

# Milk farm 2.0

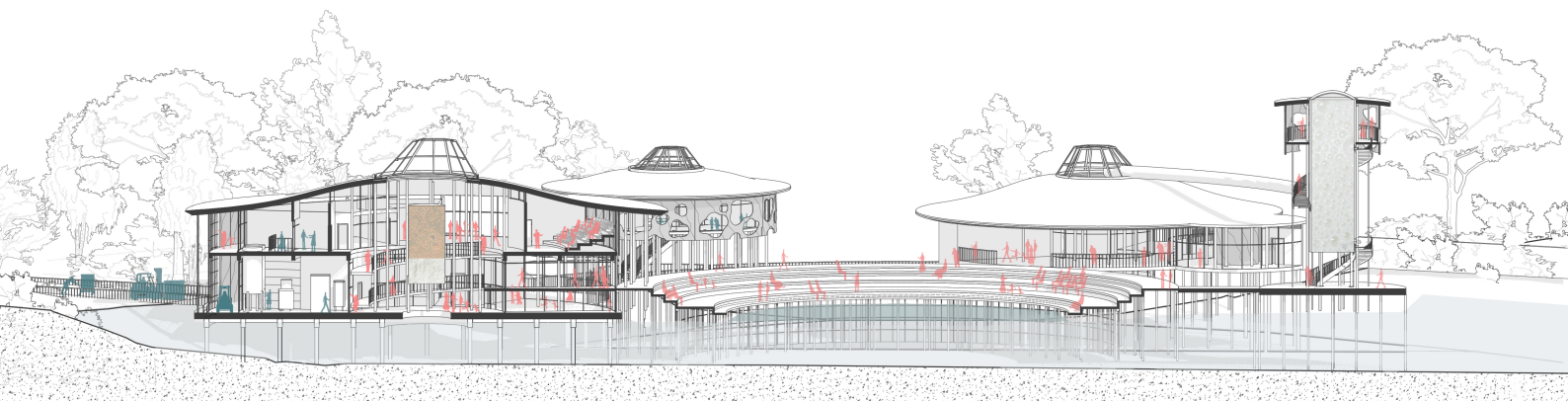
*A shift from traditional to artificial milk production*

'Reflection paper'

Graduation studio:  
**Architectural Engineering**

Elisa Pastorelli  
TU Delft - 5152801

Design mentor: Roel van de Pas  
Research mentor: Jos de Krieger  
BT mentor: Paddy Tomesen



## **00. Ambition**

The world is rapidly progressing towards more sustainable solutions in animal-based food production. The exponential population growth and the consequent increasing demand for meat and dairy has set up a production model based on intensive livestock practices, where the high productive rates are coming at the expense of our environment in terms of GHG emissions, land availability and water consume. In turn, a fast-paced and radical shift towards new food production models is crucial to reach the zero-hunger sustainable goal (SDG-2) by 2030.

The architectural engineering graduation studio gave me the opportunity to address my personal fascination about innovation and sustainability in food production in a challenging project based on an hybrid design that combine an entrepreneurial, technical and conceptual approaches.

My design consists in the first potential 'architectural scale-up' of the emergent cultured-milk technology, the production of milk in laboratory through a fermentation process. Although this technology is still at an experimentation scale, important investors are financing research and start-ups and soon artificial milk might become part of our daily diets.

Starting from the global issue of the environmental impact of intensive livestock practices in terms of GHG emissions, water consumption, land use and energy consumption, my research project narrowed down to the Dutch context. The Netherlands is experiencing a nitrogen crisis since 2018 due to the amount of manure produced by cows, that is causing an heavy pollution of the soils. Moreover the country is running out of available land due to the shrinking caused by the rising in the sea level and by the actual need of free land for new residential buildings for the growing population. Therefore, post-animal agriculture technology is explored as a potential solution to tackle those issues and an hypothetical scenario where part of the conventional milk production would be replaced by artificial milk production is studied.

But how artificial milk technology might be disruptive for the built environment?

As an architect I started to speculate about how the introduction of this technology could affect our built environment with the introduction of milk refineries where cows will be replaced by machines. This shift would entail a radical societal and cultural change towards a new food culture that will be translated in architecture with the design of a new typology of 'farm', a totally human farm. The first prototype of 'artificial milk farm' is the final product of this graduation project, an experimental design project that combines the industrial and technical side of the artificial milk production process, based on a functional design approach and aiming at an efficient and safe circulation of materials, to the public sphere, with the intention of engage and educate the local population in the attempt to build up a new and more sustainable food culture in the Netherlands.

## **01. Approach and methodologies**

My research project started with an exploration about the technology and its functioning, based on scientific papers and through the contact with the Californian start-up PerfectDay, actual leader in the technology. Unfortunately the data I required were not completely available and shareable and therefore a study about similar processes such as insulin and beer production have been conducted. The final data resulted in an intersection of the information from the different sources. The second part of the research concerned the environmental and societal benefits of replacing conventional milk production with the artificial one, studying the preliminary LCA released by Perfect Day that gave me the idea of the environmental footprint of artificial milk in relation to conventional milk production. Those data, applied to the Dutch context, resulted in a futuristic and more sustainable scenario where a big part of the land actually employed in agricultural practices could be restored and re-employed for other purposes. Finally the research

moved to the exploration of the technical feasibility of building an artificial milk farm with the development of a material flow diagram and an energy flow diagram.

The material flow diagram became the foundation of my design and informed my design process in terms of spaces and dimensioning according to the amount of milk produced. However, the lack of data about the emergent technology and the difficulty in finding data about similar production processes led to some uncertain results. In this regard, a further investigation could be done to compare the obtained results to more scientific ones. A similar approach has been used in the development of the energy flow that though remains a speculative and experimental diagram, open to further explorations and experimental applications. On the whole, I can consider the research project as relevant and useful to move towards the design process.

An investigation about the potential site for the first artificial milk refinery has been conducted in parallel to the scientific research. Strategic and logistic principles have been taken into account, considering the continuous flows of inputs and outputs from and to the artificial milk farm and its production aim. Moreover, the attention to the public dimension led to the investigation of a site that could act as a connector with the neighbourhoods and the city itself.

The Noorder IJ-polder, a former agricultural area in the North-West of Amsterdam and close to the harbour envisaged as the first potential spot for the artificial milk production. The area became a pit for the extraction of sand for the construction of the highway and residential areas and actually it's a very natural area immersed in the industrial landscape of the Amsterdam harbour, divided into two lakes. The Noorder IJ-polder is part of a bigger transformation that will take place within 2050 and will involve the entire Haven-stad area. It will become the second most important park of the city of Amsterdam and the first park that will educate people to circularity and sustainability. For those reasons suitable to host the first 'artificial milk farm'.

## **02. The relation between the graduation lab theme and subject**

The Architectural Engineering graduation studio theme deals between 'Flow', 'Stock' and 'Make' paradigms. Understanding the existing scenarios, possibilities and knowing the opportunities to renewal by discovering innovative ideas and initiate change under the umbrella of sustainability, technology and social issues. The concept of my design is related to the Flow and Stock themes. In fact my research resulted in the development of material flow diagrams with the specific site of the Noorder IJ-polder as system boundary. The diagram gave as an output the amount of milk produced and thus harvested from the 'artificial milk farm'.

## **03. The relationship between the methodical line of approach of the graduation lab and the method chosen by the student (research + design)**

The Architectural Engineering studio is centred around tackling the context using innovative solutions in the realm of sustainability in engineered architectural design. The conducted research realised the maximal potential of the topic (considering the lack of data due to the very emergent technology), translating the scientific knowledge into architectural tectonics revealed challenging.

In fact, the translation of my research into an architecture opened unlimited possibilities at the beginning of the design process. Developing a completely new architectural typology and structure, without a model to take inspiration from, at the beginning revealed as a big challenge. If on the one hand the research did inform the material flow and the dimensioning of the spaces that the artificial milk refinery would require, on the other hand designing an architecture that still doesn't exist, opened plenty of options. During that period, the inspiration and suggestions from

my tutors have been crucial to take a precise direction for my design process. My design, actually, moved from the mere design of an industrial plant to the design of a milk production pole able to become a hot-spot for the Noorder IJ-polder, connecting artificial milk production with the local community to build a new food culture. The themes of the milk industrial production and the public sphere come together in a very context-related project, connected both to the social and cultural context and to the physical site.

In fact, the first cultured-milk farm has been designed on the water, in a very natural spot. There are more than one reason for that. The Netherlands has a huge problem connected to the land availability. Partly because 1/4 of the country already lies under the sea level and the available land is further shrinking due to the rising in the sea level. Partly because the most of the Dutch land is occupied by agricultural practices and estimating an exponential population growth within 2050 there will be a huge request for new houses. A first attempt to produce milk 'on water' has already been designed in the Rotterdam harbour where alive cows are churning milk on a floating platform. So what I thought should be done in the future, considering that cow-less milk production relies on machines instead of alive animals, is to shift the industrial production of food on water. This, on the one side should re-connect people to the nature (as it was in the traditional idea of farm), but could be also an opportunity to explore more into the possibilities of designing a structure in symbiosis with nature, able to benefit the environment in terms of increasing its biodiversity. Moreover water could be employed as an energy source, able to improve the energetic performance of the building and create an energy self-sufficient building. This is something that in my design I didn't develop but could become an opportunity for further developments of the design.

On the whole, my design wants to propose as an architectural prototype, an hybrid and experimental design that on the one side is significantly radicated in the context, on the other side promotes new values related to sustainability. The prototype defines a conceptual and experimental structure of space and it's addressed to a shareability and transmissibility of the design principles that have been applied to the design, both from the theoretical point of view and its physical construction. The replicable design principles are related to the safety and efficiency of the structure on different scales. I'm talking about the use of materials, the structural considerations, the focus on certain details such as the need of high ceilings for the transportation of the machines, the need of proper industrial materials to preserve the machinery room from leaking and chemical attacks. But also a proper material circulation in a way that the inputs and outputs don't meet each other during the process.

Another replicable element is the facade, an experimental double skin facade composed by a green wall realised on climbing trellis and covered by a second mycelium layer, a series of lightweight panels that slide along the circular building and allow a natural ventilation during the summer and a wind shield during winter. This element is the most significant of the entire design because combines the main topics of the design. Beyond being climate adaptive, the facade attracts insects and other local species, benefitting the biodiversity of the Noorder IJ-polder and provides the interaction of people with the nature surrounding the artificial milk farm.

#### **04. The relationship between the graduation project and wider social, professional and scientific framework**

Since new technologies in food production are emerging as sustainable models in food production and artificial food is going to become part of our daily diets, new architectural typologies to hosts the production processes will soon disrupt our built environment. Therefore my design project wants to become an experimental model able to create and share generic and transmissible design principles (spaces required by the industry, dimensioning, efficient material circulation, safety and use of materials) that could be applied to different context. Although my prototype of 'artificial farm' is a really context-related design and the choice of the specific site is embedded in the design process, the project wants to define a new experimental architectural topology, model for further explorations and base for further modifications and

improvements. In fact, the design outcomes will change according with the specific site, the social and cultural framework and the ownership of the building.

## **05. Discuss the ethical issues and dilemmas encountered during research, design and potential application of the results**

How and when it will happen is uncertain, but it is likely that within the next decade synthetic milk proteins will enter the market and will compete against conventionally produced milk. The impact of this development on livestock production is, however, somewhat difficult to assess.

As historical analyses show, the substitution of a certain agricultural product and the introduction of a new synthetic one came where the price of the latter fell below that of producing the natural product, that in combination with the additional product consistency and security of supply, led to widespread and rapid adoption by the major industries. The point may not be far off for synthetic milk. However, I believe in a potential market bifurcation: on the one side the livestock producers that will maintain their distinct 'naturalness' advantage, standing out for their non-intensive practices and respecting the animal welfare to produce high quality milk, will survive while synthetic proteins might supply the mass market.

These considerations indeed defined the basis of my research and deeply influenced my design choices. Actually my thesis project relies on a personal theoretical and ethical position, consisting on the confidence in the emergent post-agriculture technologies as a potential solution to tackle the actual environmental impact of intensive livestock and in the build-up of a new food culture where people could still enjoy the taste of traditional food, without undermining food security and health. The research, consequently, addresses the problem statement to a precise solution whose societal and environmental benefits are investigated. Beyond the scientific results that informed the design, some societal reflections affected the design process. First of all shifting from the traditional milk productive system to the artificial one would entail a radical societal and cultural change and the population should be informed and educated about the new production process to promote public acceptance. This has been translated into an hybrid functional programme where the productive areas are complemented by public spaces aiming at the maximum transparency of the process and at the educative purpose of the architecture. Moreover, the programme of the 'artificial milk farm' aims at the engagement of various target of users, from researchers to students, families, children, young people, defining different degrees of privateness/publicness of the spaces and aiming at its full accessibility.

Considering the potential reluctance of people towards the consume of synthetic milk, the introduction of an architectural prototype able to balance traditional values and innovative values appeared as the best design solution and influenced the scale of the intervention.

The calculations on the amount of artificial milk that the hypothetical farm would have produced are based on the arbitrary scenario whereby the 50% of the daily consumption pro-capite of dairies will be supplied by artificial milk. This scenario is justified by my personal position about a potential market bifurcation and guided the design dimensioning. However, this aspect could be explored with a further research and surveys to the Dutch population.