Towards energetic circularity
Greenhouse-supermarket-dwelling energy exchange

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Graduation Studio  
Building technology sustainable graduation design  
Climate Design & Facade Design

Argumentation of choice of studio:  
Compulsory graduation studio for the Building technology student.

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Ext. involved: Lidl Nederland  
Arnold Baas

Graduation project  
Title: Towards energetic circularity - Greenhouse-supermarket-dwelling energy exchange  
[Revised version! - after P2]

Location & research context:  
Project site: Amsterdam | Oud-West  
Lidl 2e Helmerstraat 29, 1054 CB Amsterdam

This Lidl supermarket has opened its doors in 2007. In the near future this building will be completely rebuild to meet modern day supermarket standards. The new supermarket will be according to the Lidl building standards (Part I in report).

Starting point  
The new subject of circularity is quickly gaining in publicity and companies see the potentials that come with it. The Lidl has approached the TU Delft and the department of AE+T (prof. Andy van den Dobbelsteene) to explore the opportunities of circular economy for the building stock and the operational processes of the Lidl. Andy and Luuk Graamans (researcher) have picked up this research. A series of steps have been defined to organize the research (page 5). This graduation research does not directly contribute to the work of Andy and Luuk but they can provide me with data from the Lidl or from their own research. The Lidl is delighted with the inclusion of a graduation student in their circularity project and therefore we keep in good touch (Arnold Baas, team leader Energy).
Graduation plan - problem statement

Problem statement

Reaching circularity in the energetic field is a challenging task. Currently we are able to make energy neutral buildings with a positive annual energy usage and the latest Lidl supermarkets are already disconnected from the gas network. It is however not yet possible to be disconnected from the electrical grid and the new supermarket buildings are therefore not yet self-sustainable. It is a matter of years until renewable energy generating technologies or energy storage capabilities are developed enough to sustain the building throughout the whole year and not only during summer. When this moment is here, we could theoretically call the supermarket building fossil free.

In a supermarket, products are cooled and frozen throughout the year which results in a constant flow of excess heat. Depending on the produce, a greenhouse requires high temperatures for the crops to grow. In summer this is achieved with the energy from the sun, but in winter additional heating is necessary. Adjacent dwellings within the building block date back to the early 1900’s combined with sixties-seventies gallery flats. These buildings require heating in winter and optional cooling in summer that could be achieved with the flows of the greenhouse and the supermarket.

This is just a rough energetic description of a supermarket and a greenhouse. Energetically speaking, a lot is happening in both the buildings. It is worth exploring the possibilities of energy exchange as a form of reducing the total energy demand. It might be very beneficial if we can add one or two additional functions under the same roof as the supermarket, in which all functions can profit from each other’s flows in such a way that synergy will arise. Energetically connected, the buildings might achieve the neutral energy balance that cannot be achieved when the buildings operate individually from each other (figure 1 & 2).

This research is about exploring these synergy possibilities.

This research is a hypothetical: the assumption a greenhouse can contribute the mitigation of the total energy demand is researched.
Goals

Main objective Lidl
Exploring the opportunities of the circular economy for their supermarkets, distribution centres and offices.

Main objective student
Developing a local energy grid between a Lidl supermarket, a greenhouse and the adjacent dwellings (building block scale) to reduce the energetic footprint of the supermarket.

Sub objectives
- Identify and quantify the energy flows in the supermarket;
- Identify and quantify the energy flows in a greenhouse;
- Reduce the energetic demand of the building cluster;
- Find ways to store energy for later use

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?

Sub questions
- What are the energetic flows in a supermarket, a greenhouse and dwellings that can be brought into an energy grid?
- What are the possibilities of energetic synergy between a supermarket, a greenhouse and adjacent dwellings (+additional functions if needed)?
- What are the possibilities of energy storage?

Process

Method description
Phase 1: Exploratory reading
The research proposal - as mentioned in the graduation topics overview - stated two options:
- The supermarket chains as a circular economy;
- Sustainable supermarket design, integrated in neighbourhoods.

In a meeting with Andy van den Dobbelsteen, the Lidl’s vision + mission and the role of the TU Delft were explained. It became clear that within the theme of circularity, a more defined research topic was required.

To achieve this, I started reading about all kinds of topics that are more or less related to circularity. This included subjects like:
- The work and ideas of Thomas Rau and interviews with this architect;
- The position of the Dutch government in circular economy;
- Example projects;
- Short research reports by the VMRG;
- Reports by Bob Geldermans, containing general advises for circular building construction;
- TVVL articles by Sabine Jansen & Bob Geldermans;
- SBRCUR kennispapers;
- Lidl year reports;

The goal was to get a perspective on the circular economy and what it means for the building industry. Secondly it was important to get an idea of the current position of the Lidl supermarket chain on sustainability.
For my own overview and convenience, the broad theme of circularity was brought down to two subjects: 1) the reuse and preservation of raw earth materials and 2) the switch to renewable energy sources from energy sources based on fossil fuels.

The first conclusion was made to focus more on the energy flows involved in the everyday business of a supermarket.

First presentation at the Lidl
On 23-5-2017, a meeting took place in the Lidl main office with Luuk Graamans. The objective was to share the first findings of the TU Delft research and pitch my draft gradation plan.

Phase 2: Literature survey
The first part of the report gives a company profile of the Lidl and describes the current sustainability program. This is followed by a definition of circularity, which includes answers to questions like: What does circularity mean for the building industry? How do we theoretically achieve energetic circularity?

Roadmap to circularity
To guide the TU Delft research, Andy van den Dobbelsteen has proposed a 4 step roadmap (not a sequence!) a supermarket could follow to become circular in the future:
1. Become CO₂ neutral
2. Become energy neutral
3. Become fossil-free
4. Become circular
(the steps are further elaborated in the report)

This graduation research is conducted around step 2 and 3: becoming energy neutral and aiming for a fossil free supermarket by means of having buildings energetically cooperating.

Precedent studies
It is important to understand what a circular economy means for the energy in the built environment. This is followed by a handful of precedent studies that are also mainly focused on the energy theme within the CE and two urban farming studies. One study focuses on a similar energy project: The connection between Greenhouses and dwellings in Hoogeland (NL).

Supermarket activity
To design a sustainable and fossil free supermarket, it is important to get an idea of the everyday activities that are happening and what the energetic consequences of these activities are. The energy demand is translated into CO₂ emissions. Also the logistical CO₂ emission is briefly kept under the light.

Context & data
Lidl Holland provided a suitable case that will become the subject of this research. Next to this, the Lidl organization will also share energy data from their supermarkets (electricity, gas, water).


**Process**

**Phase 3: Concepts**

Based on the definitions made and the conclusions drawn in phase 2, exploratory energy grid concepts will be made. The concepts revolve around both the building related energy as well as the operational energy! One way to achieve this is by looking at the possibilities of putting several different functions under one roof that benefit from each other’s energy flows. The concepts will be based on the energy data of the current supermarket that is provided by the Lidl.

The fundamental idea and final achievement of the research is the complete disconnection from fossil energy resources. This can theoretically be accomplished by several different methods and energetically connecting buildings is one of them. Several concepts will be drafted that steer in the direction of that goal. The concepts need to be analyzed and tested for their energy circulation potentials. This will be done by means of indicative hand calculations, discussions and comparisons with similar ideas. It might already be concluded in this phase that certain fundamental elements of the concepts require a different approach. Perhaps first calculations already point out that a system needs to be scaled up or scaled down to be efficient or even work in the first place.

**Phase 4: Design and elaboration phase**

Based on the collected data, the indicative hand calculations and the conclusions drawn from the literature studies, one concept will be chosen to be further explored and optimized. At this point it is important to have a detailed view on the energetic performances of the individual buildings to determine the effect of connecting them. I hope that around this time the plans for the new Lidl supermarket in Amsterdam have been shared with me.

*Supermarket building*

The subject is an existing supermarket in a dense urban context. The current Lidl supermarket gets a large scale renovation and in that sense it can be considered as a completely new building. The adjacent dwellings are existing (historical) buildings and cannot be altered too much. Especially the street facade should remain untouched as much as possible.

*Greenhouse*

The direct vicinity of the case is a dense urban area. There is practically no space available on the street level. The greenhouse shall therefore be designed on the roofs of the adjacent structures. This research shows an example of energy demand reuse and is theoretical. For sake of the research, permissions and urban development plans + regulations regarding urban interventions are not taken into account.
Solar study
To optimize the design, a brief solar study is required. The study will cover the whole building block. Due to the different height varieties of the buildings in this block, results from this study will form a guideline for the greenhouse design.

Simulations
Designbuilder software will be used to validate the hand calculations. The supermarket can be modelled based on the Lidl renovation plans. The greenhouse will be designed from scratch and can therefore also be modelled accurately. The existing residential buildings will be modelled as accurate as possible; building or technical data that cannot be acquired, shall be estimated according to standards or comparable projects.

Phase 5: The final product
This research is not conducted to find an answer to abandon the linear economy but will describe only one option that brings a supermarket in the right direction, towards energetic circularity. That is why it is important to step back and zoom out every once in a while to check if the course of the research is still set within the energetic domain of circularity.

The final report can be used as a recommendation to future supermarkets that want to explore the possibilities of energy reuse with on-site food production.
Relevance

Our Western economy and building industry are currently based on the linear model. In a nutshell: this means that we appeal for fossil fuels to meet our increasing energy demands. Secondly, the materials we harvest from this planet are applied in such a way, that from an economical point of view they should be considered as waste. In other words: fossil fuels and raw materials are disappearing from this planet. For an economy that is organized around the consumption of fossil fuel, this means a serious problem is coming up. Our mobility, products, economies, political power are mainly dependant on fossil energy. For decades, researchers and politicians have already started the discussion about the human (irreversible?) impact on this planet. A lot of energy reducing technologies are developed and recycling programs have been organized, but up till this day we are still destroying valuable earth resources. One answer to this problem could be to switch to a circular economy, which is extremely challenging on a global scale.

A supermarket is a big consumer of energy, a node in transport lines, a transshipment of biomass (food) and a centre of activity. Supermarkets have been around since the early 20th century and will most likely still exist in their current form for years to come. It shows potential to research the opportunities of energy exchange in a supermarket.

On-site food growth

Why local food production? Road freight transport is responsible for a large part of the national fossil fuel consumption and CO$_2$ emission. In 2015, the traffic+transport sector and the built environment were responsible for 21% and 14% of the total national CO$_2$ emission (Compendium voor de Leefomgeving - Rijksoverheid, 2017). It is important to reduce the environmental impact of a supermarket building according to the new-strategy-steps and reach a point in which fossil energy is no longer needed in a building. At the same time it is also worth investigating and investing in reducing the logistical CO$_2$ impact and fossil energy consumption.

Cutting down on transport lines by bringing back a part of the food production to the site is one way towards achieving fossil independence for the total Lidl enterprise. Growing a handful of products on-site will of course not solve the global fossil energy and CO$_2$ issue, but it is a step in the right direction and it shows the goodwill of the Lidl. Urban farming would contribute to the sustainable image the Lidl is striving for, which is of course of great value from a commercial point of view.
Energy reuse

Both the supermarket and the greenhouse have interesting energy flows. Due to year around product and building cooling, a supermarket generates a lot of residual thermal energy. For this, the building requires a lot of electricity. Artificial lighting is the second largest electricity drain in a supermarket building, but improvement steps are already made by switching to LED lights. In summer, greenhouses are basically large solar collectors, storing thermal energy in the air, soil, plants and construction. Greenhouses also have a large cooling capacity due to the evaporation of water by plants. As long as there is enough water supply and dependence on the type of crops, the cooling capacity can reach up to 400W/m² (Van den Engel, 2017). If night time support lights are switched on and if in winter additional heating is used to prevent plants from getting hypothermic, the greenhouse is also a large consumer of energy. Another issue a greenhouse has to control narrowly is the air humidity: too low and the plants will overheat, too high and the risk of diseases and fungus gets too big.

It shows potential to investigate the reuse of the greenhouse and supermarkets waste heat for the surrounding residential area, either directly or through energy storage.

References:
[1] CO₂ Neutrality

Getting a large organization like Lidl Nederland CO₂ neutral is the least complex achievement of all four. Carbon dioxide neutrality can be obtained by means of compensation without structural changes for the company processes or businesses.

CO₂ compensation is based on an European wide organized trading system. 1 ton of CO₂ equals one emission right and one emission right represents a certain financial value. Participating companies determine their standard annual CO₂ emission and each year they are given that equivalent of emission rights by the emission authority. The key is to reduce the CO₂ emission in a year so that surplus emission rights can be sold to other companies that have a CO₂ emission overflow and need those rights. Rights can also be bought at the emission rights bank. The money they earn by the trade of right is invested in CO₂ reduction research or in new trees.


Energy neutrality is, according to the Dutch government, compensating the fossil energy that is used from the national network by renewable energy, calculated over 1 year. In practise this comes down to selling the electricity surplus in summer to the network and buying it back during winter. It means that energy neutral is not equal to fossil free! Energy neutrality is achieved when the EPC of a building is 0. Only the building related energy is taken in the calculation of the EPC and the energy production can take place on site or can be important from where there is space available.

Energy neutral if \( A - B > 0 \)
[3] Fossil free

The problem with this netto energy neutrality [2] is the fact that it still appeals to fossil energy in winter. The surplus that a house delivers to the network might be based on renewable energy and in the annual netto energy consumption might be zero, in winter the house still depends on grey energy. This solar intensity controlled taking and giving back pattern leads to undesirable demand fluctuations for the national grid.

To get independent from fossil energy, we either need to find an effective way to store the surplus energy from summer to later use in winter or we need to find more efficient ways to generate renewable energy during the cold days.

| A  | Electricity surplus in summer |
| B  | Grey energy use in winter     |
| C  | Demand covered by renewable throughout the year |

Fossil free if A = B

[4] Energetically circular

It is important to compare the amount of energy it takes to produce, transport and to dispose/reuse a product with the amount of energy a product can generate or save over the years. For some products and materials it is important to take this energetic payback time into consideration. This is the time it takes for a product to compensate for its own energetic investment. Recycling building products and materials, according to the principles of the circular economy, takes up much less energy and less to no raw materials. Again: the smaller the recycling loops are, the more value remains in the materials. This principle might however not account for materials and products that origin from a linear basis, as they are not intended to be reused.

The total energy demand for all of the materials in a building can be quantified. An absolute energetic circular building produces more renewable energy in a year then it requires to also compensate for the investment energy in the production phase.

| A  | Electricity surplus in summer |
| B  | Grey energy use in winter     |
| C  | Demand covered by renewable throughout the year |
| D  | Additional renewable energy generation |
| E  | Investment energy demand |

Energetic circularity if A+D = B+E
Energetic circularity goes all the way to the extend of taking responsibility for the investment energy during the manufacturing phase of building products (absolute energetic circularity). On the building scale this means that there is more generation of renewable energy than the building, the users and de processes together demand. After a certain period of time, there has been sufficient surplus production that the investment energy is compensated. In practise, this works much more complicated and as far as I know, there are no known projects that consciously and actively try to compensate the embodied energy. This makes sense as in most cases it is already enough of a challenge to make a building energy neutral on an annual basis.

Fossil free

The title of this graduation research calls Towards energetic circularity. In a sense, this is a very open title as basically any minor energy reducing intervention or application is a step towards energetic circularity.

In this research, energetic circularity is achieved if a building no longer relies on fossil energy and can sustain itself throughout the whole year, including building, user and operational energy!

In the overall scheme of the roadmap, this is one step prior to absolute energetic circularity.

In this research, a supermarket is brought as close as possible to total fossil disconnection > Towards energetic circularity. This is accomplished by sticking to the new stepped strategy: reduce, reuse & produce. Exploring the opportunities of a synergistic local energy grid would be a form of reusing energy flows, subsequently reducing the energy demand of all the involved structures.

Even though the initial goal would be to reduce the energetic footprint of the Lidl, in this research I’m looking at the effects on the whole building cluster. I’m looking at the possibilities of creating a synergistic local energy grid to reduce the environmental footprint. The word synergy in this context implies that a collaboration between functions have a bigger effect than the particular buildings. This also means that we have to look at the combined effect and not just at the effect on the supermarket.
Designing the energy system

Design sequence

1. Designing the local energy system starts with identifying and quantifying the energy flows in the supermarket. For this, the conclusions from the data analysis of the A++++ standard supermarket are combined with the design for the new Lidl supermarket in Amsterdam. (which also becomes an A++++ supermarket) Within the coming months the Lidl most likely shares the construction plans for their new supermarket with me, which will form the basis of the energy grid.

2. The second element in the local grid would be the greenhouses in the direct vicinity. Energetic performances of the greenhouse will be retrieved from literature studies and the design for the greenhouse remains rough.

3. After the greenhouse and the supermarket are connected with each other, the opportunities of integrating the adjacent dwelling will be explored. Numbers on the energetic performances will be based on key figures and educated estimations.

[1] Starting point
- Design and specifications provided by Lidl.
- Energetic picture derived from data analyses

[2] Connect with greenhouse
- Rough own design.
- Within the footprint of the building block! > local

[3] Integration in the grid & seasonal + day&night storage
- Energetic performance based on key figures and estimations.
- No drastic interventions possible!
Forming first ideas on topic, meeting with Andy & Luuk, preparing P1 presentation

Exploratory reading

Setting up report / Graduation plan / Lidl company profile

Establishing the definition of circularity

Literature research on the role of energy in circularity

Research on the flows in a supermarket / context research

Location and context analysis (rough)

Primarily supermarket concepts

Further development of concepts

Concept evaluation & conclusions of primarily concepts > chose final concept

Further development selected of concept

Further (literature) research on themes connected with the concepts

Calculations

Calculations & schematics

Simulations

Drawings (detailing)

Conclusions

Feasibility check / circularity check

Final products

Reflection
Graduation plan - Time planning & Literature