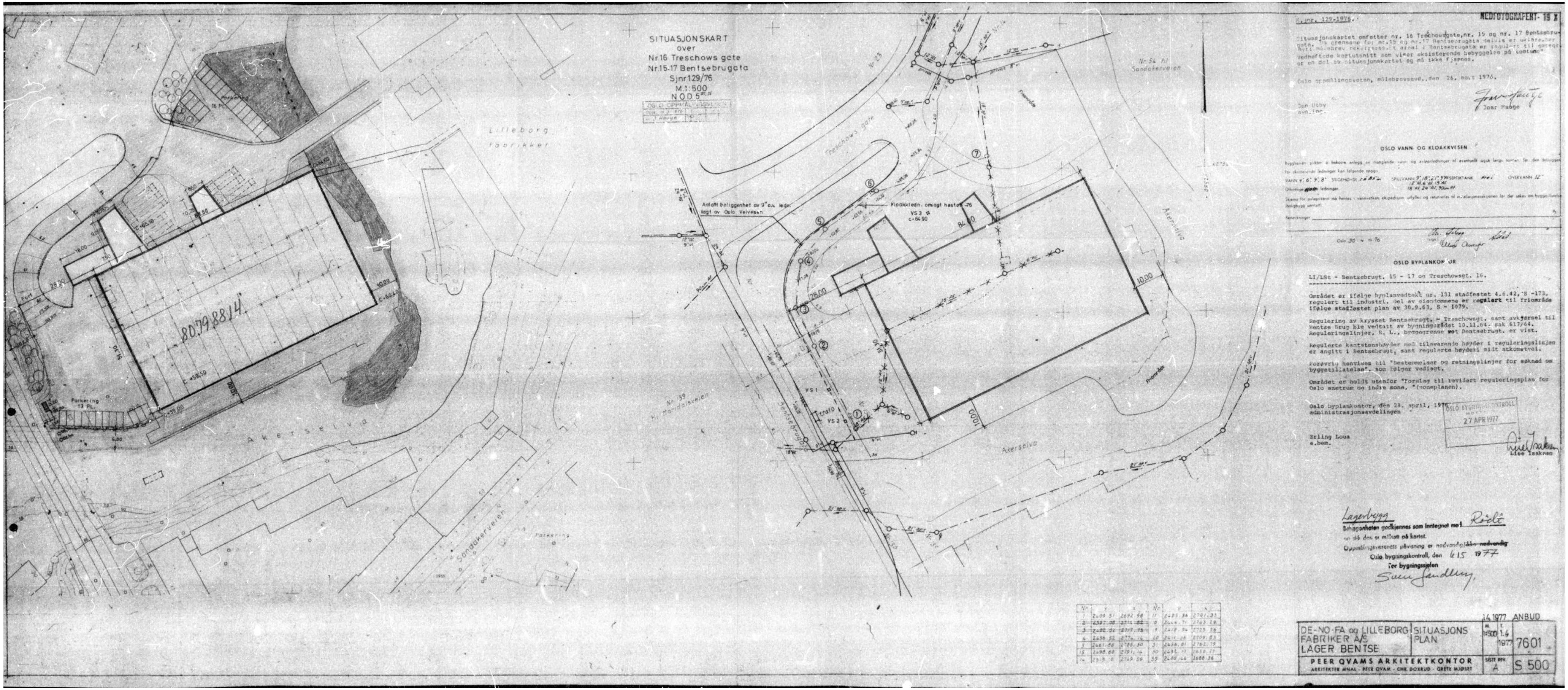
2010 Operation of the facility is closed down and moved to Ski.

2010 The site remains unused. Orkla (current owner of Lilleborg and the site) applies for building of apartments. The municipality of Osl declines and regulates the site as a park and recreational area.

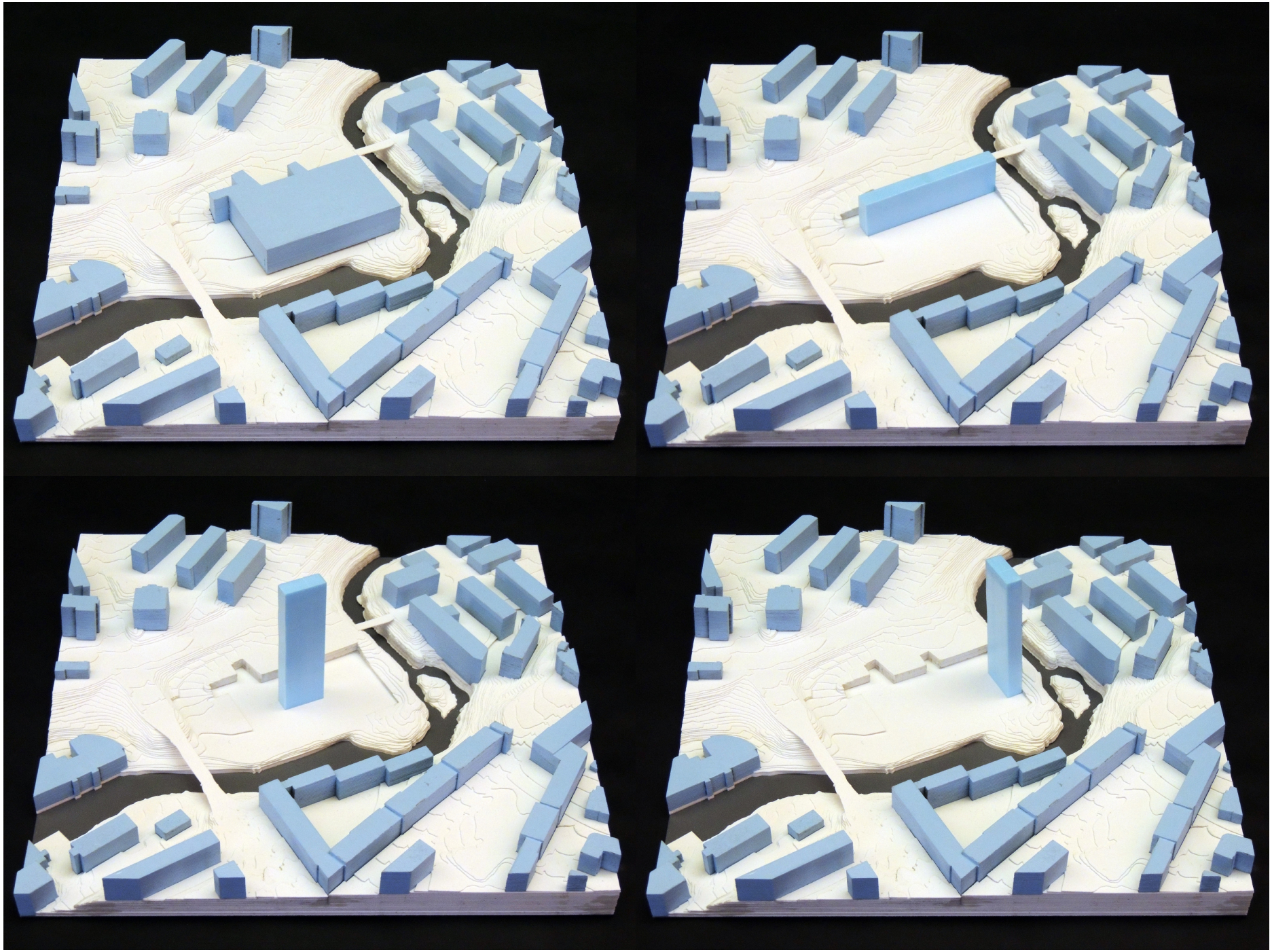
2018 No current plans for the development of the site exist.

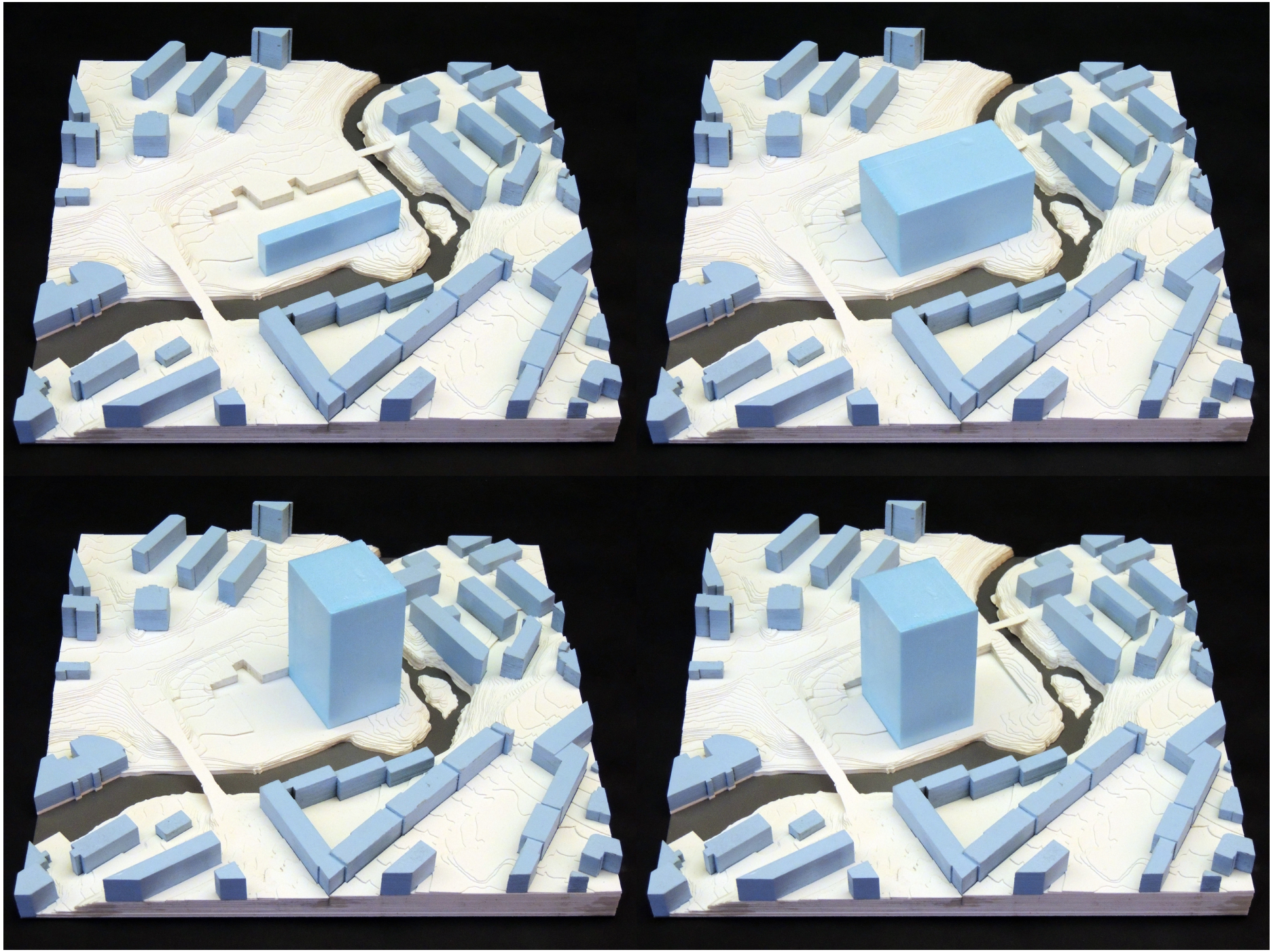
Bentse brug: The paper mill between 1863 and 1883.
Photo: Ole Tobias Olsen / Oslo Museum

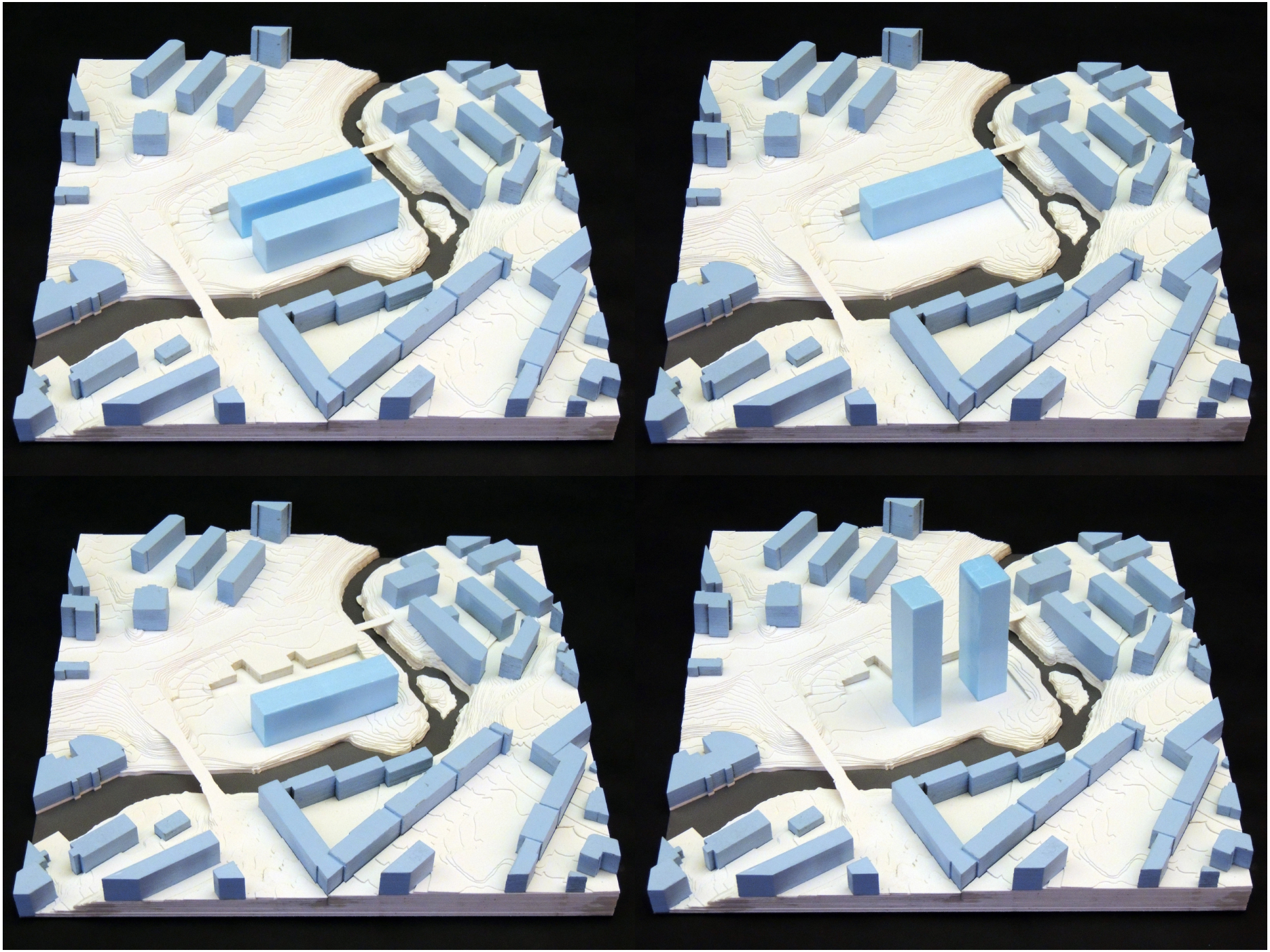
Bentse Brug: In 1937, with Arendalsgata, Bentsebrugata, Bentsegata and Treschows gate in the background.
Photo: Fritz Holland/ Oslo Museum

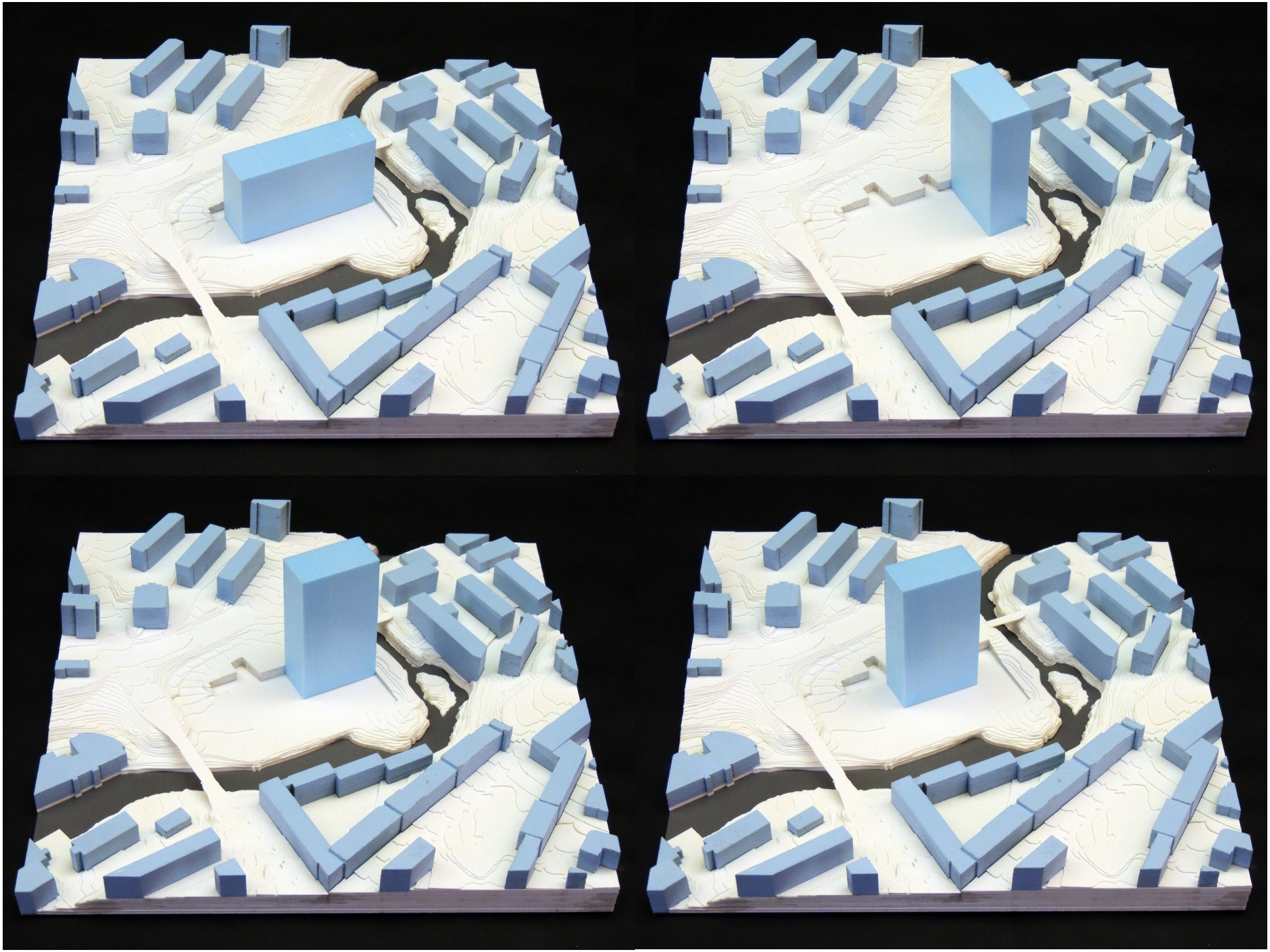


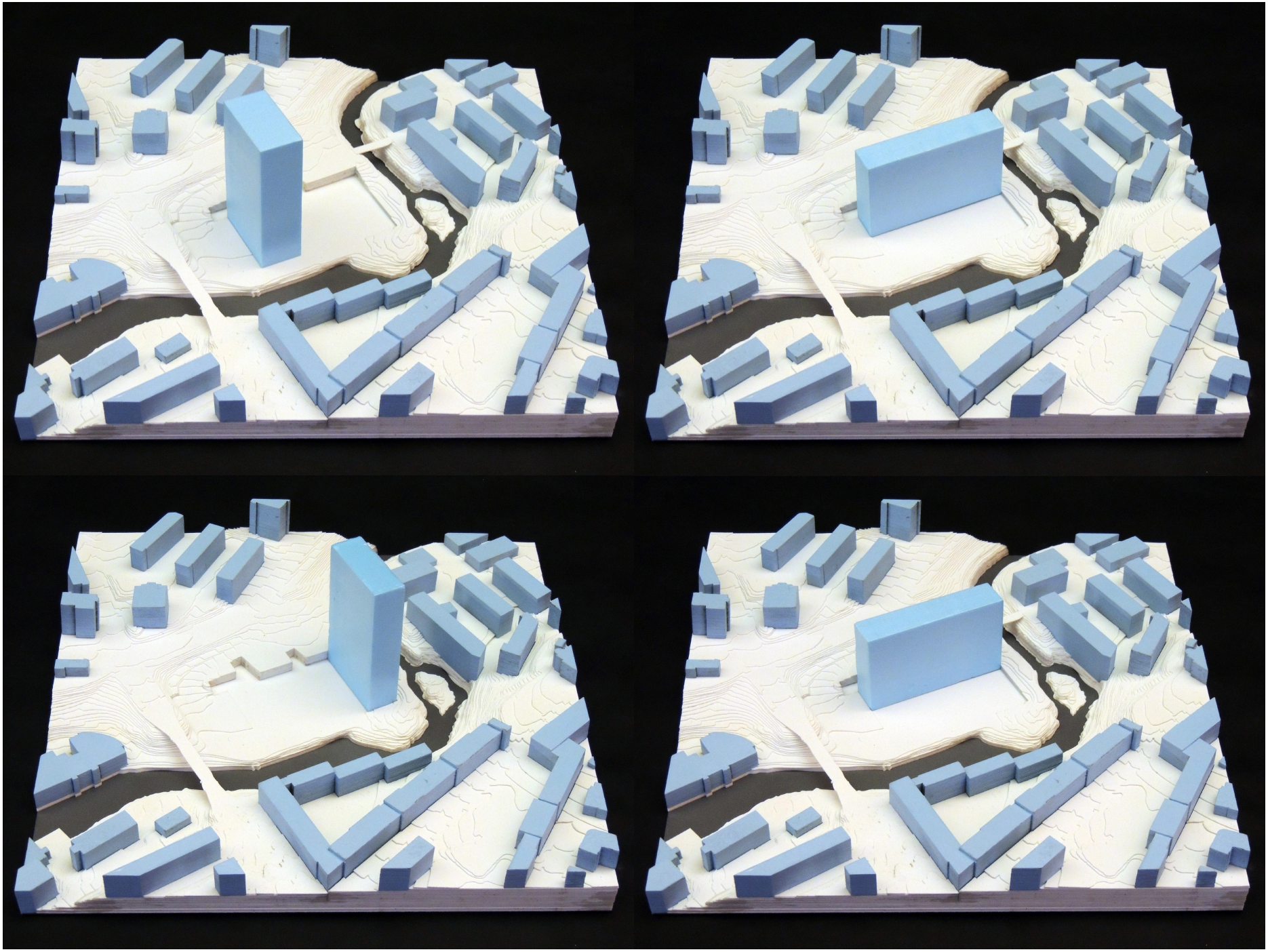
Site plan, 1977. Peer Qvams Arkitektkontor.
Source: City of Oslo, Agency for Planning and Building Services.

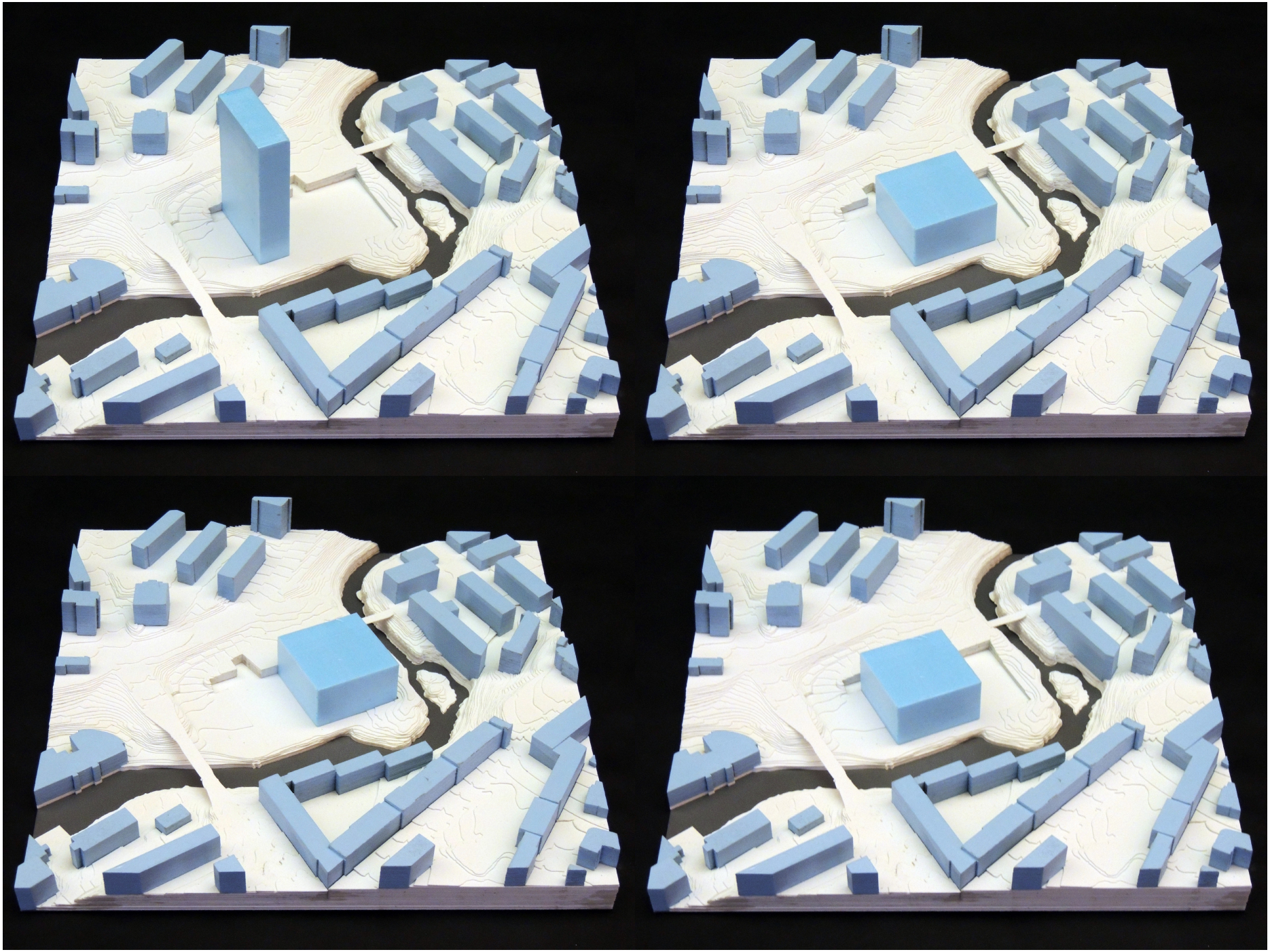


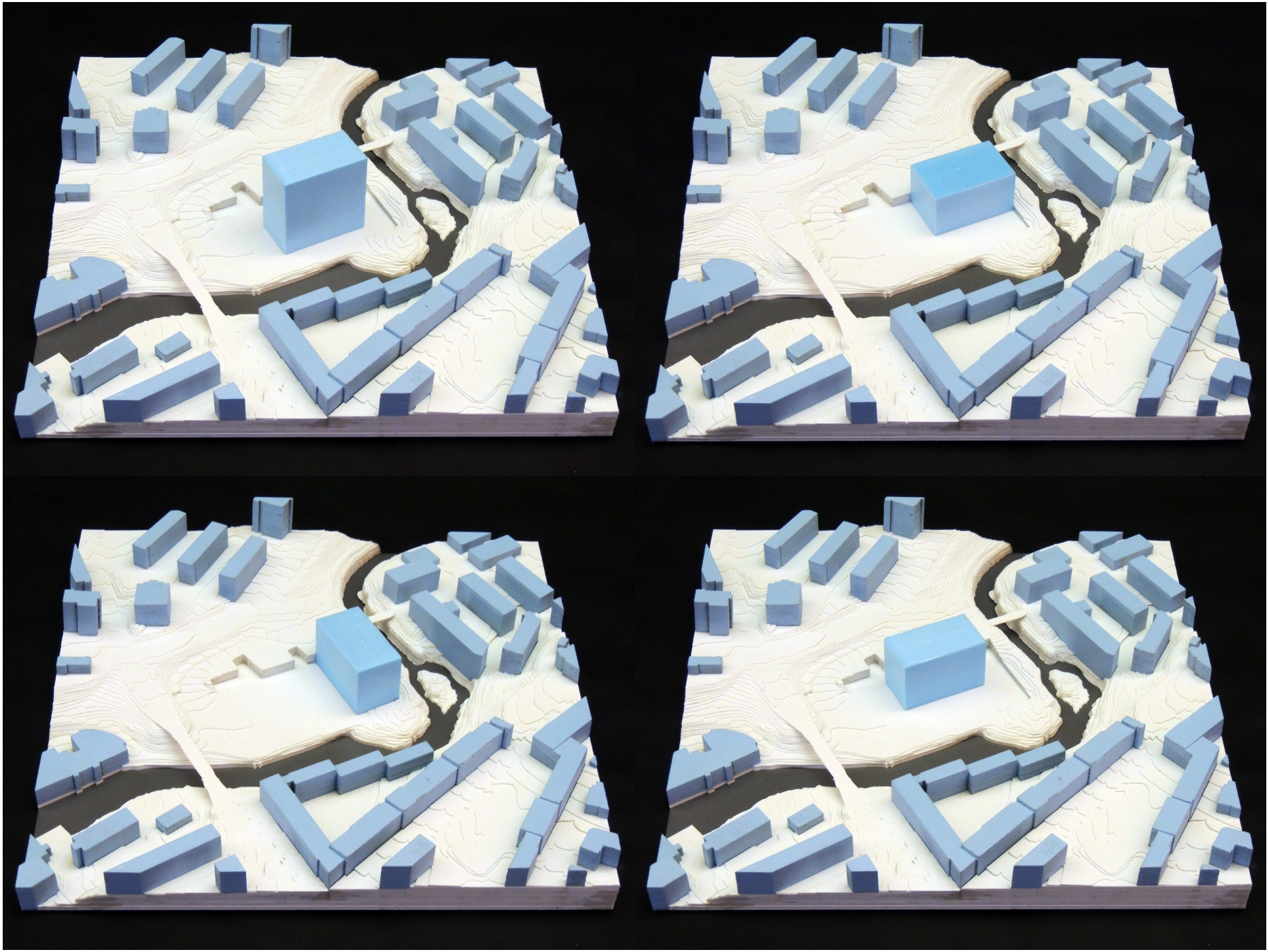












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