Reflection

Towards energetic circularity

Greenhouse-supermarket-dwelling energy exchange

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MSc thesis reflection

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This reflection describes the following aspects of the master thesis research 'Towards energetic circularity':

[1] The relationship between research and design

[2] The relationship between the theme of the graduation lab and the subject/case study chosen by the student within this framework (location/object)

[3] The relationship between the methodical line of approach of the graduation lab and the method chosen by the student in this framework

[4] The relationship between the project and the wider social context

[5] Validity and repeatability

Research summary

This research explores the potential of bringing urban greenhouse farming into the existing built environment and integration of this greenhouse in a local energy grid. Goal is to mitigate the cumulative environmental footprint on the earth. Together with a Lidl supermarket and the adjacent dwelling, an energetic triangle of 3 different functions is established. This study investigates how these components should be connected with each other, how an underground energy storage is added to the system and what the greenhouse parameters should be in order to create a balanced energy model. For both the present system, climatized by conventional means, and the new energy system, the CO_2 emission is defined. This research point out that the included components can be disconnected from the gas network and that the cumulative footprint can be reduced with 46%, or 334 tonnes.

[1] The relationship between research and design

First, the main research question:

How can we combine the energy flows of a supermarket and a greenhouse and connect them to the adjacent dwelling to reduce the cumulative environmental footprint of the three functions?

This research revolves around the energetic aspect of the building technology and the environmental impact of the built environment. Any designs made in this research are either system designs to enable energy sharing or rough volumetric designs. Architectural value or aesthetics are of submissive importance in this research.

In a nutshell, this research involved the following steps:

1. Literature study on circularity and energy;
2. Identifying and quantifying energy flows;
3. Connecting these flows in the most efficient way while keeping the whole system in balance (heating demand equals cooling demand). Enact energetic links between components;
4. Calculating the environmental impact of the present system and the impact of the new system, expressed in CO_2 emission;
5. Compare the results and draw conclusions;
6. Reflect.

Research, either by literature survey or by hand calculations, is at the foundation of every design decision made in during thesis. The links between the components in the final energy grid and the size + indoor climate of the greenhouse are based on the demands and supply of the other components.

This research can be described as a fundamental and quantitative study. Eventhough the research was initiated from a practical question by the Lidl, the research explored a theoretical solution to a larger problem. There was not a demarcated request from the Lidl for a local energy grid, powered by a greenhouse solar collector. The final design is the result of literature survey, calculations and inspirations from similar projects. The proposal is therefore not a concrete answer to the Lidl's question, nor is it the conclusive method to aid the Lidl sustainable and circular ambitions.

The final design embraces the global mission to bring down the pressure on the climate and the earth from the built environment. In this system, the supermarket plays an important energetic role. Lidl Holland could benefit from this proposal both on an energy level as well as on a social level, see page 9.

Literature studies and calculations proceeded design steps and decisions. This research is based on existing knowledge which is then applied on a new situation and context, also described as formal science.

[2] The relationship between the theme of the graduation lab and the research topic

The umbrella topic of the Building Technology Master at the TU Delft is sustainable urban design. Students are challenged to take environmental, sociological, cultural, energetic and economical aspects of sustainability in consideration when making design choices. In two years time, a consciousness is raised among the BT student on the sustainable consequences of adding elements to the built environment. To create order within this broad theme of sustainability, four building technology related fields are introduced for the student to chose from: facade, structural, climate and computational engineering/design. Four completely different themes that cannot be considered separate from each other. When starting the Building Technology sustainable graduation studio, students choose from two out of the four fields. This is not only for administrative reasons, so tutors can be distributed among students. This is to enforce the student not to focus only on their own primary field of interest, but to force them into the discovery of the link between different fields. An awareness is created that design decision in one field have consequences in the other. Integrated designing would be the word to describe this poly-thematic way of working adn thinking.

This research, *Towards Energetic Circularity (TEC)*, does however not show an distinct focus on two of the four fields mentioned above.

TEC is about energy and the impact of our way of living on the environment. The research is about bringing a urban environment one or more steps closer to energetic circularity (EC). First, the definition of energetic circularity is settled within the domains of this research. In a nutshell it can be said that EC is achieved, if a building or city is completely disconnected from fossil energy. Enough renewable energy is generated locally or distantly for the building related and user + operational related energy demand during all four seasons, including winter. Absolute EC is achieved if additional energy is generated to take retroactive responsibility of the investment energy.

The TEC study is an exploratory research on the possibilities of energy sharing. Two urban functions, dwelling and a supermarket, are energetically connected with a new urban element: the rooftop greenhouse. Together, these three can form a local energy triangle and benefit from each others energy surpluses. In the TEC research, energy streams are identified and quantified. Based on the heating demand of the apartment blocks and the thermal heat waste of the supermarket, the size, indoor climate and rough shape of the greenhouse is calculated and designed.

The obvious BT theme that is applicable to classify this study is *climate*. The second field is not instantly recognized, not even with open interpretation of the other three fields. Andy van den Dobbelsteen, first mentor of this research is leading the research group 'climate design and sustainability'. Peter van den Engel (second mentor) is part of the research group 'Building services.' Both mentors are from different research groups, but there is more overlap in their thematic fields than strict difference.
Towards Energetic circularity focuses on the broader theme of the graduation lab: sustainable design. Climate related topics are addressed during the course of the research but a second field is not strictly defined. Perhaps it makes more sense to consider this graduation thesis a collaboration between two different master tracks: Building Technology and Urbanism. Yet, I am not completely aware of the content of the Urbanism track.

[3] The relationship between the methodical line of approach of the graduation lab and the research method

In general, the methodical line of approach in the graduation studio of building technology is either *research by design* or *design by research*. My personal interpretation of these two research methods defines 'research by design' more suitable in a architectural environment. In architecture, limitations of ones own imagination might be boundaries of design capabilities. These boundaries can fade away by simply doing and reflecting: just start a session of trial and error and see what the result is. This might not always lead to the desired final result but it at least clarifies what it should not be.

Design by research is the more rational opposite. Design decisions are made based on previously gathered information and/or calculated data, either scientific or not. This method suits the building technology track better, as architectural value should be submissive to environmental impact or sustainability (but not less important!). Of course there are many exceptions to this and not all BT graduation are equal nor projects put the priority on rational sustainability.

This research is evidently categorised as *design by researc*h. The final design of the local energy grid as well as the shape, size and indoor climate are based on literature studies and calculations.

Summarized, this research developed according to the following steps:

1. Literature study on the broad topic of circularity formed the kick-off of this thesis. While collecting information, a broad interpretation on circularity converged during the first 4-5 weeks into a defined research questions relating energy;
2. Information and energy data provided by the Lidl Supermarket was analysed to see how much space for improvement was theoretically possible for only the Lidl. Analysis of the assigned city block clarified that there was potential for a local energy grid in combination with a greenhouse. The cumulative energetic benefit for the whole city block became more important then just the gain for the supermarket.
3. Potential apartment buildings (components) were chosen and roofs were scanned to find space for urban greenhouse farming. The optimum growing conditions of tomatoes were defined based on literature survey;
4. The first round of calculations pointed out that maintaining a high demanding greenhouse climate, is far from sustainable. The design philosophy was reversed: sustainability was prioritised above profitability. The scale of the greenhouse and it's indoor climate were from now on to be determined by the dwelling heat demand and supermarket energy supply.
5. Further calculations, parameters changes and greenhouse downscaling resulted in an energy system in which heat demand and cold demand were in balance (to keep the underground energy storage in balance).
6. The indoor climate and scale of the greenhouse (the design) and the design of the local energy grid are based on rational decisions.
7. The research is concluded by calculation the CO_2 emission cutback of the new gas free system relative to the present conventional system.

The research steps / decisions described in the summary above all fit in a *design by research* way of working.

[4] The relationship between the project and the wider social context

With the technological development of mankind in the past two centuries, nowadays fossil fuels are depleting more rapidly then ever before. Our mobility, products, economies and political power: a lot has been organized around the steady supply of fossil resources. We have become dependant of it and realizing this rises the question: what if we run out? Academics have different ideas on when this moment will happen but they all agree on one thing: it will happen, sooner or later. If we want to keep the lifestyles we have become used to, change is inevitable.

Many people have come to realize that we have to start taking full responsibility towards the finite resources we mine from Earth. Their are countless of recycling programs and over a decade ago the Cradle-2-Cradle ideology has been initiated. Even though these are all steps into the right direction, there is still an urge for a system takes 100% responsibility for all the materials that it claims from this planet. We have come to the point where we have to research the possibilities and opportunities of the circular economy.

Circular economy is about putting an end to the consumption of fossil fuels and rely only on renewable energy. Disconnecting the built environment from finite resources cuts down a large part of the global CO_2 emission, subsequently lowering the ecological footprint of the building on the planet.

Generally speaking, there are two basic ways to cut down the dependence on fossil energy: increase the renewable production or lower the demand. The latter one is explored in this study.

On way to cut down the energy demand is by sharing energy waste streams between different functions, building, districts+industries or cities. On the city and district scale, some projects have already been realized in the form of city heating: waste heat from nearby industry is transported to residential neighbourhoods. Logically, this is mostly done in new neighbourhoods like city expansions because it is still relatively easy and much cheaper to install the required infrastructure. Unfortunately does this lead to an exergy inefficiency as very hot water (>70°C) is pumped towards modern houses that run on low temperature floor heating systems (<35°C). A large part of the thermal energy is not used optimally and gets lost to the environment.

Nowadays, there is a call for smaller and local low temperature energy grids: that is why this research focuses on a specific city block in the old city centre of Amsterdam. This block features a Lidl supermarket and some potential residential buildings to which an urban rooftop greenhouse is added. The questions is: what are the energetic potentials of bringing these functions together and how can this reduce the cumulative energetic footprint?

This research topic was an initiative by the Lidl supermarket chain. They approached the Building Technology department with the question: how can we make our complete building stock circular? Two TU Delft researchers, prof. Andy van den Dobbelsteen and ir. Luuk Graamans, took this question upon themselves. They are developing a roadmap for the Lidl containing several milestones that in the end should lead to circularity. This student thesis study runs parallel to the TU Delft research but has no direct connection with it.

The Lidl's intention of becoming circular is part of the overall ambition of becoming known as the sustainable supermarket in the Netherlands. Already, the Lidl can be praised for investing in sustainable buildings and increasing their sustainability has conquered a permanent place in the annual year report and future ambitions.

In my personal opinion I like to think that if a supermarket want to be known for it's sustainable way of operating, it should be made visible to the customer. An awareness should be triggered so that customers understand the environmental consequences of their consuming behaviour. Preferably something interactive can be set up so that both the customers as the Lidl share responsibility for reaching the sustainable goals. One example would be to bring food production to the core of the urban environment: urban rooftop farming. Open up these greenhouses to the public and (partly) turn it into a 'by us, for us' system. In a progressive city like Amsterdam, the greenhouse could not only take the role of farm, but more importantly it could function as a social hub. A place where people from different social layers meet, work, consume and communicate. The farm could function as a social work place, where opportunities are given to the less fortunate locals with issues functioning in modern society. All this would be facilitated by the Lidl.

An inspiration to this would be the greenhouse of Urban Farmers in The Hague. Here, greenhouse production and fish farming are combined: aquaponic farming. This group has gained international attention with their rooftop greenhouse and now provides fresh vegetables and fish to the city of The Hague.

Integrating urban greenhouse farming into the build environment on a large scale will affect the built environment as we know it. Not just for local food production but -equally important- to function as the energy collecting component in local energy grids is an incentive to experiment with the concept.

[4] Validity and repeatability

Internal validity - assumptions

The energy balance of the greenhouse is partly based on assumptions and estimations. This study requires expertise on greenhouse agriculture as well as building engineering and energetics. Fundamental information for setting up an energy system, is knowing when, where and how much energy is required or available. This is done by calculating and defining the energy balances of each component. Defining an energy balance of the greenhouse relies on expertise that balances on the border of building engineering and the field of agriculture. At the base it is possible for a building engineer to calculate the in- and outgoing fluxes of a glass greenhouse construction as it shows many resemblances with standard atria. The moment plants are added to the balance, expertise on plant responsive behaviour to indoor and outdoor climatological aspects is vital. The influence of plants on the energy balance is in this research based on educated assumptions.

This research involves an existing city block. In order to determine the thermal energy demand of the specific apartment buildings, estimations on gas use have been used from literature studies. Within the limited available time for this thesis study it is not possible to examine each apartment separate to define a detailed energy balance. This does not necessary affect the reliability of the research, but a different residential gas consumption will lead to a different performance of the overall system.

Repeatability / external validity

External validity concerns the extent to which the findings from a case study can be analytically generalized to other situations that were not part of the original study Reliability refers to the consistency and repeatability of the research procedures used in a case study.

Conclusions drawn in this study are contextual and directly linked to the parameters set for the different components. The results can therefore not simply be generalized an copied onto another case. The methods applied to determine the final results can however be used for other case studies as well. An calculation tool (Excel) has been set up over the past months in which any changes made to the parameters are directly reflected in the cumulative CO_2 emission. Whole components could be added or removed in this tool if this is desired .

In the end, this research is about looking at potential energetic connections in the existing urban environment. This city block was designated because there is a Lidl supermarket located at the heart of the block. Quick analysis of the context revealed that there was potential for a greenhouse-supermarket-dwelling energy triangle. This study proves and quantifies the effect of this new energy model, relative to the current model [expressed in CO_2 emission]. The point is: the concept of the aforementioned energy triangle can be transferred to other city blocks or neighbourhoods as well. The scale, overall effect will most likely vary, as will the size and indoor climate of the greenhouse. But before doing this, first look at other potential ways of energy sharing. Adding a greenhouse is AN answer, but not always THE answer.