# E - Synergy

*Local collaboration in Agriport*

**Ewout Smits**

Student number: 1503480 // e.smits@student.tudelft.nl
Delft University of Technology, Department of Architecture
12th Graduation Lab Architectural Engineering

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**Abstract:**
The needful alteration to generate energy from renewable sources requires a radical change in our energy infrastructure. Small scale power plants like Photo Voltaic panels increasingly appear in our built environment. The current infrastructure wasn´t made for this new way of distributing energy. In this paper a decentralized paradigm is proposed as a solution for this problem. The focus of a decentralized concept lies on small clusters, rather than nationwide energy distribution. The Urban Agriculture concept, where agricultural clusters feed urban clusters with energy and food, is an example of such a decentralized concept. Agriport A7 in Middenmeer is an example of an agricultural cluster in this Urban Agriculture concept. Local energy exchange between greenhouses (waste electricity) and a datacenter (waste heat) will be complemented by a new design (swimming pool) with its own source to exchange: water. The waste streams of water of the datacenter and greenhouses are used by the swimming pool to provide clean water in return. Inspired by the cradle-to-cradle philosophy, the water treatment will be bio-based for both the clean water supply to other functions and the swimming water of the design itself.

**Keywords:** architectural engineering; Agriport; decentralization; datacenter; greenhouses; geothermal; natural pool; bio-based water treatment.

**Introduction:**

As an architectural engineer this research is an explorative study to find the most suitable function for a design. The main course is inspired by the problems caused by energy generation from renewable sources (*Part 1: Technical*). The current energy infrastructure isn't suitable for new innovations that are currently implemented in the national grid, like Photo Voltaic (PV) panels. Local energy exchange is proposed as a possible solution to this problem. Agriport A7, an agricultural cluster in the north of Noord-Holland, the Netherlands, serves as a context example of energy exchanging functions in a small cluster (*Part 2: Context*).

Current energy streams in the context example will be researched to explore the possibilities and presence of energy exchange. The main goal for the design is to be implemented in this energy exchange story with an aim on a contribution to this energy exchange, instead of just using waste energy from other functions (*Part 3: Program*).

**Research question:**

*"How can the local and decentralized energy network of Agriport A7 be more sustainable when looking at the energy exchange between the different functions being present?"*

**Methods & project boundary:**

This paper consists of three parts: the technical, context and program research. The method used for the technical part is solely literature study; the context part literature study, interviews and reference analysis; and the program part literature study, reference analysis and research by design.

The *project boundary* can be described as the explorative study towards the program of the design and the implementation in the energy exchange concept. Especially the cooperation with the datacenter and greenhouses is described, while the possible cooperation with other functions is only mentioned shortly.

**Results:**

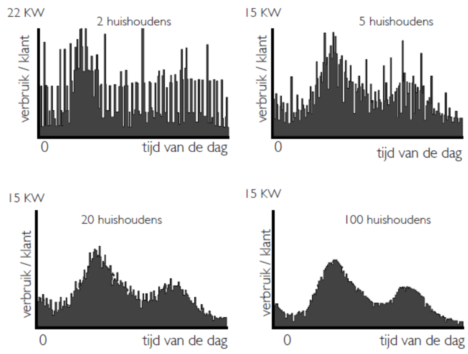
**1. Technical**

The current infrastructure of the electricity grid isn’t prepared for the future. Before 1990 it was common in many countries that one single firm took care of the generation, transmission and distribution of electricity. Nowadays it is more common to have a mixed system of firms who operate based on market competition. The infrastructure, however, was built for local service, not for competitive large-scale electricity systems. This makes the system very vulnerable. (Brown & Sovacool, 2011; Hoffert et al, 2002)

Sustainable energy solutions tend to focus solely on the generation of energy. The transmission and distribution are often not mentioned. For example, in South Africa the greatest potential for wind energy is along the west coast, which is a very remote place. (Brown & Sovacool, 2011) The fact a renewable source is being used for generating electricity is a good thing, but to get the electricity from this remote place to the user over such a long distance is not really sustainable, because long distances result in a bigger loss of energy during transmission. (van Timmeren, 2006) “The more expansive the energy infrastructure, the greater its vulnerability.” (Brown & Sovacool, 2011: 22)

A possible solution for this problem is a radical change in our energy infrastructure: decentralization. Instead of centralized power plants that generate energy based on predictions of our energy usage, decentralized small-scale power plants (i.e. PV panels) will become the major energy producer. A result of decentralization is that the energy balance will be managed in smaller clusters, instead of nationwide.

Predictions based on data of fewer participants in the energy network might not be as accurate as nationwide predictions, but following to figure 1 the graph of predictions takes a solid form from 20 households already. (van Timmeren, 2006)




**1. Daily average electricity demand of (2, 5, 20 and 100) households in the US. (van Timmeren, 2006, p. 206)**

*Benefits of decentralizing*

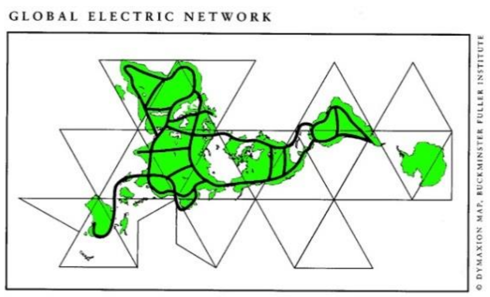
Following to Mintzberger (1993), decentralization leads to several benefits, including: the decision maker is closer to the place of the impact; and an organization can react more quickly on new developments. Following to Brown & Sovacool (2011), we can add more benefits to this list, like: simplicity; experimentation and innovation; more flexibility; greater accountability and participation; and positive competition among local actors. We can conclude from the statements of Mintzberger and Brown & Sovacool that decentralization gives more freedom for *experimentation*; there is more *participation*; and *local knowledge* is used more efficiently. These are important ingredients for a more sustainable civilization.

These ingredients sound interesting enough to choose for the decentralized energy concept, but the investment in bigger central systems is lower and still more efficient than multiple smaller decentralized systems that supply the same amount of energy. But what happens if the two different systems are combined? If the Netherlands changes the spatial planning the next few years/decades, the conventional power plants can be used as a backup in a land filled with small energy networks. By using the existing, delay in investments will be prevented, combined with bigger certainty and a more sustainable existing network. (van Timmeren, 2006)

Another advantage of combined local and large-scale systems is not only the flexibility of the decentralized system itself, but also the increased flexibility for the users of the system. For example, the infrastructure for heat requires a huge investment with the result that contracts are only made for a long time span to ensure profit. With combined local and large-scale systems the energy companies don't have to invest in new installations and substations anymore; they don't have to expand the existing infrastructure; and there is a huge reduction on transmission loss. (van Timmeren, 2006)

On top of that, the so called 'flush and forget' principle can be reduced. Now, the huge infrastructure is often hidden under the ground, which means awareness can't be provided to the users of the system. In this way the users often show careless behaviour with their waste and energy consumption. With a clearly visible decentralized system (think of PV panels on rooftops) this awareness of the users can be increased to reduce the energy consumption. (van Timmeren, 2006)

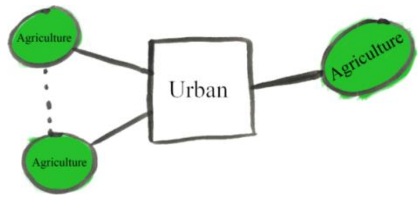
Obviously, the shift to decentralized energy systems still requires a radical change in the conventional energy infrastructure we know. Buckminster Fuller had an idea similar to the combined local and large-scale energy systems as well. Instead of solely focusing on a small electrical energy network, Buckminster Fuller envisioned a worldwide grid. The difference in electricity supply and demand on the different sides of the globe (night and day) and from pole-to-pole can make the balance more consistent. (Hoffert et al, 2002)




**2. Global electricity network of Buckminster Fuller, which is foldable into an icosahedron (GENI, n.d.)**

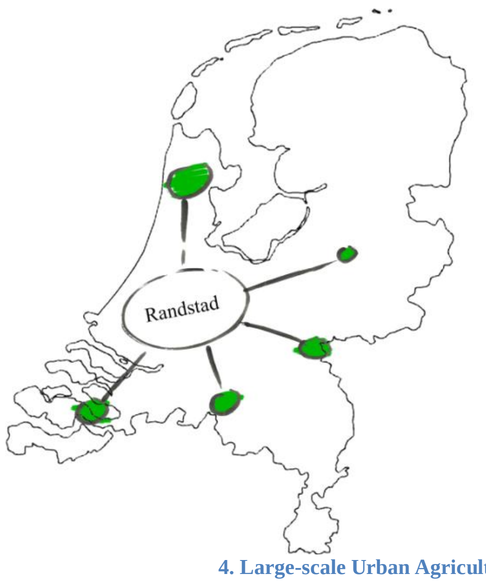
*Urban Agriculture*

Smeets introduces a decentralization structure in the Netherlands where the urbanized areas will function as 'clean' areas, fed by agroparks that scatter around the urbanized areas in clusters. In these parks the knowledge of different participants (agricultural, technical, business knowledge, etc.) can be combined for a much more efficient output of the collaboration. The waste streams of energy have to be re-used within these agroparks, but should also be exchanged with the urbanized areas: the waste of the 'clean' urbanized areas can be used as energy and as nutrients for the agriculture in the 'less-clean' agroparks. The agroparks can provide food and energy for the urbanized areas in exchange. (Volgers, 2010) This innovative form of spatial planning is called Urban Agriculture and requires a completely different infrastructure. (van Timmeren, 2006)




**3. Urban area connected to agricultural areas as an energy system.**

In the Netherlands, the urbanized areas fed by agropark clusters can be interconnected with all other urbanized areas and clusters by re-using the current conventional energy infrastructure as a backup. In this way the current infrastructure doesn't need to be upgraded or abandoned. (van Timmeren, 2006)




**4. Large-scale Urban Agriculture**

To prevent energy shortages in an Urban Agriculture cluster it is cheaper and better for the environment to interconnect to other clusters to back each other up, just like a smart grid. This concept of Urban Agriculture shows some similarities with the proposed vision of Buckminster Fuller and his worldwide grid, where night and day differences can support each other.

Assuming the Urban Agriculture system will be the future in the Netherlands, it can interconnect with all other Urban

Agriculture clusters to back each other up for energy shortages. This is good, since renewable sources are not always available. Wind can vary in velocity and sunlight can vary in radiation. Biomass for example, is a good alternative fuel for transportation and heat, but the power density of photosynthesis is too low (0,6 W/m$^2$) to contribute significantly to a cleaner planet. (Hoffert et al, 2002)

| Power source | Power density [W/m$^2$] |
|---|---|
| Nucleair | up to 4000 |
| Natural gas | 200 – 2000 |
| Coal | 100 – 1000 |
| Solar PV | 4 – 10 |
| Wind | 0,5 – 1,5 |
| Biomass | 0,5 – 0,6 |

**Table 1. Estimated power density values. (Pratt, 2011)**

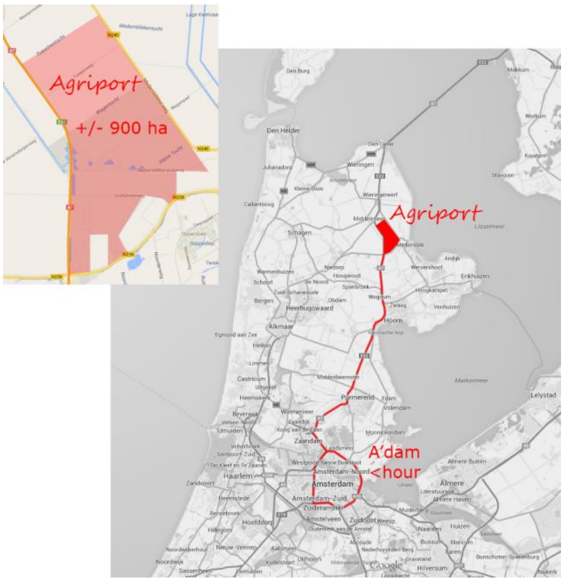
Energy generation from renewable sources requires a lot more space (table 1). On top of that, the sources are not always available or without a constant efficiency and the availability of materials to realize such small-scale power plants could be limited as well. It's therefore inevitable we can't rely on one renewable source to fulfill our needs. Our future will have a radical change in the paradigm of energy and its visibility in our built environment. Solar panels on rooftops and windmills in open windy locations are good examples of this change already.

Along with this new energy paradigm, a new sustainable consuming behaviour can be encouraged to reduce the demand for electricity in the future. 'Reduce, re-use, produce', (van den Dobbelsteen, 2008) as Van den Dobbelsteen's New Steps Strategy suggests, where the energy generation comes at the third step. It makes more sense to reduce the demand for energy first, so we can have fewer windmills to supply us the demanded energy. The fact the new energy paradigm shows the impact of our energy consuming behaviour by its visible infrastructure, can contribute effectively to the awareness of it.

## 2. Context

The proposed Urban Agriculture concept will be used as an answer to the energy infrastructure problems we're facing. With the focus on energy exchange, the agropark clusters are more interesting to look at than the urbanized clusters in this concept. One of such a cluster is Agriport in Noord-Holland, the Netherlands.

"An agropark is a cluster in which several primary producers and processors cooperate to enhance sustainable agrofood production." (Wubben & Isakhanyan, 2011, p. 145) In most cases the cooperation is limited to the field of the food industry, but Agriport also accommodates a business park and soon a datacenter will join as well. This opens many doors in terms of energy exchange. (Vreugdenhil, interview, March 3, 2014)



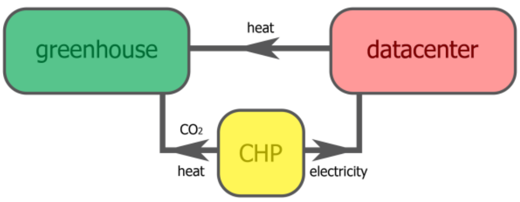

**5. Agriport in Noord-Holland**

When Agriport was founded in 2000, the existing electricity network was not built for the new functions of the area after a rapid growth with multiple greenhouses within a few years. A high voltage cable, which was needed for Agriport, should have been built by the power company, but they were reluctant to do that. The growers decided to construct the electricity infrastructure themselves in 2006 and Energy Combination Wieringermeer (ECW) was born. (Vreugdenhil, interview, March 3, 2014)

ECW is the manager of the grid in Agriport. Their goal is to contribute to a sustainable and efficient supply of energy. (Wever, interview, April 8, 2014) Currently, the demanded energy is being generated with fossil fuels, but ECW is doing research on how to implement sustainable sources in this energy network. A good example of their input is the geothermal energy that is implemented in Agriport, where eight different greenhouses participate in.

Now, the greenhouses still generate their energy with CHP's (Combined Heat and Power) to acquire heat and electricity at the same time. Usually, a CHP is primarily for the generation of power with heat as a functional side-effect. In the case of greenhouses the heat is the primary goal and the electricity a rest product. Even the $CO_2$ waste of the combustion is used by the greenhouses to enhance the growth of the vegetables. (Vreugdenhil, interview, March 3, 2014)

Although the CHP's are very efficient, they still run on fossil fuels, which do not really fit into the sustainable picture. A cleaner way of producing heat would be much more sustainable for Agriport, but with the New Steps Strategy of Van den Dobbelsteen (2008) in mind (reduce, re-use, produce), it is more sustainable to re-use heat from other buildings first. This is why the datacenter fits this sustainable picture perfectly.




**6. A datacenter and greenhouse in a heat / electricity exchange scheme**

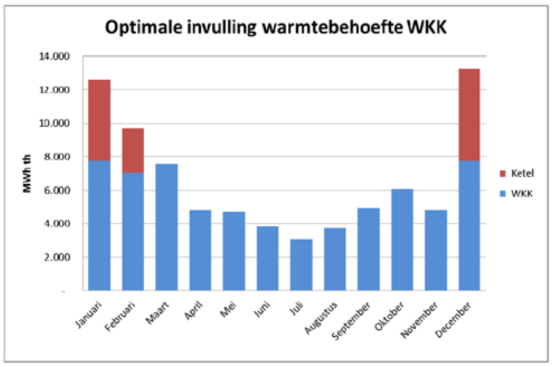
*Datacenter*

Since the datacenter in Agriport will be one of Europe's biggest when completed (with a capacity of 160 MW), this datacenter in Agriport can't be fed solely by the rest electricity from the greenhouses. The amount of electricity available is not the biggest issue. The consistency of the electricity that can't be granted is the bottleneck. This consistency is very important for a datacenter to make sure all the stored information is safe. This is why the datacenter demanded a backup connection from the network of Agriport to the national grid with a capacity of 240 MW. (Vreugdenhil, interview, March 3, 2014) Following to Masanet the datacenters of the future can reduce their electricity demand by 86% by only improving their operational system. (2013)

The chances are very great the datacenter in Agriport will be built with a conventional cooling system, based on air-cooling, which closes the doors to a possible exchange of its waste heat. (Wever, interview, April 8, 2014) The reason for this is the rating system for datacenters where its sustainability is being tested. The sustainable solution of letting other buildings re-use your waste streams doesn't score extra points. The consistency of available electricity is much more important in this rating. This is what the location of Agriport can offer and is the real reason for the location of this datacenter. (Wever, interview, April 8, 2014)

Besides this disappointment, there isn't much exchange in energy between the greenhouses either. This requires transformers for electricity and heat exchangers for heat, which will give a certain loss of energy on top of the losses of the CHP's of the greenhouses (43% becomes electricity and 49% becomes heat from the input of gas in the CHP). The losses of heat exchangers and transformers are a lot higher and are the bottleneck in the energy exchange concept. The energy is therefore being generated in the same greenhouse where it's used as much as possible. (Wever, interview, April 8, 2014)

Until recently, the energy system of Agriport uses solely fossil fuels for its heat and electricity. The heat comes from the CHP's and boilers for a total annual heat demand of 62.000 MWh for eight different greenhouses. The CHP's are generating heat throughout the year, with a maximum of approximately 8000 MWh a month. In the three winter months a total of 11.000 MWh of extra heat has to be generated by boilers to provide the greenhouses enough heat. (Wever, interview, April 8, 2014)

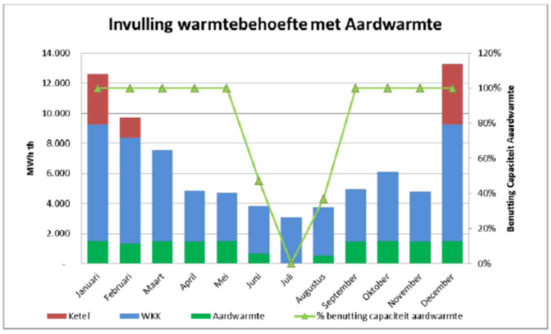



**7. Optimal interpretation heat supply from CHP's (blue) and boilers (red) (ECW, 2014)**

*Geothermal energy*

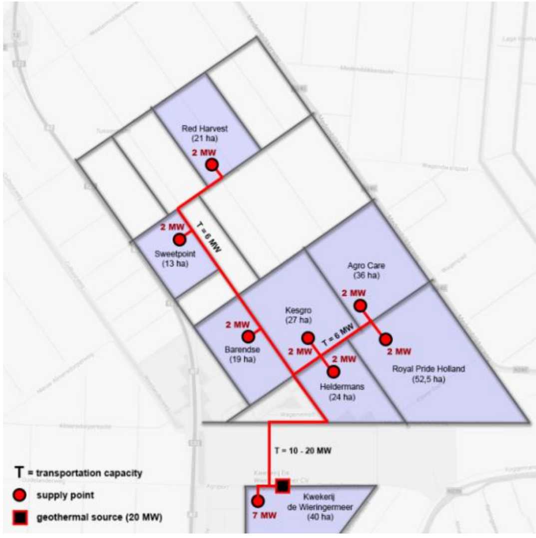
Not long ago, ECW has integrated geothermal energy in Agriport, which provides heat to the eight greenhouses that participate in the project. 10 – 15 % of the heat required for these greenhouses (currently 62.000 MWh annually) is coming from this geothermal source. Agriport has two geothermal sources with each a capacity of 10 MW. One CHP device has a capacity of 3 to 4 MW. The greenhouse of Kwekerij de Wieringermeer, on whose land the geothermal platforms are located, has got 8 CHP's for its 40 ha of greenhouses, which comes to a total capacity of approximately 24 MW.

In the figure 8, the geothermal energy is integrated with the usage of CHP's (blue) and boilers (red). The amount of energy from the boilers is mostly reduced by the geothermal energy, when comparing the graph with the previous graph. Since the boilers don't generate electricity like the CHP's, the energy output isn't that efficient. It is a good start to replace the usage rate of the boilers with geothermal energy first. The reduction of the amount of energy coming from the CHP's (blue in graph) is less obviously visible, but on the long term ECW is planning to let the geothermal energy be a replacement of the CHP's for a bigger part than just 10 – 15 %. (Wever, interview, April 8, 2014)




8. Interpretation heating demand including geothermal energy (ECW, 2014)

Another notable fact from this graph is that the geothermal energy is used significantly less during summer. The reason for this is obviously due to the warmer summer days. This period is used for maintenance of the geothermal platforms. The amount of energy of the CHP's in these summer months is not significantly less compared to the months in autumn and especially spring. The reason for this is the $CO_2$ that is produced by the CHP's is used to enhance the growth of the food. The generated heat is being stored throughout the day and still used during night. The electricity is being sold to the national grid. (Wever, interview, April 8, 2014)




9. Redrawn overview of the geothermal project in Agriport (Vreugdenhil, interview, March 3, 2014)

Eight greenhouses are interconnected with the geothermal energy sources. Each of the geothermal platforms has a capacity of 10 MW of heat. In total 20 MW of heat can be transported to all the participants. Seven of the eight participants have a supply point with a capacity of 2 MW of heat. The other one, Kwekerij de Wieringermeer, which provided half of the finances for the geothermal project, has a supply point with a capacity of 7 MW. (Vreugdenhil, interview, March 3, 2014)

*$CO_2$ shortage*

Another notable fact geothermal energy is eliminating, is the $CO_2$ that is used from the CHP's. This $CO_2$ has to be found somewhere else. One technique that really draws the attention at the moment to provide us heat, electricity and $CO_2$ indirectly is by storing $CH_4$ in our current gas infrastructure in the future. 'Power to gas', as Wever calls it, where $CH_4$ is made from $H_2$ (which requires electricity to be captured from water) and $CO_2$ and acts as an energy carrier, which can be combusted again to provide electricity (i.e. $CH_4$ as a fuel for CHP's). When combusted, water and $CO_2$ are the rest products. However, energy losses remain inevitable. The chemical reactions of this process look like this:

$$2\,H_2O\,(l) \rightarrow 2\,H_2\,(g) + O_2\,(g)$$

$$2\,H_2\,(g) + CO_2\,(g) \rightarrow CH_4\,(g) + O_2\,(g)$$

*Electricity from the CHP's*

The graph in figure 8 shows the amount of heat the CHP's are supplying to eight greenhouses. The total supply of heat minus the heat of the boilers gives the total heat supply from the CHP's. This is approximately 50.000 MWh annually. Wever (interview, April 8, 2014) said 49% of the input of fuel in the CHP's will become heat and 43% will become electricity. This means there is an electricity supply of approximately 44.000 MWh from the CHP's of these greenhouses. Compared to the average $E_{(electricity)}$ usage of greenhouses in the Netherlands, which is approximately 50% of the amount generated by their CHP's (Broersma, n.d.), 22.000 MWh of electricity waste is available in Agriport from the greenhouses that participate in the geothermal plans. For comparison: an average household in the Netherlands consumes 3,5 MWh of electricity annually. The greenhouse next to the datacenter should have approximately 3800 MWh of unused electricity left. The only problem is the availability of this electricity, because this is not constant.

*Towards the program*

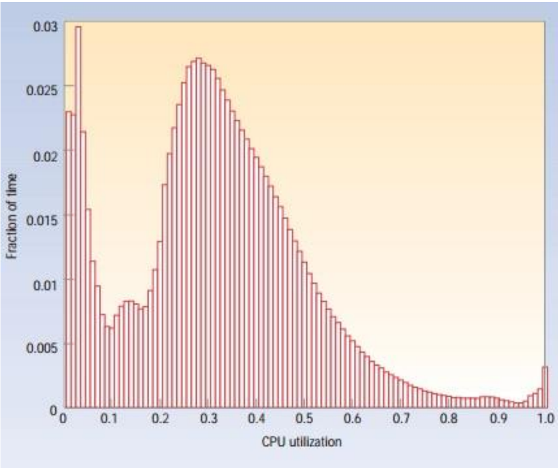
As a result of the analysis of energy stream flows in Agriport a building with a certain function has to be found which can fill the potential to complement the balance of energy. To continue the sustainable ambitions of Agriport and ECW we must keep in mind that geothermal energy will increase in the future, which has consequences for the supply of electricity from the CHP's over time. The electricity will mostly be generated from a windmill farm that has to be built in the future. Wever said in the interview (April 8, 2014) that the electricity stream flow in Agriport isn't interesting enough to be a starting point for the design. Shortages and excess of electricity is now being traded on the APX or Onbalans Markt. If we can efficiently store electricity and in an environmental friendly way, then the electricity stream flows will have much more potential to have a look at. Currently, selling the excess of electricity is part of the conventional business model, which would have to change as well for a more sustainable approach of dealing with energy stream flows.

The same counts for the garden waste stream flow of the greenhouses. Vreugdenhil said in the interview (March 3, 2014) that it isn't efficient enough for Agriport to invest in the generation of energy with biomass as a source. The only energy stream flow which has great opportunities in Agriport at this moment is heat.

In Agriport there is always a lack of high temperature heat. Geothermal energy and CHP's generate high temperature heat for the greenhouses. ECW is researching if it can provide 1 MWh of thermal energy to other functions than only the greenhouses in the future. Low temperature heat, on the other hand, is plenty available in Agriport. The temperature of low temperature heat is approximately 30 – 40 $^{o}$C. This low temperature heat is the waste product of the greenhouses and does not include the waste heat of the datacenter yet.

*Amount of waste heat*

All the datacenters in Amsterdam (accumulated capacity of 103 MW) consume 460 million kWh (0,46 TWh) per year. (le Fevre & Leclercq, 2013) Quick calculations show that these datacenters run on half capacity on average. If we take this into the calculations of the datacenter in Agriport, it will be good for an annual electricity consumption of 0,70 TWh. But collected data from 5000 servers show that the average utilization of the servers is somewhere between 10 – 50 %. (Barroso and Hölzle, 2007)




**10. average CPU utilization of 5000 datacenters (Barroso and Hölzle, 2007)**

An average utilization of 25% is more representative for conventional datacenters (see figure 10). With this new data, we can say the datacenter in Agriport will consume 0,35 TWh annually.

Because getting information about a datacenter's performances can be quite difficult, other datacenters are researched to get a scaled comparison of the performance of the datacenter in Agriport.

*(to see the whole table, see appendix 1)*

| Name | Capacity | Electricity consumption (25% utilized) | Waste heat |
|---|---|---|---|
| Stallo-2 | 2 MW | 4,38 GWh | 14.000 MWh* |

**Table 2. Comparison of datacenters (Alger, 2010; le Fevre & Leclercq, 2013; Hanssen & Dragseth, 2012)**

** based on full capacity*

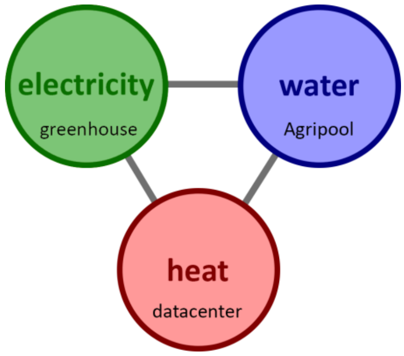
The only usable data to make a comparison is collected from the Stallo-2 from Norway. (Hanssen & Dragseth, 2012) The waste heat of 14.000 MWh is based on the datacenter running on full capacity. The Stallo-2, with a maximum capacity of 2 MW is 80 times smaller than the datacenter in Agriport. The amount of waste heat of the datacenter in Agriport that is available will be 280.000 MWh (25% utilized). This is 1 PJ annually.

In the report of Hanssen and Dragseth (2012) an aquapark is used as a reference to quantify the amount of waste heat. The Norwegian datacenter has enough waste heat available to keep an aquapark of 11.000 $m^2$ on a comfortable temperature. Theoretically, the datacenter in Agriport can heat up an aquapark 80 times this size.

### *3. Program*

The proposed approach of this research to find a function for a design to complement the energy exchange system in Agriport became a very wide field of choices, since this design will actually become the first building in Agriport that will exchange its energy at all. Even the exchange of energy between the greenhouses and the datacenter (electricity to the datacenter, heat to the greenhouses), as the media announced, is not true, because there are no plans of re-using the heat of the datacenter. On top of that, the supply of waste electricity from the greenhouses will slowly disappear when decreasing the rate of CHP-usage by increasing the use of geothermal energy. All the waste electricity is currently being sold to the national grid, as preferred by ECW. (Wever, interview, April 8, 2014)

The design will therefore not just be a building to fill potentially empty holes in an energy exchange system, but will be a role model for energy exchange in the first place. This means the design will not only use the waste heat of the datacenter throughout the year, which is very convenient, but it will also supply energy in any form to other functions to fulfill this representative role. This is why the choice was made for a swimming pool.




**11. Three buildings, with each its own theme in the energy exchange concept**

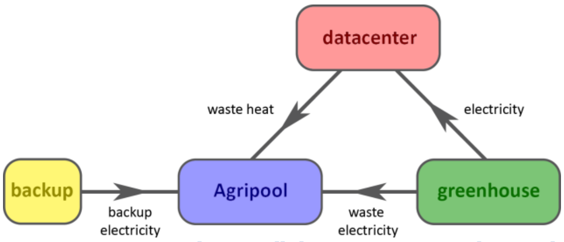
The datacenter will provide waste heat 24 hours a day and 7 days a week. A swimming pool requires a lot of heat, which makes it a perfect function to fill this hole in Agriport and re-use the waste heat of the datacenter all day long. Other examples that could've fit the picture are schools/universities, hospitals, sports arenas and commercial centers. (Hanssen & Dragseth, 2012)

The swimming pool got the upper hand, because of a potentially energy exchange form in Agriport: *water*. The combination of water and a swimming pool couldn't be a more obvious choice, since water is the one and only ingredient of its existence. The three different buildings (datacenter, greenhouse and the swimming pool) will represent each their own energy theme in the energy exchange concept: heat, electricity and water.

As concluded in the previous part of the research, a total of 280.000 MWh of waste heat from the datacenter is available throughout the year to heat up Agripool. In the future it is most likely datacenters consume less electricity and have therefore less waste heat available.

There is approximately 3800 MWh electricity per year available from the greenhouses that participate in the geothermal project. The availability of the supply of this electricity is not constant. Not that the amount isn't enough for Agripool, but the inconsistency requires a backup electricity supply, which will be generated locally with renewable sources. The amount of supply of electricity from the greenhouses will slowly decrease on the long term as well.

A combined scheme of the incoming energy for Agripool with both heat and electricity can be drawn like this:



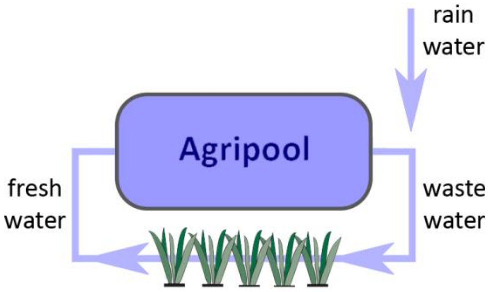

12. Energy exchange: all the energy streams that reach Agripool (electricity and heat)

In the future situation when electricity can't be supplied by the greenhouse anymore, the arrows from the greenhouse disappear and will probably be replaced by the windmill farm for the supply of electricity to the datacenter.

*Water*

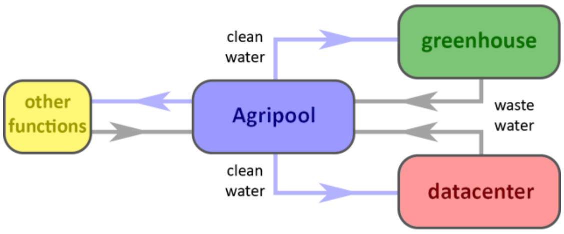
In an episode of the Dutch television program Tegenlicht, a natural water treatment was shown in a greenhouse, where bacteria do all the filtration and cleaning in a botanical garden, instead of machinery in a water treatment plant. This greenhouse has become a Hungarian export product. With an area of 345 $m^2$ in Telki, Hungary, the water treatment can serve all the waste water of 8.000 people with a capacity of 0,8 million liters of water per day. (Organica, n.d.) This Hungarian system is designed for black water, which means that even the most contaminated water can be cleaned to become clean surface water again at the end of the treatment inside the Hungarian greenhouse. Although we see the black water as waste, for this system it contains nutrients for the bacteria that live on plants.

There will be a divided water cycle system where Agripool can supply clean water to supply to other functions in Agriport in one water cycle. The other water cycle will contain the swimming water of the pool. This cycle will also include rainwater that will be collected from the roof. Rainwater can't be implemented in the black water circuit, because this will thin the concentration of nutrients in the water significantly. This will also happen in the swimming water circuit, but here it can be controlled more easily. Over- or under-fertilizing of the bacteria and plants is the biggest threat in this system.



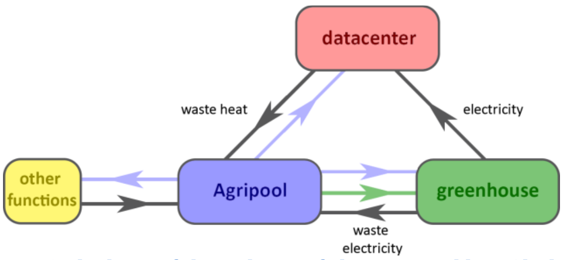

13. Internal water cycle with natural filtration

To provide clean water, it would take the least effort to make this from grey water, since this is less contaminated than black water. But with the synergy story as a background, it's better to focus on the treatment of black water, because this will otherwise be left out of the chain. Besides that, black water contains more nutrients for the bacteria in the filtering principle that will be used than grey water. In this way phosphates can be filtered out and re-used by the greenhouse as a fertilizer.




14. Energy exchange: black water treatment in Agripool (water for industrial purposes and grey water)

The scheme of figure 14 can now be completed with the stream flow of water along with heat, electricity and phosphate fertilizer (green arrow) as seen in figure 12:




15. Final scheme of the exchange of electricity and heat (dark grey arrows), water (blue arrows) and phosphate fertilizer (green arrow)

Apart from the fact the footprint of the Hungarian water treatment plant is ⅕ of the footprint of a conventional water treatment plant; the most important thing is the psychological footprint, according to Kenyeres, because this biological water treatment isn't seen as a smelly industrial building, but as a botanical garden. (Organica, n.d)

Following to the Dutch legislation this water treatment is unfortunately not a botanical garden. A conventional water treatment facility is an environmental category 4 (ISZF, n.d.). Companies are allowed in Agriport up to an environmental category 5 (Agriport, 2011), so legally it is allowed to accommodate the natural water treatment in Agriport.

*Other functions*

Although the focus of this research lies very much on the threesome in figure 11 (greenhouse, datacenter and Agripool), the 'other functions' from figure 15 must not be forgotten in the energy exchange concept. Like the proposal of aiming on a smaller scale energy exchange in the beginning of this research led eventually to a worldwide vision of Buckminster Fuller: the focus should start on a small scale, but should not end there.

The other functions in Agriport are companies in the business park. Some of them are specialized in logistics. A sustainable idea for this sector could be that instead of empty trucks returning to their home base, they are loaded with waste from the clean urbanized areas (*see: Urban Agriculture, p.3*). Other examples of companies are a restaurant and a poulterer (waste food as a rest product).

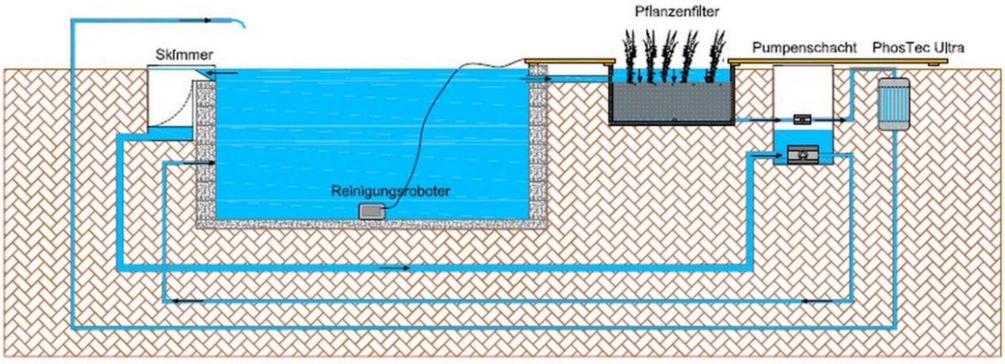
*Cradle-to-cradle*

The philosophy for the design finds its origin in the cradle-to-cradle philosophy. In short, this means the swimming pool will function as natural as possible (i.e. more windows for more daylight). The Hungarian filtration system of the black water is already inspired by the cradle-to-cradle philosophy. The filtration of the swimming water of Agripool will also be done in a natural way. Instead of resolving the problem of unwanted bacteria by killing it with chemicals, the Living Pool system aims on the prevention of bacteria by using natural filters. Algae's and other bacteria are fed by especially phosphor in the contaminated water. If the phosphor is filtered out of the water, algae's don't have food and can simply not grow. In this way you don't need chemicals to kill all the algae's and (good) bacteria. The reason why chloride is used in a swimming pool is to keep it clean from bacteria and disinfect the water. It is incredibly important to keep the chloride level in the water at a certain rate, because otherwise it will be a threat to the health of the swimmers. (Bennink, 2012)

The aim is to make a chlorine-free swimming pool, but following to Keuten this isn't possible yet for public swimming pools. Although the cleaning of the pool and the prevention of algae's and other bacteria can be done effectively with biofilters in the pools, it's the fact the users can disinfect each other in the public swimming pool so easily. (Bennink, 2012) This is why there is still chlorine required, but in a lesser quantity. For the regulations part, which is an issue for sustainable innovations, a completely chloride-free pool is not allowed in the Netherlands. The conventional chlorine in combination with other techniques (UV filters, saltelectrolysis, or biofilters) on the other hand, allows a reduction in the amount of chlorine in the swimming pool water. (VMCE, 2014)

The Living Pool system has vegetation growing in a filter, where 'friendly' bacteria live on plants and feed themselves with the contamination of the water. In this way the bacteria living in the vegetated filter leave nothing for the harmful bacteria and algae's to grow in the pool. The energy costs are 10 times lower than a conventional swimming pool thanks to a low energy pump used in the system. Usually, the natural cleaning of the water only occurs when it catches sunlight, which makes them unreliable indoors. The Living Pool makes this possible, thanks to the PhosTec Ultra filter, which is filled with grains of a non-porous natural stone that serves as a magnet for the phosphate particles. This filter has the same role as water plants: preventing the growth of algae's. The only thing the Living Pool is missing is a disinfection remedy. (Bennink, 2012)

The amount of vegetation and surface area of the biofilter must be in balance with the amount of nutrients in the water. This means that this area relies on the amount of waste from swimmers in the pool. It is hard to find this balance, especially when rainwater thins the concentration of nutrients in the water.




**16. Living Pool system. Organic impurities are transformed by bacteria in the plant filter. A second circuit comes through the PhosTec Ultra that filters the phosphates out of the water (Biotop, 2012)**

**Discussion:**

The Urban Agriculture concept as proposed in the first part of this paper doesn't necessarily have to be the answer to the energy distribution problems. There are several more spatial planning concepts that could act as a possible answer. The reason I've chosen for this concept is the fascination for the context example Agriport that can be seen as an agricultural cluster in this concept.

It's also considered energy exchange will happen in Agriport in the future. This is an uncertain fact, since the current business model prefers to sell excess of energy instead of exchanging it with other functions. An argument for this is the energy loss by transformers or heat exchangers.

The datacenter will probably be built as a conventional one without any measures of exchanging its waste heat. The proposed scheme where the pool complements the energy exchange in Agriport could therefore be far from the future perspective. On top of that, the waste electricity from the greenhouses will slowly disappear by the increasing usage rate of geothermal energy.

The 'reduce, re-use, produce' philosophy of Van den Dobbelsteen (2008) needs to be stimulated in the business model in this example to prevent buildings become isolated actors in a cluster.

Legislation is another issue in the sustainable development of especially the design. The amount of chlorine can be reduced by other measures (i.e. UV light filters), but a chlorine-free swimming pool is not allowed. Chlorine in swimming pools causes chlorine byproducts that can be really harmful to the user. Keuten is doing research with the UV-lamp being an alternative for chlorine. But this isn't safe for people either and is therefore hidden from the swimmers.

'What if Agripool is not a swimming pool, but an indoor lake?' A lake doesn't need any measurements to prevent people from disinfecting each other. A lake works naturally, just like Agripool will. There is more control than a lake and no chlorine is used. Biofilters will do all the cleaning work.

The good thing about bio-filters is, from an architectural point of view and as a sustainable activist, that the 'flush and forget' principle can be emphasized. You'll be swimming in a pool where plants will clean all the waste you put in the pool.

Some clever tricks to prevent the users from contaminating the water as much as possible have to be implemented, like inescapable and comfortable showers before entering the pool; adjusting the water temperature to achieve a perfect natural resistance of the user's bodies and to not trigger the bladder. Smart implementations like these, based on the cradle-to-cradle philosophy, prevent the requirement of this indoor lake to use chlorine.

**Conclusion:**

The problem of the imbalances the decentralized small scale power plants are causing have to be solved by aiming on decentralized clusters. The current energy infrastructure must be adapted to sustainable ways of generating energy and act as a backup in between multiple clusters. An example of this new energy concept is the Urban Agriculture concept, where Agriport is an example of an agricultural cluster. The internal energy balance should be managed first, before exchanging with other clusters.

Although Agriport has huge potential to be a frontrunner in energy exchange with the datacenter being realized, it is most likely there won't be any exchange with it at all. In this research it is assumed this will change in the future, so that a design can be implemented in this exchange and contribute to another missing form of exchanged energy: water. A swimming pool will be designed to form an energetic synergy with Agriport and a functional synergy with the region.

Waste water will be cleansed in a biological way, based on a cradle-to-cradle philosophy. Smart design will contribute to the prevention of problems, instead of solving them. Apart from the black water filtration, this principle can be found in the way the swimming pool is cleaned as well.

Fed by the datacenter (heat) and partially by the greenhouses (electricity), Agripool will do the water treatment in exchange. In this way Agripool certainly is a frontrunner in a sustainable agriculture cluster.

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Wever, A. (2014, April 8) Project manager Energy, Water, Waste – Energie Combinatie Wieringermeer (ECW)

# Appendix 1: Datacenter comparison

| | Gross Floor Area | Capacity | Electricity consumption 25% utilized | Electricity consumption 75% utilized | Investment | Waste heat |
|---|---|---|---|---|---|---|
| Agriport | 400.000 $m^2$ | 160 MW | 350 GWh | 1050 GWh | € 2 billion | - |
| Netherlands | 200.000 $m^2$ | - | - | - | - | - |
| Amsterdam | - | 103 MW | 230 GWh | 690 GWh | - | - |
| US *(medium size)* | - | - | - | - | $ 1 billion | - |
| Switzerland | 200 $m^2$ | - | - | - | - | 2.800 MWh* |
| Norway *(Stallo-2)* | - | 2 MW | 4,38 GWh | 13,14 GWh | - | 14.000 MWh* |

**Table 2. Comparison of datacenters (Alger, 2010; le Fevre & Leclercq, 2013; Hanssen & Dragseth, 2012)**

**Waste heat is based on the datacenter utilized on full capacity.*

# Appendix 2: Extended research version

An extended version of this research (+/- 50 pages) is available on request. This contains more background stories and research leading to the design principles. For the ones who're interested, send an email to *ewout_smits@hotmail.com* and I'll send it to you.

# Appendix 3: References of extended version

References from the extended version that did contribute to the research, but weren't mentioned in this compact version of the research:


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