PLEA 2017 EDINBURGH
Design to Thrive

Buiksloterham Integrated Energy Systems

S.C. Jansen[1], R.M.J. Bokel[2], M.J. Elswijk[3], Saskia Müller[4]

[1] Chairs of Building Services and [2]Building Physics, Environmental and Computation Design Section, Department of Architectural Engineering and Technology, Delft University, Delft, The Netherlands, email S.C. Jansen@TUDelft.nl, R.M.J.Bokel@TUDelft.nl
[3] EnergyGO, Alkmaar, The Netherlands
[4] Stichting Stadslab Buiksloterham, Amsterdam, The Netherlands

Abstract: The traditional way of supplying energy to the built environment is no longer suitable: New buildings with high energy performance and decentralised renewable energy generation, together with the desire to become fossil-free, involve the need for new, more flexible and more integrated energy systems. The district of Buiksloterham was a test case to develop feasible and potentially desirable energy supply scenarios for the built environment at district level. It is not possible to develop Buiksloterham, and similar areas with high density, into an energy neutral area within the current legal framework (without wind energy it is not possible). About 1/3 of the energy use in buildings (building-related and user-related) can be supplied by renewable energy. In Buiksloterham a low temperature supply of heat is essential for a maximised use of renewable input. A fourth, low temperature, energy concept, consisting of local heat generation from solar and waste, thermal storage, and heat pumps, seems the best integrated energy system. The non-technical lesson learned is that new energy-efficient energy systems require very good, early planning, appointments, and cost and support of existing energy suppliers. Extracting a CO_2 neutral society by 2050 also depends on implementation aspects i.e. not only CO_2 and costs but also circularity parameters such as the use of resources for equipment, water, biodiversity, health, adaptability and resilience must be considered.

Keywords: Energy, Systems, District

Introduction

The traditional way of supplying energy to the built environment is no longer sustainable: New buildings with high energy performance and decentralised renewable energy generation, together with the desire to become fossil-free, need new, more flexible and more integrated energy systems. The city of Amsterdam has a large programme for new buildings (Gemeente Amsterdam). At the same time, the city's ambition is to become independent of natural gas for energy supply to the built environment by 2050. New buildings, therefore, should not be connected to the gas grid anymore.

Innovative scenarios for a flexible and integrated energy system are developed within the Buiksloterham Integrated Energy Systems (BIES) project for the suburb of Buiksloterham located in Amsterdam-North, see figure 1. The results of this study should also be applicable to other new construction sites with high energy ambitions and high densities. Both technical and organisational boundary conditions are considered in this research.

The Buiksloterham area is located on the North side of the IJ-river relative to Amsterdam Central Station and can be reached within five minutes from the Central Station with a free ferry service. The construction of the new "North-South" metro line, which will link the historic centre of Amsterdam with the northern side of the river, is scheduled for completion in early 2016 and will provide an important means of additional access. Buiksloterham, a former industrial area, is one of the larger new housing estates (around 100 ha) where 3500 new dwellings and around 200.000 m^2 working space is planned within the next 10 years.

Figure 1. The area of Buiksloterham (source: Bestemmingsplan Buiksloterham 2009)

Literature

The starting point for the development of the technical energy concepts was the energy potential mapping approach by Dobbelsteen et al. (2007) and Broersma et al. (2013). The 'toolkit duurzame gebiedsontwikkeling 2012' and the report by Jablonska et al. (2011) were used for the development of both new energy concepts and new energy approaches. However, the ambitions of the BIES project went beyond matching the energy potential to the demand. The wish of the district of Buiksloterham is to become a leading example of Circular City development in Amsterdam (Circular Buiksloterham report). This enforced the development of an integrated energy system that was sustainable in all its aspects. The district of Buiksloterham as a living lab required that the economic feasibility had to be taken into account to assure an affordable integrated energy system in the near future. And last but not least, to realise an integrated energy system in Buiksloterham is impossible if the political, social, technological, legal, and governmental aspects of the PESTLEG analysis are not considered.

The detailed quantitative analysis of the energy concepts and their evaluation on all the aspects mentioned above required an enormous amount of background literature. The energy demand of the buildings is based on the Dutch RVO (2015). An overview of all the other applied literature can be found in the final report of the project (Jansen et. al, 2016, in Dutch) as the page limit of this paper it too restricted to cite them all. Apart from the literature, a lot of information was also gained from stakeholders active in the area.

Methods

For the development of the energy concept an integral approach was developed where circularity in all its aspects was taken into account as well as the political, economic, social, technological, legal and governmental aspects. The approach consisted of two routes that were followed simultaneously. The first route is the theoretical development of the basic energy concepts. The second route is the practical approach where stakeholder meetings were used, as well as meetings with potential suppliers from industry, in order to improve the basic energy concept.

The area consists of existing and new buildings. Given the diverse nature of the existing buildings, the main focus was the energy concept for the new buildings. Recommendations for the existing buildings and the integration between the two are proposed in the project but not described in this paper.

Development of the Basic Energy Concept

An inventory was made of the existing buildings and the plans for the new buildings. Use was made of the "bestemmingsplan" (land us plan set up under the authority of the municipality) and the existing report about the circular ambition of Buiksloterham (Metabolic and Delva Landscape Architects, 2014). The inventory also included an inventory of stakeholders and existing energy infrastructures.

The energy concepts were assed using Key Performance Indicators (KPI's). These KPI's are developed within the following categories: energy, economy, circularity and implementation. The implementation category, in turn, consists of the PSTLG indicators: Political, Social, Technological, Legal and Governance. The main KPI's for energy are: the fraction of local renewable energy and the amount of CO_2 with the subcategories: energy use of existing buildings, energy use of new buildings and renewable energy potential, see the annual energy flow scheme in figure 2. The energy use data of existing buildings was obtained from www.energieinbeeld.nl. The energy potential on-site was estimated based on average roof surfaces for solar and average production of waste and waste water.

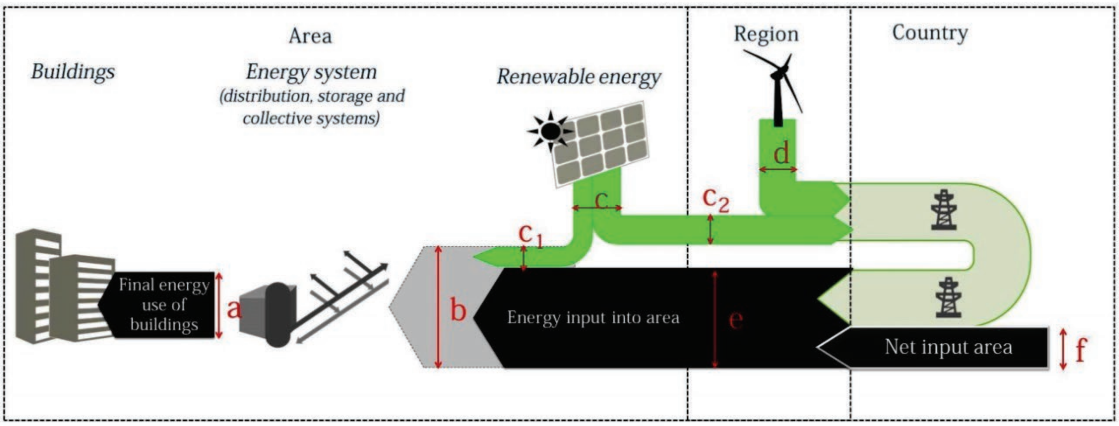

Figure 2. Schematic illustration of the Energy performance indicators in GJ/y (Jansen et al. 2015)

Two options were used as the starting point for the energy demand of new buildings. The first option has an energy efficient building skin, i.e. the Energy Performance Coefficient (EPC) of 0.4 of the building is reached with a standard energy system (HR gas boiler, electricity from the grid) and no sustainable production. In the other option, the insulation values of the building skin comply with the minimum values of the Dutch Building Regulations so that the EPC of 0.4 can be reached with efficient/sustainable energy solutions. The demand data for heating, cooling, domestic hot water and electricity consumption of the new buildings were based on reference numbers from RVO, 2015.

Three basic energy concepts for energy supply for the new buildings were developed based on proven and existing technologies: 1. Gas and electricity, 2. All-electric (heat pump and ground source thermal storage) and 3. District heating with electricity. Experience in the area and existing agreements between stakeholders were also taken into account in the development of these energy concepts. The efficiencies of the technologies involved were taken from RVO, 2015 and from the experiences of the project partners.

Development of the Energy Concept Advice

In February 2016, a first stakeholder meeting with around 25 people active in the area was organised to discuss the basic energy concepts. The discussions revealed that more attention had to be paid to the specific local situation in Buiksloterham. The evaluation of the basic variants generated ideas for improvements for the new and existing buildings. In May 2016, a second stakeholder meeting was organised where improvement ideas were presented and further developed. Finally, the basic energy concepts were evaluated and ideas for further improvements were created. Several literature sources and stakeholders were additionally consulted to obtain the most correct data.

Results

Energy demand

The total energy demand for heating and cooling for new buildings is between 40,000 and 50,000 GJ/year for heating (room heating and domestic hot water) and between 11,000 and 14,000 GJ/year for cooling, see figure 3. The electricity demand between 42,000 and 48,000 GJ/year is the sum of building related electricity (mainly lighting and ventilators) and user related electricity (computers, TV, etc.). The total energy demand for the existing buildings is the actual energy use in 2014 (data from the utility company Alliander), see table 1.

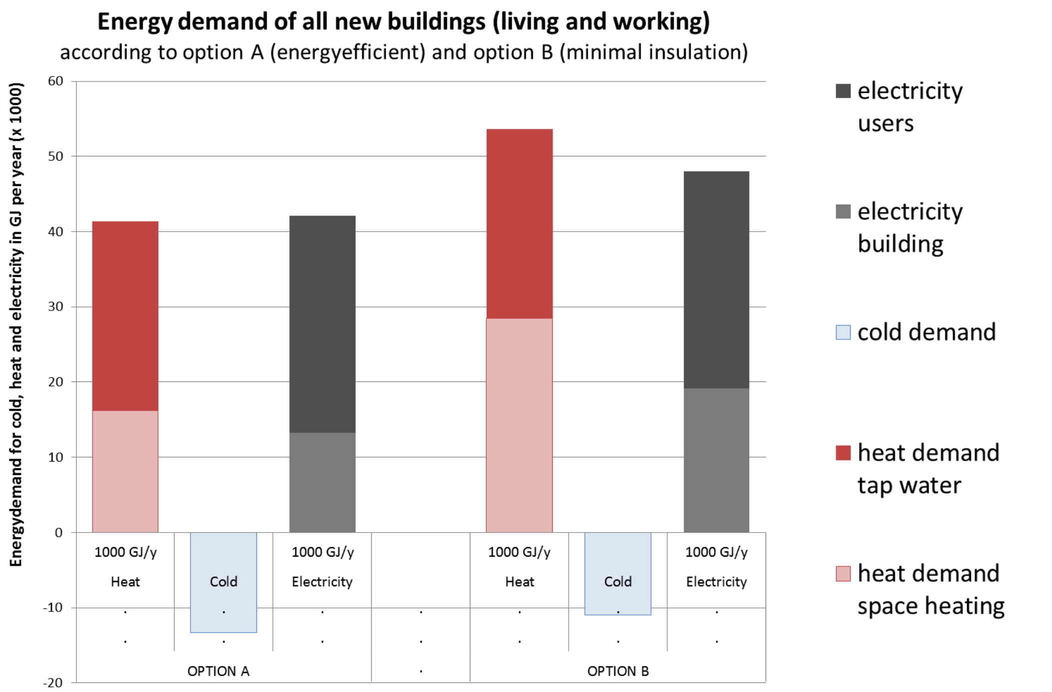

Figure 3: Total energy demand of the new buildings of Buiksloterham till 2024 for space heating, cooling and tap water. Option A and B represent different grades of insulation (A is very energy efficient and B according to the minimal values of the Dutch Building Regulations).

Table 1. Total energy use existing buildings (2014 data from utility company Alliander).

	Electricity usage existing buildings	Gas usage exisiting buildings
usual units	$27.0 \cdot 10^6$ kWh/year	$2.47 \cdot 10^6$ m^3/year
GJ/year	$97. \cdot 10^3$ GJ/year	$86.7 \cdot 10^3$ GJ/year

Energy potentials

The energy potential of the new buildings is shown in figure 4. The production of solar energy, electricity as wel as heat, is considerable as the ambitious assumption is made that almost the entire roof area of the new buildings can be used for PV. PV on the facade is not taken into account.

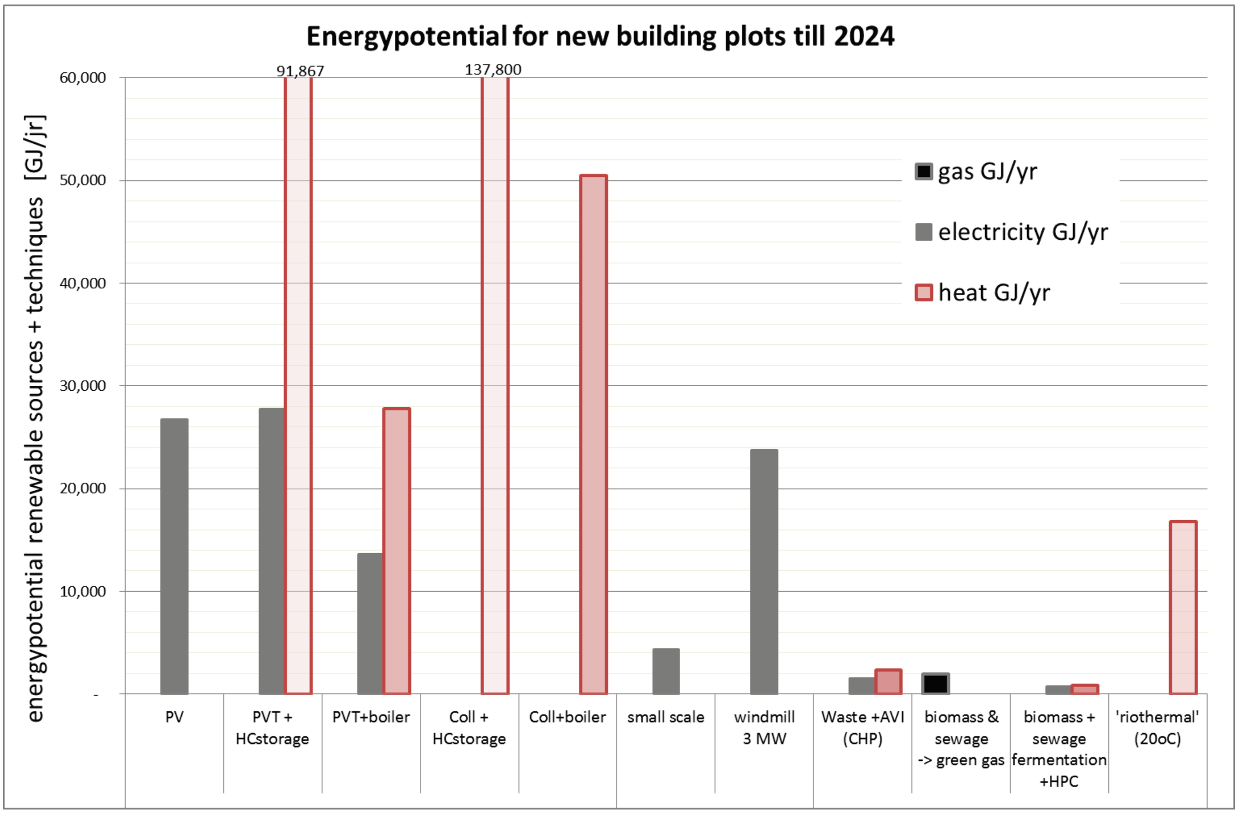

Figure 4. Energy potentials of new buildings from sun and wind on roofs and from waste and sewage.

The availability of local heat at relatively low temperatures (15 to 35 °C) is large. The PVT panels and solar collectors can produce more heat when the heat can be delivered at lower temperatures, for example combined with heat and cold storage in the ground in stead of a boiler tank. Heat recovery from the sewage system, also called 'rio-thermal' energy, is another source of low temperature heat. Rio-thermal heat recovery has the advantage that this heat is also available in winter when there is less sun from the solar systems. A heat pump is, however, always necessary to upgrade the low temperature heat for room heating or domestic hot water. Attention should be paid to the fact that the necessary electricity for the heat pump is lower when the source temperature is closer to the supply temperature, even if the necessary amount of heat is the same.

The energy potential for waste is calculated assuming maximum reuse of recyclable elements. This means a high amount of organic waste and a low amount of refuse remaining after separation of recyclable elements. The remaining refuse after separation of recyclable elements can produce electricity and heat in an waste incineration plant and the organic waste can produce electricity and heat in a heat and power plant (after fermentation). Compared to the energy demand, only a very limited amount of biogas can be produced from the available waste and black water in the area.

Energy concept assessment

Table 2 shows the assessment of the energy concepts for the new dwellings. The assessment shows that concept 1 is by far the most favourable in terms of costs, followed by concept 2, and then 3. Concept 2 is the most favourable related to energy performance and overall sustainability. Given the existing agreements in Buiksloterham only concept 3 is applicable. The assessment also shows that none of the basic concepts is truly an integrated energy system, where synergies are sought and flexibility for the grid is achieved. For example, the expected large quantity of installed PV power may even lead to an upgrade of the power grid.

Table 2. Overview of the assessment of the different energy supply concepts for new buildings

	Criterium	Concept 1	Concept 2	Concept 3
1	ENERGY			
	% local renewable	38%	55%	36%
	% Total (local + regional) renewable	54%	100%	49%
	CO2 emission [ton CO_2/y]	2.443	-	787
	Selfsufficiency	Entire heat demand not self-sufficient	Local heat covered electricity not yet	Entire heat demand not self-sufficient
2	ECONOMY			
Costs Enduser		TOTAL € 12.919,-	TOTAL € 17.482,-	TOTAL € 20.522,-
Societal costs (use of existing infrastructure and need for new infra-structure)	Infrastructure gas	neutral	average	average
	Infrastructure electricity & peak power(MWp)	average (7,65)	average (7,65)	average (7,65)
	Infrastructure district heating	neutral	neutral	average
3	CIRCULARITY			
	Use of natural resources	circularity not possible	some bottlenecks	many bottlenecks
	Water	many bottlenecks	some bottlenecks	many bottlenecks
	Energy cumulative	some bottlenecks	many bottlenecks	many bottlenecks
	Biodiv. & Ecosystems	many bottlenecks	some bottlenecks	many bottlenecks
	Heatlh & wellbeing	many bottlenecks	some bottlenecks	some bottlenecks
	Adaptivity & resilience	circularity not possible	no bottlenecks	many bottlenecks

4	IMPLEMENTATION (PSTLG)			
	Political	not possible	not possible	is promoted
	Social implications	bottlenecks	neutral	bottlenecks
	Technological	neutral	neutral	neutral
	Legal	not possible	bottlenecks	is promoted
	Governance	neutral	bottlenecks	neutral

To eliminate these shortcomings, a fourth variant was developed, based on maximum use of local heat, use of a collective heat pump and a mini heat network at low temperatures, around 40 °C, see figure 5. Storage of thermal energy is an essential part here, since in this way more local heat can be exploited and flexibility in the network is increased due to the flexible use of the heat pump. The ideal temperature and scale for such a collective energy concept and mini heat network remains to be investigated.

From the assessment of this fourth, alternative concept, it appears that the integrated approach can lead to more benefits than the basic concepts. The combination of more local heat produced with large (seasonal) thermal energy storage can increase the use of local renewable heat and increase the flexibility for the electricity grid. Collective systems can also have a higher efficiency, especially when thermal storage is involved. However, the problem with this kind of development is mainly the governance; only few parties can make large investments and exploit such systems. In Buiksloterham this proves especially difficult due to the different timing of different developments.

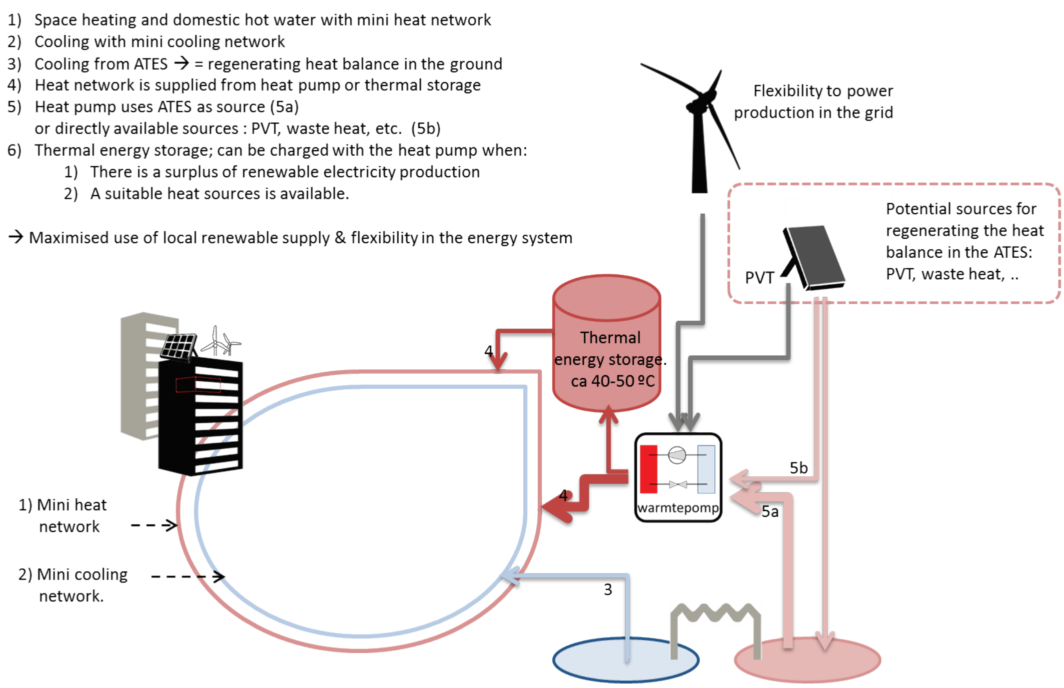

Figure 5. Scheme of a fourth energy concept for the new buildings developed to overcome the shortcomings of the basic variants 1, 2, and 3.

Conclusion

It is not possible to develop Buiksloterham, and similar areas with high density, into an energy neutral area within the current legal framework (without wind energy it is not possible). About 1/3 of the energy use in buildings (building-related energy plus user-related energy) can be supplied by renewable energy. It is possible to identify which concepts result in the highest fraction of renewable supply: The BIES project concludes that a low temperature supply of heat is essential for a maximised use of local renewable input. The fourth energy concept developed seems to meet the ambitions related to maximum renewable supply and system integration. This concept is based on local heat generation, thermal storage at relatively low temperatures, produced from solar energy or by upgrading low temperature (waste) heat by means heat pumps.

What can be learned from this project, besides the technical conclusions, is that new energy-efficient energy systems require very good, early planning, appointments, and cost and support of existing energy suppliers. Achieving a CO_2 neutral society by 2050 depends not only on technological innovation; implementation aspects have a significant impact. In the assessment of the most future proof and sustainable energy system an integrated approach is needed, that is: not only looking at CO_2 and costs but also including circularity parameters such as the use of resources for equipment, water, biodiversity, health, adaptability and resilience.

References

Bestemmingsplan Buiksloterham: www.amsterdam.nl/projecten/buiksloterham/stedenbouwkundige, retrieved October 2017, *in Dutch*.

Broersma, S. Fremouw M and Dobbelsteen A.van den., *Energy Potential Mapping: Visualising Energy Characteristicsfor the Exergetic Optimisation of the Built Environment,* Entropy 2013, 15, 490-506; doi:10.3390/e15020490.

BUIKSLOTERHAM INTEGRATED ENERGY SYSTEM: Naar een duurzaam en geïntegreerd energiesysteem voor een wijk in transitie, November 2016, *in Dutch.*

Dobbelsteen, A. A. J. F. vd., Jansen, S. C. and Timmeren, A. v. (2007). *"Naar een energiegestuurd omgevingsplan Groningen"* (In Dutch). Delft, Delft University of Technology, *in Dutch.*

Gemeente Amsterdam, Koers 2025: https://www.amsterdam.nl/bestuur-organisatie/volg-beleid/koers-2025-amsterdam/, rectrieved 17/3/2017, *in Dutch.*

Jablonska,B. et al., *Innovatieve energieconcepten en pilots voor energieneutrale gebiedsontwikkeling in 2050,* ECN-0--10-037, January 2011, *in Dutch*

Jansen, S.C., Bokel, R.M.J., Müller, S., Elswijk, M., Roossien, B., Odijk, S. van., Vries, S. de, *BIES (2016).* http://www.ams-institute.org/solution/bies-buiksloterham-integrated-energy-system/, *in Dutch.*

Kleerekoper, L., Taleghani, M. , Dobbelsteen van der A.A.J.F., Hordijk, G.J. *Urban Measures for hot weather conditions in a temperate climate condition: a review study*, Renewable and Sustainable Energy Reviews 2017, 75, 515-533.

Metabolic, Studioninedots & DELVA Landscape Architects, *Circulair Buiksloterham. Een Living Lab voor circulaire gebiedsontwikkeling,* Creative Commons licentie (CC-BY-NC-ND 2014), *in Dutch.*

RVO, *Uniforme maatlat gebouwede omgeving, rekenmodel versie 3.5.* Online download from www.agentschapnl.nl/new --> instrumenten. Retrieved October 2015, *in Dutch.*

Toolkit duurzame gebiedsontwikkeling*, Met 20 bouwstenen naar een energieneutraal gebied; gids voor initiatiefnemers en projectleiders,* Æneas, uitgeverij van vakinformatie bv, Boxtel, 2012, *in Dutch.*

www.energieinbeeld.nl, retrieved October 2016, *in Dutch*