ENERGY STORAGE IN PARKSTAD

Jornt Walsweer
Faculty of Architecture & the Built Environment, Delft University of Technology
Julianalaan 134, 2628BL Delft
`jwalsweer@student.tudelft.nl`

ABSTRACT

Parkstad is planning to power most of its electrical grid by solar energy, resulting in an intermittent power supply. One of the methods to solve this intermittency is to create facilities for energy storage. The landscape differs from the rest of the Netherlands by its hilly profile. The most important difference is presence of a large subterranean infrastructure which is a relic from the mining past. This vast infrastructure holds potential for energy storage. Energy storage demand exists on three levels. Daily storage demand, inter seasonal storage demand and incidental storage demand could benefit from energy storage among other solutions. The actual methods to achieve this energy storage are mechanical, electrochemical, chemical and thermal. For Parkstad compressed air storage, underground pumped hydro and gravitational storage hold potential.

KEYWORDS: *Energy storage, Parkstad, Former mining, CAES, Hydropower, Gravitational, Architecture*

I. INTRODUCTION

The energy transition towards renewable energy sources is in full swing. In the Netherlands the most important renewable energy sources are geothermal, solar, wind and biomass. (ECN, 2017) These sources will provide the heat and power that is necessary to power the whole country. Simultaneously a development towards more local generation en consumption is happening in several communities. The amount of local energy corporations has grown from roughly 300 in 2012 to about 392 in 2017. (Schwenke, 2017) Other ambition documents also show a shift from the traditional national scale toward a smaller regional of local scale. The Parkstad area in Limburg fits this picture perfectly, since it has elaborately pinpointed its ambitions in a series of documents by the name of PALET.

The PALET documents propose a scenario where for the whole of parkstad, solar energy is going to form a large portion of the new energy mix. (Parkstad Limburg, 2017) Since solar energy is a highly intermittent form of energy, which means that additional measures are necessary to provide a stable power supply for the area. Diversification of energy sources, international or interregional energy trade, flexible demand and energy storage could stabilize peaks and valleys. Since the diversification of energy sources by wind and hydropower is difficult in Parkstad (Parkstad Limburg, 2017), bulk energy storage combined with solar energy could provide the desired stable power supply for the region. In order to design such a system in Parkstad, it is necessary to analyze the potentials for a system is this region. The research question is:

"Which local conditions in Parkstad can be utilized for visible long-term energy storage and what are the programmatic requirements that flow from these possibilities?"

II. METHOD

The research methods used in this paper are literature study, energy data evaluation and research by design. The structure of the paper is divided in three parts. Part 3.1 will focus on the local conditions. The local characteristics will be analyzed by studying relevant physical features of the Parkstad area. For this previous research will be consulted. The current energy infrastructure will be analyzed by map analysis. Furthermore typical spatial and physical potentials for energy storage will be analyzed. In part 3.2 the demand for storage will be determined by studying literature and by combining known energy data to make a gross estimate for storage. Part 3.3 will focus on actual energy storage methods that are possible for Parkstad. Storage methods will be assessed on several criteria, which will result in a list of potential applications for energy storage. These methods will be further analyzed for their spatial requirements.

III. RESULTS

Parkstad aspires to go completely energy neutral by 2040. The most important method of generation will be photovoltaics (Parkstad Limburg, 2017). The intermittent nature of solar photovoltaics asks for additional measures to provide a stable power supply. Bulk energy storage is a possible method to provide stable power supply in combination with solar photovoltaics. Bulk energy storage means storage is centralized in a region (Van der Linden, 2004). First the current situation of Parkstad and its assets will be analyzed. Then the actual demand for storage will be established. With this demand the known methods will be analyzed. Possible methods for Parkstad will be selected by several criteria. The selected methods will be further described for their spatial and technical requirements.

3.1 Parkstad characteristics and assets

The Parkstad area has dominantly been shaped by the coalmining history. Since the closing of the mines the region has been in economic decline and is searching for a new identity. The energy transition and the concrete ambitions of Parkstad in transitioning to renewables have ironically created the potential the area to revive itself as an energy region. Parkstad is planning to generate more energy than it will use. This will create revenue and will therefore reverse the current state where money is flowing out of the area to buy energy (Parkstad Limburg, 2017).

3.1.1 Current energy infrastructure

The current energy infrastructure is clearly present in the Parkstad area. High voltage pylons transmit high voltage power to transformations stations, where power is transformed to usable voltages. Appendix 1 holds a map with the current infrastructure. Parkstad is connected to the rest of national grid in the north and west of the region. The map shows that the power stations are mostly placed at central positions within or in between residential neighborhoods. The power lines mostly avoid crossing over residences, although they sometimes cross each other. An unused connection with Germany connects the power station at Terwinselen with a German power station. (Hoogspanningsnet, 2018)

3.1.2 Physical and spatial characteristics

The physical characteristics of Parkstad differ strongly from the rest of the Netherlands. The most obvious characteristic is the hills which almost exclusively exist in this part of the country. Potentially they could be an asset for energy storage. Appendix 2 holds a map of the relative height differences of the region. The spatial structure of the area and its largest cores has developed since the start of the mining in the early 19th century. The current major cities Heerlen and Kerkrade transformed from villages of moderate proportions to medium size cities in the Netherlands. Heerlen, Kerkrade and several other cores form an interconnected patchwork of built surface and open green surfaces. The open areas are used for agriculture, recreation, mineral extraction and nature.

A physical characteristic that is not notable from the surface are the mining shafts and tunnels below the surface. These relics from the mining past could potentially be utilized for energy storage. Currently the tunnels and shafts are submerged by groundwater. A project known as the *mijnwaterproject* is currently using the water for heating and cooling (Minewaterproject, 2008). The project has drilled new shafts to extract and return the water to deep and less deep tunnels. This location specific approach makes use of some of the relics of the mining past. Although abundant other abandoned mining shafts and tunnels remain to be utilized. This subterranean infrastructure has been documented in 2012 by Voncken and de Jong. This document states that 11 different mines left behind 31 mining shafts, ranging from depths of 183 meters till 1058 meters. This height holds potential for energy storage facilities.

3.2 Storage demand

To determine the capacity for energy storage for parkstad, it is necessary to separate different kinds of storage demands. Demand for storage exists when demand and supply do not match. The storage demands are separated based on their duration and their occurrence. The first being the difference between demand and supply during the day, the second being the demand between the different seasons and the third the occasional demand when there is no sun and wind. All three storage demands could benefit from storage to ensure security of supply to the grid.

3.2.1 Daily demand and supply difference

The first and most obvious form of storage demand is the difference that occurs daily between demand and supply. In California a model was developed to describe the typical demand during the day in relation to the solar yields. In the early morning when people get up and prepare for work and school they use light and electrical appliances for different purposes. In the late afternoon when people come home from work and prepare dinner and turn on their lights and appliances the second peak occurs. In between this morning and afternoon peak the demand ducks (Jones-Albertus, 2017). During this period solar yields are generally the highest. The duck curve has been extrapolated for the coming years with the assumption that with increasing installed solar photovoltaics the demand for remaining generation methods will vary more heavily over the course of the day. Although the duck curve isn't developed for the Netherlands, the model clearly explains the discrepancy between demand and supply during the day.

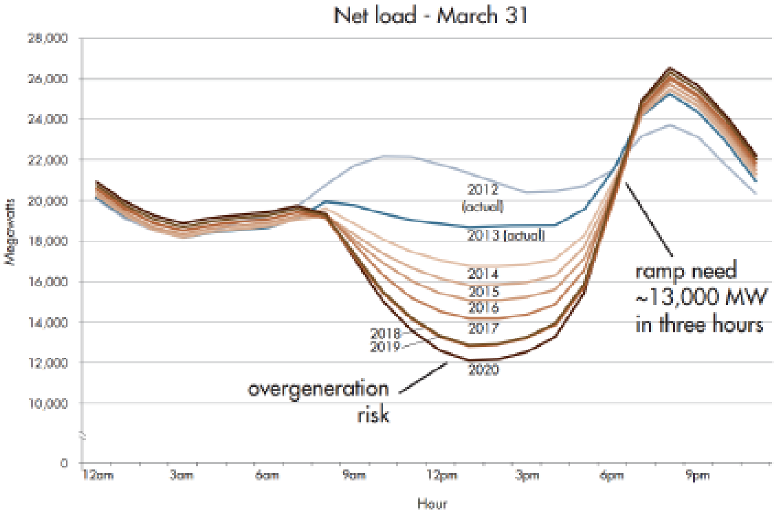

Figure 1 – Duck-curve development over course day. (Source: Jones-Albertus, 2017)

In the current Dutch non-renewable energy system a base load is usually supplied by traditional coal fired power plants. Peaker power plants, commonly fueled by natural gas, supply the additional power in case of increased demand. A future scenario with wind, solar and hydroelectric power as energy sources, would additionally increase the disequilibrium between demand and supply since the demand and supply would both be fluctuating.

Parkstad is planning to harvest around 88% of their electrical energy by solar photovoltaic panels in 2040 (Parkstad Limburg, 2017). With solar yields changing over the course of the day, a difference between demand and supply will become a fact in the proposed future scenario. Appendix 3 holds a calculation which roughly approaches the daily demand for electricity. The calculation is based on the percentage of demand and supply in a solar energy scenario as proposed by PALET. The average energy consumption over the last five years of the Netherlands has been converted to the approximate quantities for Parkstad. This conversion is based on the amount of inhabitants of Parkstad versus the amount of inhabitants of the Netherlands. This amount has been further reduced by 1/3 since Parkstad aims to reduce its use in 2040 by one third. The calculation shows us that the demand peaks in January when on average the daily demand for electrical energy is around 2,96 GWh TJ. On an average April day the demand is the lowest at 2,54 GWh. A part of this demand can be supplied by storage, although this would require further analysis and simulation with the consideration of other solutions

3.2.2. Inter seasonal demand and supply difference

The second form of storage is demanded when energy yields in different seasons do not match with their demand. Generally speaking the amount of electrical energy used in winter is higher than in summer. (CBS, 2018) This is caused by increased use of artificial lighting, among other factors. Electricity yields of the two most dominant renewables, wind and solar, change over the course of the year. Where wind generally has higher yields in wintertime, solar energy peaks in summertime due to higher solar irradiance (Segaar, 2016). An optimal renewable year round scenario would therefore involve both solar and wind generation to ensure year round energy supply. Unfortunately Parkstad is not able to install sufficient wind power due to limitations by Nationaal Landschap Zuid-Limburg and the public opinion (Parkstad Limburg, 2017). A partnership with a wind powered region elsewhere could technically furnish a complementary year round energy supply. Inter seasonal energy storage could also solve the discrepancy between supply and demand.

Parkstad is planning to generate most of their electricity from photovoltaics. This will lead to an electricity shortage in winter time, when electricity demand is the highest. Appendix 4 holds a spreadsheet which places the demands of electricity per month versus the solar yields per month. The demands have been based on the annual distribution of electricity of the Netherlands and have been converted to the quantities of Parkstad. The annual solar irradiation has been analyzed at a weather station in Valkenburg (Segaar, 2016), making it a highly representative analysis due to the small distance to Parkstad. The spreadsheet shows that shortages are to be expected in the period of November till March, while surpluses are expected in the remaining period. The cumulative shortage of 0,52 PJ or 144 TWh over the course of a year would be then be the desired capacity for inter seasonal storage. This demand however does not incorporate possible imported energy and can therefore be heavily reduced if not eliminated by importing energy.

3.2.3 Incidental storage demand

Incidental storage demand occurs when power supply cannot match the demand due to low solar irradiation and low wind speeds. This situation has been named “Dunkelflaute”, which translates to dark doldrums in English (Morris, 2017). Situations as such can last up to ten days. A situation as such happened on the 30th of April 2018. TenneT quickly had to buy additional power from surrounding country to meet the demand at that time. (TenneT, 2018) Ancillary with these periods are the fact that more artificial lighting is used, thus increasing the power demand. In a future 100% renewable scenario such periods will have a higher impact, since the current fossil fueled plants will have been closed. Energy storage can then secure supply to the grid. The desired energy storage for these situations would be the typical duration of these periods of 10 days multiplied by the daily demand. This would amount to about 9,8 GWh.

3.3 Storage methods

Energy storage can be achieved in several ways. To select a method for Parkstad, methods will be assessed by their fitness to store electricity for several hours, dynamic components, scalability, maturity, efficiency and applicability in Parkstad. The methods as a whole can be categorized in seven categories. The complete field of energy storage holds the following categories:

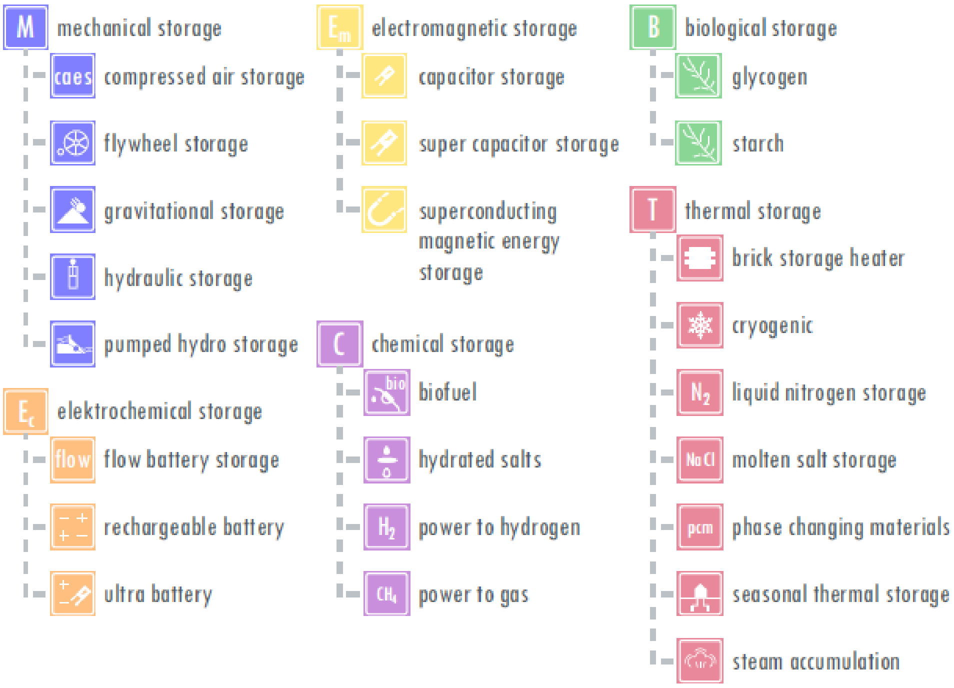

Figure 2 - Overview of the known energy storage methods

3.3.1 Method assessment

Appendix 5 holds an elaborated overview of the most known energy storage methods. From these methods several are not usable for electrical long term energy storage. Electromagnetic energy storage is limited to a timescale of seconds till minutes. Biological storage relies on natural processes in living organisms and is therefore not relevant for electrical energy. Thermal energy storage is dependent on the temperature a thermal medium is stored. The generation of electricity with thermal storage is tied to ability to produce steam and drive a turbine. The thermal medium should therefore exceed the temperature of boiling water at atmospheric pressure, to be able to produce steam. This results in the remaining of two thermal methods. Solar thermal plants generally are not placed in temperate climate zones. Steam accumulation still remains in the realm of industrial processes and its efficiency is still not that high.

Several proven technologies reside within the category of mechanical storage. Hydroelectric power for instance has become an established technique in mountainous regions. Also compressed air storage has been applied in Germany and the USA since the 1970s, making it one of the more mature technologies. Flywheel energy storage also falls under the more mature techniques. A 20 MW flywheel facility has been constructed in the USA. Flywheel storage however has a limited storage time, because the friction reduces the stored energy over time. Gravitational storage for grid applications is currently being developed though the ARES initiative in California. It holds the climbing and descending of heavily loaded train cards and generating electricity in their descent (Díaz-González, F., Sumper, A., & Gomis-Bellmunt, O. ,2016).

The chemical storage category holds possibilities for storage based on the composition of certain chemicals. Biofuels are interesting for renewable energy, although they cannot be produced by excess electrical energy. Hydrated salt energy is typically bound by the presence of salt and fresh water. Since Parkstad is not located near the sea, this method is not applicable. Power to hydrogen and power to methane have potential for the future, but are not yet mature enough for massive application.

Tabel 1 - Method assessment analysis

Method assessment analysis	Electricty storage for hours	Visible dynamic component	Scalability for bulk storage	Maturity	Applicability in Parkstad
Mechanical storage					
Compressed air	**Y**	**Y**	**Y**	**Y**	**Y**
Flywheel	N	N	Y	Y	Y
Gravitational	**Y**	**Y**	**Y**	**Y**	**Y**
Hydraulic	Y	Y	Y	N	Y
Pumped hydro	**Y**	**Y**	**Y**	**Y**	**Y**
Electrochemical					
Flow battery	Y	N	Y	Y	Y
Rechargeble battery	Y	N	Y	Y	Y
Ultra battery	Y	N	Y	N	Y
Thermal					
Molten salt storage	Y	Y	Y	Y	N
Steam accumulation	Y	N	Y	Y	Y
Chemical storage					
Biofuels	N	N	Y	Y	Y
Hydrated salts	Y	Y	Y	N	N
Power to hydrogen	Y	Y	Y	N	N
Power to methane	Y	Y	Y	N	N

3.3.2 Programmatic requirements

Three potential methods have been selected for bulk energy storage in Parkstad. Each of these methods has several programmatic requirements that would influence the spatial program of such a facility. Several built or proposed storage facilities are analyzed for their spatial composition.

The compressed air energy storage plant in Huntorf, Germany is one of the two CAES plants in the world. The other plant is located in Alabama, USA. The layout for storage has been given in appendix 6. The most important aboveground parts of a CAES facility are the compressor operation, the turbine operation, the gas supply and the connection to the grid (Castellani et al., 2015) . Hypothetically the gas supply could also be biogas or synthetic methane, which would make the process carbon neutral. The underground infrastructure is the most important of the facility. In the case of Parkstad the air cavern would be the abandoned mine. The application for CAES in old coal mines has been explored in *An overview of potential benefits and limitations of Compressed Air Energy Storage in abandoned coal mines* by Lutyński, 2017. Most important limitations for old coalmines are fire risk, soil instability and water penetration. In order to apply this energy method in the old coal mines these limitations have to be overcome.

The proposed pumped hydro plant for Parkstad would be an underground pumped hydro plant. Such a plant has been proposed for another part of the Limburg, but was cancelled because of a denied subsidy (O-pac, 2008). The layout of this plant has been included in appendix 6. The most important aboveground parts of the facility are the water reservoir and the connection to the grid. The underground facilities would involve the most crucial technical parts. The pump and the generator are located here, as well as the lower reservoir. The lower water reservoir would ideally be isolated from groundwater penetration, which would involve additions to the current mine tunnels.

A gravitational energy storage facility in Parkstad would also make use of the existing mine shafts. The significant height of the shafts could potentially storage significant amounts of energy. Although an existing facility cannot be analyzed, an elaborate overview of the general concept has been given by gravitybattery.info, which is included in appendix 6. The most important aboveground parts of this concept are the generator, the engine, the coil and the connection to the electrical grid. The underground facilities would be the shaft and the mass, although this could also be applied aboveground.

IV. CONCLUSION

This paper has explored the possibilities for energy storage in Parkstad. Based on previous research and literature and own analysis conditions of Parkstad have been mapped. Literature, ranging from scientific books to press releases, has clarified the demand for energy storage. Further literature study has given an overview of potential energy storage methods. These methods have been assessed for certain criteria, resulting in several potential methods. The selected methods have been analyzed for their programmatic requirements.

Parkstad is characterized by hills and a typical morphological structure. The relative height difference between these hills however is quite small. The most important potential for creating energy storage in Parkstad are the abandoned coal mines. The significant height and volume could potentially be reused for energy storage. Close proximity to existing electricity infrastructure facilitates easy access to the grid.

The demand for storage occurs on several occasions. The daily demand for energy for the whole of Parkstad is around 2,98 GWh maximum, from which at least a part should be supplied from storage. Inter seasonal takes up to around 144 TWh, which makes it advisable to look at other solutions before storing energy. An incidental storage demand of several days when a Dunkelflaute occurs, can take up to around 30 GWh. Further analysis and simulation is desired to actually quantify storage capacity.

The method assessment analysis shows that three methods are fit for possible application in Parkstad. All methods however require further development to be applied in this specific region. The programmatic requirements flowing from the possibilities can be divided in aboveground and underground components. The compressed air storage and the underground pumped hydro methods require the most underground measures, while gravitational batteries would require additional research for up scaling.

This research is limited by the methods used and the field of expertise of the author. Advanced energy simulations could better map and establish the required storage capacities. Also several other solutions should be taken into consideration when calculating these required capacities. The results of this paper cannot be generalized for similar projects, since specific criteria have been incorporated in the analysis. However the location specific approach could serve as an example for similar projects.

Further research could typically better analyze and quantify storage demands. Also more specific analyses should be added from the field of electrical engineering to cover the explored storage methods to their full extend.

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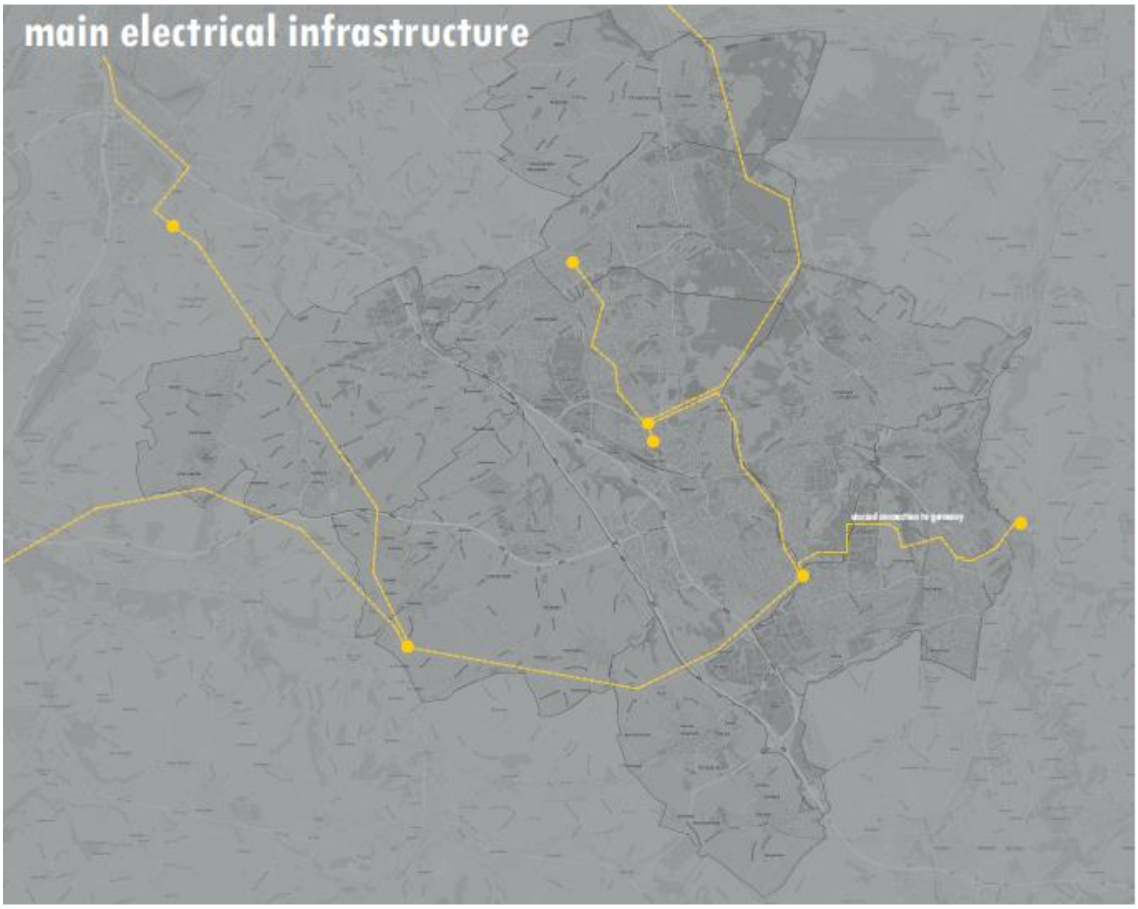
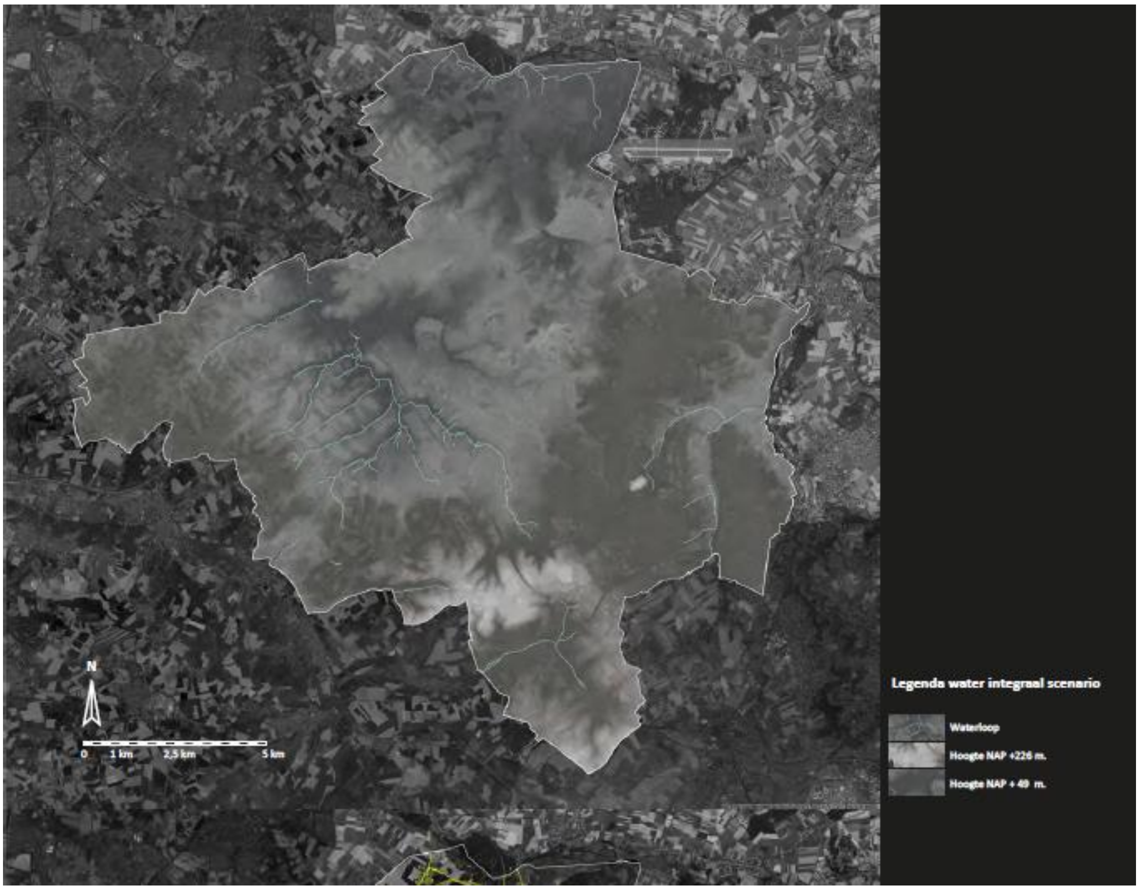
APPENDIX 1: CURRENT ENERGY INFRASTRUCTURE



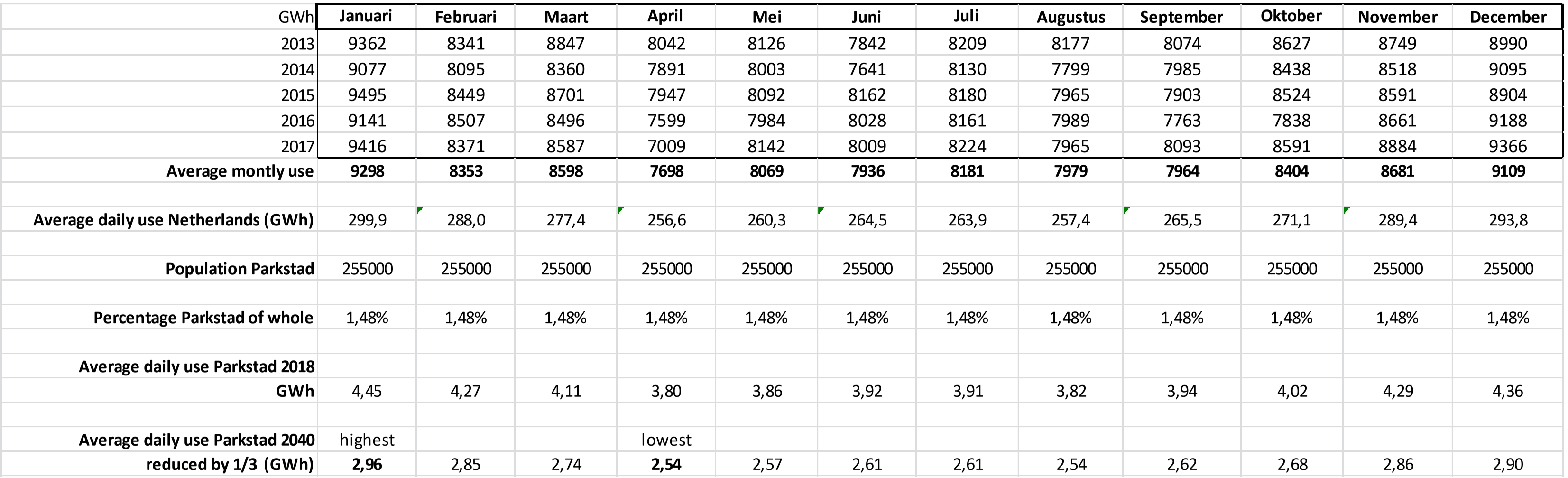
(Hoogspanningkaart, 2018)

APPENDIX 2: RELATIVE HEIGHT DIFFERENCE



(Parkstad Limburg, 2017)

APPENDIX 3: ENERY CALCULATION DAILY DEMAND



GWh	Januari	Februari	Maart	April	Mei	Juni	Juli	Augustus	September	Oktober	November	December
2013	9362	8341	8847	8042	8126	7842	8209	8177	8074	8627	8749	8990
2014	9077	8095	8360	7891	8003	7641	8130	7799	7985	8438	8518	9095
2015	9495	8449	8701	7947	8092	8162	8180	7965	7903	8524	8591	8904
2016	9141	8507	8496	7599	7984	8028	8161	7989	7763	7838	8661	9188
2017	9416	8371	8587	7009	8142	8009	8224	7965	8093	8591	8884	9366
Average montly use	**9298**	**8353**	**8598**	**7698**	**8069**	**7936**	**8181**	**7979**	**7964**	**8404**	**8681**	**9109**
Average daily use Netherlands (GWh)	299,9	288,0	277,4	256,6	260,3	264,5	263,9	257,4	265,5	271,1	289,4	293,8
Population Parkstad	255000	255000	255000	255000	255000	255000	255000	255000	255000	255000	255000	255000
Percentage Parkstad of whole	1,48%	1,48%	1,48%	1,48%	1,48%	1,48%	1,48%	1,48%	1,48%	1,48%	1,48%	1,48%
Average daily use Parkstad 2018												
GWh	4,45	4,27	4,11	3,80	3,86	3,92	3,91	3,82	3,94	4,02	4,29	4,36
Average daily use Parkstad 2040	highest			lowest								
reduced by 1/3 (GWh)	**2,96**	2,85	2,74	**2,54**	2,57	2,61	2,61	2,54	2,62	2,68	2,86	2,90

(Data source: CBS statline, 2018)

APPENDIX 4: ENERY CALCULATION MONTLY DEMAND

	montly energy usage (mln kWh)				Solar			Storage		
	Quantity Netherlands	Percentage of whole	Quantity Parkstad	Amount Parkstad (PJ)	Solar irridiation (J)	Percentage of whole	Amount Parkstad (PJ)	Difference (PJ)	Shortage (PJ)	Surplus (PJ)
jan	9298	9,27	137,9	0,31	8000	2,07	0,14	-0,16	0,16	
feb	8353	8,33	123,8	0,27	13000	3,36	0,23	-0,04	0,04	
mrt	8598	8,58	127,5	0,28	28000	7,24	0,50	0,22		0,22
apr	7698	7,68	114,1	0,25	45000	11,63	0,80	0,55		0,55
mei	8069	8,05	119,6	0,27	59000	15,25	1,05	0,79		0,79
jun	7936	7,92	117,7	0,26	60000	15,50	1,07	0,81		0,81
jul	8181	8,16	121,3	0,27	59000	15,25	1,05	0,78		0,78
aug	7979	7,96	118,3	0,26	49000	12,66	0,87	0,61		0,61
sep	7964	7,94	118,1	0,26	31000	8,01	0,55	0,29		0,29
okt	8404	8,38	124,6	0,28	20000	5,17	0,36	0,08		0,08
nov	8681	8,66	128,7	0,29	9000	2,33	0,16	-0,13	0,13	
dec	9109	9,08	135,0	0,30	6000	1,55	0,11	-0,19	0,19	
	100269	**100**	**1486,5**	**3,3**	**387000**	**100**	**6,9**	**3,60**	**0,52**	**4,12**

(Data source: CBS statline, 2018)

APPENDIX 5: ENERGY STORAGE METHODS MATRIX

IMAGE SOURCES

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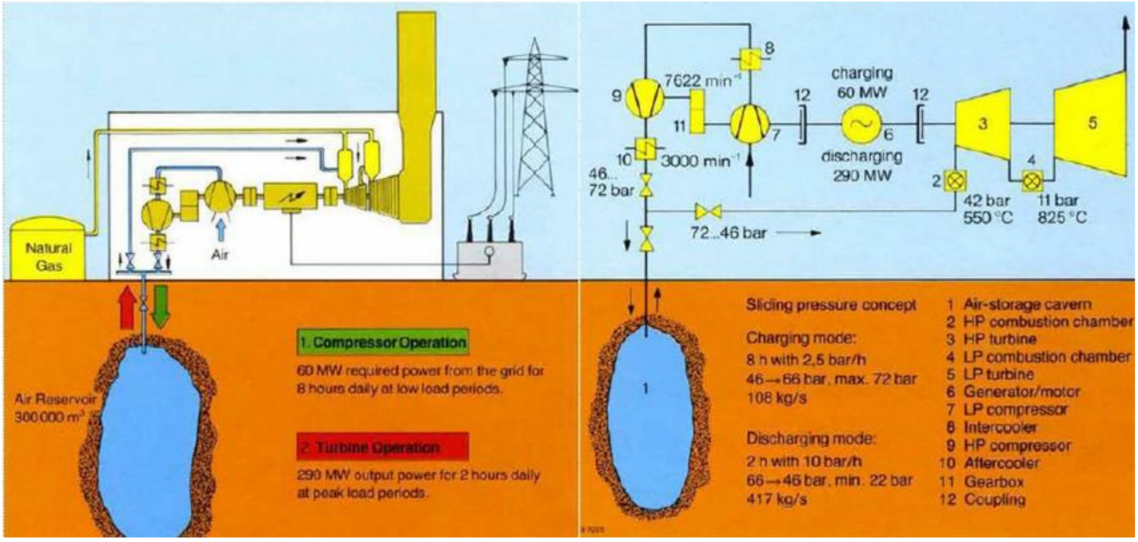
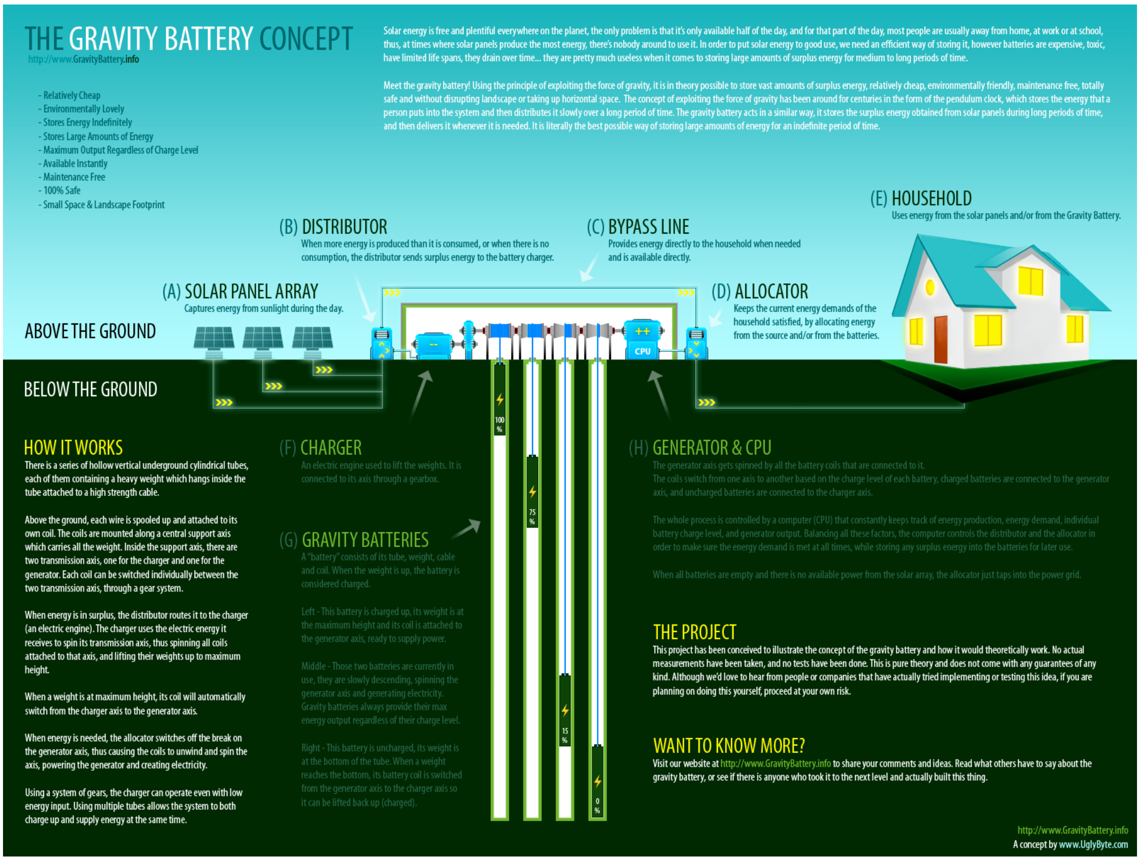
APPENDIX 6: LAYOUTS OF REALIZED AND PROPOSED STORAGE FACILITIES



(Castellani et al., 2015)



THE GRAVITY BATTERY CONCEPT

http://www.GravityBattery.info

- Relatively Cheap
- Environmentally Lovely
- Stores Energy Indefinitely
- Stores Large Amounts of Energy
- Maximum Output Regardless of Charge Level
- Available Instantly
- Maintenance Free
- 100% Safe
- Small Space & Landscape Footprint

Solar energy is free and plentiful everywhere on the planet, the only problem is that it's only available half of the day, and for that part of the day, most people are usually away from home, at work or at school, thus, at times where solar panels produce the most energy, there's nobody around to use it. In order to put solar energy to good use, we need an efficient way of storing it, however batteries are expensive, toxic, have limited life spans, they drain over time... they are pretty much useless when it comes to storing large amounts of surplus energy for medium to long periods of time.

Meet the gravity battery! Using the principle of exploiting the force of gravity, it is in theory possible to store vast amounts of surplus energy, relatively cheap, environmentally friendly, maintenance free, totally safe and without disrupting landscape or taking up horizontal space. The concept of exploiting the force of gravity has been around for centuries in the form of the pendulum clock, which stores the energy that a person puts into the system and then distributes it slowly over a long period of time. The gravity battery acts in a similar way, it stores the surplus energy obtained from solar panels during long periods of time, and then delivers it whenever it is needed. It is literally the best possible way of storing large amounts of energy for an indefinite period of time.

(A) SOLAR PANEL ARRAY
Captures energy from sunlight during the day.

(B) DISTRIBUTOR
When more energy is produced than it is consumed, or when there is no consumption, the distributor sends surplus energy to the battery charger.

(C) BYPASS LINE
Provides energy directly to the household when needed and is available directly.

(D) ALLOCATOR
Keeps the current energy demands of the household satisfied, by allocating energy from the source and/or from the batteries.

(E) HOUSEHOLD
Uses energy from the solar panels and/or from the Gravity Battery.

HOW IT WORKS

There is a series of hollow vertical underground cylindrical tubes, each of them containing a heavy weight which hangs inside the tube attached to a high strength cable.

Above the ground, each wire is spooled up and attached to its own coil. The coils are mounted along a central support axis which carries all the weight. Inside the support axis, there are two transmission axis, one for the charger and one for the generator. Each coil can be switched individually between the two transmission axis, through a gear system.

When energy is in surplus, the distributor routes it to the charger (an electric engine). The charger uses the electric energy it receives to spin its transmission axis, thus spinning all coils attached to that axis, and lifting their weights up to maximum height.

When a weight is at maximum height, its coil will automatically switch from the charger axis to the generator axis.

When energy is needed, the allocator switches off the break on the generator axis, thus causing the coils to unwind and spin the axis, powering the generator and creating electricity.

Using a system of gears, the charger can operate even with low energy input. Using multiple tubes allows the system to both charge up and supply energy at the same time.

(F) CHARGER
An electric engine used to lift the weights. It is connected to its axis through a gearbox.

(G) GRAVITY BATTERIES
A "battery" consists of its tube, weight, cable and coil. When the weight is up, the battery is considered charged.

Left - This battery is charged up, its weight is at the maximum height and its coil is attached to the generator axis, ready to supply power.

Middle - Those two batteries are currently in use, they are slowly descending, spinning the generator axis and generating electricity. Gravity batteries always provide their max energy output regardless of their charge level.

Right - This battery is uncharged, its weight is at the bottom of the tube. When a weight reaches the bottom, its battery coil is switched from the generator axis to the charger axis so it can be lifted back up (charged).

(H) GENERATOR & CPU
The generator axis gets spinned by all the battery coils that are connected to it.
The coils switch from one axis to another based on the charge level of each battery, charged batteries are connected to the generator axis, and uncharged batteries are connected to the charger axis.

The whole process is controlled by a computer (CPU) that constantly keeps track of energy production, energy demand, individual battery charge level, and generator output. Balancing all these factors, the computer controls the distributor and the allocator in order to make sure the energy demand is met at all times, while storing any surplus energy into the batteries for later use.

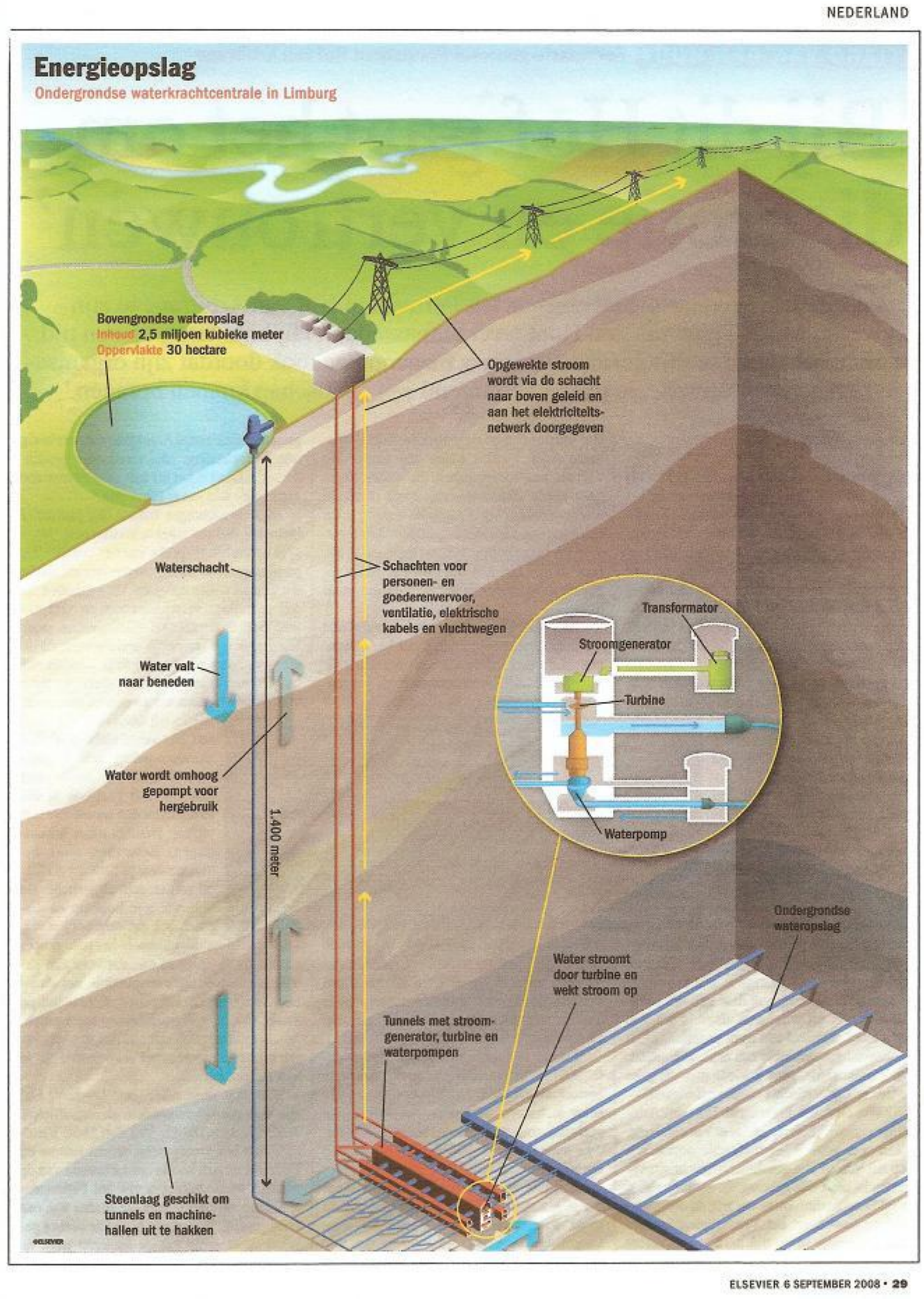
When all batteries are empty and there is no available power from the solar array, the allocator just taps into the power grid.

THE PROJECT
This project has been conceived to illustrate the concept of the gravity battery and how it would theoretically work. No actual measurements have been taken, and no tests have been done. This is pure theory and does not come with any guarantees of any kind. Although we'd love to hear from people or companies that have actually tried implementing or testing this idea, if you are planning on doing this yourself, proceed at your own risk.

WANT TO KNOW MORE?
Visit our website at http://www.GravityBattery.info to share your comments and ideas. Read what others have to say about the gravity battery, or see if there is anyone who took it to the next level and actually built this thing.

http://www.GravityBattery.info
A concept by www.UglyByte.com

(Gravity battery, 2018)



NEDERLAND

Energieopslag

Ondergrondse waterkrachtcentrale in Limburg

ELSEVIER 6 SEPTEMBER 2008 • 29

(O-pac, 2008)