SPATIAL CONSEQUENCES OF A NEIGHBOURHOOD SCALE HEAT AND ELECTRICITY GRID SYSTEM

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ABSTRACT

This paper focusses on the spatial consequences of local sustainable centralized mini heat and electricity grid systems for the transformation of post war neighbourhoods in the Netherlands. The energy transition is the result of urgent and ambitious goals of governments and municipalities to reduce the demand of energy and prevent further pollution. The measures that often have to be taken are radical and have a big influence on everyday life. They also have to be fitted within the current building stock. Post war neighbourhoods are often seen as an opportunistic place to implement environmental changes because the building stock is often owned by housing corporations. Therefore changes can be implemented on larger scales in comparison to places with a lot of private housing. However, post war neighbourhoods are also having problems on a social and spatial level that need urgent attention. These are often initiated from a bottom up approach. This paper is a first step in an attempt to integrate social and spatial necessities with the technical measures for sustainability. By applying the new step strategy[1] for energy reduction a case study neighbourhood was made sustainable. First the building types, the amounts of each type and the state were determined. Then the average energy demand was calculated and a flow scheme was produced. Next, the energy demand was reduced followed by the introduction of sustainable measures. Lastly the sustainable measures were made explicit by contacting manufacturers and consultants to get an idea of what the spatial consequences would be. The results show that the heating grid can be constructed by using a DATES system combined with central heat pumps and heat exchangers. For the electricity grid PV panels are used together with solar inverters and neighbourhood batteries. The total amount of technical consequences gives a good overview and encourages architect and designers to integrate these systems in a creative way together with necessary social and spatial necessities within a post war neighbourhood.

KEYWORDS:

Centralised energy grid, Centralised heat grid, Neighbourhood energy system, Post War Neighbourhood, Flowstudy, Community, Social Sustainability, Central heat pump, Neighbourhood battery.

I. PROBLEM STATEMENT

After signing the Paris Climate Agreement in 2015 the Netherlands is striving to reduce the demand for heating and replace natural gas for sustainable heating systems by 2050[2]. Another ambition is to produce 70% of all electricity from sustainable sources in 2030[3].

Governments and municipalities are often looking with a top down approach and on the larger scale to create the most efficient systems. On the other hand, engaged citizens are encouraged to initiate local sustainable projects from a very bottom up approach. This often works with privately owned buildings or housing, but knowing that almost 30% of the total housing stock in the Netherlands are owned by housing corporations[4], these very small initiatives are sometimes hard to realize. The situation is especially complicated in Dutch neighbourhoods that are built between 1945 and 1965. Formally known as the Dutch post war

1 (Dobbelsteen et. al., 2008)
2 (Ministerie van Economische Zaken en Klimaat, 2019b)
3 (Ministerie van Economische Zaken en Klimaat, 2019a)
4 (Centraal Bureau voor de Statistiek (CBS), 2020)

neighbourhoods.

Once a Walhalla for the Dutch middle class, currently a complicated environment with outdated spatial principals, social problems and a wide variety of nationalities and age groups are inhabiting these neighbourhoods. Another aspect is that the housing is often in need of urgent renovations. Professional plans are presented to guide these neighbourhoods through the energy transition, but none of the plans have a direct benefit for the social problems within these communities.

In an essay Veer and Schuiling explain the importance of a broader understanding of sustainability and emphasize the involvement of corporations to also develop the public space and increase diversity and liveability around their properties. This strengthens the satisfaction of inhabitants for the long term.[5]

But the corporations are being held back. Since 2013 the Dutch government introduced a tax on social housing owners[6] which limited the potentials of corporations and resulted in higher rents for tenants. On top of that the government also reduced the diversity of projects housing corporations are allowed to perform. This limits their abilities to improve the liveability of new developments and create necessary spaces for small businesses.

Together with the need for one million homes and the inevitable challenge for densification of cities, architects and designers have a great chance to create smart and creative solutions. Current design practice suffers from the segregation of activity and specialization. This has led to designers to become dependent on external specialists and losing one of their primary capacities: to integrate.[7]

This research will focus on the question: Which technical solutions are necessary for a locally centralized mini heat and electricity grid system in a Dutch post war neighbourhood and what are the spatial consequences of this system?

The goal of the research is to provide an inspirational vision of the possibilities of upscaling specialized sustainable measures to a neighbourhood scale. For this research the focus will be on the heat and electricity grid. For a sustainable system new technical machines will need to be added into the public space. This research will provide the technical solutions and their dimensions based on a case study in Amsterdam Slotermeer. The results from this research will be integrated with further social and local analysis. This will lead to an integrated densification that is beneficial for the sustainable ambitions of the municipality and government as well as for the local inhabitants and their community. The data used in this research is based on general usage of electricity and heating. For a specific plan more detailed data should be gathered from all the involved parties.

II. THEORETIC FRAMEWORK

In 1996 Lysen introduced the Trias Energetica principal[8] with three rules to reduce the usage of energy. These three rules were further developed at the TU Delft by Duijvenstein and formulated in an order for the best results.

Step 1: Reduce the energy demand.

Step 2: Use energy from renewable sources.

Step 3: Make efficient use of fossil fuels.

5 (van der Veer & Schuiling, 2016)
6 (Ministerie van Financiën, 2019)
7 (‘FLOWS - Research Group’, 2017)
8 (Rijksdienst voor Ondernemend Nederland (RVO), 2015)

Tillie et. al. notes that these rules are a logical environmental friendly solution, but in the course of 20 years since they had been introduced, they haven't accomplished their initial goal for the envisioned sustainability. He continues that in the Netherlands the first two steps have mostly been neglected and therefore step 3 was seen as the first step. This resulted in a missed opportunity for the development of sustainable resources. In 2008 Dobbelsteen et. al. reformulated the steps into the new step strategy.

Step 1: Reduce the energy demand.

Step 2. Reuse residual flows.

Step 3a: Solve the remaining energy demand in a sustainable way.

Step 3b: Waste = resource.[9]

In the thought of the new step strategy Tillie et. al. stress the importance to apply the steps in a broader context than just the building scale. Although the benefits for a building can be of great significance for the building itself and reuse of flows within a building is a necessary step, there is more potential. A better approach would be to consider energy flows on a building cluster or neighbourhood scale. This way residual flows could be exchanged, stored or cascaded to create a mutual benefit. When an efficient system is created step 3a can be addressed and potentials for sustainable energy generation can be explored. Although this is possible on a building scale, it is more economic to consider on a larger, neighbourhood scale.[10]

The benefits of large scale implementation of the new step strategy is clear, but these kind of developments include new kinds of considerations. When a whole neighbourhood is being linked to a beneficial system, the social impact cannot be neglected. Bus[11] explains that there are many opposed interests and high costs involved in a sustainable transformation of post war neighbourhoods. It is unlikely that these kind of changes to the existing physical environment would be initiated solely from an environmental perspective and that for these changes to happen they have to be placed and considered within a broader social framework.

Walker and Simcock[12] are specialised in community energy systems and list the benefits of integrating the local community with sustainable measures. Firstly they point out that a community energy system can generate income. Second, they think it's possible to provide energy more cheaply. Third, projects that are owned or partly owned by the community show evidence of more local acceptance for the sustainable developments. Besides, they also point out that getting people involved can be seen as education on benefits of sustainable energy. This will increase awareness on energy consumption practises of the daily life.

To get acquainted with the possibilities in technical and sustainable solutions the Routekaart 2050[13] and the City-Zen research were consulted.[14] The Routekaart 2050 made clear what actual ambitions the municipality of Amsterdam has, to become a sustainable city in 2050. The City-Zen Research was a parallel study conducted earlier and, in the end, even inspired some points of the Routekaart 2050 with their roadmap for Amsterdam. In the City-Zen Roadmap Dobbelsteen et. al. proposed schematic scenarios for sustainable energy grid systems in the post war neighbourhood of Slotermeer in Amsterdam. These schemes were fragmented and based on individual solution specifically for a certain type of building or

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9 (Dobbelsteen et al., 2012)
10 (Tille et al., 2009)
11 (Bus, 2001, p. 269)
12 (Walker, Simcock, 2012)
13 (College van B&W, 2020)
14 (Broersma & Dobbelsteen, van den, 2018)

building configuration. Although there was a fragmentation, the measures that are showed seem to overlap in some way. After consulting with one of the researchers, the main sustainable solutions of implementing heat pumps, thermal storage and solar panels could be extracted. This made the research applicable on a broader scale and thus suitable to implement in a neighbourhood scale system.

In this research the focus lies on the translation of neighbourhood scale mini energy grids and their schematic components towards actual, physical necessities in the spatial environment. By knowing these actual spatial consequences, architects and designers can provide a creative approach towards integrating technical solutions for a sustainable neighbourhood with further research on necessary functions that form a benefit for the community in a social way as well.

III. Method

To determine the spatial and technical necessities for sustainable mini heat and electricity systems the energy demand was researched. This was done by determining the different types of dwellings and public buildings inside a selected area of a post war neighbourhood in Amsterdam (more about the case study in the next chapter). With the amount of types and the amount of buildings within these types a calculation could be made for an average demand for heat and electricity.

The results are translated into a flow diagram for the current unsustainable and the preferred sustainable grid system. The flow diagram is based on the INSIDE Flows method which creates a systematic understanding of the working of flows in the environment and is using the knowledge of these systems to give a positive contribution to design.[15] Flow research aims at: *1, understanding the processes and flows in an environment.; 2, Identifying the losses and the needs and pains in that environment.; 3, Identifying which losses can be turned into resources and value.; 4, Proposing an intervention both in a spatial and systemic way.; 5, Choosing the proper site, form, construction and materialisation to host the intervention.; 6, Evaluating the effect.*[16]

It's an analytical method of quantifying flows in a well-defined system. With the flow diagram losses can be identified and improvements can be implemented in logical places in the diagram to check their potential benefits.

By knowing quantitatively what amounts of resources are needed for the system, and knowing what systems need to be added to facilitate a sustainable heat and electricity flow, the physical dimensions of these systems can be defined. This was done by contacting manufacturers of these systems and presenting them with the quantitative values of the research. With their expertise they provided options of suitable machines that could process the demands that are necessary and the spatial consequences of these machines.

With this information the research question could be answered and recommendations could be made for architectural integration of these machines with beneficial social functions within a post war neighbourhood.

IV. Case Study: Louis Couperusbuurt

The Louis Couperusbuurt is a neighbourhood located in the district of Slotermeer. This district is part of the Amsterdam Expansion Plan by van C. van Eesteren. The plan was developed in 1933 but the realisation only started after the second world war. Because there

15 (Jongert, Dirkx, Venhuizen, van der Burgh, 2013)
16 (SUPERUSE Studio, 2020)

was a high demand for dwellings, building plots were filled quickly and left a post war zeitgeist in the whole area. Currently the area has changed demographically and the needs of the inhabitants are different than during the developments in the ’50. The dwellings are in need of renovations and the social structure lacks stability. An important spatial aspect of these social problems are the many undefined public spaces throughout the neighbourhoods and the lack of diversity in functions and dwelling types.

The Louis Couperusbuurt has an area of approximately 26 hectares and houses approximately 1650 people. 86% of the housing is owned by the housing corporation Stadgenoot.[17] According to the senior area manager the technical state of the dwellings is moderate, while the structures are reasonable. He addresses the needs for renovation. When asked about the ambition of the renovations and the energy transition, Stadgenoot is mostly focussed on reducing the CO_2 emissions. Currently the process of the renovations is still in the preparation phase. The explicit plans are yet to be developed and the negotiations with the inhabitants are still to be held. Assumingly the very first step of the renovation will be providing the dwellings with proper insulation. For further measures to increase sustainability only a few options were considered, but explicit strategies are not yet developed.

As mentioned in the introduction of this paper the neighbourhood scale involves more interests from different parties than the building scale alone. So in the case of the Louis Couperusbuurt there are the owners of the buildings itself, which differ from Stadgenoot with the most of the ownership of the dwellings but there are also privately owned dwellings in the neighbourhood. Of course the inhabitants of the dwellings form an important group and are constantly in discourse about the plans for the neighbourhood, besides their involvement in the renovation process, they also mirror the social necessities for an improved liveability.

Furthermore there are also a few public buildings present. Elementary schools for different target groups, a mosque, a church and some small offices and local shops complete the list of the local parties. Another large party involved in the neighbourhood is the municipality of Amsterdam, the ambition to become a sustainable city by 2050 has a large impact on the developments within the Louis Couperusbuurt. In the next chapter the building types will be discussed in more detail.

Figure 1, Map of Louis Couperusbuurt with indications of the different building types, 1:15000 (own illustration, 2020)

17 *(Gemeente Amsterdam, 2019)*

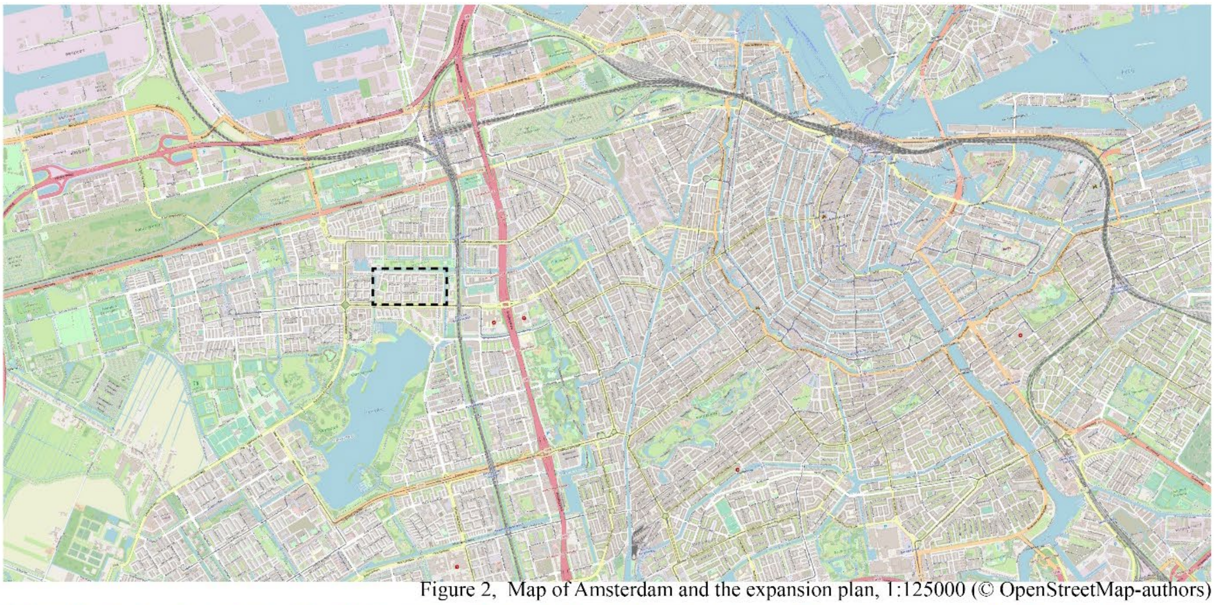

Figure 2, Map of Amsterdam and the expansion plan, 1:125000 (© OpenStreetMap-authors)

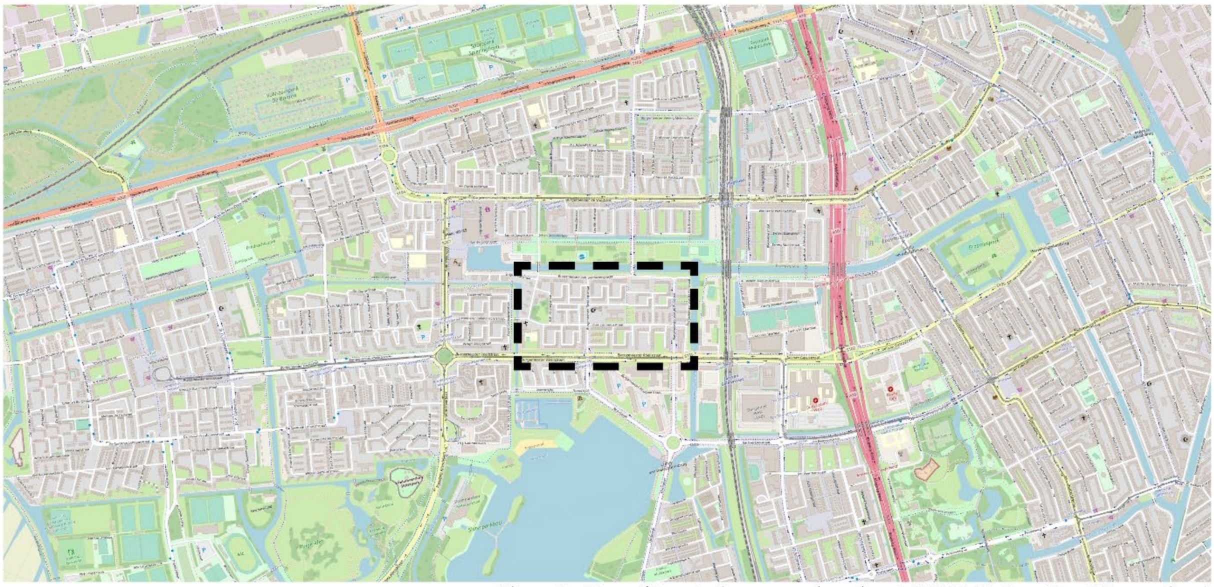

Figure 3, Map of Amsterdam expansion plan, 1:50000 (© OpenStreetMap-authors)

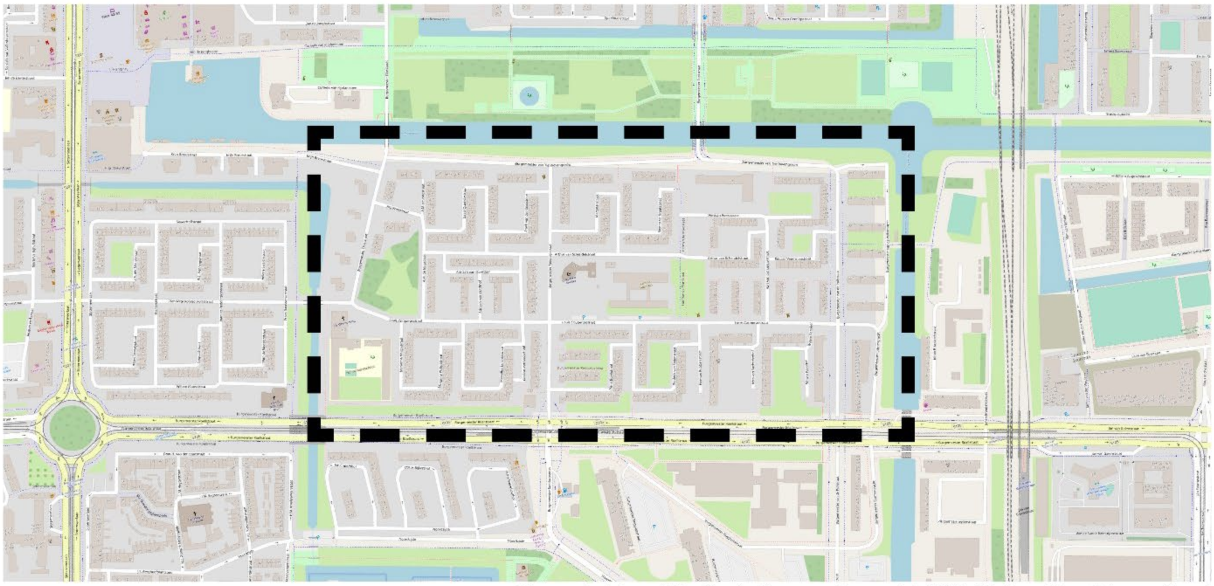

Figure 4, Map of the Louis Couperusbuurt, 1:15000 (© OpenStreetMap-authors)

V. Results

5.1. Types

The Louis Couperusbuurt can be divided into six categories. For each category the average energy consumption was calculated for the current situation, as well as for the renovated situation where the buildings are properly insulated and connected to the District Heating Network (DHN).

*figure 5**

DUPLEX HOUSING (B, C, F, G, I)	Single household	Louis Couperusbuurt As is	Louis Couperusbuurt Renovated
Build	1953-1957		
Average square meters	55 m²		
Average annual electricity use	2767 kWh	6894 GJ	6205 GJ
Average annual gas use	1675 m³	36680 GJ	12838 GJ
Total amount of type	692		

*figure 6**

TERRACED HOUSING (D, H)	Single household	Louis Couperusbuurt As is	Louis Couperusbuurt Renovated
Build	1953		
Average square meters	86 m²		
Average annual electricity use	2945 kWh	1410 GJ	1269 GJ
Average annual gas use	1721 m³	7244 GJ	2535 GJ
Total amount of type	133		

*figure 7**

TENEMENT HOUSING (E, J)	Single household	Louis Couperusbuurt As is	Louis Couperusbuurt Renovated
Build	1953-1954		
Average square meters	76 m2		
Average annual electricity use	2408 kWh	2115 GJ	1904 GJ
Average annual gas use	1263 m³	9752 GJ	3413 GJ
Total amount of type	244		

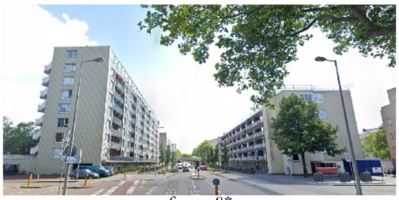

*figure 8**

GALLERY FLAT (K)	Single household	Louis Couperusbuurt As is	Louis Couperusbuurt Renovated
Build	1958		
Average square meters	83 m²		
Average annual electricity use	2408 kWh	1092 GJ	983 GJ
Average annual gas use	1263 m³	5036 GJ	1763 GJ
Total amount of type	126		

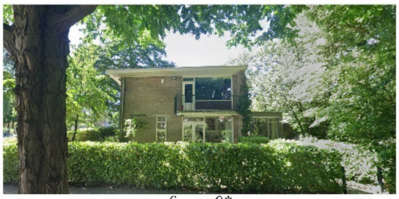

*figure 9**

INDEPENDENT DWELLING (A)	Single household	Louis Couperusbuurt As is	Louis Couperusbuurt Renovated
Build	1956-1959		
Average square meters	208 m²		
Average annual electricity use	4544 kWh	82 GJ	74 GJ
Average annual gas use	2943 m³	466 GJ	163 GJ
Total amount of type	5		

*figure 10**

PUBLIC BUILDING (L)	Single household	Louis Couperusbuurt As is	Louis Couperusbuurt Renovated
Build	1954-1965		
Average square meters	1500 m²		
Average annual electricity use	varies	1890 GJ	1701 GJ
Average annual gas use	varies	4621 GJ	1617 GJ
Total amount of type	6		

All data is calculated over the course of an annual average (kWh/year; m3/year; GJ/year)

1 kWh = 0,0036 GJ

1 m3 = 0,0316 GJ

* figure 5 UTAI figure 10 (Google Maps, 2019)

5.2. Flow Diagrams

5.2.1. Situation 1, Current State

The first scheme represents the current situation. The dwellings and public buildings are not properly insulated and still in moderate state. The heating is supplied by natural gas. The scheme shows that resources are used in a linear way and that there is no circular approach or benefit for the surroundings. If considered within the new step strategy this is the situation on which the first step will be taken on. In the INSIDE Flow method this step covers the 1st and 2nd step: Understanding the processes and flows in an environment an identifying the losses and the needs and pains in that environment.

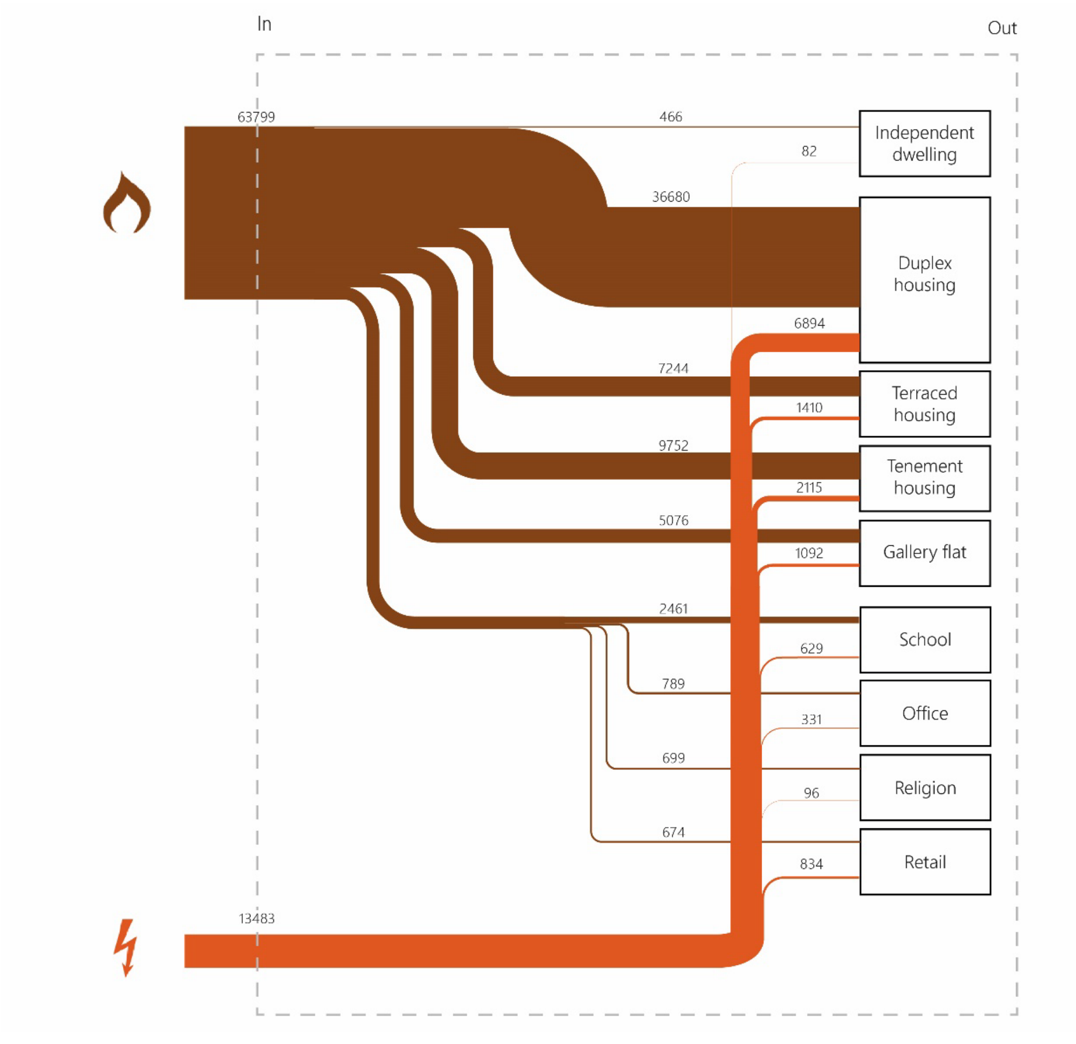

Figure 11, flowdiagram situation 1, Louis Couperusbuurt, All data[18,19,20,21] in GJ over the course of one year [GJ/year], Dark brown: Heating flow, Orange: Electricity flow (own illustration, 2020)

18 (Liander, n.d.)
19 (CBS, 2020)
20 (Broersma & Dobbelsteen, van den, 2018)
21 (Gemeente Amsterdam, n.d.)

5.2.2. Situation 2, Reducing the Energy Demand

According to the Roadmap Amsterdam[22] moderate renovations like insulation and the change to a District Heating Network (DHN) can lower the heating demand up to 60%. In this second situation the energy for heating is delivered by a DHN High Temperature (HT) input. After heating the buildings there is still energy left in the form of Medium Temperature (MT) heating. This will be given back to the DHN return system. The MT heating can be used for the heating of newly build buildings which have a higher insulation value and more sustainable and advanced heating systems.

For the electricity demand a reduction of 10% is being applied in comparison to the first situation. This is related to the expectations of the Roadmap Amsterdam in which a prognosis was made that by 2030 the electricity demand will naturally decrease because of more energy efficient products.

By using a district heating system, steps 1 and 2 of the new step strategy have been addressed. The energy demand is reduced and the residual flows are being used. Within the INSIDE Flow method the steps 3 and 4 have been crossed. The losses have been identified and turned into resource and value. Besides there is a proposition for a new system.

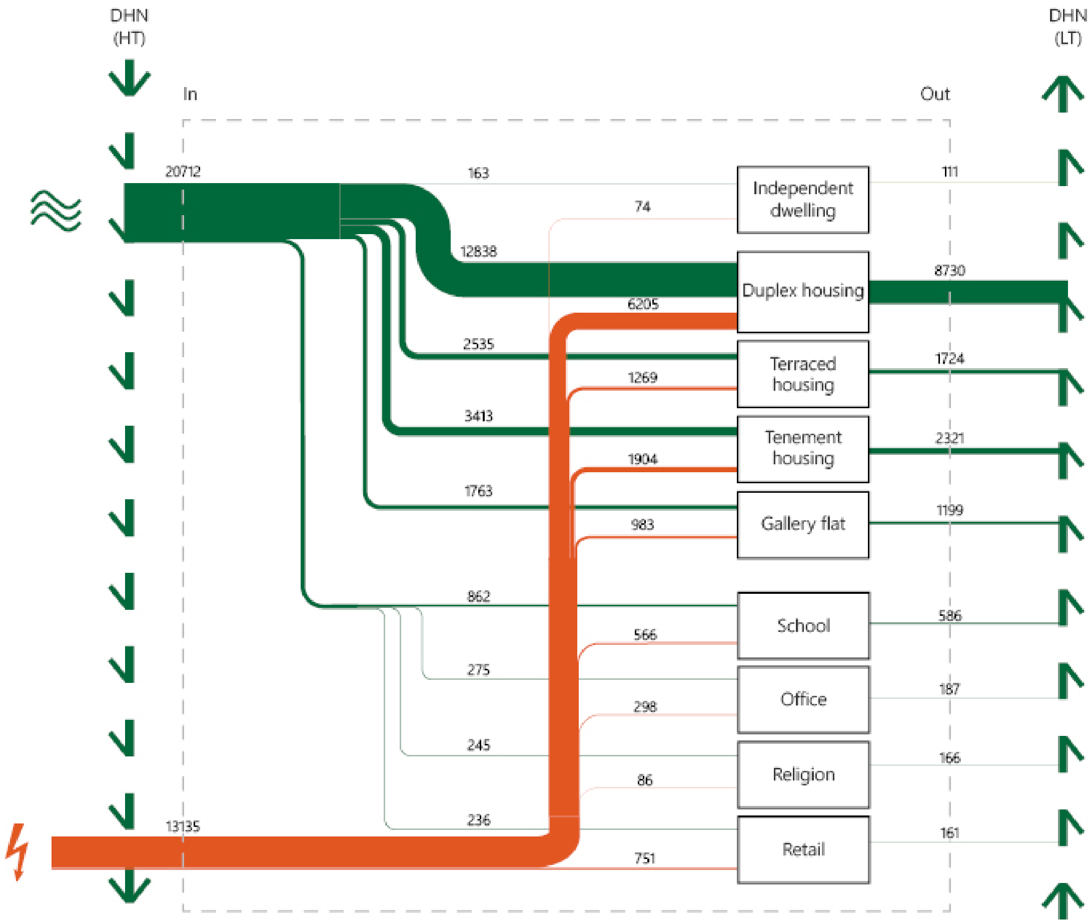

Figure 12, flowdiagram situation 2, Louis Couperusbuurt, All data[23] in GJ over the course of one year [GJ/year], Dark green: District heating flow, Orange: Electricity flow (own illustration, 2020)

22 (Broersma & Dobbelsteen, van den, 2018)
23 (Liander, n.d.), (CBS, 2020), (Broersma & Dobbelsteen, van den, 2018), (Gemeente Amsterdam, n.d.)

5.2.3. Situation 3, Sustainable Louis Couperusbuurt

To comply with the final steps of the new step strategy the third situation explores the general sustainable measures extracted from the overall fragmented solutions of the Roadmap Amsterdam. In this sustainable situation a District Aquifer Thermal Energy Storage (DATES) system is introduced.

The DATES system has many similarities with an Aquifer Thermal Energy Storage (ATES) system, which is more common, but where the ATES is usually applied on one building of a small group of buildings, the DATES system is capable of creating a network on a larger scale for a more efficient use of the stored heating and cooling. Velvis and Buunk explain that this network will prevent the numbers of wells that need to be drilled for the storage. Other benefits that are pointed out are the flexibility of the system and the resulting benefit of placing wells freely in the network. They also claim that there are more possibilities for buildings to exchange energy because they are all connected to the same system, resulting in more usage of residual flows. In their paper Velvis and Buunk[24] explain more benefits of the system, but also point out some technical points of attention for the system to work properly. These points have been left out intentionally and are important to apply in a latter and more detailed design of the actual system.

Besides the DATES system other, more common, sustainable measures are introduced. Centralised industrial heat pumps are introduced instead of individual heat pumps for each dwelling. Due to the ownership of the largest part of the dwellings by Stadgenoot, this is a logical solution. The heat pumps will boost the temperature of the heat stored water of the DATES system and make it suitable for domestic usage in the dwellings. Since the dwellings only have a heating demand there is no need for a heat exchanger in this situation. The rest of the buildings, on the other hand, do have a cooling demand. In summer the DATES system can provide cooling through the heat exchanger to the system for the buildings. The cooled water will then bypass the heat pump and provide cooling for the buildings. In winter a similar process will take place as for the dwellings and the heat pump will be activated again.

Besides the DATES system for sustainable heating and cooling, there is also a new system for sustainable electricity production. PV panels are introduced to generate electricity for the whole neighbourhood. The PV panels convert sunlight into electricity, but in the form of direct current. To make this electricity suitable for home appliances the current has to be inverted by solar inverters to an altering current.

When a whole neighbourhood will switch to electricity instead of gas, this will generate a higher demand for electricity. Especially in the evenings when everyone starts cooking, a daily peak could be expected. To prevent stress on the electricity network during these moments and the resulting operation of replacing the current cables for larger ones, the implementation of a neighbourhood battery could form a solution. This device will store the surplus of electricity produced by the PV panels during the day and release it when the evening peak demand occurs.

With these measures the Louis Couperusbuurt is now producing sustainable energy and using its waste flows as resource, complying with the steps 3a and 3b of the new step strategy. The steps of the INSIDE Flow method are retaken from step 4. There has been a search for new spatial and systematic interventions.

24 (Velvis & Buunk, 2017)

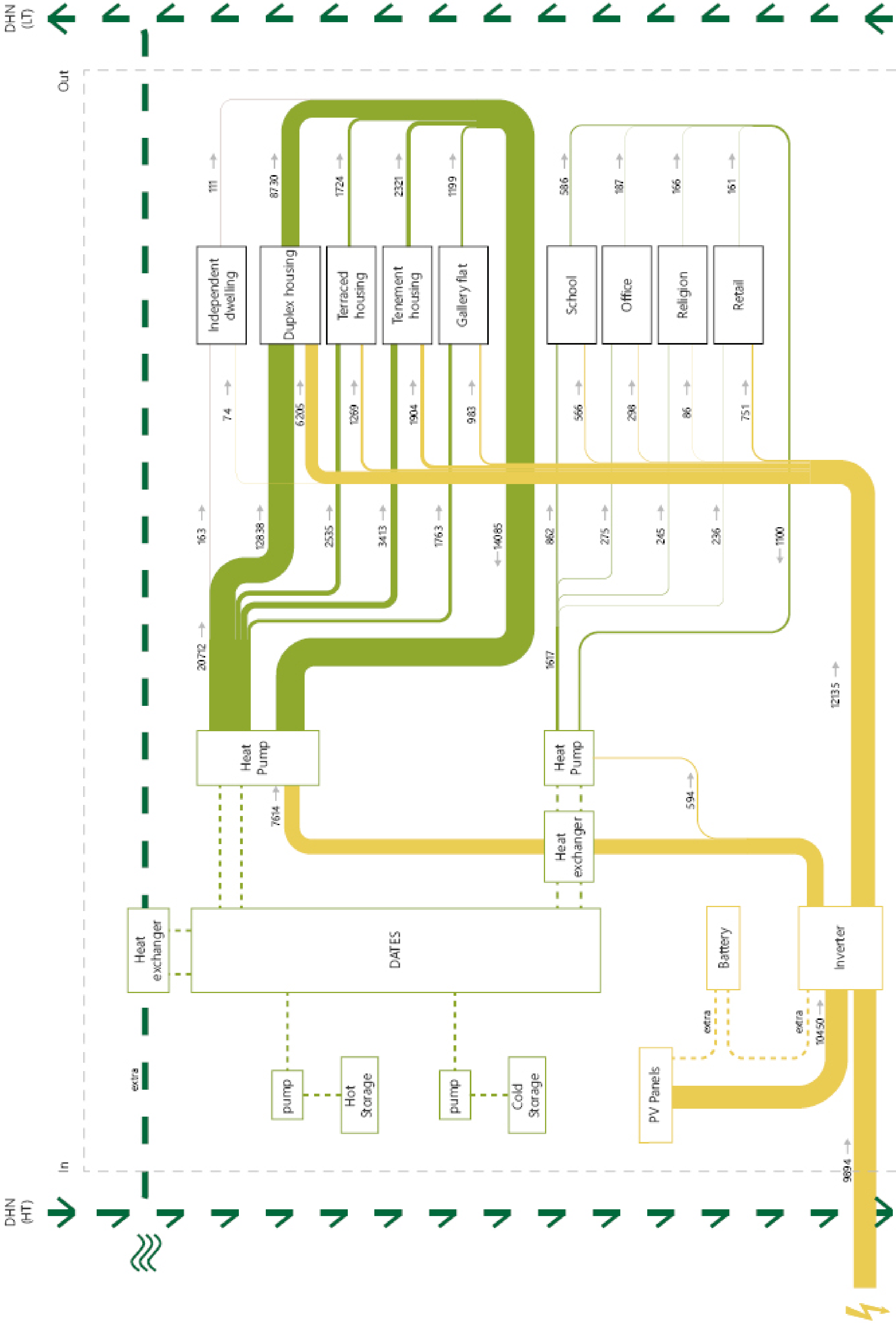

Figure 13, flowdiagram situation 3, Louis Couperusbuurt, All data[25] in GJ over the course of one year [GJ/year], Dark green: District heating, Light green: Residual flow heating, Yellow: Sustainable electricity flow (own illustration, 2020)

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25 Liander, n.d.), (CBS, 2020), (Broersma & Dobbelsteen, van den, 2018), (Gemeente Amsterdam, n.d.)

5.2.4. Technical Measures[26]

HEATPUMP		Single unit	Neighbourhood
Quantity	pcs	1	5
Dimensions (l*w*h)	mm	7000*1800*2350	7000*9000*2350
Footprint	m²	12.6	63.0

figure 14, (GEA, n.d.)

DATES*		Single unit	Neighbourhood
Quantity	pcs	1	5
Dimensions (l*w*h)	mm	≈ 10240*6034*3000	≈ 51200*6034*3000
Footprint	m²	61.8	309

figure 15, (GeoComfort, n.d.)

HEAT EXCHANGER		Single unit	Neighbourhood
Quantity	pcs	1	2
Dimensions (l*w*h)	mm	1639*480*1494	1639*960*1494
Footprint	m²	0.8	1.6

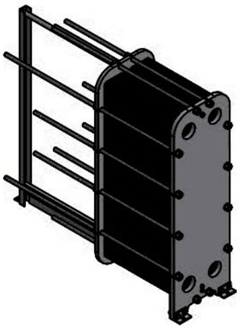

figure 16, (Danfoss, n.d.)

PV PANELS		Single unit	Neighbourhood
Quantity	pcs	1	22162
Dimensions (l*w*h)	mm	1650*1000*35	191413*192000*35
Footprint	m²	1.65	36751.3

figure 17, (Kingspan, 2019)

SOLAR INVERTERS		Single unit	Neighbourhood
Quantity	pcs	1	117
Dimensions (l*w*h)	mm	569*621*733	≈ 6828*6210*733
Footprint	m²	0.4	42.0

figure 18, (SMA, n.d.)

BATTERY		Single unit	Neighbourhood
Quantity	pcs	1	3
Dimensions (l*w*h)	mm	5890*2350*2360	5890*7050*2360
Footprint	m²	13.8	41.4

figure 19, (Ateps Nederland, n.d.)

* The measurements for the DATES system are taken from a reference project by GeoComfort and are based on the space of the room where the machines are placed. This also includes the space necessary for service operations.

26 See appendix 4 for calculations

VI. Conclusion

The results show what spatial consequences are necessary for a sustainable, neighbourhood scale heat and electricity grid. A separation can be made for the solutions necessary for the heating grid and for the electricity grid.

For the heating system of the Louis Couperusbuurt the DATES system, central heat pumps and heat exchangers are necessary measures. Together they are responsible for a total sum of approximate 440 square meters. All the machines should be facilitated in weather proof spaces and have enough room for maintenance workers. When active, the machines can become warm and the area where they are placed needs to be cooled and ventilated. The positioning of the wells for the DATES system can be used as a design strategy to increase the efficiency even more. With this positioning the heat pumps and heat exchangers could be clustered together on several places. This way an optimal controlled environment could be created.

A important note for the DATES system is that the heating demand drastically outbalances the cooling demand within the neighbourhood. This will prevent the optimal operation of the system. Possible solutions are increasing the demand for cooling by adding high cooling functions (supermarket, ice skate ring, etc.) or manually rebalancing the system by specialists.

The impact of the electricity grid is quite significant. The total sum of the measures results in approximate 3.7ha. The largest part of this sum are the PV panels. A big part can be mounted on the roofs of the existing buildings. The total surface area for the PV panels is 36567.3 m2. The total roof surface of the neighbourhood is approximately 42327.0 m2. Even though the roof area seems large enough, not all the roofs are suitable or perfectly oriented for optimal efficiency of the PV panels. An expert analysis should clarify how much of the total roof area is suitable for the PV panels, and how much should be integrated through other, non-rooftop, systems. One of the possibilities is integrating PV panels in the public space as additional shade constructions or above parking lots.

The additional measures to the PV panels are the solar inverters and the neighbourhood batteries. Both are suitable for outdoor positioning, but are aesthetically not very appealing. Calculations show that there is need for 117 pieces of solar inverter units. These would need to be spread out through the neighbourhood since one unit can only supply approximately 190 PV panels, split into 6 groups of approximately 32 panels. Because their relatively small size, vulnerability and safety regulations, placement should be chosen wisely. This could be together with existing technical facilities for electricity, on the territory of the public buildings, or on a semi private space of the community. Because the inverters have a direct impact on the neighbourhood the expectation exist that it would be easier to implement them in private spaces.

Another measure of the electrical grid are neighbourhood batteries. These are facilitated in 20ft containers. Currently they are placed as-is in the public space, but there are plenty of potentials to integrate these containers into the landscape resulting into a better integration within the neighbourhood. Projects with neighbourhood batteries have shown that there can be noise complaints coming from the unit. This is the result of the need for cooling and ventilation of the batteries. During the design this should be kept in mind.

Since developments never stop and the future of neighbourhoods can never be predicted perfectly the proposed heat and electricity grid is adaptable to changes. It can be expanded or optimised if new functions will be added or when functions change or disappear. This makes the system future proof and thus sustainable in the short and long term.

The method that is used to develop the results can also be used in other post war neighbourhoods. It's important to know which period the buildings are from and what their current state is. This way the general energy demand can be calculated and the same measures can be applied. Although this can be see as a general solution, there is always the need to properly explore the potentials of the context. This way other measures of collaboration between system and environment can be added or functions can be formed to achieve maximum symbiosis.

The knowledge on the explicit consequences of technical solutions for a sustainable local heat and energy grid is a small step in a complete sustainable energy transition of neighbourhoods. With the results of this research architects and designers can integrate these systems into the public space. A study on the social situation is one of the necessary future studies. The results of the social study will show what functions are necessary to improve the neighbourhood and the community. These results can be integrated with the results of this research. Another study can be conducted on the urban fabric of the area through different scales. What changes need to be made to optimise the usage of the public space and how can the technical solutions of this research be integrated in these changes?

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Figure 1. Own Illustration, 2020

Figure 2. ©OpenStreetMap-authors

Figure 3. ©OpenStreetMap-authors

Figure 4. ©OpenStreetMap-authors

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APPENDIX 1 CALCULATIONS BUILDING TYPES

Stamp	Type	Amount
A	Independent Dwelling	5
B.1	Duplex Housing	18
B.2	Duplex Housing	18
C.1	Duplex Housing	74
C.2	Duplex Housing	66
C.3	Duplex Housing	69
C.4	Duplex Housing	72
C.5	Duplex Housing	73
C.6	Duplex Housing	73
C.7	Duplex Housing	73
D.1	Terraced Housing	31
D.2	Terraced Housing	54
E	Tenement Housing	108
F	Duplex Housing	42
G.1	Duplex Housing	18
G.2	Duplex Housing	20
H	Terraced Housing	48
I	Duplex Housing	96
J.1	Tenement Housing	68
J.2	Tenement Housing	68
K.1	Gallery Flat	44
K.2	Gallery Flat	83
L.1	School	1
L.2	Mosque	1
L.3	School	1
L.4	Church	1
L.5	School	0
L.6	Office	1

Figure 1, Map of Louis Couperusbuurt with indications of the different building types, 1:15000 (own illustration, 2020)

APPENDIX 2 CALCULATIONS SURFACE AREA

	Total number of types	Total floor Surface Area	Average floor surface area
		[RUDIFUN]	Totaal floor area / amount of types
		[m2]	[m2]
Independent dwelling	5	1041	208
Duplex housing	692	39342	55
Terraced housing	133	11481	86
Tenement housing	244	18516	76
Gallery flat	126	10489	83
L1 School (1965)		3306	
L2 Mosque (1959)		888	
L3 School (1954)		4596	
L4 Church (1962)		635	
L5 School (1962)		984	
L6 Offices		1775	
L7 Stores		1055	

Source: Planbureau voor de Leefomgeving. (2019, May 13). Ruimtelijke dichtheden en functiemenging in Nederland (RUDIFUN). Retrieved from https://www.pbl.nl/publicaties/ruimtelijke-dichtheden-en-functiemenging-in-nederland-rudifun

Appendix 3 Calculations Situation 1, 2, 3

Average electricity demand	Average gas demand	Total electricity demand	Total electricity demand	Total gas demand	Total gas demand	Total electricity demand	Total electricity demand	Total gas demand	Total gas demand	Residual flows		Gem. Total electriciteits behoefte	Gem. Total electriciteits behoefte
[kWh/year]	[m3/year]	[kWh/year]	[GJ]	[m3/year]	[GJ]	[kWh/year] 10% besparing	[GJ]	[m3/year]	[GJ]	[GJ]		[kWh/year]	[GJ]
		Situation 1	Situation 1	Situation 1	Situation 1	Situation 2	Situation 2	Situation 2	Situation 2	Situation 2		Situation 3	Situation 3
4544	2943	22721	82	14714	466	20449	74	5150	163	111		20449	74
2767	1675	1915041	6894	1159100	36680	1723537	6205	405685	12838	8730		1723537	6205
2945	1721	391685	1410	228910	7244	352517	1269	80118	2535	1724		352517	1269
2408	1263	587552	2115	308172	9752	528797	1904	107860	3413	2321		528797	1904
2408	1263	303408	1092	159138	5036	273067	983	55698	1763	1199		273067	983
[kWh/m2]	[m3/m2]	[kWh/year]	[GJ]	[m3/year]	[GJ]	[kWh/year]	[GJ]	[m3/year]	[GJ]	[GJ]		[kWh/year]	[GJ]
19	8	61492	221	26779	847	55342	199	9373	297	202		55342	199
18	15	15540	56	12876	407	13986	50	4507	143	97		13986	50
19	8	85486	308	37228	1178	76937	277	13030	412	280		76937	277
18	15	11113	40	9208	291	10001	36	3223	102	69		10001	36
28	14	27650	100	13776	436	24885	90	4822	153	104		24885	90
52	14	91945	331	24850	786	82751	298	8698	275	187		82751	298
220	20	231784	834	21311	674	208605	751	7459	236	161		208605	751
											Heatpump dwelling	2115098	7614
											Heatpump rest	165127	594
		[kWh/year]	[GJ]	[m3/year]	[GJ]	[kWh/year]	[GJ]	[m3/year]	[GJ]	[GJ]		[kWh/year]	[GJ]
	School Total	174628	629	77782	2461	157165	566	27224	862	586	School Total	157165	566
	Office Total	91945	331	24850	786	82751	298	8698	275	187	Office Total	82751	298
	Religion Total	26653	96	22084	699	23987	86	7729	245	166	Religion Total	23987	86
	Store Total	231784	834	21311	674	208605	751	7459	236	161	Store Total	208605	751
	Total Dwelling	86%		93%		86%					Total Dwelling	2.898.366	10434
	Total Rest	14%		7%		14%					Total Rest	472.508	1701
	Total	3745415	13483	2016060	63799	3370874	12135	705621	22330	15184	Mechanical systems	2.280.225	8209
	Dwelling	3220407	11593	1.870.033	59178	2.898.366	10434	654.512	20712		Total	5.651.099	20344
	Rest	525009	1890	146027	4621	472.508	1701	51.109	1617				

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APPENDIX 4 CALCULATIONS TECHNICAL NECESSITIES

Calculations Heat pumps							
	Dwelling	Rest					
Annual Heat Demand (Flow scheme)	20712	1617	GJ per jaar				
Average Daily Heat Demand	57	4	GJ per dag				
Peak usage	5,25	0,41	MW				
Heat Source	6	6	°C				
Hot water circuit	85	85	°C				
Average COP	2,7	2,7	-				
Yearly electricity usage	2115098	165127	kWh				
Beer, de, T., & De Kleijn Energy Consultants & Engineers. (2019, 8 October). *De Kleijn Energy Consultants & Engineers*. Consulted from: https://energyconsulting.nl/nl/							
Heating capacity HP GEA RedAstrum (heating only)	1120-2000	kW	Average	1560	kW	5,6	GJ/h
Average Year Heat Demand Dwellings	20712	GJ/year	=			2,36	GJ/h
Peak capacity of heat demand	5,25	MW	=			18,9	GJ/h
Total need of heat pumps to manage PC Dwelling					Precise	3,4	Heat pumps
					Actual	**4**	**Heat pumps**
Heating capacity HP GEA RedAstrum (heating/cooling)	770-1430	kW	Average	1100	kW	3,96	GJ/h
Average annual Heat Demand CB Rest	1617	GJ/year	=			0,18	GJ/h
Peak capacity of heat demand CB	0,41	MW	=			1,48	GJ/h
Total need of heat pumps to manage PC Rest					Precise	0,4	Heat pumps
					Actual	**1**	**Heat pumps**

Beer, de, T., & De Kleijn Energy Consultants & Engineers. (2019, October 8). De Kleijn Energy Consultants & Engineers. Retrieved from https://energyconsulting.nl/nl/

Calculations DATES System
1200 dwellings x 2,5 kW = 3.000 kW Heatingcapacity
Rest Functions = 800 kW Heatingcapacity
Total = 3.800 kW
Nescessarry: 500m3/h
1 SKID = 100m3/h = 650kW
3800/650= 5,8
6 SKIDS in total

GeoComfort

Calculations PV Panels		
Awarage Revenue 1 PV panel	300	Wp
Correction Wp -> kWh = 0,85	255	kWh
Average annual electricity demand (including machines)	5651099	kWh/year
Amount of PV Panels needed	22161	Pieces
Surface area 1 PV Panel	1,65	m2
Total surface area PV Panels for Couperusbuurt	36567	m2
Dimensions total surface area of PV Panels	191x191	m
Aproximate roof area Louis Couperusbuurt	42327	m2
VoltaSolar. (2020, May 19). Opbrengst berekenen. Retrieved from https://www.bespaarbazaar.nl/kenniscentrum/zonnepanelen/financieel/zonnepanelen-opbrengst/		

Calculations Solar Inverter

MSA Solar sunny portal tool

SMA Solar. (n.d.). SMA Solar Technology AG - Sunny Portal. Retrieved from https://www.sunnyportal.com/register

Calculations Neighbourhood Battery			
1mWh = 20ft container			
Average 200 kWh electrical cooking / dwelling			
1200 x 200 = 2400 kWh			
2400 kWh = 8,6 gj			
1 mWh = 1000 kWh			
2400 kWh = 2,4 mWh			
2,4 -> 3 Batteries for the whole neighbourhood			
	l	**w**	**h**
1Battery	5,89	2,35	2,36
3 Batteries	17,67	7,05	7,08
Surfacearea	125	**m2**	

Ateps Nederland. (2018). Peak Shaving voor EV's – Enexis. Retrieved from https://www.ateps.com/nl/portfolio-item/interflex-enexis/