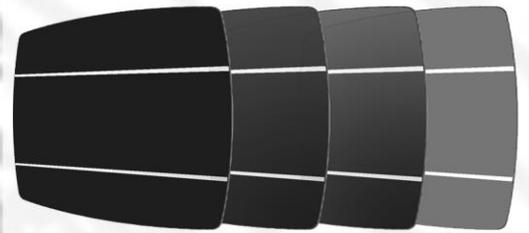

DECENTRAL SOLAR ENERGY DATABASE



EXTERNAL GEOMATICS SYNTHESIS PROJECT Q3

Providing a reliable and up to date
registration of the installed
decentral PV panels

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1. INTRODUCTION

In the second year of the MSc Geomatics, given at the Delft University of Technology, the students participate in the Geomatics Synthesis Project (GSP). This project is meant to combine all the knowledge which is learned in the first year of the master program.

This Synthesis Project 2014/2015 Q3 is a part-project of the CERISE Topsector Switch2SmartGrids research program (www.cerise-project.nl), which is a program that has the aim to create future proof and efficient information exchange between the energy sector, eGovernment and geo- world. This Synthesis Project focuses on the recent development of renewable decentralised energy sources applied by private owners in the Netherlands. With this principle, energy consumers become energy suppliers (Verbree, 2015). Decentralised energy sources include: solar energy, wind energy (wind turbines), combined heat and power (CHP) and biogas (LFG). This Synthesis Project focuses on solar energy in the form of electricity via PV (photovoltaic) panels and not solar energy in the form of heat via solar collectors. Both decentralised energy suppliers as the regular central energy suppliers are connected to the entire nationwide energy network. Current decentralised energy sources can be part of a Smart Grid; an advanced electrical grid that via technologies controls and accurately regulates energy demand and supply. The energy supply and demand of this network should always be in balance.

In case of calamity - e.g. a dike breach - parts of the nationwide electric network can fall out. In these occasions it is evident to figure out whether the Smart Grid decentralised energy sources can contribute to balancing out the fluctuations of the energy network. In this manner, parts of the built environment - e.g. hospitals - that are in need of a continuous power flow, could then be secured of this power. In the case of a calamity, information about the smart grid is necessary to control the crisis and to ensure a shared view on the energy networks for both the crisis managers and network operators.

In chapter 2 the focus will be on the research description, followed by the related work of this research in chapter 3. Chapters 4, 5 and 6 describe the research in terms of the methodology, analysis and statistical analysis. The possible application of the database, including map visualization and application in Crisis Management, is described in chapter 7. Chapters 8, 9 and 10 finalize this report with the results, conclusion and acknowledgement. As an addition the project management and process are recorded in Appendix A with the Flow Down chart in Appendix B.

1.1 Problem statement

Nowadays, there is no reliable information available about the current number, physical location, and capacity of installed decentralised PV panels. The general objective of the Synthesis project is to validate the current registration (EDSN-PIR) of the installed decentralised PV panels, which is possibly not that well and up-to-date. The desired result is a reliable and up-to date database with a total overview of where and how energy is produced, and what is the amount of power (kilo watt hour, kWh) produced by PV panels in a chosen test area, to show the accuracy of the EDSN-PIR.

The focus for this project is on the network operator Alliander. The project incorporates an important Geographic component, cause of the importance of the precise knowledge about the location (longitude and latitude), orientation and inclination of the PV panels, and the chosen test area.

In Germany there is a big amount of PV panels present (PowNed, 2012), which has already resulted into balancing problems of the energy network. The partition of produced solar energy in 2013 was 0.4% in The Netherlands. In Germany the partition was already at 5% (CBS, 2014). In 2013 the news (NOS) also mentioned that PV panels of the brand 'Solar' had a risk of catching fire. The recent boom in PV industries and its global deployment ensures that this risk will increase (Verhees, Raven, Veraart, Smith, & Kern, 2013). The risks of PV panels (e.g. fire safety, correct installment, electric circuits) will be important for safety regions, crisis managers, network operators and energy suppliers. The only way to support such cases is to know exactly where the PV panels are installed. This information must be stored accurately in a reliable and up-to-date database which can be used to validate and improve the current registration of installed decentralised PV panels in the Smartgrid. This database can be used for Crisis Management to ensure the delivery of energy in case of a calamity, e.g. if the existing energy fails.

1.2 Research question

How to create a database which can be used to validate and improve the current registration of installed decentralised PV panels in the Smart Grid usable for an application in Crisis Management?

1.3 Geographical area concerned

The research will cover the area of Stevenshof in Leiden, which is district nine.

1.4 Scientific contribution

The relevance of this research project is that the prototype database developed during this project does not yet exist in the Netherlands. Building this prototype covers a new methodology in locating and combining the necessary input data from multiple sources. Furthermore, the consequential future applications (like a calamity application or green energy mapping) may evoke new perspectives and interest in the accurate knowledge about PV panel locations in the Netherlands. Among others, these interests include new statistical insights and analysis that can be executed.

2. RESEARCH DESCRIPTION

2.1 Analysis requirements

2.1.1 Main objective

The main objective of the Synthesis project (2014/2015) was to validate the current registration (EDSN-PIR) of the installed decentralised PV panels in a chosen test area. The desired result was a reliable and up-to date database with a total overview of where and how energy is produced, and what the estimated amount of power (kWh) is produced by PV panels. For this project the focus was on the network of operator Alliander.

2.1.2 Other objectives

- To provide a next step in the CERISE Topsector Switch2SmartGrids research program*
- To figure out the importance of Dutch decentralised energy sources for the nationwide energy network
- To set up recommendations for future research
- To propose guidelines for continuations of the delivered prototype

* The Synthesis project 2014/2015 Q3 is part of this research program – a program that has the aim to create future proof and efficient information exchange between the energy sector, eGovernment and geo- world.

2.1.3 Study goals

- A synopsis of the different disciplines
- Practice teamwork in small groups
- Experience the entire process (from project definition, measurement (data gathering), data processing and analysis, to presentation and delivery, and application)
- Encourage collaboration between students and staff of the groups involved
- Be of interest to the sections defining / supervising / controlling a project

2.1.4 Team expectations / prototype

The prototype (database) should be up-to-date and reliable. It should cover a test area and should show where and how energy is produced, and what the estimated amount of power (kWh) is, produced by PV panels.

2.1.5 Geomatics for the built environment/geo-information

This project will incorporate the following Geomatics courses:

- GEO1001 (Sensing Technologies for the Built Environment);
- GEO1002 (GIS and Cartography);
- GEO1003 (Positioning and Location Awareness)
- GEO1004 (3D Modelling of the Built Environment)
- GEO1005 (Spatial Decision Support for Planning and Crisis Management);
- GEO1006 (Geo Database Management Systems);
- GEO1007 (Geo Web, Sensor Networks and 3D-GeoVisualisation Technology)
- GEO1008 (Geo Datasets and Quality)
- GEO1009 (Geo-information Organization and Legislation).

The knowledge and skills of the 1st year were combined. Geo-data is collected by using images from space. Afterwards the geo-data is processed, managed, visualized and stored in an accurate and meaningful way. Finally there is dealt with the legal and social aspects (privacy, management, collection and cost). An overview of the courses in relation to the Synthesis Project can be seen in the following table.

Course Relevance Table

Course Relevance Table

Course	Project Subject	Section	
GEO1001	Sensing Technologies for the Built Environment	Image Matching	4.2; 5.1
GEO1002	GIS and Cartography	Map creation, Shapefile filtering	4; 7.3
GEO1003	Positioning and Location Awareness	Positioning, Aerial Pictures (incl. GPS, flight path, orientation), Research formulation, Ionospheric errors	1; 5.1
GEO1004	3D Modelling of the Built Environment	PV Power methodology calculation	5.2
GEO1005	Spatial Decision Support for Planning and Crisis Management	Crisis Management Scope, Map creation	7.4
GEO1006	Geo Database Management Systems	Database design & processing	3.3; 4; 5.3; 5.4; 5.5
GEO1007	Geo Web, Sensor Networks, and 3D Geo Visualization	KML/KMZ Creation, HTML	7
GEO1008	Geo Datasets and Quality	Quality assignment	3.3; 4
GEO1009	Geo-information Organization and Legislation	Privacy issues	3.5; 5.5

2.2 Research questions

The purpose of the requirement specification is to specify the top-level requirements. In other words, which questions are going to be answered within the framework of the project?

Main research question:

How to create a database which can be used to validate and improve the current registration of installed decentralised PV panels in the Smart Grid usable for an application in Crisis Management?

Final product: An up-to-date and reliable database (prototype) with an overview of where and how energy is produced, and what the amount of power (kWh) is produced by PV panels in a chosen test area.

1. What data can be provided by the different stakeholders?
2. What is the most effective way to retrieve the data regarding the location and the maximum capacity at any time (kWp¹) of the installed decentralised PV panels?
3. Where is decentralised energy in the form of PV panels produced?
4. What is the amount of power (kWh²) produced by PV panels?
5. What are the current ways to publish and store the derived data?
6. How to improve the current situation of publishing and storing the derived data?
7. How can this stored data be a solution for an application in Crisis Management, regarding offensive indoor efforts of the fire brigade?

¹ kWp: Max. capacity at any time

² kWh: Amount of power (per year)

2.3 Related work

There are numerous studies to map the renewable energy potential, while not including information about the possible installed capacity of a PV installation. This information is available through different atlases, like: <http://maps.amsterdam.nl/> and <http://www.rotterdamclimateinitiative.nl/nl/energieatlas/energieatlas-rotterdam/zonne-energie>. The potential mapping of roofs for PV panels is available through applications like: <http://zonnekaart.nl/>, <http://www.zonatlas.nl/home/>, and <http://www.zonnescanbrabant.nl/>.

The municipality of Amsterdam has a map that should portray the exact location of PV panels; <http://www.zonopdekaart.amsterdam.nl/zon-op-de-kaart/>. Though, this map of Amsterdam does not seem to be complete.

With specific log-in codes for Leiden accurate solar energy data can be retrieved via this website <http://www.energieinbeeld.nl/>, including: energy production data of PV panels on PC5 level in kWh. Estimations are based on the PIR. There is a possibility to view the data on a map (see Figure 1), and to download .csv of the data (tab 'Rapportages').

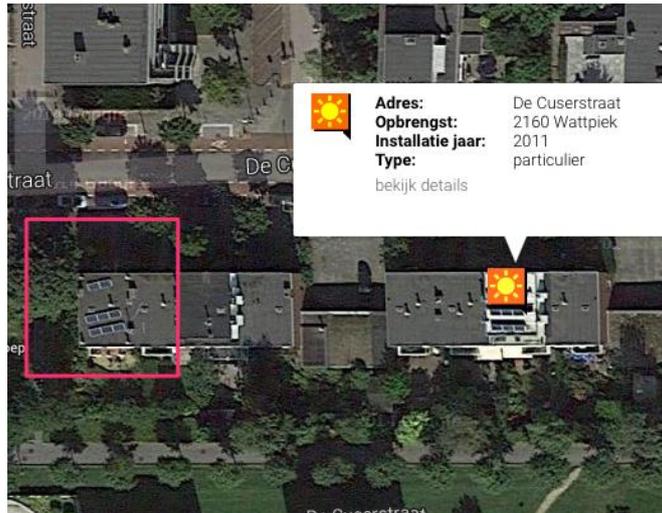


FIGURE 1: ENERGIE IN BEELD

However, there is no reliable information available about the current number, physical location, and capacity of installed PV panels. The same holds true for the other energy sources of the Smart Grid, like: wind turbines, biogas installations, and combined heat and power installations.

2.4 Rich picture

This rich picture has been made to explore, acknowledge and define the Synthesis Project and express it. In Figure 2 the complete rich picture is visualized.

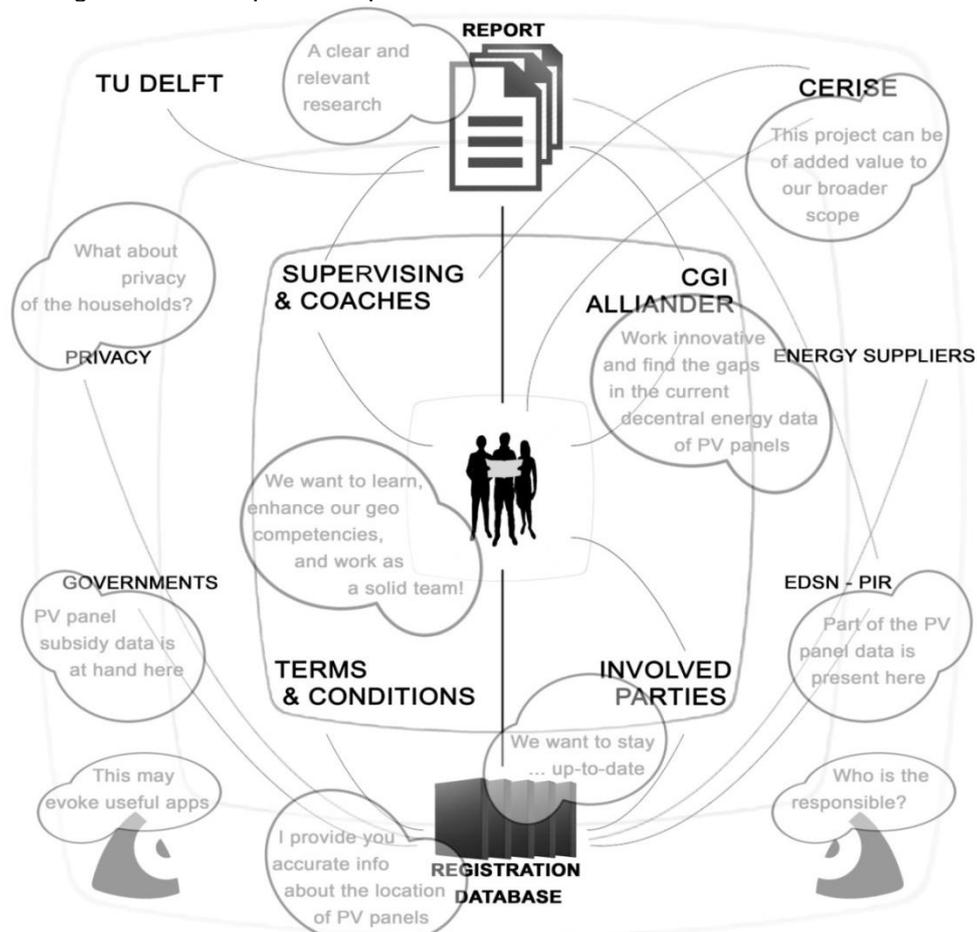


FIGURE 2: RICH PICTURE

3. RELATED WORK

3.1 General

PV is an abbreviation of the English word 'Photo Voltaic'. This means 'light' (= Photo) and 'electricity' (Voltaic). PV panels convert solar energy into electrical energy. The electrical energy which is generated by these panels will enter the house, in the form of direct current (DC) voltage. This DC voltage has to be converted into alternating current (AC) voltage to be able to be incorporated into the electrical grid. This conversion of DC to AC voltage happens in the inverter. After converting, the power goes directly to the meter before it enters the normal circuit. The principle can be found in Figure 3. PV panels consist of PV cells which capture sunlight and convert it into usable electricity. The generated electricity can be used immediately, stored in a battery or delivered to the grid.

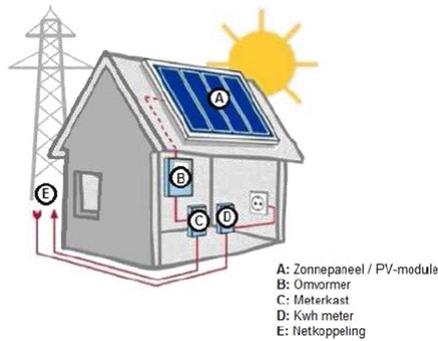


FIGURE 3: SOLAR ENERGY

The highest revenue of PV panels achieves an efficiency of almost 20%. The maximum capacity at any time of PV panels is expressed in: kilo Watt peak (kWp).

A general example: if one has a household with an annual consumption of 4,000 kWh, and one puts 19 PV panels of 250 Watts on the roof (with an orientation to the south and an inclination of 30 degrees), then each PV panel should give 212,5 kWh per year. The total yield is 4037.5 kWh. At certain times the installation will generate too much electricity and this energy can be delivered back to the grid - or stored in batteries at home, this technique is already adopted in Germany, according to Leen van Doorn (domain and innovation expert of Alliander). At other times less energy will be generated than the energy that is needed. At that time, extra energy can be taken from the net (HVP Duurzaam, 2010).

kWh: Amount of power (per year)

kWp: Max. capacity at any time

3.2 Alliander

Alliander is the designated network operator which consists of Liander, Liandon and Endinet. It is one of the largest energy providers of the Netherlands. Alliander manages large parts of the electricity network. Alliander is an organization that manages both the electricity and gas grids in large parts of the Netherlands. This Synthesis Project focuses solely on the electricity grid of Alliander. While central and decentralised power stations can deliver their energy to this grid, several energy suppliers (e.g. Eneco, Greenchoice) sell energy to their customers. Network operator Alliander is the party that facilitates this energy market, according to Leen van Doorn (of Alliander). In case of a power cut, Alliander reorganizes their electricity grid in order to provide affected objects with electricity again. In Figure 4 is visualized where Alliander operates.

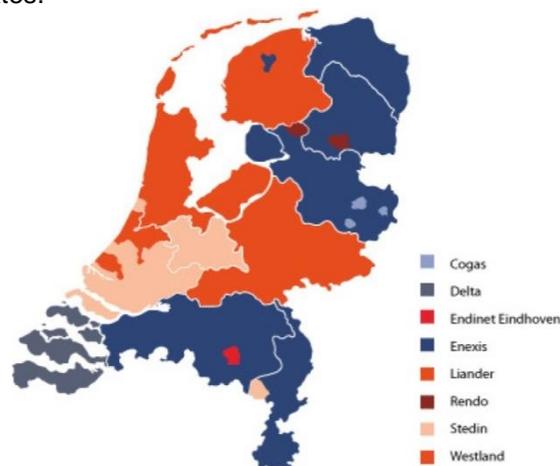


FIGURE 4: LOCATIONS WHERE ALLIANDER OPERATES

3.3 The current ways of publication and storage

3.3.1 Production Installation Register (PIR)

The current registration of installed decentralised PV panels is set in the Production Installation Register (PIR). The PIR is a national registry where consumers can register (voluntarily) their sustainable decentralised production installation. The registration and cancellation of production installations by the customer (or the installation company on his behalf) can be done via a number of ways, such as through the website www.energieleveren.nl. Via this website <http://www.energieleveren.nl> more than 28.000 installations have already been registered (Energieleveren.nl, n.d.). With the PIR network operators want to get an overview of the development of PV panels, wind turbines and other renewable installations in the Netherlands.

Of the production installations the following information will be registered:

- Address-data (Streetname; Housenumber; Postcode; Livingarea)
- Connecting-data (Eancode connection; Name Netmanager)
- Installation-data (Building year; Type of installation; Power; Date in use)

It was decided to keep the registration of the production installations for customers easily accessible. Thereon the number of input and controls is minimized. The PIR is online since about the year 2011. Therefore many old, mostly smaller installations will never be included in the PIR, because they were already there for, when the PIR was non-existent.

Figure 5 provides an overview of the parties involved in the notification and retrieval of production installation data.

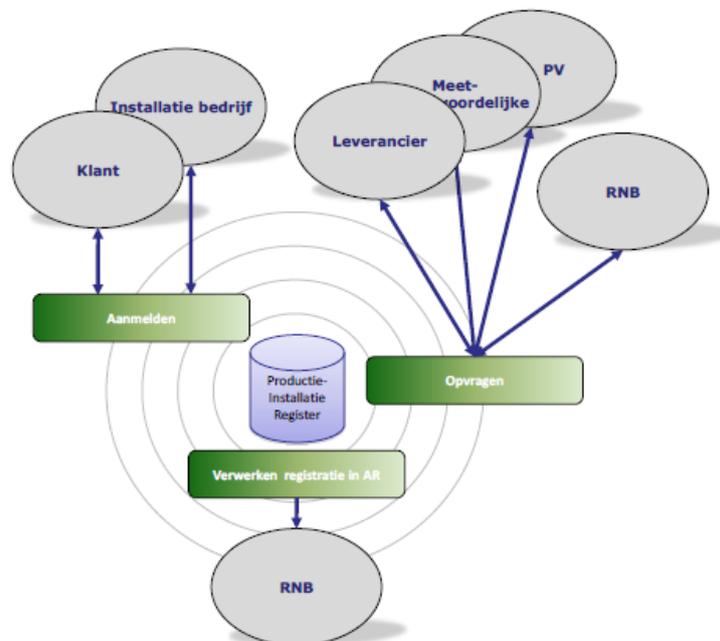


FIGURE 5: PARTIES INVOLVED IN PIR DATA

The PIR is only accessible to network operators and energy suppliers. The database of the PIR is extensive (e.g. Installation year / incline / energy feedback to the net, etc.). Furthermore, the PIR is not reliable and complete, because consumers can register voluntarily. A part of the (anonymized) PIR data can be found on the website called: www.klimaatmonitor.databank.nl. At the website of the klimaatmonitor can be found that the klimaatmonitor is using other sources for rectifying the amount of PV panels, registered at the PIR. This notion will be explained with numbers in section 3.3.2.

There are two tabs on this website which are useful, namely 'Database' and 'Download'. Below the tab 'Database', 'Data at district and neighbourhood level' and 'PV panels' can be selected. An example of this information can be found in Figure 6 left. Below the tab 'Download' the latest state of cases of records of actual PV panels per postal code area (PC6) can be downloaded (from the end of 2014). This file is a CSV, and consists of information from various sources (nine in total). An example of this information can be found in Figure 6, right.

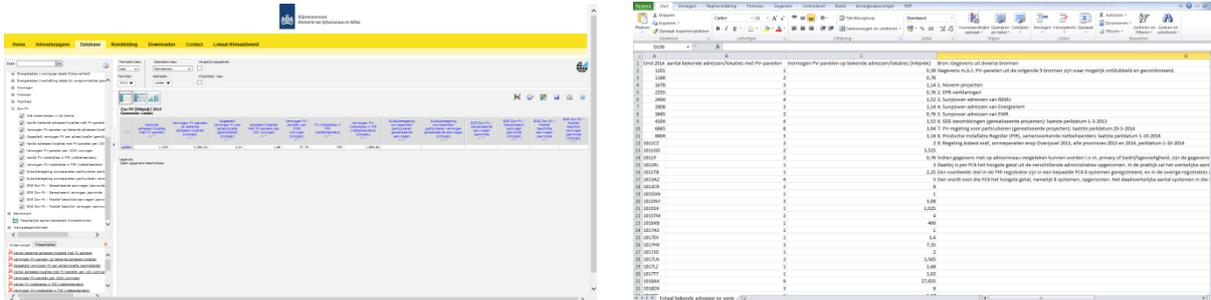


FIGURE 6: 'DATABASE' AND 'DOWNLOAD'

3.3.2 PV panels information on the website ('Database')

There are two types of information which are interesting (see Figure 7), and can be found via the tab 'Database', namely:

- (Amount of) Known addresses/locations with PV-panels
(See section 3.3.4 (about the nine sources) to discover how this data is known)
- (Amount of) PV-installations in PIR (net-operators)

The fact that the klimaatbank is using other sources to rectify the amount of PV panels of the PIR emphasize that it is known that the PIR is not up-to-date and reliable.

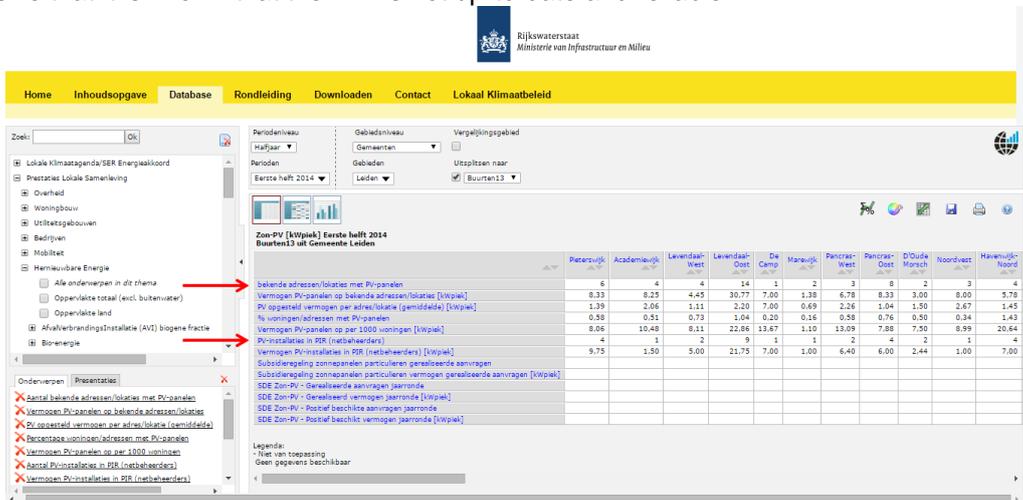


FIGURE 7: TWO TYPES OF INFORMATION

	Stevenshof				
	Schenkwijk	Kloosterhof	Dobbewijk-Noord	Dobbewijk-Zuid	TOTAL
Known addresses/locations with PV-panels	23	23	24	74	144
Max. capacity of PV-panels of known addresses/locations [kWp]	61,67	34,51	42,93	125,50	264,60
PV-installations in PIR	21	16	13	53	103
Max. capacity of PV-panels in PIR (netbeheerders) [kWp]	59,84	27,90	34,00	109,98	231,72

3.3.3 PIR data confidential (not on the website) of stakeholder

The data of the PIR is confidential and not published on a website on PC6 level. This confidential data of Stevenshof is obtained via Gert Nijsink (advisor at RWS).

3.3.4 PV panels information on the website ('Download')

The data source closed means that the data source will not be updated anymore. Ongoing means that it still will be updated. Since the PIR is included in the 'Existence 9' registry (nine different sources, see below), an overlap between 'Existence 9' is present with solely this PIR database (row number 8).

	Sources:	Data source:	Last reference date:	
1.	Novem-projecten	Closed		Novem is derived from Senternovem – the predecessor of Rijksdienst voor Ondernemend Nederland (RVO). Senternovem has become RVO http://www.rvo.nl/
2.	EPR-verklaringen	Closed		EPR is the Energy premium arrangement for energy efficient and renewable energy facilities.
3.	Sunpower-adressen van REMU	Closed		REMU is the predecessor of Eneco. Registration of addresses connected to solar energy.
4.	Sunpower-adressen van Energierent	Closed		Energierent is the predecessor of Nuon. Registration of addresses connected to solar energy.
5.	Sunpower-adressen van EWR	Closed		EWR is the predecessor Nuon. Registration of addresses connected to solar energy.
6.	SDE+-beschikkingen (gerealiseerde projecten)	Ongoing	1-3-2013	SDE+ is the abbreviation of Stimulerend Duurzame Energieproductie, which is the current subsidy arrangement. SDE+ starts on the 31 st of March 2015.
7.	PV-regeling voor particulieren (gerealiseerde projecten)	Closed	20-5-2014	It is the predecessor of RVO. All the information of Agentschap NL is currently visible on RVO.nl. http://www.energiebesteding.nl/voor-thuis/nieuws/2408/zon-pv-regeling-voor-particulieren-groot-succes.html
8.	Productie Installatie Register (PIR), samenwerkende netbeheerders	Ongoing	31-12-2014	PIR – EDSN. Production Installation Register (PIR).
9.	Regeling Asbest eraf, zonnepanelen erop Overijssel 2011, overige provincies 2013 en 2014	Ongoing	1-10-2014	Project 'Asbest eraf, zonnepanelen erop' http://www.asbestvanhetdak.nl/

3.3.5 UML diagram of the PIR

The CERISE-project provided us with the UML diagram of the PIR. This UML diagram gave insights how the database of the PIR is composed (see Figure 8).

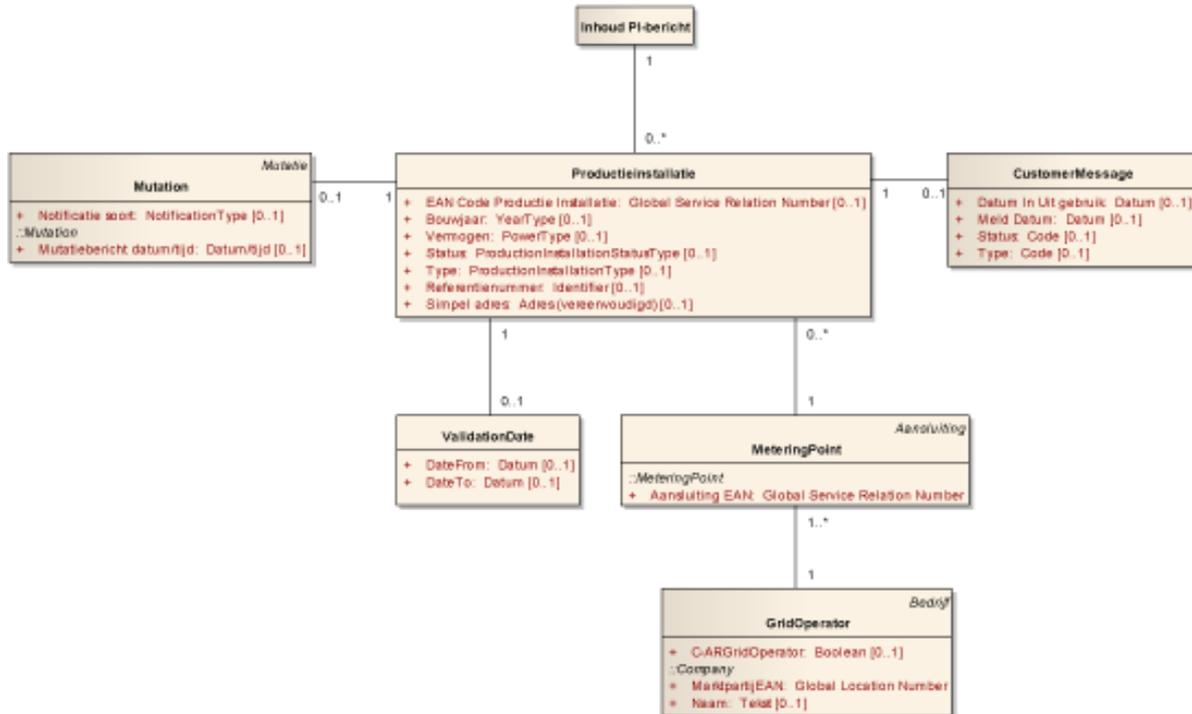


FIGURE 8: UML DIAGRAM OF THE PIR

3.4 SDE+ arrangement

Entrepreneurs, who purchase PV panels and want to resupply energy, may receive compensation for this. With the SDE+ subsidy the Ministry of Economic Affairs encourages the production of renewable energy. SDE+ is the abbreviation of Encouraging Sustainable Energy (nld. Stimulerend Duurzame Energieproductie (SDE+)) (Rijksdienst voor Ondernemend Nederland, 2015).

All the existing SDE+ registers are tracked regarding the purchase of PV panels, from 2008 up until the end of 2014, via the following link: <http://www.rvo.nl/subsidies-regelingen/toezeggingen-en-realisatie-SDE+>

This search converged on the test area Stevenshof. Unfortunately, not all expenditures of the SDE+ program are listed with postal code, some only by city name. This inaccuracy might result in subsidy cases which are located within the test area, but which are impossible to track. All the same, no SDE+ expenditures were processed in district Stevenshof, which leads to one less possible usable data source.

3.5 Privacy issues

There are different forms of privacy; one of these forms is 'Informational privacy'. Informational privacy involves the establishment of rules governing the collection and handling of personal data such as credit information, and medical and government records. It is also known as "data protection" (NOS, 2013).

Aerial images are personal data. They identify parcels which are owned by natural persons. Personal information can be anonymized, in such a way that the principles of protection do not apply anymore to this data. The data is in such a way anonymized that the person, to whom the data referred, is no longer identifiable (Consideration 26 EC 95/46).

Even though aerial imagery is personal data, adopting this kind of imagery in applications does not immediately mean that privacy manner are violated. Future investigating should explicate in to what extant retrieving distinct information from aerial imagery and connecting that to premises, is privacy sensitive.

3.6 Stevenshof in Leiden

The research has covered the area of Stevenshof in Leiden, which is district nine. It consists of four neighbourhoods, namely: Kloosterhof, Schenkwijk, Dobbewijk-Zuid and Dobbewijk-Noord, and is a densely populated district. On January 1, 2013, there were around 11.500 inhabitants and around 4700 households.

- Kloosterhof: 2890 inhabitants 1225 households
- Schenkwijk: 2000 inhabitants 805 households
- Dobbewijk-Zuid: 5135 inhabitants 1940 households
- Dobbewijk-Noord: 1510 inhabitants 750 households

Energetic Leiden, which is committed to a sustainable city, did a PV purchasing action in Stevenshof (Figure 9) in June 2013. This district was chosen by Energetic Leiden, because many roofs were empty and there were basically no restrictions by complex licensing procedures.



FIGURE 9: STEVENSHOF IN LEIDEN (IN RED)

3.7 Case study Germany (what is already out there)

Germany is ahead regarding the amount of renewable energy that is produced, compared to the Netherlands. Furthermore, related applications are in an advanced stage. An interesting, interactive one is the so-called Infosystem EEG-Einspeisungen Deutschland (Figure 10-12). This web application – based on among others Google Maps, OSM and network operator TenneT – aims to bring a transparent overview of renewable energy sources in use, e.g. solar panels and wind turbines. These registered sources are pinpointed on location, revealing more detailed information as the user zooms in on the map. Both the renewable energy data and location information are abstract, though the application gives insights in renewable energy use per region and municipality. The actual EEG Index is determined by the installed capacity of the renewable sources, in proportion to the amount of inhabitants in a certain region – making a valid quantitative comparison possible between the nationwide and local regions scale (Energis Suisse AG, 2015).

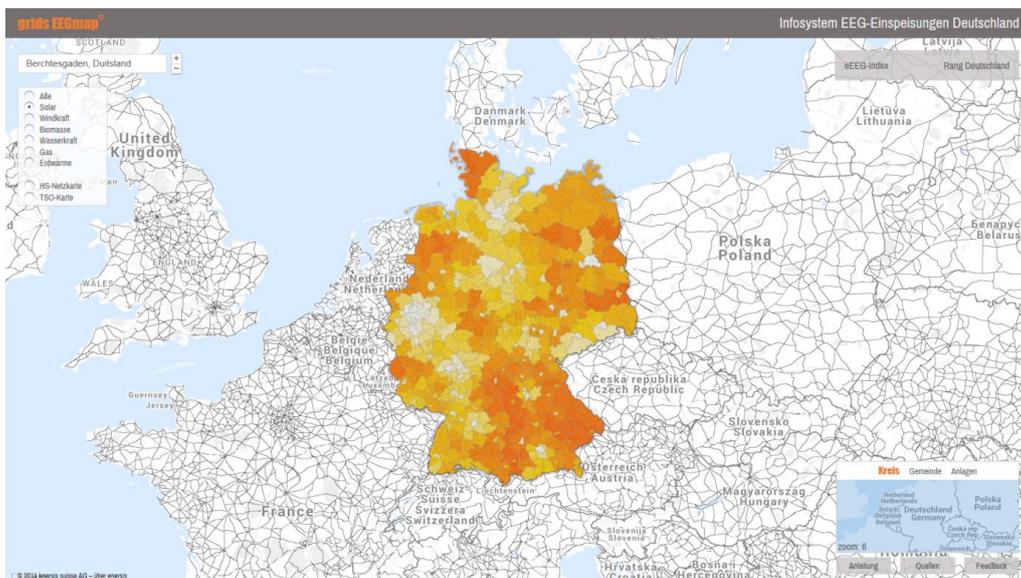


FIGURE 10: GRIDS EEGMAP

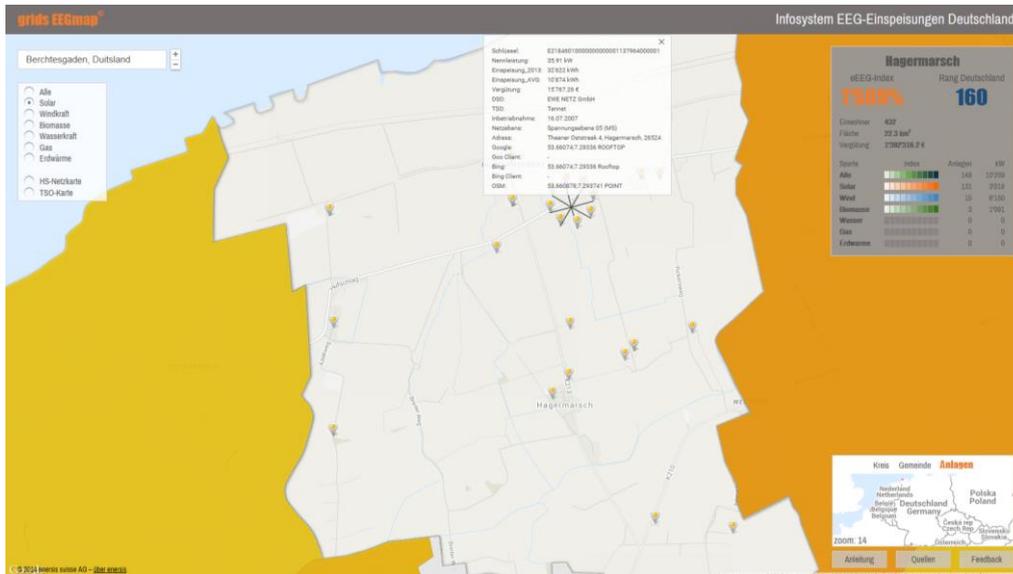


FIGURE 11: GRIDS EEGMAP

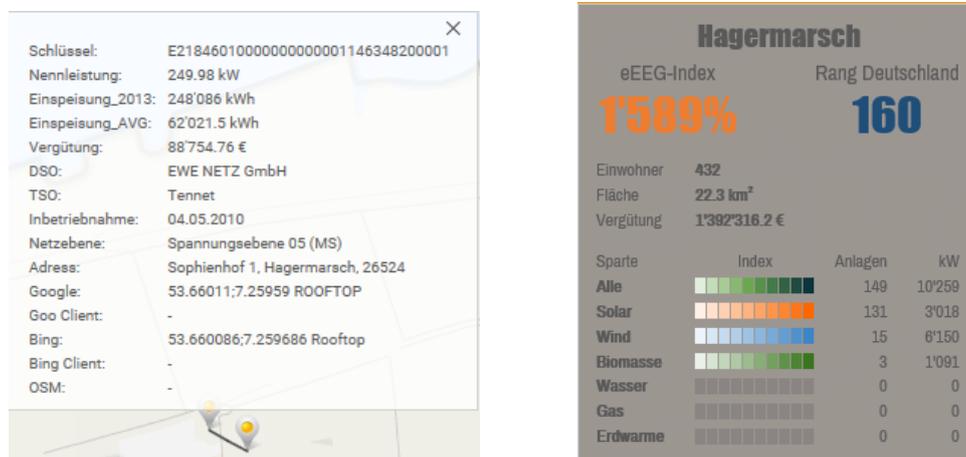


FIGURE 12: DATA AND INFORMATION FOR A SPECIFIC LOCATION

Part of the data that is used for the EEG mapping application, can be found and downloaded in .csv format. This .csv data gives insights in renewable energy use per region. Though this database might not be fully complete (different network operators, data formats, data inaccuracy, difficult to retrieve the data etc.), it provides possibly the only public tender that gathered renewable energy source data in Germany (EnergyMap, 2014).

4. METHODOLOGY

The main goal of this research is to create a new up-to-date and reliable database of PV panels. Ideally this database has to incorporate data of existing sources (e.g. the PIR and Existance9). This database must allow linking possibilities with other applications, such as the BAG, in order to increase the usability of this data. But before creating this database the accurate location data of PV panels must be retrieved. This accurate location will be computed with help of image processing or aerial imagery.



4.1 Data obtainment

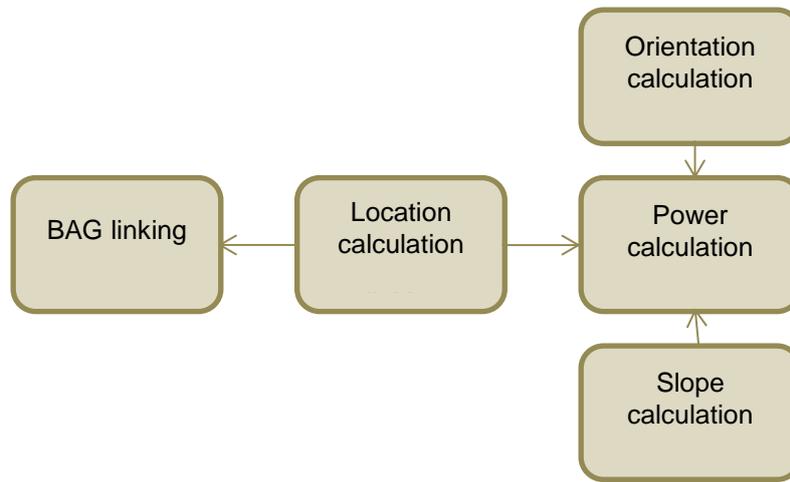
Before computing the location and power of PV panels and designing the database it is evident to retrieve all necessary data. With help of contacting stakeholders and combing data the following data has to be retrieved:

- Existing data of the location of PV panels
 - PIR
 - Existance9
 - Other reliable sources
- BAG database dump
- Postal code division in the focus area per neighbourhood
- AHN data of focus area
 - For determining the slope and orientation (power calculation)
- Aerial data for computing the location of PV panels
 - LiDAR Dataset
 - Aerial Imagery
 - Preferable with larger time span

4.2 Data processing

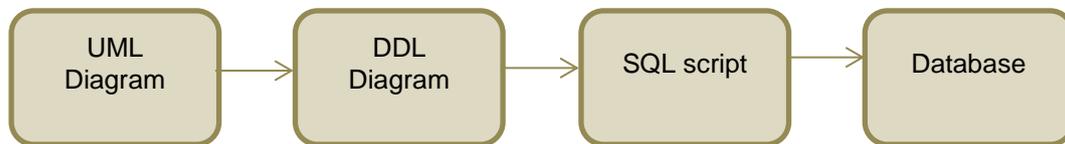
When all necessary data has been obtained it is possible to process this data for designing the database. First it is important to compute the location of PV panels with help of aerial imagery. Besides the location computation of the PV panels in aerial imagery the feasibility of additional methods (LiDAR Dataset) will be investigated. After computing the location of the PV panels these locations must be clustered. This clustering will be done with help of the BAG database. By linking the PV panels to a premise in the BAG the postal code and other relevant information can be retrieved. For clustering this PV panels with their postal code it is important to know which postal codes belong to which neighbourhood. This can be done by combining the neighbourhood boundaries (CBS) with the postal code points of Geodan (Bert Scholten).

When the location of PV panels is known the power of these PV panels can be computed. This can be done by calculating the slope and orientation. This has been done with help of the AHN data. For the limited time of this research project the calculation of the slope will be done by making a Digital Elevation Model (DEM) and creating a slope map in QGIS. The orientation has been done with Google Compass. If this research must be done on a larger scale (e.g. national level) this information must be computed with help of the point cloud of the AHN data. This methodology will be given in this report. The power calculation itself will be done with help of JRC, an online program for computing the power.



4.3 Database design

For designing the database an UML diagram has to be made. This UML diagram visualizes the interdependencies of each class related to each other. This UML diagram can be converted to a DDL diagram for generating a SQL script. This database must combine and cluster all data in order to make comparisons for a statistical analysis and enable application linking.



4.4 Evaluation methodology

For evaluating the Peer+ (image processing method) with the PIR and Existance9 the data has to be compared on postal code level. If some postal codes are recorded in the PIR and Existance9, but not in the Peer+ a validation survey has to be done to see if the PV panels are present on this location. This will lead into new insights of this methodology. It might be the case that there is a difference between the obtained aerial imagery and PIR/Existance9, because both data record a different time stamp of 2014. With help of a survey this difference in time stamp will be limited.

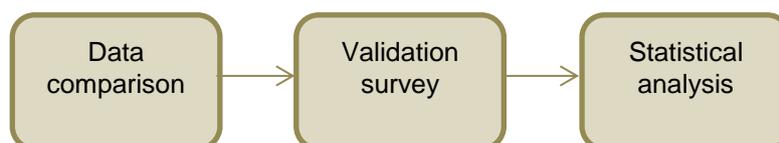
In order to compare the PIR, Existance9 and Peer+ the following data has to be compared:

- Amount of PV panels
- Amount of households with PV panels
- Max. capacity at any time (kWp)
- Amount of power (kWh)
- Total addresses

With help of the Peer+ additional analysis can be done, regarding:

- Azimuth
- Slope
- Trend analysis
 - With help of aerial imagery of larger timespan

This statistical information will answer the contribution and reliability of having the Peer+ as a central database for PV panels, compared to the PIR and Existance9.



5. ANALYSIS

5.1 Where is decentralised energy produced

Two methods were used to detect the location of PV panels in Stevenshof.

Firstly, an algorithm made by buro Karto detected positions (longitude and latitude) of the PV panels. The source where the algorithm was applied to is an aerial image (.ecw file) with a 10 cm accuracy level. This imagery is retrieved via Aerodata, a specialized geo-information company based in Antwerp, Belgium. The date stamp of the image files was of 2014, which is currently the most up-to-date aerial imagery of Stevenshof. Buro Karto used his algorithm and detected **778** PV panels (see Figure 13).

After the aerial image processing, two aspects were checked (manually), namely which PV panels were not found by the algorithm of buro Karto, and whether the derived PV panels/markers (of the algorithm) were PV panels or not. Possibly, roof windows could be detected as PV panels, though this was not the case here. The locations of the missing PV panels in Stevenshof were manually pinpointed via the aerial image of Stevenshof. This process was done in QGIS. In total **118** more PV Panels were detected. So in total **896** PV panels were detected.

This means that **13%** of the PV panels were not found with the algorithm of buro Karto. Note; this research is conducted with the detection algorithm of Karto in test phase.



FIGURE 13: PRINTSCREENS OF QGIS

Afterwards, this data, retrieved via the image processing method, was stored in the table named 'Aerial'.

5.1.1 Aerial image retrieved via Aerodata

Aerodata International Surveys is an innovative and hands-on airborne surveying and mapping company. They own a diverse range of dedicated twin engine survey aircraft to address all kinds of aerial survey missions. The aircraft are all equipped with camera holes and special racks and facilities for auxiliary equipment. The digital aerial frame cameras of Aerodata have a wide range of uses and applications, combining project variables as resolution (from super high like 2,5cm to low like 50cm) , surface area (from small to country-wide), overlap (for mapping or 3D modeling) and spectral bands (IR in addition to RGB for forestry).



FIGURE 14: ULTRACAM CAMERA

The aerial image of Stevenshof (from 2014) were obtained by Aerodata has a resolution of 10cm. This image is obtained by a survey aircraft with an 'Ultracam camera' (see Figure 14). This UCXp camera has an image footprint of 17.310 x 11.310 pixels, which is the largest image footprint of all available large format digital frame cameras. UCXp can be seen as the most productive camera system available with 4-band capture.

In total three aerial images were obtained by Aerodata, namely one of:

2014, 2013 and 2012. The aerial image of Stevenshof of 2015 was not yet available. Mostly the aerial survey missions are performed in February (when the sun has a high position during Spring) up to April. The survey aircrafts of Aerodata flies once a year (Vegt, 2015). Aerodata provides aerial images for the whole Netherlands under license. It will cost about 100.000 euros and four weeks to obtain these aerial images. Also it will take 2-3 weeks to obtain the aerial images of Stevenshof of 2011 and earlier. Because of the time limit, for this project is only looked at the three aerial images of: 2014, 2013 and 2012. This information is retrieved by Aerodata.

5.1.2 Detection algorithm of buro Karto

Aerial Imagery is digital imagery, built out of pixels. Depending on the color model used for the aerial image, each pixel comprises of a color value. The imagery used for this report adopts the RGB – Red Green Blue – additive color model on its image sensor. RGB colors are part of the visible part of the Electro Magnetic spectrum, namely in the part of Blue Green Red 0.4 – 0.7 μm . Based on the intensity of light, an RGB image that incorporates a pixel which has zero intensity value, results in a black pixel. While a pixel with maximum intensity, results in a pixel with a white color.

In order to automatically track – detect – specific features in an aerial image, an algorithm can be built. The feature that needs to be tracked here, is a PV panel. Various programming languages might be suited to build a detection algorithm based on Template Matching. Note that in such image processing algorithms, the digital image is seen as raster data: each cell of the raster (pixel) represent simply a value (RGB light intensity).

The main principle of Template Matching is that a template of pixels – e.g. a square of 3 by 3 pixels, also called kernel, filter, operator or convolution matrix – with certain intensity values, ‘moves’ over the entire original aerial image while multiplying the pixel intensity values of the template, with the pixel values of the original image. This multiplying, ‘moving’ template results in a new raster file, with new intensity values (see Figure 15). In general, in this new raster the pixel that appears to fit best the initial template values – depending on which kind of template is used – will portray maximum intensity values. One can now state that on this specific location with maximum values, a certain feature is detected, namely the feature that represent the moving template.

Note that eventually several other factors determine the final template calculation:

- Regarding the template/kernel shape and size, only the centre pixel of this template results in a new pixel value, for instance with a template size of 3 by 3 pixels, the centre pixel will receive a new intensity value.
- Template matching calculation can be executed twice, with a template for horizontal calculation (g_x), and a template for vertical calculation (g_y).
- Depending on the kind of template, new calculated intensity values have to be divided by a certain number.
- More elaborate calculations such as slope (magnitude) and aspect (direction/orientation), e.g. when adopting edge detection, can also be performed.

A Template Matching algorithm can be enhanced in several ways, for instance to execute the multiplication only if a certain threshold of value similarity is present.

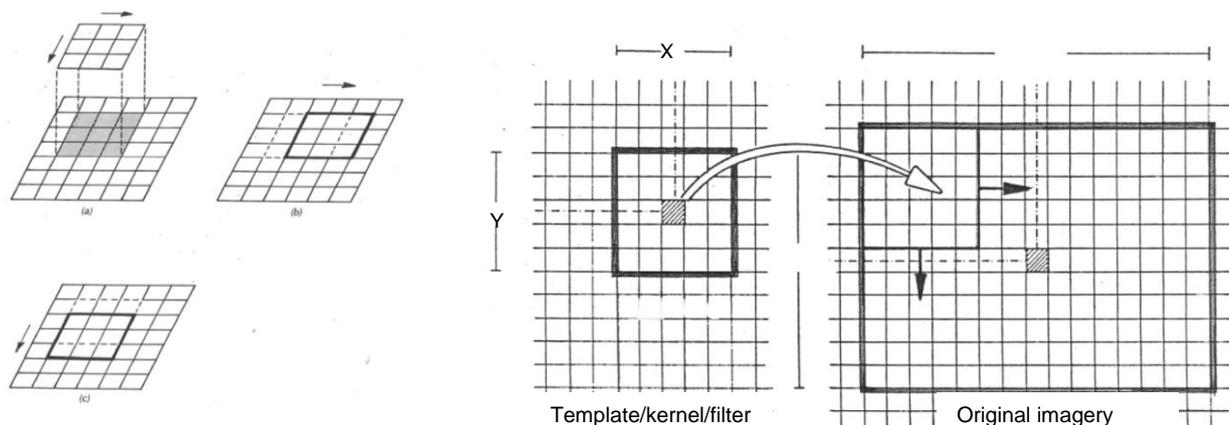


FIGURE 15: PRINCIPLE OF A MOVING IMAGE KERNEL (LEMMENS, 2014A)

In image processing, already several ‘base templates’ are discovered, known and used for different kind of purposes, for instance to sharpen images, smoothen images (e.g. the Gaussian operator) add noise to images, or to detect edges (e.g. the Laplace, Prewitt and Sobel operator). Edge detection

deals with the computation of identifying pixels in a digital image where there is a solid change in the brightness value of pixels, indicating the representation of an edge.

The appliance of templates such as the edge detecting Prewitt kernel, but also the Foerstner operator, can be seen in the scope of stereo image matching techniques as the first of several matching checks the so called 'discreteness check'. Several other checks can be executed, listed in order as follows:

- Similarity check: adopts cross correlation of a pixel, this can be obtained when the derivative is zero, then a maximum value can be retrieved.
- Consistency check: the steepness check and subpixel location. The consistency check validates the correctness, of the cross correlation. This is done via the steepness check, in two parameters of curvature k_1 and k_2 . In the case of matching across a boundary, the steepness check will have one curvature parameter which is significantly larger than the other curvature parameter; $k_1 > k_2$ (see Figure 16).

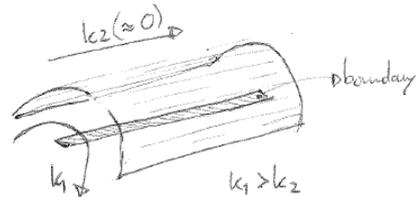


FIGURE 16: OWN IMAGE CONSISTENCY CHECK

Regarding the subpixel location: of all values the value with the highest cross correlation is taken, to get from pixel to subpixel: (i) approximate a surface with the 2nd order polynomial, (ii) derivative is zero on the highest cross correlation, thus differentiate this 2nd order polynomial.

- The last necessary 'check' is manual editing (Lemmens, 2014b).

Furthermore, the algorithm of buro Karto is based on a combination of aerial imagery and multiple other data sources, The detection is done via object recognition techniques and further enhanced using multiple templates.

5.1.3 Sources of error

However there are some possible errors, which are not taken into account in the algorithm of buro Karto:

- Aerial pictures could be outdated;
 - Municipalities can have possession of high resolution, up-to-date aerial imagery, costs may be involved.
- Some PV panels are located on walls, vertically;
 - There are some, but it is not very likely since the power output will be less compared to an overall horizontal positioning. Vertical PV panel are not that efficient.
- Some PV panels may be located under a tree, so these cannot be detected by the image processing method.
 - In practice it is not very likely that PV panels are located under trees.
- The development of PV panels in the form of roof tiles may not be tracked (Appendix D);
 - Such technological developments are currently not yet widely adopted in the Netherlands.
- Semi glass – PV panels may not be tracked (Appendix D).
 - Occurring mainly in larger structures.
- Water collectors
 - Some tracked water collectors may be assigned as PV panels on aerial imagery. Note that this is just a small amount of all tracked PV panels.
- Some PV panels may be located in a shadow area in the aerial imagery, so are hard to track.
- Thin film PV panels are difficult to track by the image processing method, so are hard to track.

However the other forms of PV panels (see appendix D) are not commonly used and the production is expensive. In the future these PV panels may become affordable. If this occurs, the algorithm has to be adjusted, to mainly focus on color/saturation/contrast values and size of the PV panels.

5.1.4 Alternative detection method – LiDAR dataset

The LiDAR dataset, obtained from Ravi Peters, shows the point density of the municipality of Rotterdam of 2012. This dataset has a point density of 30+ points per square meter. In this dataset the location of a PV panel can be seen (Figure 17-18). On this specific location the point density of the LiDAR dataset is less. Less points are visible, because the LiDAR pulses will not be reflected (back) to the LiDAR system (in the airplane). The point density of the LiDAR dataset is therefore lower at the location of a PV panel, plus the color is darker as well. In addition, some points are visible at the

location of the frame of the PV panel. Also some points are located underneath the PV panels, but these are (as expected) from the wall around it (for example of a wall of glass).

The detection of PV panels by a LiDAR dataset is difficult. What can be done is to make one raster with the point density, one raster with the heights (z-values) (see Figure 19-20) and one with the slope values. These rasters can be made by using LAStools (see: <http://rapidlasso.com>). For example the Las2dem is a tool that triangulates LiDAR points from the LAS/LAZ format (or some ASCII format) into a temporary TIN and then rasters the TIN to create a DEM.

These rasters can then be used as a verification method to improve the accuracy. These rasters can be used as different layers on top of an aerial image.

The following figures (17-20) show the LiDAR dataset of Rotterdam CS. The figures are made by Ravi Peters. The first two visualize the point density in black and white. The figures with the different colors show different height values. Figure 21 and Figure 22 visualize how the dataset looks like regarding roof windows (instead of PV panels). These are looking very similar to PV panels.

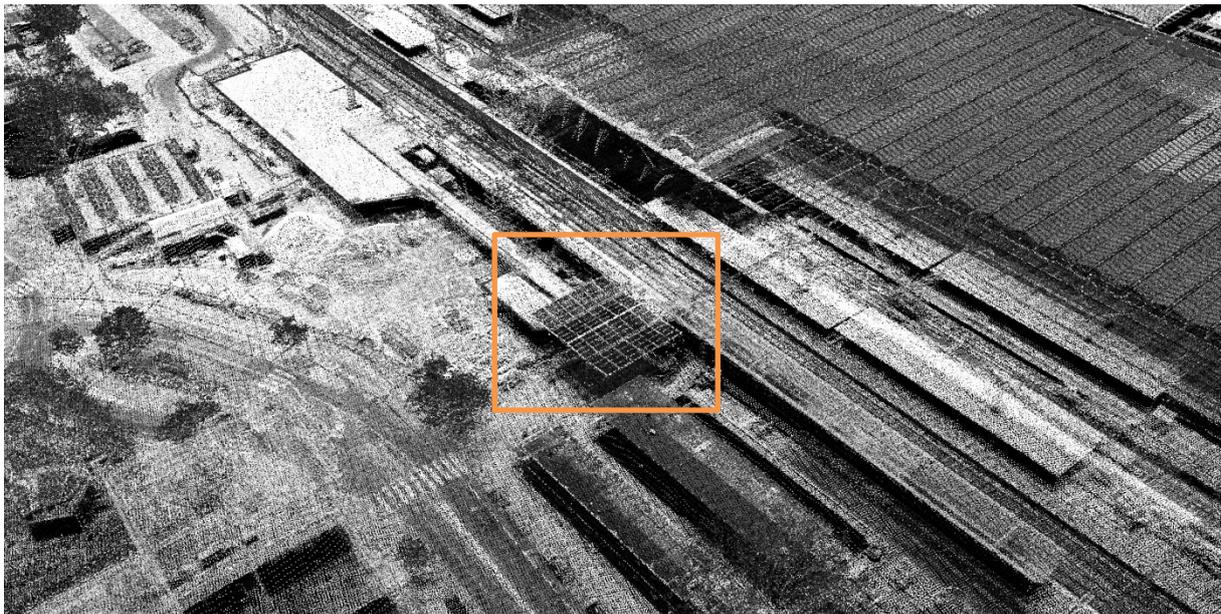


FIGURE 17: LIDAR DATASET OF ROTTERDAM CS WITH PV PANEL, POINT DENSITY

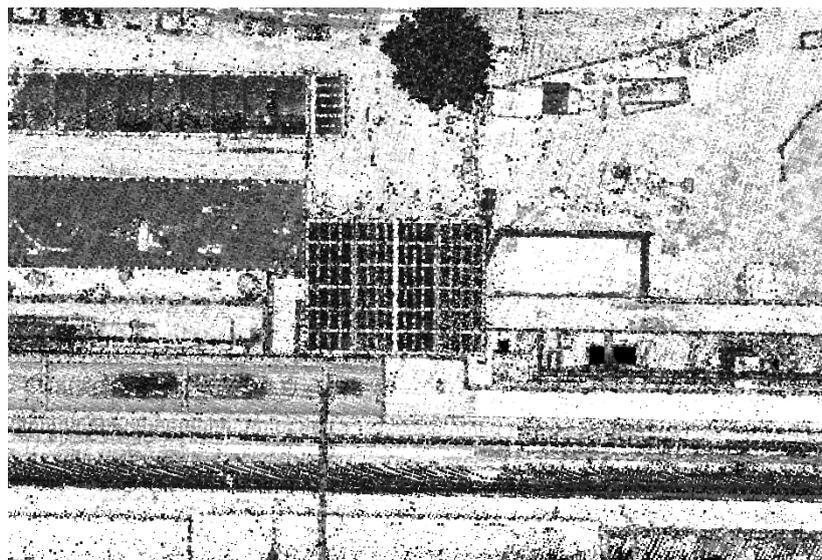


FIGURE 18: LIDAR DATASET OF ROTTERDAM CS (FROM ABOVE), POINT DENSITY

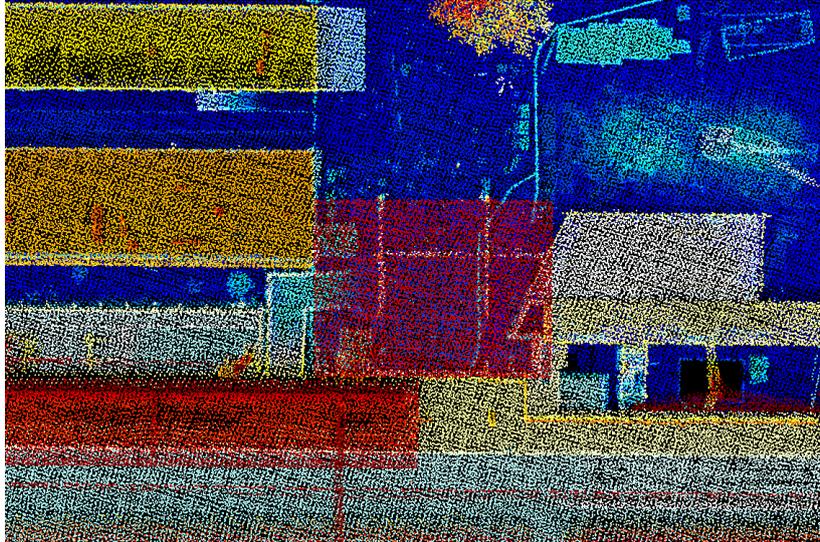


FIGURE 19: LIDAR DATASET OF ROTTERDAM CS (FROM ABOVE), HEIGHT

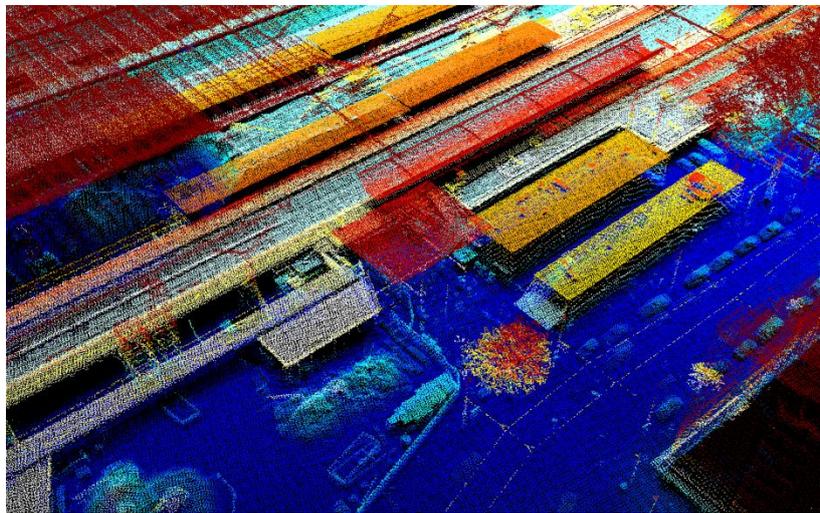


FIGURE 20: LIDAR DATASET OF ROTTERDAM CS, HEIGHT

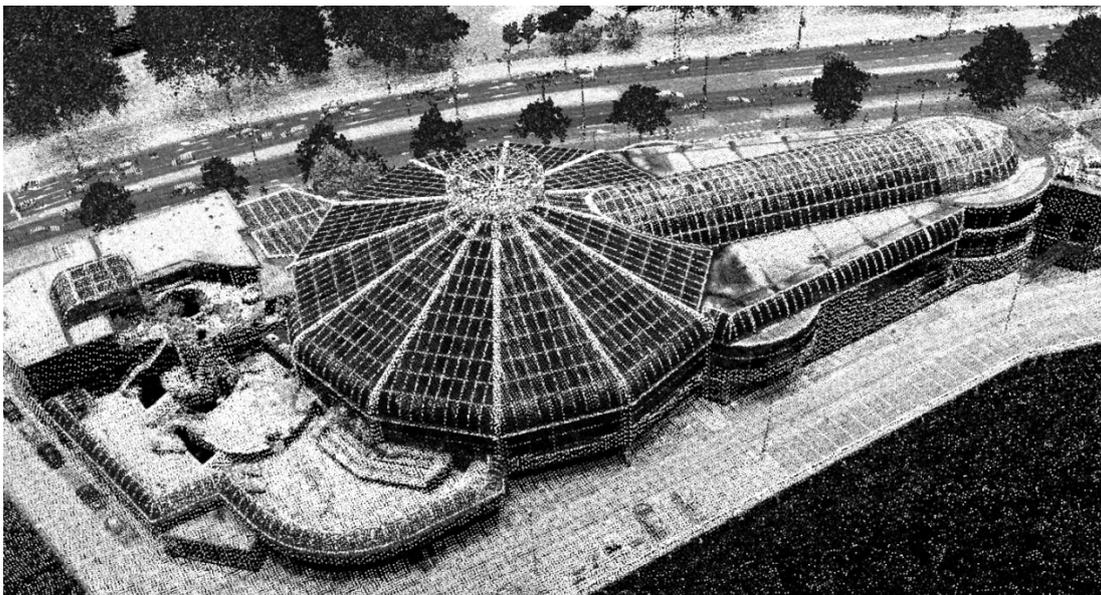


FIGURE 21: ROOF WINDOWS ROTTERDAM TROPICANA, POINT DENSITY



FIGURE 22: ROOF WINDOWS ROTTERDAM TROPICANA (FROM ABOVE), POINT DENSITY

5.1.5 Validation survey of eight addresses

Eight addresses in Stevenshof (on the 19th of March 2015) were checked for which no PV panels were discovered via the image processing method, but for which PV panels are registered in the PIR and/or Existence9. The validation consist of manual inspection of aerial images and of a direct visit to the site. Below a summary of the eight addresses is given. In Figure 23 the walking path is visualized from station 'the Vink' via the eight addresses back to the station.

PC6	Neighbourhoods	Method
2331GN	Kloosterhof	-
2331BK	Dobbewijk-Noord	Survey Detected
2331JC	Dobbewijk-Noord	-
2331NG	Dobbewijk-Zuid	Survey Detected
2331NK	Dobbewijk-Zuid	Survey Detected
2331NZ	Dobbewijk-Zuid	Survey Detected
2331KP	Schenkwijk	Aerial Detected After Survey
2331HT	Schenkwijk	Aerial Detected After Survey



FIGURE 23: THE WALKING PATH THROUGH STEVENSHOF

For the two postal codes 2331GN and 2331JC, PV panels were not discovered via the image processing method. By checking these addresses in Google Maps (which probably consist of aerial imagery which is older than 2012), it can be found out that one house in postal codes 2331GN had PV panels in the past (see Figure 24, note that these PV panels are not visible from street side). So maybe that is why (via historic data) PV panels in this postal code are included in the Existence9.

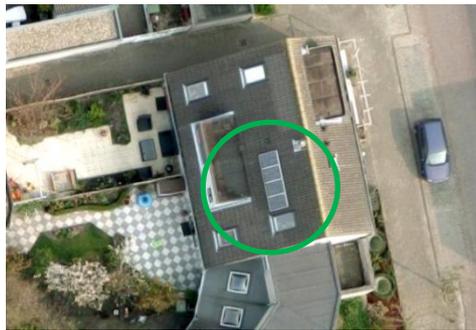


FIGURE 24: PICTURE OF GOOGLE MAPS

A few pictures made during the survey which are visualized in Figure 25.



FIGURE 25: PICTURES MADE DURING THE SURVEY

During the survey 'thin film' PV panels were discovered (see Figure 26). By looking at the aerial imagery of 2014 it can be noticed that these thin film PV panels are very hard to track. The most likely method to track these thin film PV panels is to compute the change of the roof, as can be seen in the Figure 26.

Detected PV panels after field survey at Stevenshof

In total 984 PV panels in Stevenshof were detected. This is the subdivision:

1. 896 - Aerial Detected
 - Visible in the aerial image, immediately discovered via the image processing method
2. 32 - Aerial Detected AS
 - Visible in the aerial image after survey. Not visible before survey due to shadow and/or these were Tin Film PV panels.
3. 56 - Survey Detected
 - Not visible in the aerial image, but these PV panels were detected during the survey. These PV panels were installed after the aerial image was taken (probably after April 2014)



FIGURE 26: UPPER RIGHT PV PANEL IS VISIBLE, LOWER LEFT IS NOT

5.2 Amount of power (kWh) produced by PV panels

If one wants to determine the amount of power (kWh) produced by PV panels, one has to decide how accurate this calculation should be. Firstly, it is necessary to know the concept of PV systems.

5.2.1 Concept of PV systems

According to Nishant Narayan (PhD Candidate at the TU Delft, at the department of Photovoltaic Materials and Devices, EWI), a distinction can be made between two systems, namely: Grid-connected systems and Off-grid system. In Figure 27 this distinction is visualized.

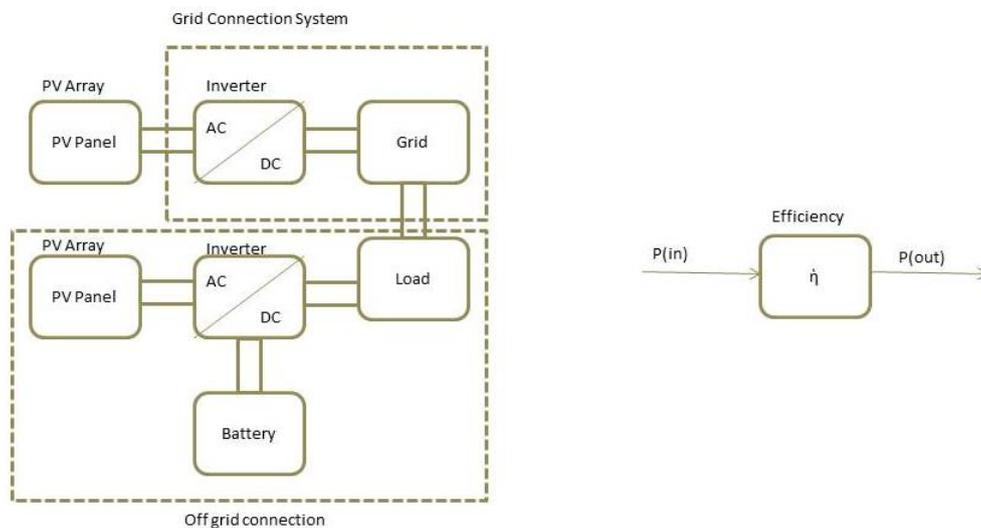


FIGURE 27: PV SYSTEMS

5.2.2 Grid-connected (nld. stroomnet) systems

A grid-connected system consists of four components, namely the: PV array (which is another word for PV panel), inverter, grid and load (e.g. light) (see Figure 27). 99 Percent of the PV systems in Leiden should have a Grid-connected system.

Example:

*If 100 Watt/m² of sun power goes into a Grid-connected system and a PV array has 17% efficiency, 17 Watt/m² is left afterwards. This is the first efficiency loss. If the converter has an efficiency of 95%, then roughly 16 Watt/m² is left. This is of course dependent on the power that is going in. At the end for example (100*0.17*0.95=) approximately 16 Watt/m² will be left (load), for the projector, the lights, etc. There is always an efficiency loss.*

The power which goes out (load) is the power which goes in multiplied by the efficiency. The total efficiency of a grid-connected system = efficiency (PV array) * efficiency (Inverter) * efficiency (Grid) * efficiency (Load)

5.2.3 Off-grid systems

One can also have off-grid systems, which consist of almost the same component as the grid-connected systems, but a battery is added (see Figure 27). This load can be a street light for example, according to Nishant Narayan. With an off-grid system the produced energy by PV panels cannot be added to the grid. Note: An off-grid system does not always have to be connected to the grid.

5.2.4 Methodology description for the calculation

In accordance to Nishant Narayan, four steps can be distinguished:

1. Get the input data (from NASA or KNMI website)
For each PV panel location, an artificial horizon is determined. The temperature of PV panels influences the efficiency. For this the wind-speed is needed for calculating the temperature of the PV panels (for cooling).
 - ✓ Irradiance
 - ✓ Temperature
 - ✓ Wind-speed
2. Determine the Sun path
Note: North = 0°, East = 90°, South = 180°, West = 270°
Along this horizon, the orbit of the sun is generated, resulting in data that provides whether a panel is in catch of the sun – for each hour of the day and for each day of the year. Together with the inclination and orientation of the panel, the theoretical direct irradiance is now known.
 - ✓ Shading related parameters, elevation, angle and orientation with respect to the azimuth.
3. Execute irradiance / tilt / orientation studies
The diffuse irradiance (containing indirect sunlight, dependent on an unobstructed view) is added to the direct irradiance value. In this manner, the total irradiance on the flat panel surface can be calculated.
 - ✓ Direct, diffuse and albedo irradiance (*Power in*)
$$\text{Irradiance}_{\text{Total}} = \text{Irradiance}_{\text{direct}} + \text{Irradiance}_{\text{diffuse}} + \text{Irradiance}_{\text{albedo}}$$
 - ✓ Tilt_{Optimal} = 36° (de Keizer & Alsema, 2008)
In the summer the sun is at a relative short distance, so the tilt value of the PV array can be less (for example to 20°). But in the winter the sun at a relative long distance, so the tilt value can be more (for example to 60° - 70°), to get most power from the sun.
4. Standard Test Conditions (STC). Throughout the day the irradiance changes (through the temperature variations outside). With an increase of temperature of the actual PV module (thus not the surrounding atmosphere temperature), the efficiency of the PV panel installation will be less.

5.2.5 Azimuth PV panels

With Google Compass (website: <http://googlecompass.com/>) the orientation of a roof can be determined in comparison to the Azimuth. With this free online program a compass can be put in Google Maps on top of a building which results in the orientation (in degrees). In Figure 28 an example is visualized.

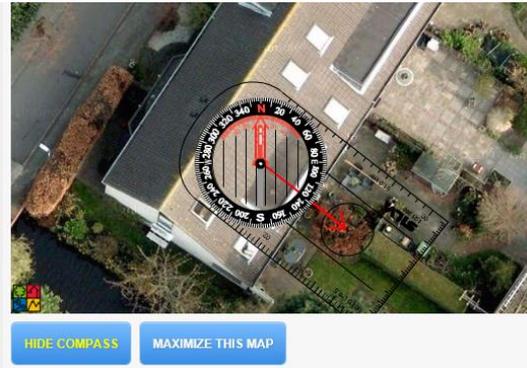


FIGURE 28: GOOGLE COMPASS

5.2.6 Roof slopes PV panels

In order to calculate the power of each PV panel it is necessary to have other specifications than longitude and latitude (retrieved via aerial imagery). These other specifications can be retrieved via the AHN2 data (nld. Actueel Hoogtebestand Nederland).

On the website: <http://3dsm.bk.tudelft.nl/matahn/> it is possible to select a region of the AHN2 data. From the AHN data of Stevenshof a slope map was made. With LAStools it is possible to convert the AHN data to a DEM (Digital Elevation Model) with the following code (in command prompt):

```
-i stevenshof.laz -o slope.tif
```

This has resulted into the following height map (see Figure 29 (left)). This can be converted (in QGIS) to a slope map with the terrains analysis tool (see Figure 29 (right)).

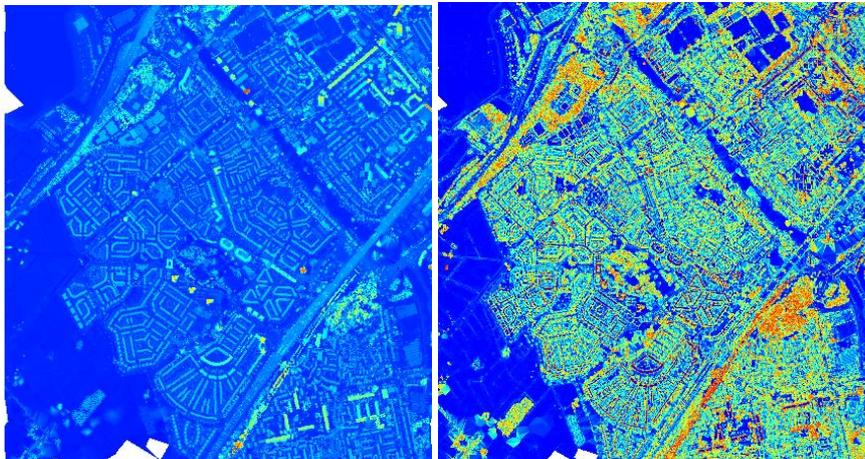


FIGURE 29: SLOPE MAP

Figure 30 demonstrates the two maps in more detail:

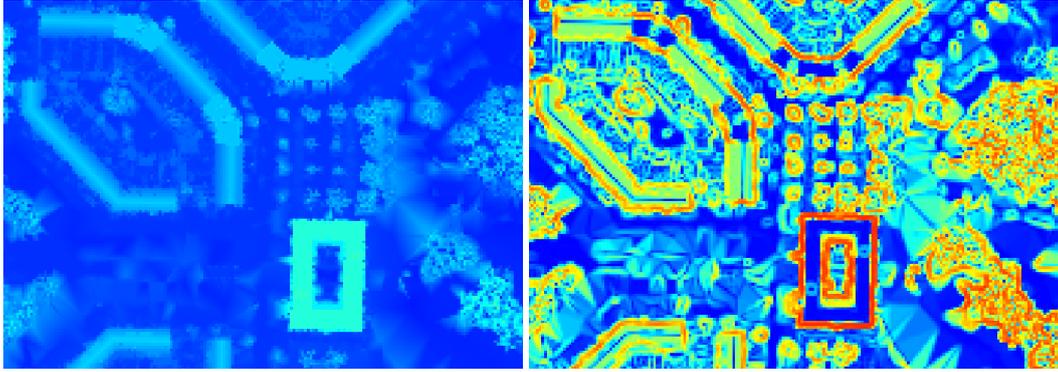


FIGURE 30: SLOPE MAP IN DETAIL

5.2.7 Automation of the slope and azimuth determination

The computation of the slope and azimuth of PV panels can also be automated. Before processing the AHN2 dataset, it is important to test the algorithm (given below) on a much smaller scale. Therefore this algorithm was tested on house level, as can be seen in Figure 31.



FIGURE 31: TEST HOUSE IN STEVENSHOF

For calculating the slope and azimuth of each PV panel the algorithm (in flowchart and pseudocode) can be used which is visualized in Figure 32.

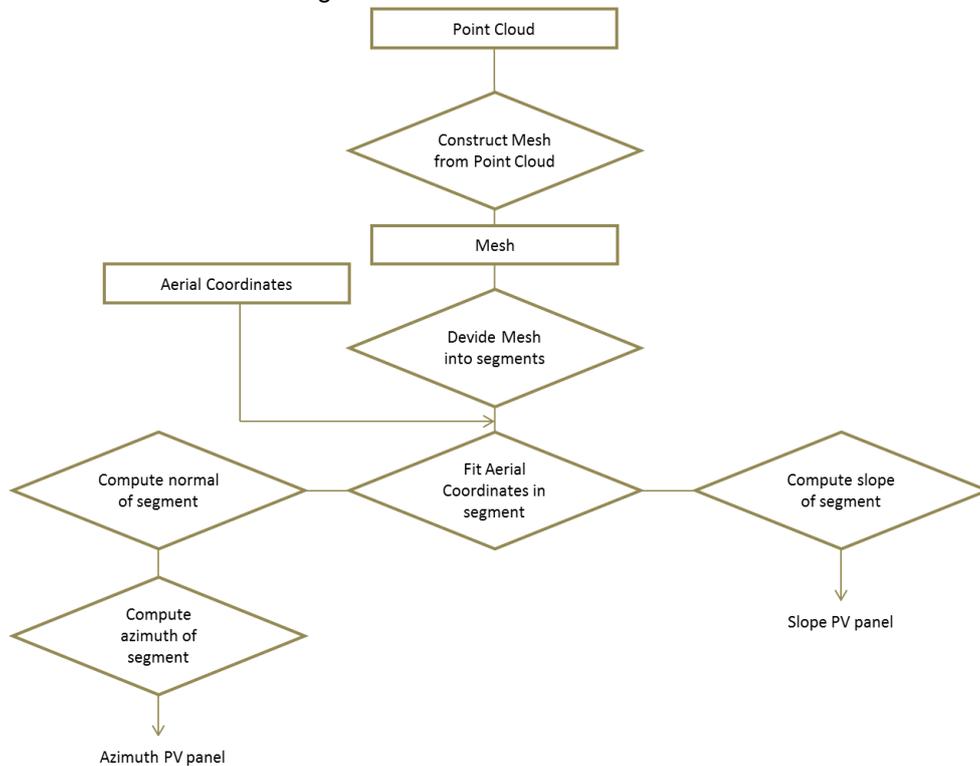


FIGURE 32: FLOWCHART ALGORITHM

```

set pointcloud as pc
set aerialPV as pv

#construct mesh from pc
pcMesh = constructmesh (pc)

#deconstruct mesh into normal vectors
demesh = deconstructmesh (pcMesh)

#group mesh according to normal vectors
segments = vectorgrouping (demesh)

#choose segment where pv panel is
roof = segment(pv)
normal = roof.normalvector

slope = normal - 90

#If there is a flat roof, then the ideal installed angle is used
if slope == 0 then:
    slope == 36

#deconstruct normal into xyz- components
component = deconstructnormal (normal)

#construct direction
direction = squareroot(square(component.x) + square(component.y))

#set north direction as 0
north = 0

#compute azimuth
azimuth = Angle(north, direction)

```

5.2.8 Calculation of the amount of power (kWh)

The power of the PV panels is calculated via the website:

<http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php>

There are different fields on this website that has to be filled. The following values were used for the performance fields:

Performance of Grid-connected PV

<i>Radiation database:</i>	<i>Climate SAF PVGIS</i>
<i>PV technology:</i>	<i>Crystalline silicon</i>
<i>Installed peak PV power</i>	<i>= 0,25 kWp</i>
<i>Estimated system losses [0;100]</i>	<i>= 14 %</i>

The assumptions for calculating the power:

1. All PV panel modules in Stevenshof are powered by Yingli ;
2. All PV panel modules in Stevenshof consist of 60 PV cells with a peak power of 250 Wp (which is 0,25 kWp);
3. All the PV panel modules in Stevenshof have PV panels out of crystalline silicon ;
4. The estimated system losses is 14% ;
5. For a PV panel on a flat roof a slope of 35° is assumed.

Below the reasoning for the assumptions (the numbers correspond):

1. On the website of PolderPV it is described that most customers of Stevenshof in Leiden have PV panel modules from the biggest manufacturer in the world, called Yingli Green Energy (from China). So this assumption will cause the most likely amount of power calculating.
2. Most of the sold modules of Yingli consist of 60 PV cells with a peak power of 250 Wp (Solar, 2014). This is specified in the specification of the YGE 60 Cell Series (Module type: YL250P-29b).
3. In the specification of the YGE 60 Cell Series is specified that these modules consist out of crystalline silicon.

4. According to Nishant Narayan, the estimated system losses will be around 14%. So this assumption will cause the most likely amount of power calculating. ;
5. The maximum radiation is received by the PV panels at an angle of around 36°. Therefore the assumption is made that PV panels on a flat roof will have a slope of, the rounded number, 35° (de Keizer & Alsema, 2008).

Sources of error

However there are some possible errors, which are not taken into account in the calculation of the amount of power (kWh). Below a summary is given:

- PV panels which are oriented in South direction but lies in the shadow of a house cannot deliver the maximum capacity at any time (see Figure 33). Also if one of the PV panels or more are shaded, dusty or faulty this will have an influence on the output voltage of the others in the same group (Tabanjat, Becherif, & Hissel, 2014).
- Some people have no idea what the difference is between kWp and kWh. So they fill in the registration of their PV panels incorrect. Private individuals and companies often enter wrong information and numbers about their PV panels.
- It is also not clear whether the ordered PV panels are also the PV panels installed on a roof. So whether the peak power of a PV panel is correct.
- A PV panel can be out of position, which causes a performance failure. For example when a PV panel is oriented to the South, it can be out of position to South-West direction.
- PV panels can lie on the border of two postal code areas. So it is hard to assign one postal code to these PV panels. There are no postal code areas/clear boundaries. The exact border area of the postal code does not exist (see Figure 34).



FIGURE 33: PV PANEL WHICH LIES IN SHADOW

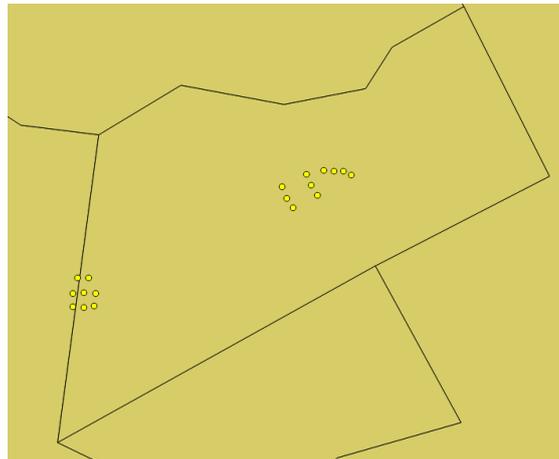


FIGURE 34: PV PANELS IN TWO POSTAL CODE AREAS

5.3 Connection of PV panel modules to the BAG

When connecting the PV panel modules to the BAG, a lot of errors can occur. Below a summary is given of the encountered errors.

1. Error for BAG (huishouden -> Imgeol Iden) connect to the PV panel modules (Figure 35).



FIGURE 35: BAG – IMGEO IDEN NUMBER

- The selected building in orange (nld. bijgebouw) has no Imgeo Iden number. So the PV panel modules cannot be connected to the BAG (Figure 36), because when a PV panel lies within a BAG geometry, which does not have a Imgeo Iden number, it is not possible to link the PV panel to an object in the BAG. In this situation there is no reference key available for linking.



FIGURE 36: NO IMGEO IDEN NUMBER

- Flat with multiple households (Figure 37-38)



FIGURE 37: MULTIPLE HOUSEHOLDS



FIGURE 38: MULTIPLE HOUSEHOLDS 2

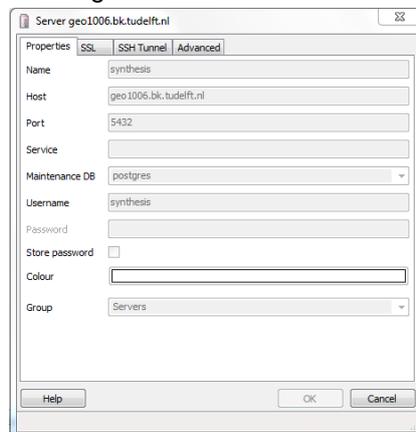
5.3.1 How to connect the BAG register of 'geovlak' to an area of interest

The algorithm of buro Karto provided the precise locations of PV panel – pinpoints comprising point geometry. These locations can be visualised in the program QGIS. In order to create a connection between this pinpoint PV panel data and the BAG, the register of 'geovlak' (polygon of the footprint of the building), was linked to these pinpoints. The table BAGIntermediate was made with data extracted from the BAG in order to connect the BAG with the Peer+ database.

In more detail: the 'geovlak' register of the BAG is present in the 'pand' table. Unfortunately, this specific BAG table does not incorporate registers that can link a 'geovlak' to an area of interest. This area is first of all a *district* in Leiden (Stevenshof, PC4: 2331), and secondly this district contains multiple *neighbourhoods*.

As seen in the UML for the Peer+ database, the BAG forms an important input source. The BAG data for the whole Netherlands is downloaded via internet, as it is Open Data. Though, for the pilot database, the BAG data regarding the test area should suffice. The methodology to extract this site specific data is done via the database software pgAdmin, and the actual retrieval of this data via the SQL query language.

Firstly, the BAG data was loaded on the geo1006.bk.tudelft.nl server, as provided by Wilko Quak.



For making an extraction of the BAG the following code is made:

```
SELECT
    pand.identificatie,
    pand.geovlak,
    postcode
FROM
    bagactueel.verblijfsobjectactueelbestaand vbo,
    bagactueel.verblijfsobjectpandactueel vbo_pand,
    bagactueel.pandactueelbestaand as pand,
    bagactueel.nummeraanduidingactueelbestaand nummer
```

WHERE

```
postcode LIKE '2331%' AND  
vbo.identificatie = vbo_pand.identificatie AND  
pand.identificatie = vbo_pand.gerelateerdpand AND  
vbo.hoofdadres = nummer.identificatie;
```

Within this code the geovlak of each premise has been extracted in postal code 2331. The linking has been done according to Figure 39:



FIGURE 39: FLOWCHART BAG EXTRACTION

5.3.2 Automation of the BAG linking

Linking the Peer+ (automatically), via the Aerial table, with the BAG could be done by linking every spatial BAG object (premise) with the PV panels. If a PV panel is located in a BAG object, then the PV panel must be assigned to the BAG object. This method has an error percentage of 2.7 %, which are 27 points of the total point of 984. In some situations the PV panels of one premise overlap with the other premise. This is not the case in reality, but happens by linking the data. The reason behind this is that the BAG uses the ground outline. When linking PV panels (which are located on the roof) with the BAG (using ground outline) this may cause errors in some cases: cause there is not always a one to one match between the footprint of a building and its roof. In Figure 40 the flowchart is given of this method.

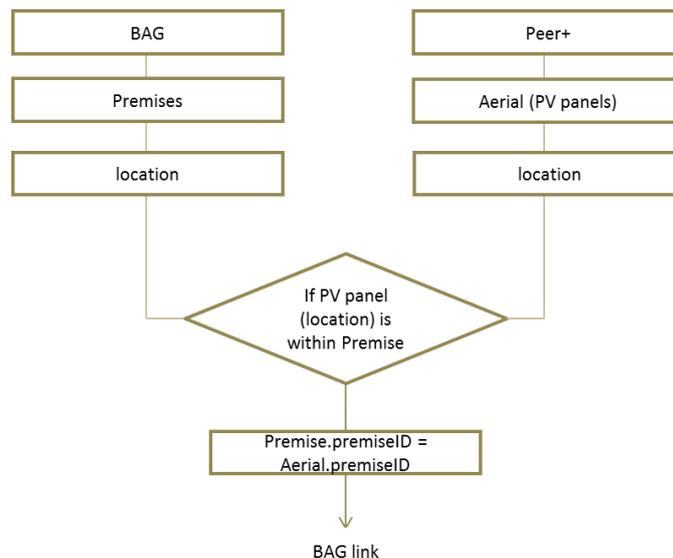


FIGURE 40: FLOWCHART

Note that this method can be done via a spatial query (PostGIS or similar program) and linking Shapefiles (QGIS or similar program).

The error of 2.7% may be improved by using another method for assigning the PV panels to the BAG objects. This can be done by using the centroid of the BAG object (with assigning the PV panel to the closest distance) or buffering the BAG object (to assign the PV panels within this buffer). These methodologies are visualized in Figure 41.



FIGURE 41: ERROR METHODOLOGIES BAG LINKING

As could be seen in the Figure 41, the centroid and buffer methodologies are no solid methodologies. On the contrary the clustering methodology is a promising methodology for reducing the error of 2.7%. Note that this methodology has some down sides. When a group of clustered points lies on the border of two geometries an assumption has to be made:

- If the clustered points are laying in two geometries:
 - The cluster has to be divided to the two geometries;
 - The cluster has to be assigned to the geometry with the biggest overlap ;

When combining this knowledge to the three situations in Figure 41 the first notion causes an error in the first (upper) situation. The second notion causes an error in the last (lower) situation in Figure 41. In order to fix this error another assumption has to be made:

- If the clustered points are laying in two geometries:
 - The amount of points in the two geometries has to be calculated
 - If the amount of point in one of the two geometries is 2 or less:
 - The cluster has to be assigned to the geometry with the biggest overlap;
 - If the amount of point in one of the two geometries more than 2 and:
 - The cluster has to be divided to the two geometries.

When using this methodology for improving the error of 2.7% a consideration has to be made, whether fixing this error is worth increasing the possible processing time.

5.4 Storing the derived data

The current ways in publishing and storing the derived data can be improved by linking all usable data sources into a new database called: Peer+.

In Dutch speech, the pronunciation of the word 'PIR' (as in the PIR database), is similar to the pronunciation of the word 'peer', actually meaning the fruit pear. Since the Synthesis project 2014/2015 Q3 is part of the CERISE Topsector Switch2SmartGrids research program which has as logo of a Cherry, the name *Peer+* came into existence. While the Peer of the Synthesis project refers to the Cherry of the Cerise project, and the PIR database, the '+' sign stands for an elaboration and improvement of current PV panel registries.

With this new database it will be possible to link this database to other applications (e.g. BAG) in order to make this data more usable.

5.5 UML with 6 tables (Enterprise Architect)

Before making a database (to store the data) it is necessary to create a UML diagram, to see the interrelations between all the tables of the database. These tables are represented as classes in the UML diagram. This UML Diagram (Figure 42) can also be found in the appendix C.

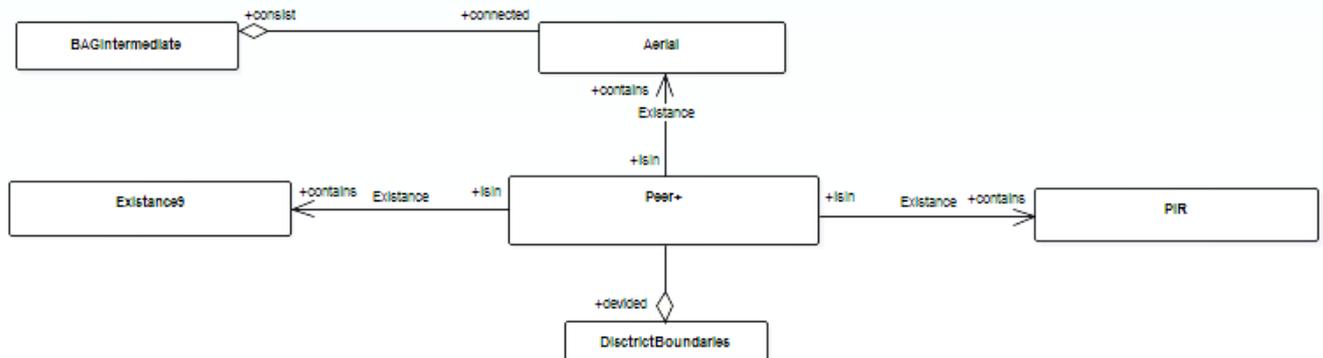


FIGURE 42: UML DIAGRAM

The new PV panel database consists out of three sources:

- Existence9 - This data is retrieved from the website: <http://klimaatmonitor.nl> and is available for the whole Netherlands.
- Aerial - This data is retrieved via the image processing method.
- PIR - This data is retrieved from the PIR database (on PC6-level), if they are willing to cooperate with the Peer+ in the future.

The Peer+ will be published as open data at neighbourhood level. This level is chosen because it might be privacy sensitive to publish the coordinates of every PV panel and it is more accurate, as for PC6-level one apartment building contains more than one PC6 so this is less accurate.

Within this Peer+ database it will be possible to validate the amount of PV panels (per neighbourhood level) recorded in the PIR and Existence9. This validation will be displayed with TRUE/FALSE statements. E.g. TRUE refers that the PV panels for area are also recorded in the Existence9/PIR.

Note that this database design only is focusing on a complete and reliable database for PV panels. In future this design might be adapted for incorporating other specifications of the PV panels, such as orientations, rotation, etc.

The BAGIntermediate class has been made in order to give the possibility to link the BAG-database to the Peer+ database. This linkage is necessary in order to link every PV panel to a premise geometry object in the BAG. This linkage will give the possibility to cluster the single PV panels. This linkage will also be beneficial for e.g. crisis management.

5.5.1 From UML to database (pgAdmin)

When the UML diagram is complete it is possible to convert this diagram to a SQL script for creating a database. First it is necessary to create a DDL schema. This DDL diagram of the Peer+ (Figure 43) can also be found in appendix E.

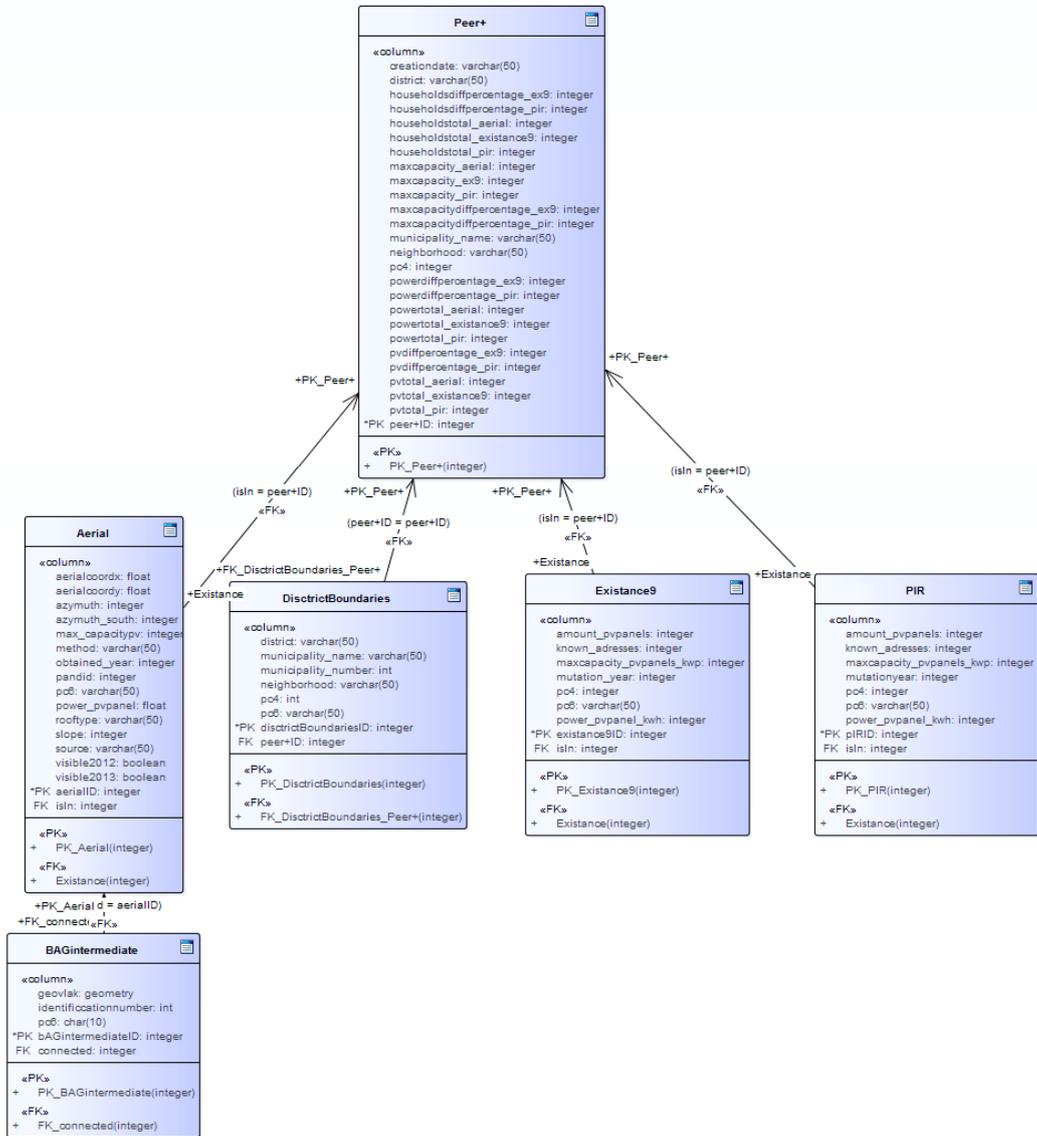


FIGURE 43: DDL DIAGRAM

This DDL schema can be converted into a SQL script. Note that this SQL script needs to be adjusted, because the generator misses some statements. This SQL script generates a database in PostGIS (see appendix F).

Below the print-screens can be found of the six tables in the database.

Table 1: Peer+

In this table, Peer+, all information (detected PV panels via the image processing method, PIR, Existance9) is combined. This data is publicly accessible and gives an up-to-date overview of all decentralised installed PV panels per neighbourhood. Within this table the total amount of PV panels, households, capacity and power is shown from the three sources (Aerial, PIR and Existance9). The Peer+ also shows some statistical information regarding the difference what is not in the PIR and Existance9 (but is in the Aerial table).

	municip_nam character(50)	district character(50)	neighborhooc character(50)	pc4 integer	pvtotal_aeria bigint	pvtotal_exni bigint	pvtotal_pir bigint	pvpercentage double precis	pvpercentage double precis	householdsto bigint	householdsto bigint	householdsto bigint	householdsto double precis	householdspe double precis	capacitytotal numeric	capacitytotal numeric
1	Leiden	Stevenshof	Dobbewijk-N	2331	162	176	140	-9	14	26	25	14	4	46	40.5	43.9
2	Leiden	Stevenshof	Dobbewijk-2	2331	554	503	444	9	20	124	74	53	40	57	138.5	125.5
3	Leiden	Stevenshof	Kloosterhof	2331	126	135	108	-7	14	19	22	15	-16	21	31.5	33.5
4	Leiden	Stevenshof	Schenkwijk	2331	142	246	240	-73	-69	18	23	21	-28	-17	35.5	61.7

capacityperc double precis	capacityperc double precis	powertotal_a bigint	powertotal_e bigint	powertotal_p bigint	powerpercen double precis	powerpercen double precis
-8	14	40066	37337	29750	7	26
9	20	134364	106677	94350	21	30
-6	14	29772	28484	22950	4	23
-74	-69	32973	52422	51000	-59	-55

This data is retrieved automatically from the tables Aerial, PIR, Existance9 and Districtboundaries via a SQL script. This SQL script is shown in appendix G.

The following alias table illustrates the types and definition of the Peer+ table.

Attribute name	Alias	Type	Notes
municip_name	Municipality name	Character	
district	Wijk	Character	
neighbourhood	Buurt	Character	
pc4	Postal code digits	Integer	
pvtotal_aerial	Total amount of PC panels	Integer	Source: Aerial
pvtotal_exnine	Total amount of PC panels	Integer	Source: Existance9
pvtotal_pir	Total amount of PC panels	Integer	Source: PIR (EDSN)
pvpercentage_not_ex9	Percentage of PV panels not present in Existance9	Float	Output is percentage
pvpercentage_not_pir	Percentage of PV panels not present in PIR	Float	Output is percentage
householdstotal_aerial	Total amount of households present in Aerial	Integer	
householdstotal_existancenine	Total amount of households present in Existance9	Integer	
householdstotal_pir	Total amount of households PIR	Integer	
householdpercentage_not_ex9	Percentage of households not present in Existance9	Float	Output is percentage
householdpercentage_not_pir	Percentage of households not present in PIR	Float	Output is percentage
capacitytotal_aerialkwp	Total capacity present in Aerial	Float	kWp
capacitytotal_exninekwp	Total capacity present in Existance9	Float	kWp
capacitytotal_pirkwp	Total capacity present in PIR	Float	kWp
capacitypercentage_not_ex9	Percentage of capacity not present in Existance9	Float	Output is percentage
capacitypercentage_not_pir	Percentage of capacity not present in PIR	Float	Output is percentage
powertotal_aerialkwp	Total power present in Aerial	Integer	kWh
powertotal_exninekwp	Total power present in Existance9	Integer	kWh
powertotal_pirkwp	Total power present in PIR	Integer	kWh
powerpercentage_not_ex9	Percentage of power not present in Existance9	Float	Output is percentage
powerpercentage_not_pir	Percentage of power not present in PIR	Float	Output is percentage

Table 2: BAGIntermediate (Crop of BAG -> Stevenshof)

With this table it is possible to link every single PV panel to a premise with help of the premise identification in the BAG. With this link it is possible to retrieve more information of the linked premise of the BAG (e.g. the amount of households in a premise) and vice versa (e.g. a premise has PV panels).

	identification_nr character(16)	geovlak text	pc6 character(6)
1	54610000000095	POLYGON Z ((90872.507 462689.	2331PB
2	54610000000095	POLYGON Z ((90829.804 462678.	2331PC
3	54610000000095	POLYGON Z ((90835.216 462686.	2331PC
4	54610000000095	POLYGON Z ((90835.216 462686.	2331PC

The following alias table illustrates the types and definition of the BAGintermediate table.

Attribute name	Alias	Type	Notes
identification_nr	Identification number	Character	Identification number is originally from the BAG database
geovlak	Geometry surface	Geometry	
pc6	Postal Code / Zip Code	Character	

Table 3: Aerial

The Aerial table contains all PV panels, obtained by the image processing method which gives the coordinates (longitude and latitude) per PV panel. For every single PV panel the azimuth (north and south), roof type, slope, power, maximum capacity, postal code, source, obtained year, premise identification (from BAG) and the amount of households within the premise is given. For the maximum capacity it is assumed that every single PV panel can generate 0.25 kWp. The power of every PV panel is calculated with help of the location, azimuth and slope.

This has resulted into the following table:

	oid	long double p	lat double p	azymuth_south integer	azymuth integer	rooftype character	slope integer	power_kwh integer	max_capacity_kwp double p	pc6 character	source character(50)	obtained_year integer	pandid character(16)	amount_households integer	visible2013 boolean	visible2012 boolean	method character(50)
1	30122	52.15313	4.45676	-20	160	oblique	40	236	0.25	2331GR	TUDeift stude	2014	5461000000001	1	TRUE	TRUE	Aerial Dete
2	30123	52.15314	4.45677	-20	160	oblique	40	236	0.25	2331GR	TUDeift stude	2014	5461000000001	1	TRUE	TRUE	Aerial Dete
3	30124	52.15314	4.45678	-20	160	oblique	40	236	0.25	2331GR	TUDeift stude	2014	5461000000001	1	TRUE	TRUE	Aerial Dete
4	30125	52.15314	4.45679	-20	160	oblique	40	236	0.25	2331GR	TUDeift stude	2014	5461000000001	1	TRUE	TRUE	Aerial Dete

The following alias table illustrates the types and definition of the Aerial table.

Attribute name	Alias	Type	Notes
long	Longitude	Float	WGS84
lat	Latitude	Float	WGS84
azymuth_south	Azimuth with south as 0 degrees	Integer	
azymuth	Azimuth with north as 0 degrees	Integer	
rooftype	Roof type	Character	
slope	Slope of the roof in degrees	Integer	If the roof is flat, the PV panels are placed on an angle of 35 degrees
power_kwh	Power of the PV panel	Integer	In kWh
max_capacity_kwp	Maximum capacity of the PV panel	Float	In kWp
pc6	Postal Code / Zip Code	Character	
source	Obtained source	Character	
obtained_year	Obtained year	Integer	
pandid	Pand ID	Character	Obtained from BAG
amount_households	Amount of households the premise of this PV panels exists	Integer	

visible2013	PV panels are also shown in the aerial imagery of 2013	Boolean	
visible2012	PV panels are also shown in the aerial imagery of 2012	Boolean	
Method	Retrieving method of PV panels	Character	Aerial Detected or Aerial Detected AS (After Survey) or Survey Detected

Table 4: PIR

The PIR table is a subtraction of the PIR dataset, sorted on PC4 and PC6. This subtraction contains the capacity and the power, calculated with the following formula:

Amount of power = capacity x 850 hours
(where 850 is an assumption about the 'standard' amount of sun hours in a year in NL).

This table also contains the amount of PV panels which was calculated with the following formula:

Amount PV panels = capacity / 0.25
(where 0.25 is the assumed maximum capacity that every single PV panel can generate).

This has lead into the following table:

	oid	amount_pvpanels integer	known_adresses integer	pc4 integer	pc6 character(6)	max_capacity_pv_kwp double precis	power_pv_kwh integer	obtained_year integer
1	72602458	4	1	2331	2331AH	1	850	2014
2	72602459	16	3	2331	2331AJ	4	3400	2014
3	72602460	8	1	2331	2331AM	2	1700	2014
4	72602461	16	2	2331	2331BE	4	3400	2014

The following alias table illustrates the types and definition of the PIR table.

Attribute name	Alias	Type	Notes
amount_pvpanels	Amount of PV panels	Integer	(calculated)
known_adresses	Amount of known addresses in the PIR	Integer	
pc4	Postal Code Digits	Integer	
pc6	Postal Code / Zipcode	Character	
max_capacity_pv_kwp	Maximum capacity PV panels	Float	kWp
power_pv_kwh	Power of PV panels	Integer	kWh (calculated)
obtained_year	Obtained year (from the PIR)	Integer	

Table 5: DistrictBoundaries

The information of the table DistrictBoundaries is made by combining information of the boundaries of neighbourhoods (CBS) with the postal code points of Bert Scholten (of Geodan). This table will give the possibility to filter the database per district of neighbourhood.

This has resulted into the following table:

	oid	pc6 character(6)	pc4 integer	municip_nr integer	municip_name character(50)	district character(50)	neighborhood character(50)
1	72599857	2331AX	2331	546	Leiden	Stevenshof	Dobbewijk-Noord
2	72599858	2331BD	2331	546	Leiden	Stevenshof	Dobbewijk-Noord
3	72599859	2331BE	2331	546	Leiden	Stevenshof	Dobbewijk-Noord
4	72599860	2331BG	2331	546	Leiden	Stevenshof	Dobbewijk-Noord

The following alias table illustrates the types and definition of the DistrictBoundaries table.

Attribute name	Alias	Type	Notes
pc6	Postal Code / Zipcode	Character	
pc4	Postal Code Digits	Integer	
municip_nr	Municipality number	Integer	
municip_name	Municipality name	Character	
district	Wijk	Character	
Neighbourhood	Buurt	Character	

Table 6: Existence9

The existence9 table has been filled with data from the "klimaatmonitor" (CSV-file). This data has been processed by filtering this data for the test area (postal code 2331). After having this selection an extra row has been added for the PC4 (postal code, only four digits) as an extension of the PC6 (postal code). This table contains the capacity and the power, calculated with the following formula:

$$\text{Power} = \text{capacity} \times 850 \text{ hours}$$

This table also contains the amount of PV panels which was have calculated with the following formula:

$$\text{Amount PV panels} = \text{capacity} / 0.25$$

This data has been imported into the existence9 table of the database.

	oid	amount_pvpanels integer	known_adresses integer	pc4 integer	pc6 character(6)	max_capacity_pv_kwp double precis	power_pv_kwh integer	obtained_year integer
1	72602513	6	1	2331	2331AH	1.5	1275	2014
2	72602514	16	3	2331	2331AJ	4	3400	2014
3	72602515	2	1	2331	2331AK	0.38	323	2014
4	72602516	8	1	2331	2331AM	2	1700	2014

The following alias table illustrates the types and definition of the Existence9 table.

Attribute name	Alias	Type	Notes
amount_pvpanels	Amount of PV panels	Integer	(calculated)
known_adresses	Amount of known addresses in the PIR	Integer	
pc4	Postal Code Digits	Integer	
pc6	Postal Code / Zipcode	Character	
max_capacity_pv_kwp	Maximum capacity PV panels	Float	kWp
power_pv_kwh	Power of PV panels	Integer	kWh (calculated)
obtained_year	Obtained year (from the klimaatmonitor)	Integer	

5.5.2 Querying the database (pgAdmin)

When the Peer+ database is filled it can be used to query the stored data. Below some examples queries are given:

Roof slopes PV panels

This example queries all the slopes with the amount of PV panels.

```
SELECT slope, count(slope)
FROM aerial
GROUP BY slope
ORDER BY slope ASC;
```

	slope integer	count bigint
1	10	21
2	20	37
3	25	5
4	30	50
5	35	631
6	40	179
7	45	25
8	50	36

Azimuth PV panels

This query selects all azimuth degrees with the amount of PV panels.

```
SELECT azymuth, count(azymuth)
FROM aerial
GROUP BY azymuth
ORDER BY azymuth ASC;
```

	azymuth integer	count bigint
1	90	10
2	120	6
3	125	6
4	130	8
5	140	59
6	150	81
7	160	113
8	180	290
9	190	61
10	200	100
11	210	219
12	220	12
13	230	5
14	240	14

Comparing PIR with the Peer+

This example compares the PIR with the Peer+.

```
SELECT aerial.pc6 AS aerial, pir.pc6 AS pir
FROM aerial FULL JOIN pir ON aerial.pc6=pir.pc6
GROUP BY aerial.pc6, pir.pc6;
```

	aerial character(6)	pir character(6)
1	2331NG	2331NG
2	2331GP	2331GP
3	2331AJ	2331AJ
4	2331DX	2331DX
5	2331MR	2331MR
6	2331SK	2331SK
7	2331MA	
8	2331MZ	
9	2331PK	2331PK
10	2331SM	
11	2331BL	2331BL
12	2331MN	2331MN
13	2331BN	
14	2331SE	
15	2331PJ	2331PJ
16	2331KP	2331KP
17	2331GT	2331GT

Extracting PV panels

This example extracts all PV panels which are detected after surveying the district Stevenshof and where installed before 2013.

```

SELECT*
FROM aerial
WHERE visible2012=TRUE AND
method='Aerial Detected AS';

```

	aerialcoordx character(100)	aerialcoordy character(100)	azymuth_so integer	azymuth integer	rooftype character(50)	slope integer	power_kwh integer	max_capaci double prec	pc6 character(6)	source character(50)	obtained_year integer	pand chara
1	4.444775024	52.15508114	0	180	flat	35	251	0.25	2331HT	TUdelft stuc	2014	5461
2	4.444792194	52.15507977	0	180	flat	35	251	0.25	2331HT	TUdelft stuc	2014	5461
3	4.444809343	52.15507941	0	180	flat	35	251	0.25	2331HT	TUdelft stuc	2014	5461
4	4.444827308	52.15507905	0	180	flat	35	251	0.25	2331HT	TUdelft stuc	2014	5461
5	4.4448461	52.15507819	0	180	flat	35	251	0.25	2331HT	TUdelft stuc	2014	5461

6. STATISTICAL ANALYSIS

Different statistical analysis were made. To make it possible to compare the PIR, with the Existance9 and the Aerial, different transformations of units and calculations had to do done.

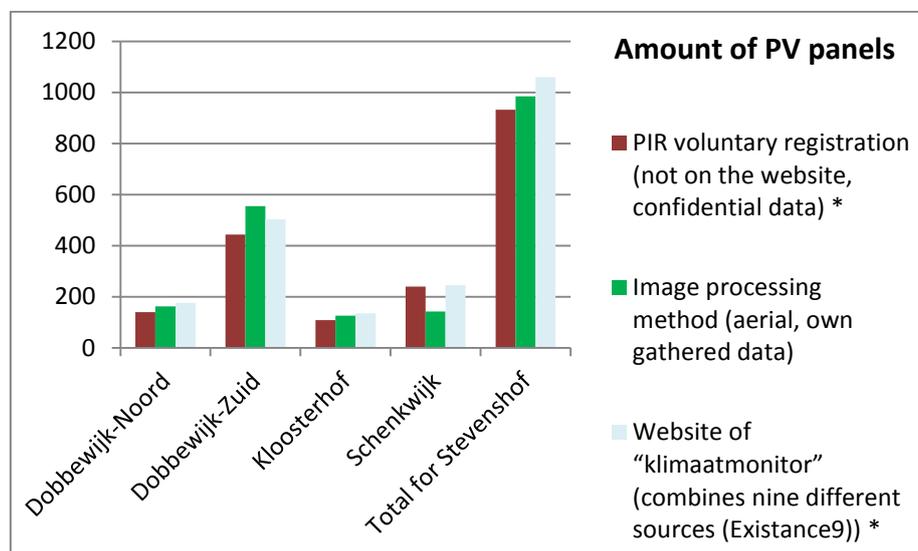
6.1 Comparison: Amount of PV panels and households with PV panels

The given data from the PIR and Existance9 consist of Known addresses with PV panels, while the data obtained via the image processing method, consists of the amount of PV panels.

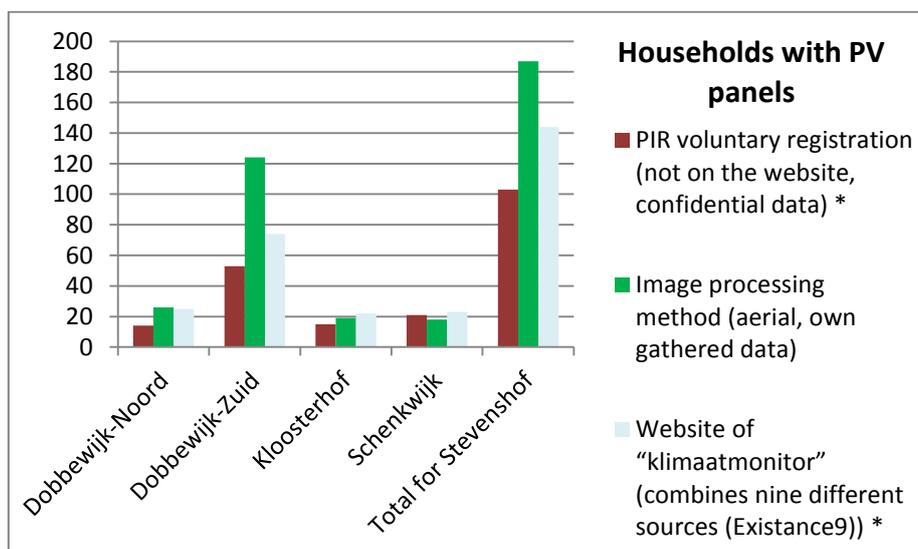
Two calculations for the comparison:

1. The amount of PV panels (instead of only the households with PV panels) is determined. For the 'klimaatmonitor' data and the data from the PIR we computed this amount by dividing the total power (kWp) by 0,25 kWp (see section 5.5.1).
2. The households with PV panels (instead of only the amount of PV panels) is determined for the data of Aerial. This has been done via the BAG connection with PV panels, which consists of the amount of households (see section 5.5.1).

Graph 1-2 compare the three sources, namely the website of klimaatmonitor (which combines nine different sources (Existance9)), PIR data (which is a voluntary registration and not published on the website), and the data obtained via the image processing method (aerial, own gathered data). In the first graph, the symbol '*' means that this data is computed. When this symbol '*', is not shown, this means that it is the received data (from the website of "klimaatmonitor" or from the PIR registration).



Graph 1: Amount of PV panels



Graph 2: Households with PV panels

From the graphs can be concluded that Dobbewijk-Zuid has the most installed PV panels. These graphs also show that the method can detect more households of PV panels in comparison to the PIR and the existing nine sources. The method can detect more PV panels than the PIR, but less PV panels than the existing nine sources.

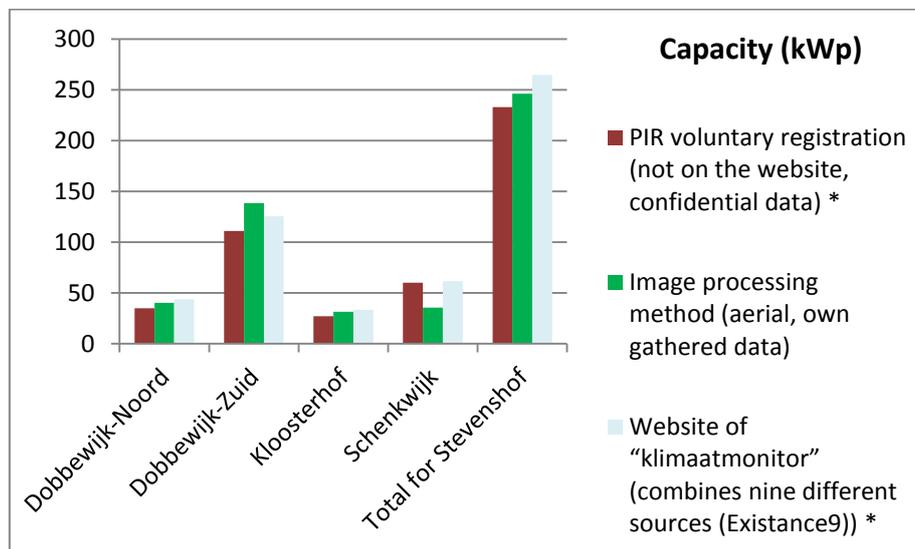
	Total households	Households with PV panels	Percentage of households with PV panels
Dobbewijk-Noord	750	26	3.5 %
Dobbewijk-Zuid	1940	124	6.5 %
Kloosterhof	1225	19	1.5 %
Schenkwijk	805	18	2 %

6.2 Comparison: Max. capacity at any time (kWp) and the amount of power (kWh)

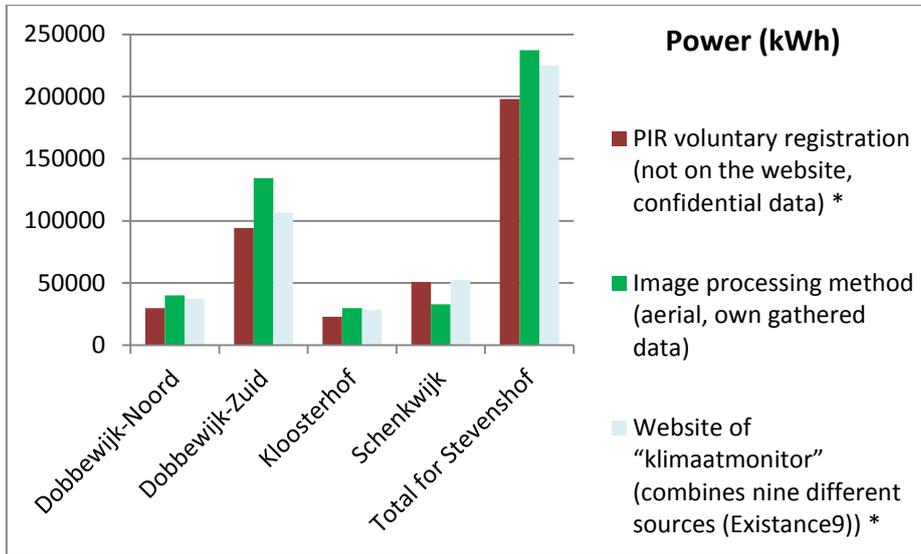
The given data from the PIR and Existance9 consisted of three columns, included: Maximum capacity at any time (kWp). The data obtained via the image processing method (and the algorithm of buro Karto consist of the power (kWh).

Two calculations for the comparison:

1. For the PIR and Existance9 determine the annual power (kWh) is determined (see section 5.5.1). The conversion factor is based on the average hours of Sunshine in the Netherlands per year.
2. For the data obtained via the image processing method, the maximum capacity at any time (kWp) is determined (see section 5.5.1).



Graph 3: Capacity (kWp)



Graph 4: Power (kWh)

From the graphs can be concluded that most of the power and capacity will be generated in Dobbewijk-Zuid. Another conclusion is that the power obtained via the image processing method is similar as the existing nine sources. But for this conclusion the conclusions of section 6.1 can be taken into consideration.

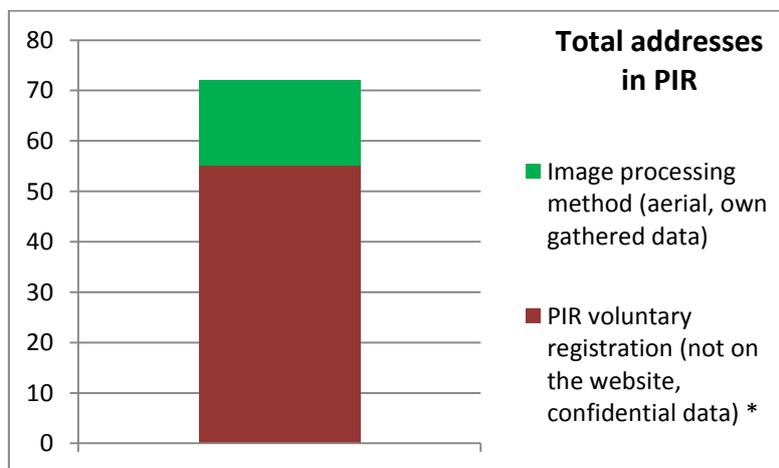
6.3 Comparison: Total of addresses (PC6)

Furthermore the amount of addresses in the PIR, Existance9 and the data obtained via the image processing method is compared.

In graph 5, the total of addresses (PC6) is visualized, which is 74. There are 72 addresses (PC6) in Aerial and 2 addresses in Existance9 which are not in Aerial. These two addresses were checked by a survey, but PV panels within these two PC6 were not discovered. This may be explained by the fact that the Existance9 is incorporating old data (section 3.3.4). Furthermore all the addresses in the PIR are also in Aerial.

<i>Existance9 (PC6) not in Aerial</i>	<i>Aerial (PC6) not in EX9</i>
2331GN	2331CG
2331JC	2331SM

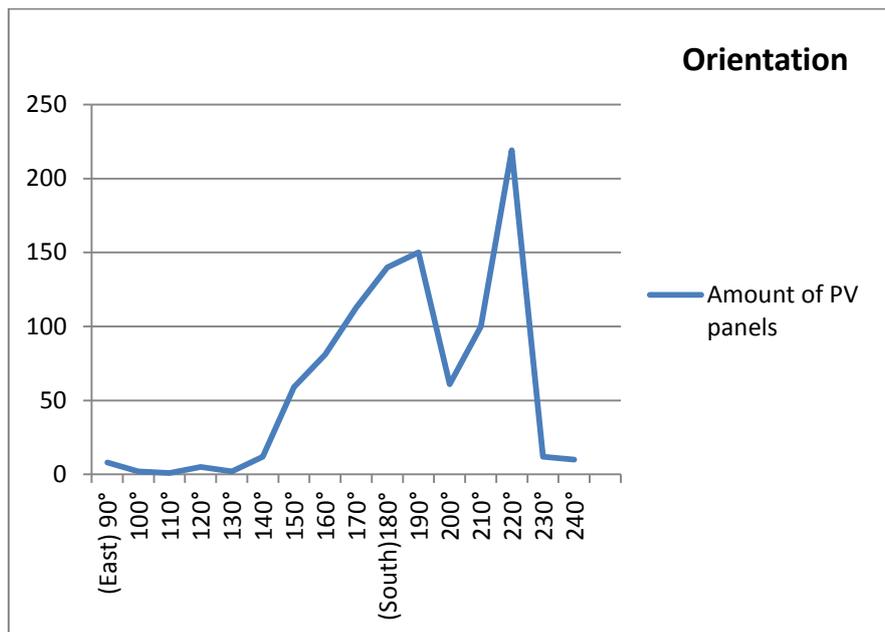
In graph 5, the total addresses (PC6) in PIR is also visualized, which is 55. The PIR lacks 17 addresses.



Graph 5: Total addresses (PC6) in PIR

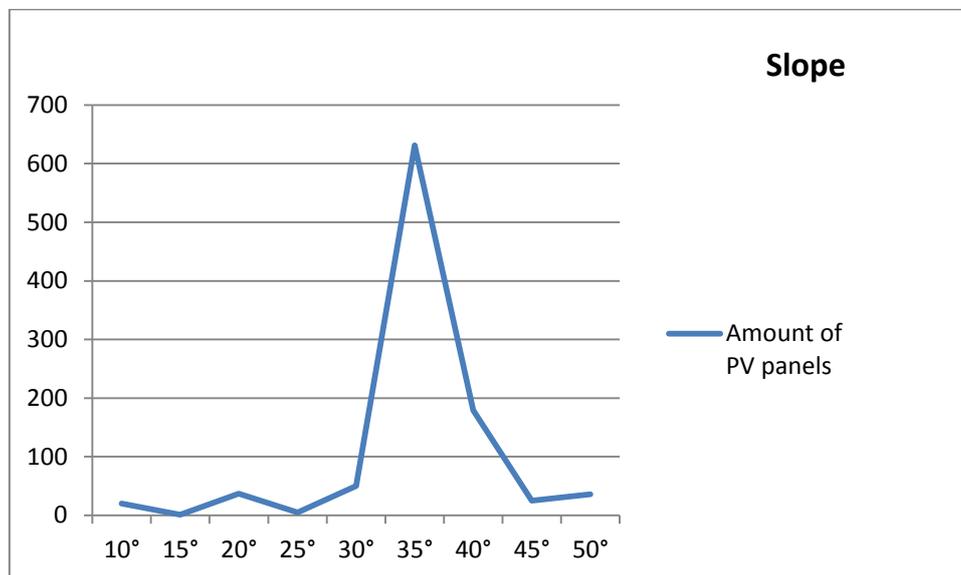
6.4 Comparison: Azimuth and slope

The azimuth which appears most frequently is South (0°).



Graph 6: Azimuth of the PV panels

The slope which appears most frequently is 35° . This can be explained by the fact that there are a lot of flat roofs with PV panels in Stevenshof (namely 613 PV panels lie on a flat roof), for which the assumption was made that the slopes of the PV panels is 35° . There are also 18 PV panels which lie on an oblique roof with a slope of 35° . A certain amount of slopes were detected, because the slope values (in degrees) are rounded to integers (so 10° means a slope-value between 5° - 14°).



Graph 7: Slope of the PV panels

6.5 Comparison: Aerial images of different years (2012, 2013 and 2014)

The aerial images (from Aerodata) are of three different years, to visualize the increase of PV panels (from 2012 to 2014) and to detect whether the algorithm of buro Karto had some errors (which was not the case). The algorithm of buro Karto detected the same PV panels in the different years.

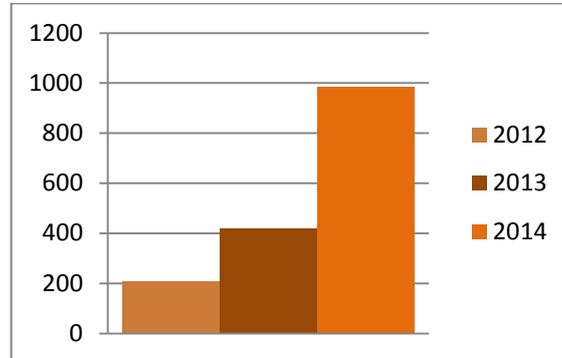
6.5.1 Query to retrieve the data from 'Aerial' (pgAdmin)

```
SELECT count(oid) AS vis2012
FROM aerial
```

```
WHERE visible2012=TRUE;

SELECT count(oid) AS vis2013
FROM aerial
WHERE visible2013=TRUE;

SELECT count(oid) AS vis2014
FROM aerial
```



GRAPH 8: AMOUNT OF PV PANELS PER YEAR

Notes on the statistical analysis

Regarding the statistical comparisons (time span mutations) of PV panel registrations on a yearly base, one should consider the level of representative aspect of that data. For instance, due to the start of a subsidy programme, one particular month in a year could show a rapid increase in PV panel registrations and detections, compared to other months in that same year. One should be aware of these discrepancies when comparing data over entire years.

7. APPLICATION

7.1 Benefits for Alliander

An isolated up-to-date database is not of much use, no matter what its content is. It becomes useful if it is well integrated into the current data architecture of a network operator, like Alliander. The text below is based on a Lync interview with Paul Wassenberg, Datamanager at Alliander, on the 6th of March 2015.

Alliander has its own Logical Object Model, as a so-called ERD diagram – Entity Relation Diagram, giving information on a logical level about several databases Alliander is working with. In the ERD, an entity can be regarded as kind of a class which has the attributes (e.g. the EAN code; an unique number of each individual electric connection with the electric grid, provided by the network operator). Plus, one entity may house several tables in a database. The Logical Object Model is made for the owners of the data that are involved with Alliander. The databases of Alliander are part of an overarching SHP system; comprising a large database.

- Due to the fact that the LOM of Alliander is confidential company information, the actual diagram is left out in this report -

The entity 'Production Installation' (nld. 'Productie Installatie') holds account for decentralised energy source registration of the PIR; the PIR serves as the benchmark for Alliander. Even though, besides the PIR input, Alliander tracks their own decentralised registrations and adds them to their own database – which for Alliander is the leading database. The necessity for a comprehensive and complete database of all decentralised energy sources (solar/ wind/ biomass/ geothermal energy) will become stronger in the near future, as these decentralised sources are expected to take a larger percentage in the total nationwide energy generation. Though, energy sources that are outside the scope of network operator Alliander are not taken into account.

The entities that contain 'generator' (nld 'Opwekker'), include among others the larger energy generators, e.g. a wind turbine park. Currently, small production installations and large energy generators are two separated databases. Preferable, these databases should become one database system.

For a network operator like Alliander, a registry containing the exact positioning (coordinates) of PV panels (small production installations) plus the estimated power generation, are definitely useful for example balancing purposes of the electric grid.

Regarding the data exchange principle Linked Data, Alliander is in a thoughtful, but cautious stage. Behind the scenes, Linked Data is practiced at Alliander. Even some parts of data of Liander are available as Open Data via the Liander website, on grouped PC6 level. Future interests will have to show if this Open Data will be converted to a Linked Data format. But there are limitations with Linked Data.

Concerning Crisis Management, the current focus of Alliander on this topic, is not aimed at decentralised PV panel installations. Even though, this Synthesis Project, the expected results and the applied and described methodology can be an enrichment for the databases that Alliander has currently in use.

7.1.1 Linked data

An innovative and complete way to connect, share and exchange data is via the Linked Data principle. Linked Data uses the Semantic web – where web content is incorporated into semantics via URI and RDF – to generate new links between data that hasn't been linked before (Heath, 2015).

A practical and relevant example can be found in Crisis Management:

Linked Data is a way of data sharing providing the possibility to query the data and retrieve implicit relationships. According to Ramona Roller (intern at the independent Dutch applied science and knowledge organization TNO), this solution is supposed to improve Crisis Management because:

- All stakeholders base the data sharing on the same conceptual model (use same terms for concepts and their relationships): fewer interoperability problems ;
- Additional datasets can easily be added by generating new triples ;
- The data is available to all stakeholders ;

- Implicit relationships between data concepts can be made visible and in this way dependencies will become apparent (Roller, 2015).
For example, when comparing the Peer+ database to the current PIR database.

7.2 Possible applications

The aspiration for this Synthesis Project is to come up with a prototype database comprising a complete registry of PV panels in the chosen test area in the Netherlands. This Peer+ database should give insights in where, how and how much energy decentralised installed PV panels produce. Currently such a complete database does not exist. All the more, it is important to explicitly state the possible future application this database should evoke. These applications are able to fill crucial gaps in both the public and private market, and therefore provide a fair base for initiating the prototype database.

According to Ramona Roller, a notion that should always be taken into account regarding the applications, is the fact that PV panel power generation has a 'high weather dependency: no reliable electricity production'. Also, the Peer+ database might evoke thoughts on a new subsidy approach on PV panels, while the Peer+ shows estimated insights in PV panel power generation numbers (kWh). Subsidy could for example be given on the base of these kWh values, instead of subsidy that is given solely on the installation of PV panels themselves.

Moreover, numerous possible applications can be divided into three main groups; future apps with a strong public character, apps with both public as private interests, and finally applications for the private market with possible commercial interests.

Public interests:

- Calamity application
 - *Stakeholders:* Fire Brigade, Crisis Team Alliander, Safety Regions
 - *Elaboration:* in case of a calamity, the national electric network can be negatively affected, causing a downturn in power. In order to face this issue, decentralised energy sources may provide the network with necessary back-up power: 'For the reconfiguration of the grid in case of a breakdown of a power station or in case new power stations are constructed/ old ones are demolished.'
- Network operator
 - *Stakeholders:* among others, Alliander
 - *Elaboration:* when the percentage of renewable decentralised energy sources increases in the Netherlands, it is crucial to know detailed data regarding those energy source, in order to balance out the energy network correctly: 'Decentralised electricity production: grid becomes more robust, flexible and scalable.'
- Statistical validation and enhancement
 - *Stakeholders:* EDSN – PIR, CBS
 - *Elaboration:* the prototype database can offer a replenishment to current decentralised energy related registers.
- Green energy mapping
 - *Stakeholders:* e.g. provincial/ municipality interests, in order to evoke mutual competition
 - *Elaboration:* as done in Germany (database: <http://www.energymap.info/download.html>), map application: <http://eeg.grids.enersis.ch/>), Open Data concerning decentralised energy sources indicates the 'green' energy characteristic of an area.

Public and commercial interests:

- The Linked Data principle
 - *Stakeholders:* all involved, responsible parties in the energy sector
 - *Elaborations:* an accessible web- based data exchange principle allowing innovative data connection; relate data to each other that initially wasn't linked to each other.

Commercial interests:

- Insurance policies
 - *Stakeholders:* multiple insurance companies
 - *Elaboration:* e.g. height of contribution when PV panels installed.

- Focused marketing research
 - *Stakeholders*: advertising companies
 - *Elaboration*: if a household installed PV panels, the chance is significantly higher that they buy other 'green' products.
- Insights for PV panel manufacturers
 - *Stakeholders*: producers of PV panels
 - *Elaboration*: the map application can visualize the area in the Netherlands which is not 'covered' by PV panels. A future application combining mapped Aerial/Peer+ data together with a solar potential map, can give even more insights: which roofs are suited for PV panels that have not already PV panels installed.

7.3 Map visualisation (neighbourhood level)

A free domain and host via the web software service WordPress was created. This enables a vast, solid and reliable online platform to view and share the derived data and generated map. In Figure 44, two screenshots and a link of the website: <https://decentralsolarenergydatabase.wordpress.com/>

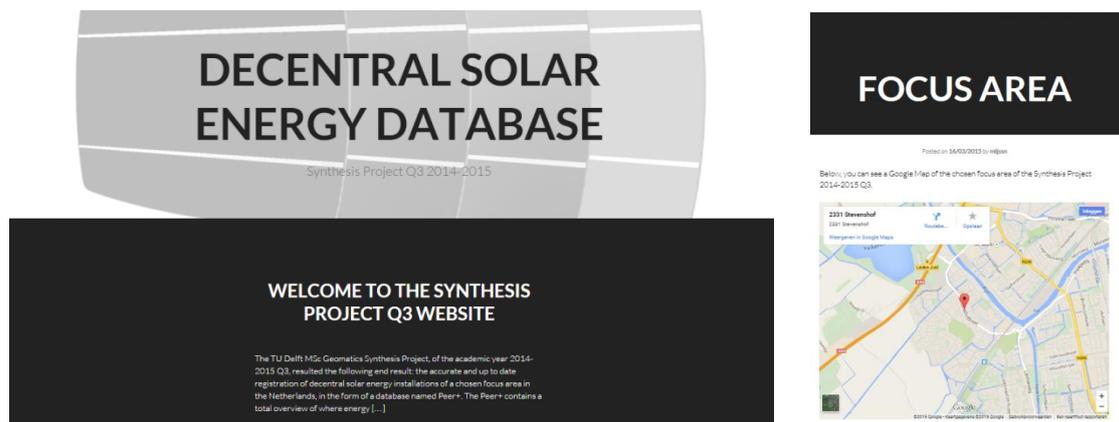


FIGURE 44: WEB SOFTWARE SERVICE - WORDPRESS

7.3.1 Google Fusion Table

In order to get to the comprehensive Peer+ database, several other databases needed to be generated first. One of these initial databases, the 'Aerial' database, lends itself ideally for mapping purposes. Therefore, this data is literally mapped via the Google Fusion Table application. This web application is chosen for its simple yet effective processing options (use of layers, geo reference), and for the fact that the data can be interactively published and easily accessed on the web. The 'Aerial' database consists of the following attributes, in *italic* the visualised attributes:

- *aerial longitude [float]*
- *aerial latitude [float]*
- *azimuth_south [integer]*
- *azimuth [integer]*
- *rooftype [character]*
- *slope [integer]*
- *power-kwh [integer]*
- *max_capacity [integer]*
- *pc6 [text]*
- *source [character]*
- *obtained_year [integer]*
- *pandid [integer]*
- *household [integer]*
- *visible2012 [boolean]*
- *visible2013 [boolean]*
- *method [character]*

Below the workflow of the fusion tables can be found in five different steps.

7.3.2 Right composition of tables

The Google Fusion Table application automatically selects the Latitude/ Longitude coordinates as registered in the input .csv file. Though, a correct ordering and naming of the tables matter (e.g. the table 'Latitude' should be positioned before 'Longitude'). For the 1st layer, displaying the PV panel geometry points, the following order is adopted:

Latitude	Longitude	Azimuth	Roof/inst	Roof type	kWh	kWp	PC6	Source	Obtained	Detection	Household	Pand_id
52.15215	4.45646	-20	40	oblique	236	0.25	2331GR	TU Delft st	2014	Aerial Det	1	5.46E+14
52.15215	4.456474	-20	40	oblique	236	0.25	2331GR	TU Delft st	2014	Aerial Det	1	5.46E+14
52.15215	4.456486	-20	40	oblique	236	0.25	2331GR	TU Delft st	2014	Aerial Det	1	5.46E+14

7.3.3 Map generation

With the 'FusionTablesLayer' Wizard multiple layers were added to the Fusion Map. These layers display the following:

1st layer: Geometry points indicating the centroid of a PV panel location.

- Clicking on the points, an info box appears displaying part of the information of the Aerial database.

2nd layer: CBS neighbourhoods (nld. wijken), visualising the boundaries within the district of Stevenshof.

- Clicking on the polygons, an info box appears displaying mainly the neighbourhood number and name, number of PV panels, their max. capacity at any time in kWp and power in kWh. All aggregated on neighbourhood level.

3^d layer: Ideally, part of the KLIC database (which visualize the location of cables) portraying low voltage network of Liander, as present in the Stevenshof.

For combining all these layers into one Google Map frame a HTML script was generated. This HTML script is stated in appendix H.

7.3.4 Final map

Below a few screenshots of the final map are visualized in Figure 45-47.

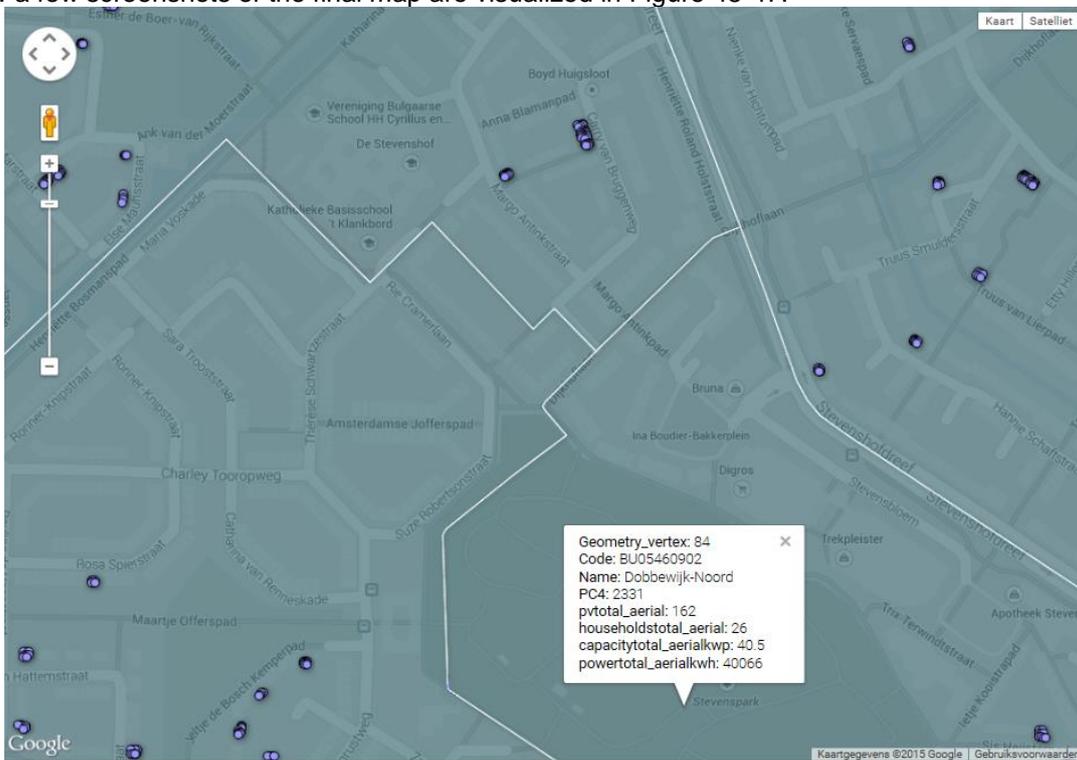


FIGURE 45: INFO BOX DISPLAYING AGGREGATED NEIGHBOURHOOD INFORMATION (DOBBEWIJK-NORTH)

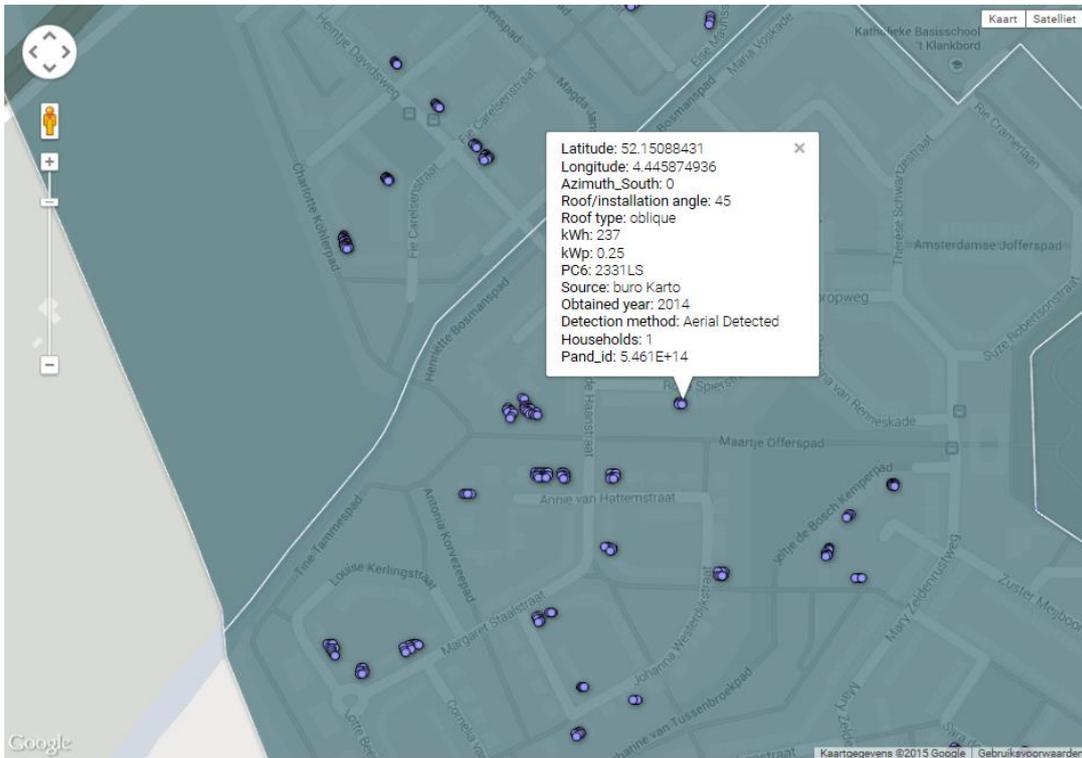


FIGURE 46: INFO BOX DISPLAYING SPECIFIC PV PANEL INFORMATION

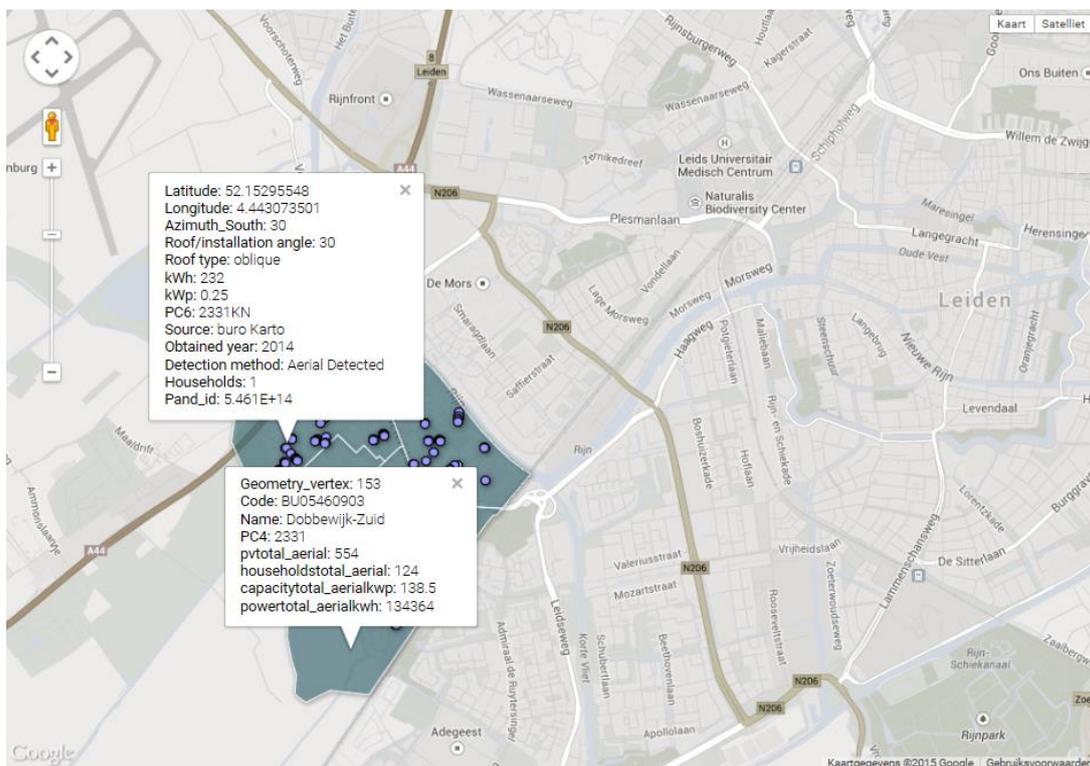


FIGURE 47: DISTRICT STEVENSHOF IN LEIDEN

7.4 Application in Crisis Management

The Peer+ database is built for certain applications. An application can be of added value, regarding the data of the exact location of PV panels. A lot of parties could be interested in the exact location of PV panels, for example market- and taxation researchers. Market researchers are really interested in the amount of PV panels on the roofs. The Peer+ database can help resellers and solar panels distributors to discover the solar potential of buildings. For insurance-company it is an asset to know where PV panels are installed and the amount of power (kWh) they produce, because the presence of installed PV panels can alter the firefighters procedures, and they can cause fire themselves. A proper example of an application for Crisis Management is the plan of attack (nld: Aanvalsplan) and DBK

(digital map, nld. Digitale Bereikbaarheidskaart) by the Fire Brigade. In this chapter focuses on one field of application regarding offensive indoor efforts of the fire brigade (Figure 48).

This chapter consists of three sections. In the first section a summary of the correspondence with Michael Bertels, a project manager at Brabant-North Fire Services, can be found. Furthermore the dangers of PV panels during firefighting are described with reference to The Underwriters Laboratory and NFPA. Finally a conclusion is given.



FIGURE 48: PV PANELS IN FIRE (BACKSTROM & DINI, 2011)

7.4.1 Correspondence with Michael Bertels

According to Michael Bertels, Project manager at Brabant-North Fire Services, the fire brigade eliminates the energy power before entering the building, assuming there are no PV panels present. When this assumption is incorrect it may cause injury. Michael Bertels also mentioned that a firefighter in Germany was electrocuted, because he was crawling across broken wires of PV panels. From these notions it may be concluded that PV panels obstruct firefighters.

7.4.2 Correspondence with Vincent Baartmans

According to Vincent Baartmans of the Safety region Central & West Brabant, there is a need to have a central registration of PV panels, for the Fire Brigade. However, such a registration is cost dependent. A complete PV panel database will then be used in two ways:

1. The information will be incorporated in the so-called DBK (Digitale Bereikbaarheidskaart). The DBK is a map composed out of various data sources, displaying important information relevant for the Fire Brigade.
2. Awareness of the presence of PV panels; the Fire Brigade commander can put out a warning before tackling a building that caught fire, and has PV panels installed.

PV panels deliver DC voltage (nld. gelijkspanning), which is of a larger risk than AC voltage (nld. wisselspanning). DC voltage distributes voltage throughout the entire wiring of a building, this can become a threat. Also, when a calamity or fire has to be tackled during evening or night time, the Fire Brigade uses bright spotlights which may influence the production of a PV panel installation. The necessity of including accurate data of decentralised installed PV panels, can be proofed by accidents that happened to fire fighters in Germany.

7.4.3 Dangers of PV panels during firefighting

The Underwriters Laboratory and NFPA have investigated the dangers of PV panels during firefighting.

➤ **Underwriters Laboratory**

According to Backstrom and Dini (2011) firefighters are vulnerable to electrical and casualty hazards when mitigating a fire that involves PV systems. There is not much knowledge and data available to understand the risks for developing safety solutions in order to respond in a safe manner (Backstrom & Dini, 2011) has conducted an experiment with roof mounted PV panels, which has resulted into the following tactical considerations firefighters have to take into consideration:

- “Shock hazard due to the presence of water and PV power during suppression activities”
- “Shock hazard due to the direct contact with energized components during firefighting operations”
- “Emergency disconnect and disruption techniques”
- “Severing of conductors “
- “Assessment of PV power during low ambient light, artificial light and light from a fire”
- “Assessment of potential shock hazard from damaged PV modules and systems.”

Backstrom and Dini (2011) emphasize that every fire event is unique and the following notions are only concepts what a firefighter has to take into considerations when providing help:

- “The electric shock hazard due to application of water is dependent on voltage, water conductivity, distance and spray pattern.”
- “Outdoor weather exposure rated electrical enclosures are not resistant to water penetration by fire hose streams. A typical enclosure will collect water and present an electrical hazard.”
- “Firefighter’s gloves and boots afford limited protection against electrical shock provided the insulating surface is intact and dry. They should not be considered equivalent to electrical PPE.”
- “Turning off an array is not as simple as opening a disconnect switch. [...]On a PV array, there is no single point of disconnect.”
- “Tarps offer varying degrees of effectiveness to interrupt the generation of power from a PV array, independent of cost. Heavy, densely woven fabric and dark plastic films reduce the power from PV to near zero.” However “a wet tarp may become energized and conduct hazardous current if it contacts live equipment.”
- “When illuminated by artificial light sources such as fire department light trucks or an exposure fire, PV systems are capable of producing electrical power sufficient to cause a lock-on hazard.”
- “Severely damaged PV arrays are capable of producing hazardous conditions ranging from perception to electrocution.”
- “Damage to modules from tools may result in both electrical and fire hazards.”
- “Severing of conductors in both metal and plastic conduit results in electrical and fire hazards. Care must be exercised during ventilation and overhaul.”
- “Responding personnel must stay away from the roofline in the event of modules or sections of an array sliding off the roof.”
- “Fires under an array but above the roof may breach roofing materials and decking allowing fire to propagate into the attic space.”

According to Backstrom and Dini (2011) “the limited number of fire events [...] have not resulted in fire fighter fatalities.”

➤ **NFPA**

Buildings equipped with solar power systems introduce unfamiliar hazards that require new firefighting strategies and procedures. Statistical data involving solar power systems is not readily available to provide quantifiable data analysis of these systems. But as solar power systems continue to proliferate, the likelihood of fire fighters encountering them at a structural fire will similarly increase. There are very few incidents of fires originating with or directly involving solar power systems. The two following reported incidents provide information on distinctly different fire emergency scenarios (Grant, 2013):

1. The first incident involved photovoltaic panels in May 2008 on a structure at the University of San Francisco. Figure 49 (left) provides an illustration of the type of arrays involved in this event, which was a relatively extensive installation and had the potential for significant fire spread. However, the building engineers on site were certified to handle high voltage, and the local electrical utility crew also arrived early in the event, and they took multiple steps to isolate energized conductors and power down the system, allowing responding fire fighters to extinguish the fire in one of the combiner boxes using portable extinguishers and a blanket of

foam. Property damage was kept to the components of the solar power system involved in the fire, with minimal damage to the host building.

2. The second fire occurred in California during April 2009 and involved a large PV array comprised of 166 strings of 11 modules each on the roof of a department store. Figure 49 illustrates the solar power system involved in this event. Two separate electrical fires broke out remote from each other, and were caused by electrical arcing. One of these fires consumed a complete string of PV panel modules. The resulting two-alarm fire was confined to the PV panel modules and was kept from penetrating the store's roofing materials. The arcing occurred when metal electrical conduits separated at their couplings due to significant contraction and expansion from sunlight, which exposed wiring that ultimately shorted. Figure 49 (right) illustrates one of the arrays damaged by fire.



FIGURE 49: DIFFERENT FIRE EMERGENCY SCENARIOS

From a fire service perspective, a photovoltaic system includes an electric shock hazard. Below a summary of the primary hazards of solar power systems for emergency responders (Grant, 2013):

- Tripping/Slipping (may occur on a rooftop in dark or smoky conditions)
- Structural Collapse due to Extra Weight
- Flame Spread
- Inhalation Exposure
- Electrical Shock
- Battery Hazards.

The upper two are described in more detail below.

Electrical Shock

The electrical shock hazard of photovoltaic systems presents an additional challenge, although it is one that firefighters can readily handle once equipped with the proper operational knowledge. Thus, the need to identify and determine the type of solar power system is a critical step for emergency responders. Electrical shock while extinguishing a building fire is a realistic fire ground hazard. A critical task during fireground operations at any building fire is to shut down the utilities, including the electrical utilities to remove the electrical shock hazard. This is a relatively straightforward one-step process for a building receiving electrical power from the local communities' power grid. However, it becomes considerably more challenging when multiple sources provide electrical power such as with a building equipped with a photovoltaic power system (Grant, 2013).

Battery Hazards

An additional electrical concern exists for systems that have an optional battery storage arrangement as part of the PV system. The batteries can maintain electrical current at nighttime and when the rest of the system has been isolated, thus presenting an additional electric shock hazard (Grant, 2013).

The most important issue for emergency responders that need to be considered and/or addressed for emergency events involving solar power systems is that the components are always hot. Always consider photovoltaic systems and all their components as electrically energized (Grant, 2013).

7.4.4 Conclusion

The location of PV panels can be important in Crisis Management. Taking all resources into account it can be concluded that it is still an open issue whether there is a need for a map application of PV panels or not. The goal of the map with the location of PV panels, households, max. amount of capacity at any time and power, can assist firefighters in their decision making processes at emergencies involving decentralised installed PV panels on buildings.

8. RESULTS

During this Synthesis Project, a general research has been done within the scope of the overarching Cerise SG Project. There was a focus on the registration of the location, amount of power (kWh) and maximum capacity at any time (kWp) of decentralised installed PV panels, and the improvement of the current way of storing and retrieving this data. Cooperation has been achieved with different stakeholders and experts in the project. The cooperation of these external specialists has given the possibility to carry out and complete the research in a proper way. With help of Aerodata and buro Karto it was made possible to detect PV panels via the image processing method. This data can be stored into the generated Peer+ database, functioning as a prototype PV registration database, which is reliable and up-to-date.

It is investigated that publishing PV panel registration data on PC6-level is not a proper way. It is inaccurate to assign PV panels to a PC6, because for instance an apartment building may contain three different PC6's. For this reason it is better to assign the PV panels to a premise, and not to a PC6 (in contrary to the Existance9 and PIR). However publishing the data on premises level may be privacy sensitive. Therefore, it is also decided to aggregate and publish the PV panel registration data on neighbourhood level.

Furthermore, an assessment of the application of the accurate PV panel data for Crisis Management is made, based on reports and correspondences with experts.

Also, a web accessible, interactive map is created displaying the test area. This Fusion Map is to be published on the website <https://decentralsolarenergydatabase.wordpress.com>. This map application displays the accurate location of PV panels, and part of the aggregated Peer+ data on neighbourhood level.

The results of this project, as presented in this report, consist out of the following:

- Validation of the results and quality control (how trustable are the results);
- Statistical information regarding the reliability of the Existance9, PIR compared to the Peer+;
- A database where all the PV panel registration data is visualized;
- Linking possibilities with other stakeholders (mainly focusing on BAG);
- The necessity of this database (mainly focusing on Crisis Management);
- A web accessible map visualizing quantitative data on neighbourhood level.

9. CONCLUSIONS

In this conclusion an answer will be given to the following research question:

How to create a database which can be used to validate and improve the current registration of installed decentralised PV panels in the Smart Grid usable for an application in Crisis Management?

The answers on this question will be divided according to the sub-questions presented in section 2.2 'Research questions'.

1. What data can be provided by the different stakeholders?

During this research several stakeholders have been contacted.

- Data of PV panels can be retrieved via the website of "klimaatmonitor", which has the EDSN PIR data published, combined with nine other sources ;
- The confidential data of the PIR on PC6 level (of Stevenshof) is obtained via Gert Nijsink (advisor at RWS) ;
- The aerial images of Stevenshof are obtained by Jan Willem van der Vegt of Aerodata;
- A part of the detected markers (longitude and latitude) of PV panels in Stevenshof were obtained via the algorithm made by buro Karto ;
- Other specifications (e.g. the slope) were retrieved via the AHN2 data (nld. Actueel Hoogtebestand Nederland) which were obtained via Ravi Peters (TU Delft) ;
- Nishant Narayan (PhD Candidate at the TU Delft) explained us how to calculate the amount of power (kWh) in an accurate way ;
- Bert Scholten (Geodan) provided us with the postal code areas of Stevenshof (Shapefiles) ;
- The database of the BAG was retrieved via the website <http://www.nlextract.nl/> ;
- The Postgresql server is obtained via Wilko Quak by Paul Keekstra (TU Delft) ;
- Michael Bertels (Project manager at Brabant-North Fire Services) and Vincent Baartmans (of the Safety region Central & West Brabant) provided us with information about the need to have a central registration of PV panels ;
- On the website of PolderPV, made by Peter Segaar (independent PV panel researcher and expert in the Netherlands) , it was discovered that Energetic Leiden did a PV purchasing action in Stevenshof in June 2013. This is why the test area: Stevenshof in Leiden was chosen ;
- A Lync interview with Paul Wassenberg (Datamanager at Alliander) was made, to discover the benefits of the database for Alliander ;
- Ramona Roller (Intern at TNO) provided us with information about Crisis Management and linked data.
- Paul Janssen (Geonovum) did a KLIC-notification for Stevenshof (raster data).

2. What is the most effective way to retrieve the data regarding the location and the maximum capacity at any time (kWp) of the installed decentralised PV panels?

The most effective way to retrieve the location of installed decentralised PV panels is via the website of "klimaatmonitor". On this website the locations are published per PC6. These PC6 locations are not accurate, so it is necessary to retrieve the location of installed decentralised PV panels via the image processing method and the PIR data (which is confidentially).

The output of installed decentralised PV panels can be subdivided into the amount of power (kWh) and the maximum capacity at any time (kWp). The maximum capacity at any time (kWp) can be retrieved via the website of "klimaatmonitor" (on PC6 level). For the data obtained via the image processing method, the maximum capacity at any time (kWp) is determined. The assumption is made that all PV panel modules in Stevenshof consist of 60 PV cells with a peak power of 0,25 kWp.

3. Where is decentralised energy in the form of PV panels produced?

The detection of PV panels was possible via accurate, captured aerial imagery, a detection algorithm (buro Karto) and verification of this algorithm in the program called QGIS. Via this methodology, a large amount of installed PV panels is detected in Stevenshof. With an image processing method it is possible to retrieve the longitude and latitude of installed PV panels. However, the detection methodology that is used contains to a certain extent some sources of error, e.g. vertical installed PV panels are not taken into account.

4. What is the amount of power (kWh) produced by PV panels?

The amount of power (kWh) is determined for the PIR and Existance9 tables. This was done with the following formula:

Estimated power (kWh) = Maximum capacity at any time (kWp) x 850.

The conversion factor is based on the average hours of sunshine in the Netherlands per year. For the data obtained via the image processing method, the amount of power (kWh) was determined via the website: <http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php> by making a few assumptions.

5. What are the current ways to publish and store the derived data?

The current way to publish and store PV panel data is via the PIR database (csv-file) and the website of "klimaatmonitor" (an online-table). The SDE+ (subsidy arrangement) has some data, but not all data is stored on PC6 level. For this reason this data is not reliable and accurate enough.

6. How to improve the current situation of publishing and storing the derived data?

The current ways in publishing and storing the derived data can be improved by putting data of all usable sources into a new central database. Via this new database it will be possible to combine all data in order to find how accurate the data of all sources is. By combining this data it will be possible to improve all usable sources (e.g. large differences between different sources show that the data of certain sources is not reliable). With help of aerial imagery it is possible to visualize the data as a map: because the data is retrieved via an image processing method, longitude and latitude per single PV panel are available. In the future, it is possible to link this database to other applications (e.g. in Crisis Management, BAG) and publish the data (anonymously) via a csv-file or map, usable for other parties.

7. How can this stored data be a solution for an application in Crisis Management, regarding offensive indoor efforts of the fire brigade?

PV panel data, stored in a database on longitude and latitude, can be a solution for an application in Crisis Management, because there is a need to have a central registration of PV panels. By linking this data to a premise (in e.g. the BAG, Google Maps) it can be used to assist decision making processes at emergencies involving solar power systems on buildings. The fire brigade can use this data to take several strategic methods into consideration.

Overall conclusion

It can be concluded that the biggest problem in having a reliable and up-to-date database is the cooperation between different stakeholders. A lot of data regarding PV panel registration is available, but this data is either not shared with other parties, or it is not recorded properly (for exchange and linking). In this manner, it is evident to combine multiple existing sources of data, and to come up with other resources to get reliable data. The most obvious stakeholder to invest in the Peer+ is the EDSN who are currently maintaining the PIR database, which is not reliable and up-to-date.

The most important statistical information is the postal code PC6 statistic, because (related to the other statistics) no conversion has been done of units. The Peer+ contains more postal codes than the PIR, so it can be concluded that the Peer+ is more accurate and reliable than the PIR.

By having a central, reliable 'Peer+' database where the accurate location of PV panels is stored in coordinates, more linking possibilities regarding other applications and stakeholders can be made. The Peer+ makes the PV panel registration data more usable.

Furthermore, the reliable Peer+ database makes various new statistical analyses possible, e.g. power estimation by PV panels aggregated on neighbourhood level. Future applications based on the Peer+ database can provide useful and up-to-date insights regarding Crisis Management.

A notion to be aware of is the possible privacy violation, when publishing the found PV panel registration data of the concerned test area as Open Data, on premises level.

9.1 Future work

One of the insights which were gained during this Synthesis Project regarding PV panels in The Netherlands, is that it is very important to set up an up-to-date and reliable database of PV Panels with help of aerial imagery. During the survey in Stevenshof it was noticed that there is a need for an algorithm (or an enhancement of the detection algorithm of buro Karto) which can detect for instance Thin film PV panels. These Thin film PV panels are currently an error source in the detection algorithm and they are hard to detect on aerial imagery. The algorithm of buro Karto that was adopted for this project, focuses solely on standard PV panels with a frame.

As a future work it might be interesting to investigate the difference between the private database of network operators (related to the EAN code), like Alliander, and the Peer+. It would be interesting to

know why network operators are only using the PIR as a benchmark and not feed / adapt the registration of PV panels in the PIR. The possible cooperation of these two stakeholders could benefit the PIR in having a more reliable database. If this cooperation is possible it would be interesting to do a comparison once again between the PIR and Peer+.

If the Synthesis Project Q3 would consist of a significant extra amount of time, the following aspects would have (possibly) been incorporated in the research:

- To make a step forward in the automatization processes of the databases themselves, as in several calculation processes.
- The adoption of 3D city models in the calculation processes, and in the visualization purposes.

These aspects are elaborated in the following segment 'Feasibility on National Level'.

9.1.1 Feasibility on national level

Due to the fact that the duration of the Synthesis Project Q3 is set for seven weeks, an appropriate scope of test area was chosen; district Stevenshof, Leiden. The methodologies described in this report, could also be applied on a bigger scale, from cities, provinces to eventually a nationwide scope. In this case, the Peer+ will be usable for external parties. Though, certain factors should be taken into account to make this larger coverage possible.

For conducting this research on national level the following points has to be done:

- The evolvement of the detection algorithm, so it can deal with several sources of error
- The assumption that all PV panels are produced by Yingli has to be adapt
- A suitable verification method (regarding e.g. vertical placed PV panels)
- Availability of accurate and up-to-date aerial imagery (preferably including older aerial imagery for mutation over a time span).
- A fully automated workflow of linking, deduplicating and verifying existing databases (e.g. klimaatmonitor, PIR)
- Automatization scripting
- Buro Karto could also detect the geometry of the PV panels.
- 3D city models are perfectly suited to determine slope, elevation values and orientation of the roofs. Though, the 3D models of cities are not yet available for the whole NL, but for LOD2 and LOD3 they can make a proper determination of the properties of roofs. Slope, elevation and orientation are easier to extract from 3D city models, possibly via an automatized way.
- The following aspects of every single PV panel must be automatized with scripting:
 - BAG Linking: Linking the PV panels to a premise of the BAG
 - Slope calculation
 - Orientation determination
 - Power and capacity calculation
- Districtboundaries table adaption

During the research is noticed that there is no reliable data available of which postal code (PC6) belongs to which neighbourhood (*Dutch: CBS wijk/ buurt niveau*). To support (environmental) policy issues, the Peer+ will be published as open data at neighbourhood level.

Also, a larger coverage would mean that larger PV panel projects initiated by energy suppliers (Backstrom & Dini, 2011) and other commercial companies might also be detected. These larger projects may not be integrated in existing decentralised registrations such as the PIR. The PV panel data set of buro Karto will be available in Summer 2015. The algorithm of buro Karto has a processing time of approximately 2 months.

When all these points have been taking into account, it is important to find a stakeholder who is willing to invest in the Peer+ database. The most forehand stakeholder to be responsible for the database is the: EDSN PIR.

9.1.2 Recommendations

Another approach to retrieve locations of PV panels on premises level, is to look at Smart Meter installations of households. However, with this method, accurate coordinates per PV panel are not

possible to obtain, though Smart Meter data might be suited for validation purposes for a complete PV panel registration in the Netherlands.

It is important to get the concept of Linked Data more common and widespread. Linking Data is an innovative way for sharing information between different stakeholders and experts. However, this solution is not the optimal resolution for now, because this concept is not well used. In the future, when the Link Data principle will become more common, this way of sharing information will be promising.

10. ACKNOWLEDGEMENT

The topic of this project is discussed with different stakeholders. We would like to thank the project coordinators and coaches.

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APPENDIX A - PROJECT MANAGEMENT AND PROCESS

A.1 The team



Myron Ramkisoen
Coordinator

During this project I hope to gain more experience in GI-systems (and if needed programming) and organizing a complete project with a whole group.



Rosann Aarsen
Secretary

I expect and hope to learn about applying the knowledge we learned so far. Also to be an effective communicator, take charge and to make a nice database (prototype) which is reliable and up-to-date.



Milo Janssen
Communicator

I would like to gain distinct and specialized knowledge in GIS and Web related applications. Preferably, I would like to touch upon a possible 3D implementation of the prototype.

A.2 Technical requirements with MoSCow

A detailed list of the requirements of the method will be drafted in this subchapter, which is divided into 5 sections.

2.1 What is known? What is not known?

Known

- Software:
 - PostGIS – to make a database
 - QGIS – as a data viewer/link to database
 - Google Drive - as a file sharing platform
 - Dropbox - as a file sharing platform
- Hardware:
 - Personal laptops
- Organizational:
 - Team capabilities
- Information:
 - Smart Grid and Smart-Meter principle (Measurement: gas, electricity and redelivery)
 - > <http://www.slimmemeters.nl/>
 - > <http://energy.gov/oe/services/technology-development/smart-grid>
 - Location and function of power assets (transformer stations, power stations, etc.)
 - > Information available from Alliander
 - Height above ground of power assets
 - > Information available with Station Location & “AHN2”
 - Supply areas/energy generation of power assets
 - > Information is only based on an assumption using Postal codes
 - Location of cables
 - > KLIC
 - Energy network of Alliander
 - > *Information available from Alliander*
 - > http://www.brandweerkennisnet.nl/publish/pages/21797/uitval_stroom_-_alliander.pdf
 - Registration of (some) renewable decentralised production-installations (PV panels, etc.) of consumers
 - > EDSN (PIR: Productie Installatie Register), which gives an indication (non- reliable) Nowadays there are more than 28.000 installations registered.
<http://www.edsn.nl/productie-installatie-register/>
 - > EDSN (CAR: Centraal Aansluitingen Register)
<http://www.edsn.nl/centraal-aansluitingenregister/>
 - Sun maps, studies for PV panels potentials
 - > Among others; Mapgear geo apps & services,
<http://www.mapgear.nl/web/zonnekaart.html>
 - Division in large and small wind turbine installations
 - > Windturbined (WindStat): <http://windstats.boschenvanrijn.nl/>
 - Risk map (nld: Risicokaart)
 - > <http://www.risicokaart.nl/>
 - BAG (Basis registraties Adressen en Gebouwen)
 - > <https://bagviewer.kadaster.nl/lvbag/bag-viewer/index.html>
 - Alliander exchanges data with safety region (Veiligheidsregio's), not with the Department of Transportation (nld: Rijkswaterstaat (RWS))
 - > See also:
http://www.brandweerkennisnet.nl/publish/pages/21797/uitval_stroom_-_alliander.pdf
 - No compulsory PV panel registration in the Building act (nld: Bouwbesluit)
 - > Information from the Building act: <http://www.bouwbesluitinfo.nl/pages/posts/pvda-wil-zonnepanelen-verplichten-via-bouwbesluit-57.php?p=30> and info from Rijksoverheid:
<http://www.rijksoverheid.nl/documenten-en-publicaties/brochures/2010/07/20/zonnecollectoren-en-zonnepanelen.html>

- Plan of attack (nld: Aanvalsplan) by the Fire Brigade comprises no detailed location of decentralised installations, though it entails only point for consideration, in the Attentional maps (nld: Aandachtskaarten).
 - > Examples are shown here: http://www.brandweer.nl/zuid-limburg/organisatie/risicobeheersing/veilig_optreden/
- Weather data (from KNMI)
 - >20150128 Presentation Cerise, WP00
http://www.knmi.nl/waarschuwingen_en_verwachtingen/
- Energy data (included electricity return and consumption, gas consumption), Smart meter data (anonymously), BAG, weather data, and in future also NHR, MPAR (real time energy data).
 - > <http://research.geodan.nl/sites> (demonstrator EIR Energy Information Broker)
 - >20150128 Presentation Cerise, WP00

Unknown:

- Organizational:
 - Working schedule of all team members
- Information:
 - Smart Grid risks, failure of amenities, trends, balancing of the network principles about the Smart Grid in NL, and related projects
 - ><http://tki-switch2smartgrids.nl/projecten/>
 - Test area – country, city, village, neighbourhood
 - > Alliander dependent
 - > Julianadorp or smaller (form Demo EIR)
 - Precise or average power usage per cluster households
 - > Demo EIR data (Smart meter data, BAG, weather-data)
 - Capacity of decentralised Smart Grid energy sources (wind, solar, biogas, heat)
 - > Solar: Weather data and Area PV-panels or amount
 - > Wind: Weather data; diameter wind turbine
 - > Biogas: ?
 - > Geothermal heat: ?
 - Exact location, amount of energy that is produced and type of decentralised renewable energy installations (location, how, amount)
 - >PV panels: Extraction from AHN2 (PV panels reflect) & BAG; EDSN-PIR (although not complete); extraction from subsidy of PV panels at the municipality? Extraction from Alliander?
 - > Wind turbines: WindStat (although not complete)
 - > Biogas: ?
 - > Heat: Greenhouses?
 - Exchange of information (now there is a lack of connection between central and decentralised networks)
 - > ??
 - Buffer capacity of the energy network
 - > Alliander?
 - Principle of automatic balancing on the network (e.g. increase voltage on the net, automates a smaller amount of energy delivery of PV panels)
 - > ??
 - Predictability of the network in case of calamity
 - > Alliander and/or safety regions?
 - Overview of all risks regarding the power network in case of any calamity (for example fire risks PV panels)
 - > Alliander and/or safety regions?
 - Aerial pictures for remote sensing analysis
 - > Information available from CGI?
 - DBK, digital access map of the Fire Brigade
 - > Contact Fire Brigade
 - Who is the manager of all the wind turbines in NL, TenneT/ Department of Transportation (nld. Rijkswaterstaat (RWS))?
 - >Various websites
 - Acquiring an extra code of the network operator when installing decentralised energy
 - > Info from energy suppliers of NL, among others Eneco, Nuon, GreenChoice

- Subsidy regulations PV panels (per municipality, comparisons ; possible tracking of registers at governments)
 - > Municipalities
- Importers PV Panels
 - > Holland Solar

2.2 Identification and contact with stakeholders and experts

Stakeholders (*names and functions*)

- Designated network operator – Alliander (Liander, Liandon, Endinet)
 - Maintenance, distribution of energy, construction of the infrastructure.
 - One of the largest energy providers of the Netherlands.
 - Manages large parts of the electricity network. Alliander runs power stations and supplies objects with electricity (such as schools). In case of a power cut, Alliander reorganizes their electricity grid in order to provide affected objects with electricity again.
- Fire Brigade (nld: Meldkamer)/ safety regions (nld: Veiligheidsregio's) / Regional Crisis Management Systems
 - Ensure the safety of people and the environment
- Owners of decentralised installations
 - Additional energy suppliers
- Energy suppliers (Eneco, Nuon, etc.)
 - Delivering power to household and companies
- Department of Transportation (nld: Rijkswaterstaat (RWS))
 - Executive organization of the Ministry of Infrastructure and Environment

Experts:

- Geonovum
 - Ensures and provides accessible geo information for the public
- Geodan
 - Geo ICT consultant
- Kadaster
 - Data provider, manager of Basis registrations
- TNO
 - Knowledge and research, interoperability in semantics
- TU Delft
 - ICT and GIS technology

2.3 MoSCoW rules

MoSCoW stands for must, should, could and would (Wikipedia):

- **MUST** = Must have this requirement to meet the business needs.
- **SHOULD** = Should have this requirement if possible, but project success does not rely on it.
- **COULD** = Could have this requirement if it does not affect anything else in the project.
- **WON'T** = Would like to have this requirement later, but it won't be delivered this time.

The MoSCoW method is a technique to reach a common understanding with the different stakeholders on the importance that they put on requirements (Wikipedia, 2015).

The requirements are listed below in brown, in grey the knowns, *in italic the unknowns*:

MUST:

- Explore different ways to find data of decentralised energy supplied to the network
- A method to analyze the data about decentralised supply via existing software/ algorithm
- One decentralised energy supply type must be processed: solar energy - PV panels
- Determination of the test area
- Require data, information and knowledge about decentralised renewable energy data for Crisis Management, Energy mapping, Insurance interests
- Investigate what the influence could be when the subsidy of municipalities force the registration of the EDSN-PIR and when not

- Registration of renewable decentralised production-installations (PV panels, etc.) of consumers
- Sun maps, studies for PV panels potentials

- *Exact location, amount of energy that is produced and type of decentralised renewable energy installations (location, how, amount)*
- *Regulation acquiring an extra code of the network operator when installing decentralised energy*
- *Subsidy regulations PV panels*
- *Importers of PV Panels*
-> *Holland Solar (brand organizations)*

SHOULD:

- Provide a successful prototype (web-application) including aspects related to Crisis Management

- Energy network of Alliander
- BAG (nld: Basisregistraties Adressen en Gebouwen)
- AHN2 - density values
- Aerial imagery of a high definition
- Smart Grid and Smart-Meter principle (Measurement: gas, electricity and redelivery)
- Location and function of power assets (transformer stations, power stations, etc.)
- Energy data (including electricity return and consumption, gas consumption), Smart meter data (anonymously), weather data, and in future also NHR, MPAR (real time energy data)

- *Exchange of information (now there is a lack of connection between central and decentralised networks)*
- *Predictability of the network in case of calamity*
- *Overview of all risks regarding the power network in case of any calamity*
- *DBK, digital access map of the Fire Brigade*

COULD:

- Provide more decentralised energy supply types (i.e. wind, biogas, geothermal heat)

- Risk map (nld: Risicokaart) of the Netherlands
- Supply areas/energy generation of power assets
- Plan of attach (nld: Aanvalsplan) by the Fire Brigade comprises no detailed location of decentralised installations, though it entails only a point for consideration, in the Attentional maps (nld: Aandachtskaarten)
- Weather data (from KNMI)
- No compulsory PV panel registration in the Building act (nld: Bouwbesluit)

- *Precise or average power usage per cluster households*
- *Capacity of decentralised Smart Grid energy sources*

WON'T:

- *Focus on all decentralised energy supply methods*
- *Extend the research to the country scope*
- *Incorporating real time decentralised energy supply related to the network in the prototype*
- *Divide all households into clusters, useful for Crisis Management*
- *Look at solar heat*

- *Division in large and small wind turbine installations*
- *Height above ground of power assets*
- *Location of cables*

- *Smart Grid risks, failure of amenities, treads, balancing of the network principles about the Smart Grid in NL, and related projects*
- *Buffer capacity of the energy network*
- *Principle of automatic balancing on the network*
- *Who is the administrator/ manager of all the wind turbines in NL*

2.4 Identification of any killer requirements

- *To have access to the necessary data*
- *Reliability of the derived data*
- *Cooperation of the stakeholders*
- *Privacy issues (address)*
- *Time limitation (7 week project)*

A.3 Organizational Breakdown Structure (OBS)

The Organizational Breakdown Structure (OBS) is a model which describes the organizational framework for project planning. An OBS is also a good communication tool and defines the responsibilities (by linking names to the different defined categories (the upper names are the most responsible for the category)) and control factors during the project: time, quality, information, organization and communication. An OBS has a typical tree structure (see Figure 50).

Team tasks and functions:

Coordinator	Define the agenda Responsible for the planning Establish relationships with Partners
Secretary	Define the formats Maintaining effective records and administration Deals with organizational and legal aspects
Communicator	Define main message Communication between production team and client Make agreements on daily meetings to harmonize

Defined categories:

Requirements	Requirements analysis Software selection
Analysis	Conceptual analysis (involved parties)
Planning	Logbook function, project planning and responsibility
Information gathering	Information combining Finding data
Documentation	Responsibility for the quality Maintenance of the data
Database management	Make and manage a database

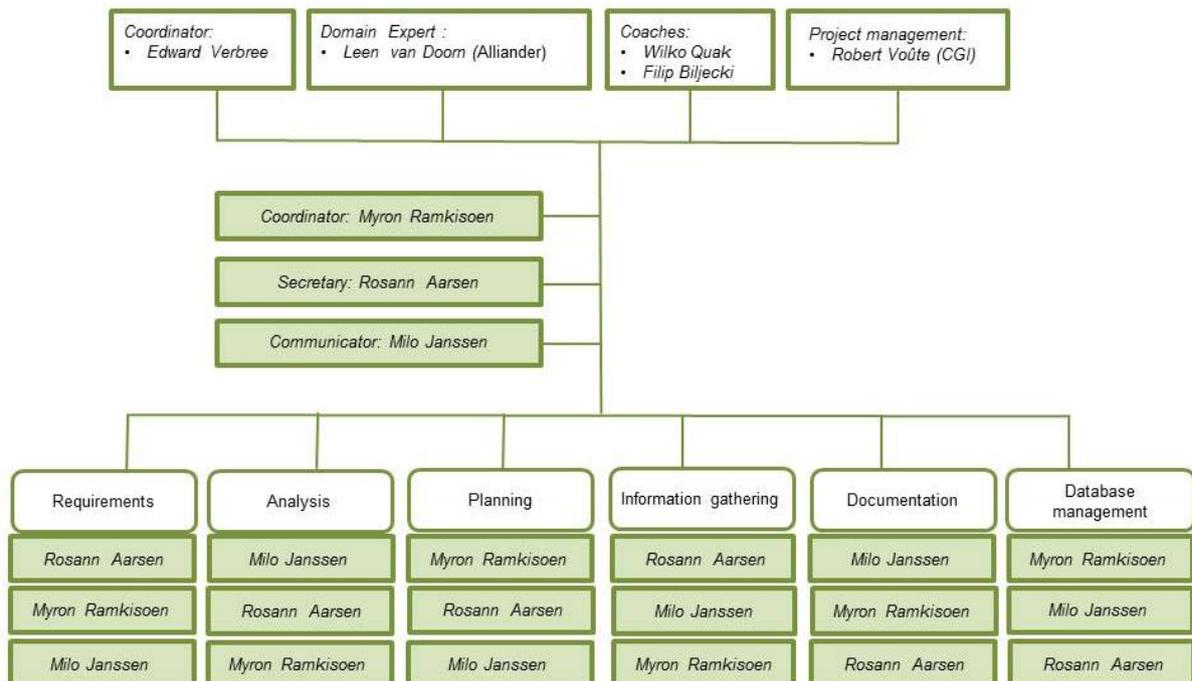


FIGURE 50: ORGANIZATIONAL BREAKDOWN STRUCTURE

A.4 Work Breakdown Structure (WBS)

The Work Breakdown Structure (WBS) is a hierarchal framework of a project which decomposes the project into smaller components (see Figure 51).

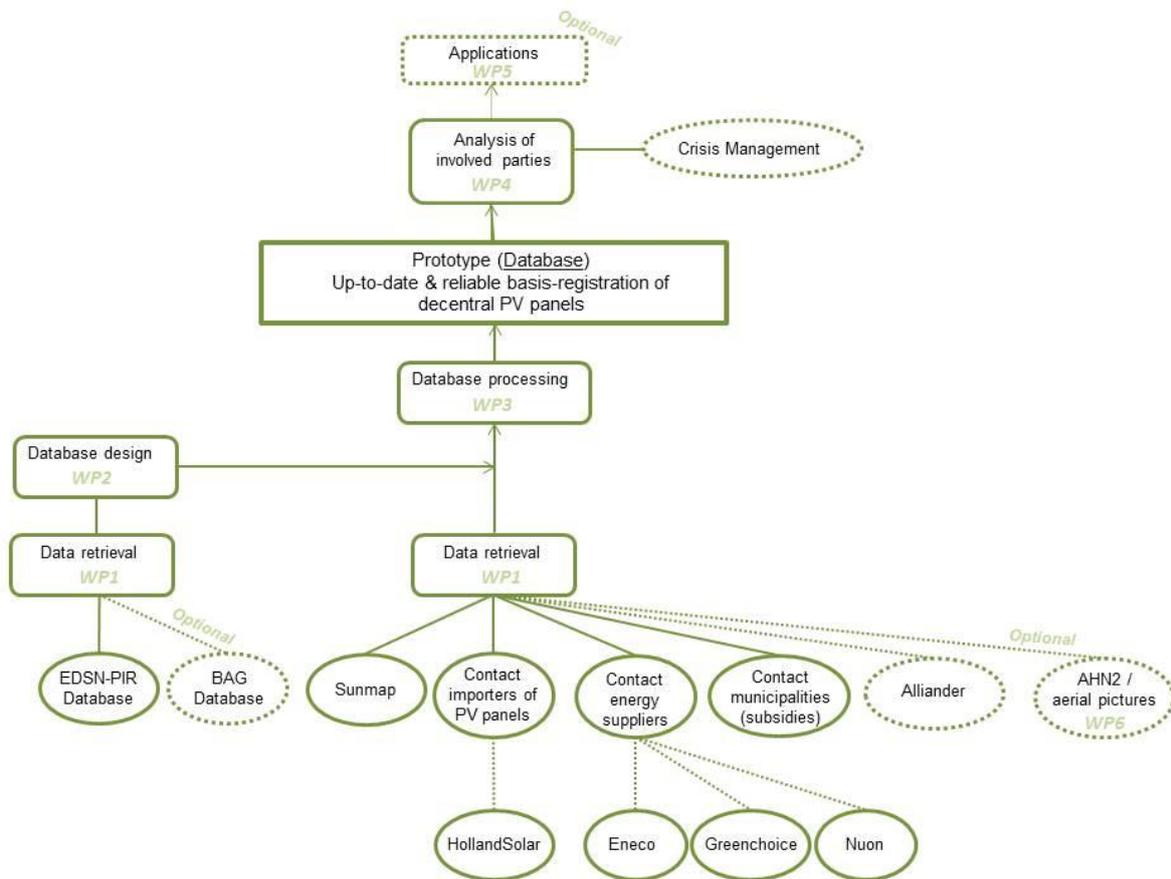


FIGURE 51: WORK BREAKDOWN STRUCTURE

The smaller components of the WBS are further divided into Work Package Descriptions.

A.5 Work Package Descriptions (WPD)

In *Italics* non-compulsory tasks are described.

WPD1: Data Retrieval (Information Gathering)	
Description	Within this WPD usable & existing databases have to be discovered, what can be used for creating a database of PV panels. This WPD also include the privacy issues regarding PV panels.
Output	Location data of PV panels, specifications of PV panels, amount energy PV panels, database design (EDSN-PIR & BAG), <i>Aerial Imagery, AHN2</i>
Relation to other WPD's	WPD2: Basic database structure WPD3: Input of database

WPD2: Database design	
Description	Within this WPD the database will be designed, with the database of the EDSN-PIR register as basis.
Output	Database
Relation to other WPD's	WPD3: For processing the database

WPD3: Database processing	
Description	Within this WPD the database will be filled with a sample of data.
Output	Prototype (Database)(up-to-date and reliable)
Relation to other WPD's	WPD5: For adapting the prototype, suitable for other parties

WPD4: Analysis Involved parties	
Description	Within this WPD an analysis will be made about the parties which are (possibly) interested in a connection or access to the database.
Output	Analysis of Involved Parties
Relation to other WPD's	WPD5: For connection to other parties and development of Web Application (for registry of PV Panels)

WPD5: Application	
Description	<i>Within this WPD the prototype will be developed, suitable for the application for involved parties.</i>
Output	<i>Database of PV panels, up-to-date and reliable</i>
Relation to other WPD's	

WPD6: Methodology Development	
Description	<i>Within this WPD a methodology will be developed on how it will be possible to compute the location of PV panels, based on aerial imagery, AHN2 (based on reflectance) & BAG data. Note that this method only defines the location of the PV panels. If the database is no accurate enough, this method should be used to increase the accuracy of the database.</i>
Output	<i>Location of PV panels</i>
Relation to other WPD's	WPD3: Input of database

A.7 Project Logic Diagram

The Project Logic Diagram is based on Prince2 (Office of Government Commerce, 2010), see Figure 53. The process of developing a database of PV panels will contain the following mile-stone products:

- Input Data (WPD1)
- Demo Database (WPD2)
- Prototype Database (WPD3)
- Analysis of involved parties (WPD4)
- *Web Application (optional) (WPD5)*
- *Database (optional) (WPD5)*
- *Theoretical methodology for location retrieval of PV panels (optional) (WPD6)*

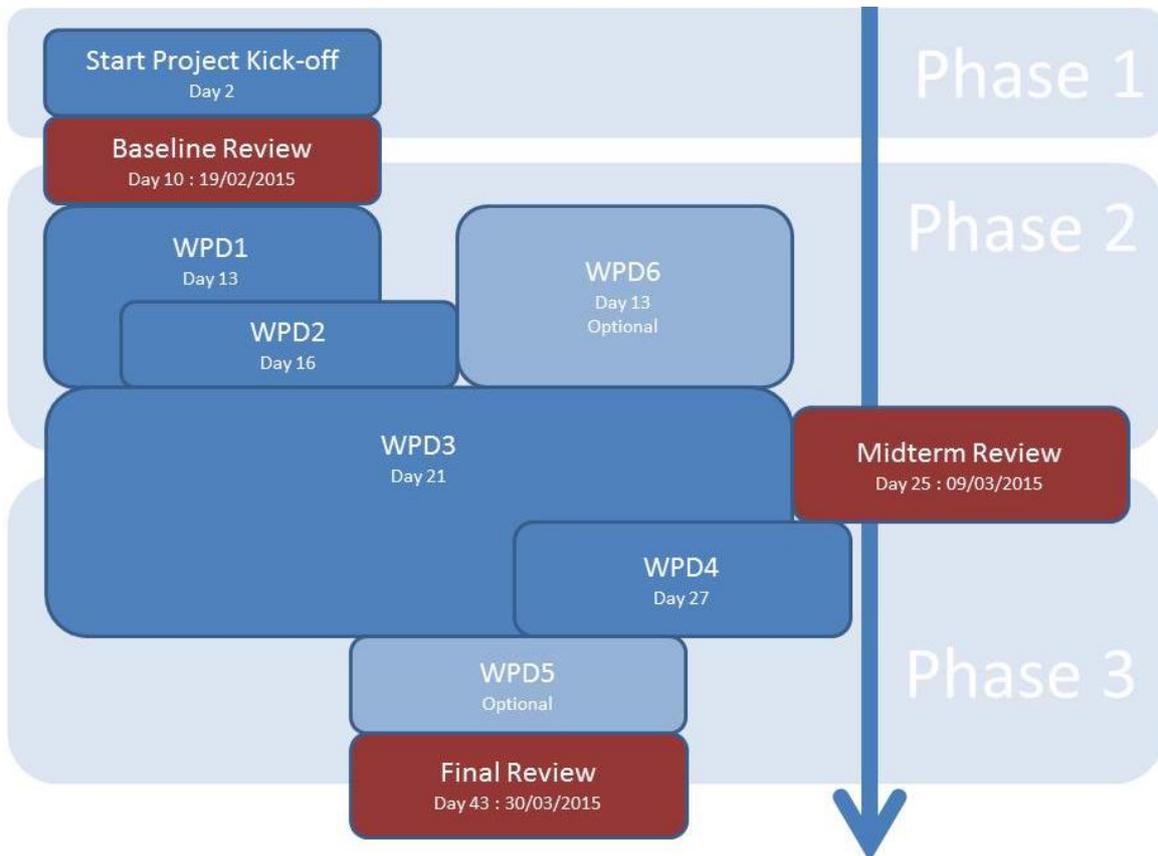


FIGURE 53: PHASES (UNTILL THE FINAL REVIEW)

Within this Prince2 method the Web Application and database will be designed with the Agile/Scrum method (Project and Program Management, 2007), see Figure 54.



FIGURE 54: AGILE

APPENDIX B - FLOW DOWN

Figure 55 illustrates the MosCow flow down.



FIGURE 55: MOSCOW FLOW DOWN

APPENDIX C - UML DIAGRAM PEER+

Figure 56 illustrates the UML diagram of the Peer+.

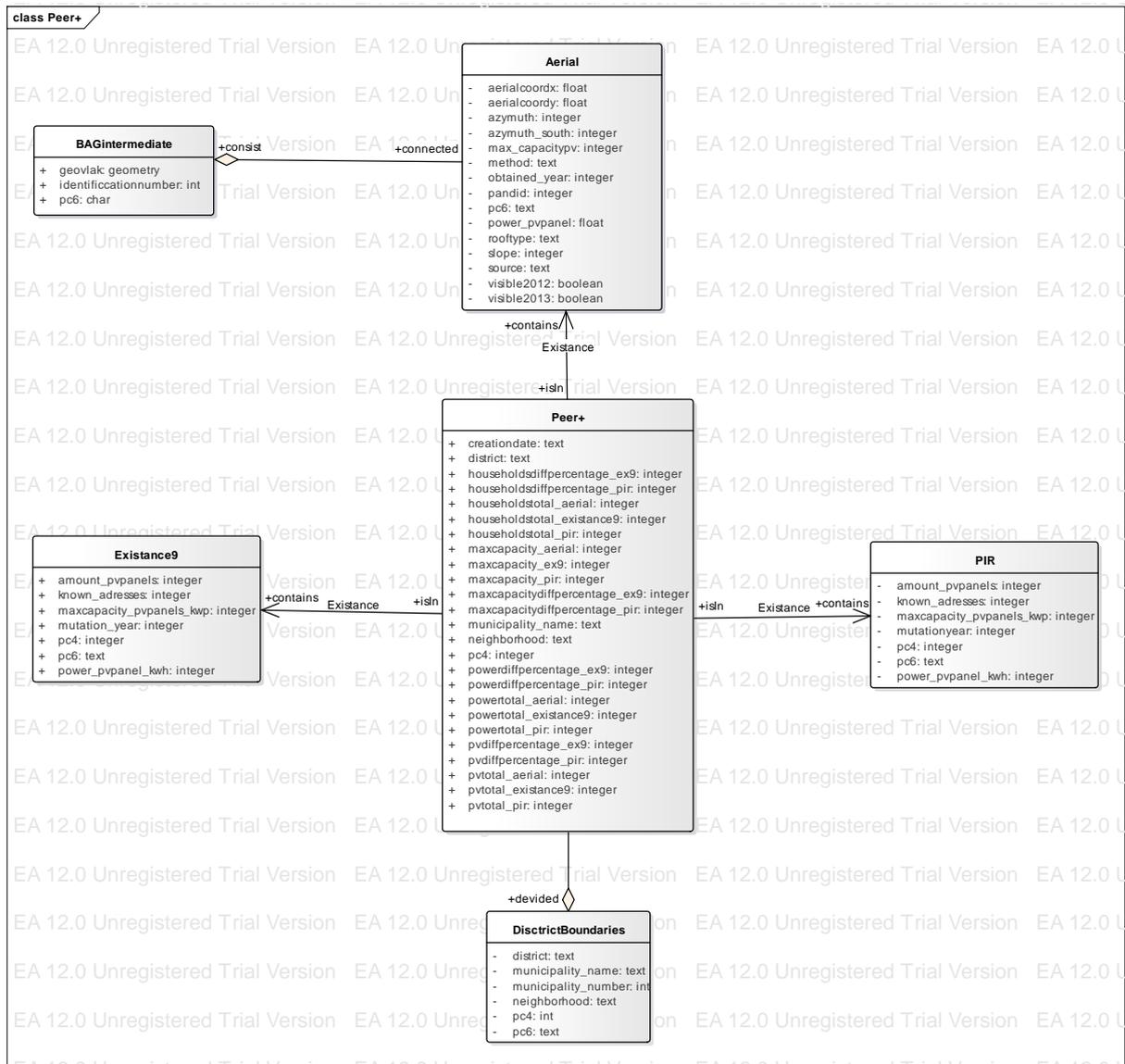


FIGURE 56: UML DIAGRAM PEER+

APPENDIX D - OTHER PV PANEL FORMS

Figure 57-60 illustrate other PV panel forms.



FIGURE 57: SEMITRANSSPARENT PV PANELS (SOLAR CONSTRUCTION, N.D.)



FIGURE 58: PV PANELS IN FORM OF ROOF FILES (ZONNEPANEELWIJZER, 2014)



FIGURE 59: PV PANELS IN FORM OF ROOF FILES (ZONNEPANEELWIJZER, 2014)



FIGURE 60: PV PANELS SHAPED LIKE A ROOF SHINGLE (GRANT, 2013)

APPENDIX E - DDL DIAGRAM PEER+

Figure 61 shows the DDL diagram of the Peer+.

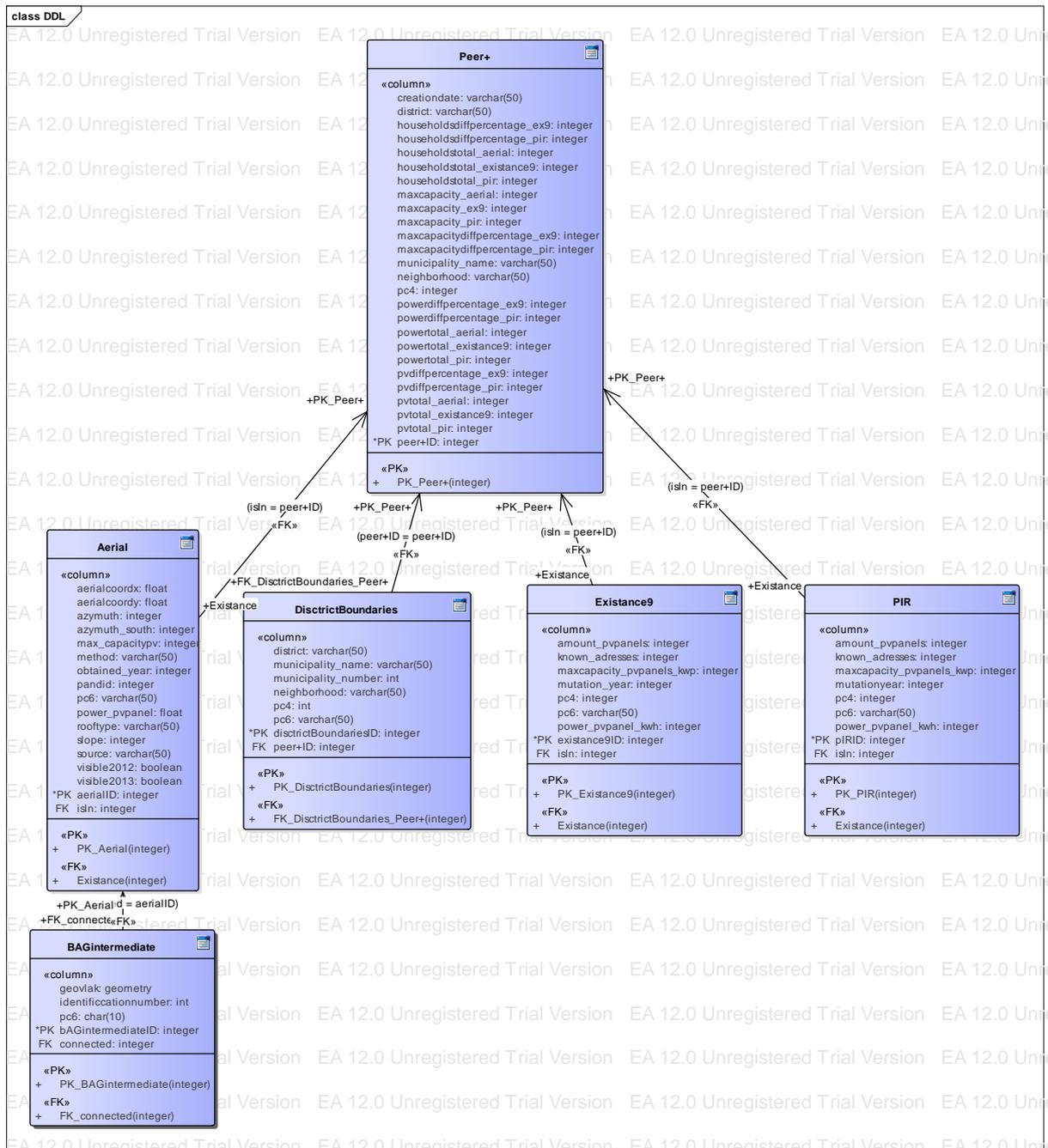


FIGURE 61: DDL DIAGRAM PEER+

APPENDIX F - SQL FILE FOR DATABASE CREATION

```
DROP TABLE IF EXISTS "aerial" CASCADE;
DROP TABLE IF EXISTS "bagintermediate" CASCADE;
DROP TABLE IF EXISTS "districtboundaries" CASCADE;
DROP TABLE IF EXISTS "existancenine" CASCADE;
DROP TABLE IF EXISTS "peerplus" CASCADE;
DROP TABLE IF EXISTS "pir" CASCADE;
```

```
CREATE TABLE "aerial"
```

```
(
    "aerialcoordx" character(100),
    "aerialcoordy" character(100),
    "azymuth_south" integer,
    "azymuth" integer,
    "rooftype" character(50),
    "slope" integer,
    "power_kwh" integer,
    "max_capacity_kwp" float,
    "pc6" character(6),
    "source" character(50),
    "obtained_year" integer,
    "pandid" character(16),
    "amount_households" integer,
    "visible2013" boolean,
    "visible2012" boolean,
    "method" character(50)
```

```
)
```

```
WITH (
```

```
    OIDS=TRUE
```

```
);
```

```
CREATE TABLE "bagintermediate"
```

```
(
    "identification_nr" character(16),
    "geovlak" geometry,
    "pc6" character(6)
```

```
)
```

```
WITH (
```

```
    OIDS=TRUE
```

```
);
```

```
CREATE TABLE "districtboundaries"
```

```
(
```

```

        "pc6" character(6),
        "pc4" integer,
        "municip_nr" integer,
        "municip_name" character(50),
        "district" character(50),
        "neighborhood" char(50)
    )
WITH (
    OIDS=TRUE
);

```

```

CREATE TABLE "existancenine"
(
    "amount_pvpanels" integer,
    "known_adresses" integer,
    "pc4" integer,
    "pc6" character(6),
    "max_capacity_pv_kwp" float,
    "power_pv_kwh" integer,
    "obtained_year" integer
)
WITH (
    OIDS=TRUE
);

```

```

CREATE TABLE "peerplus"
(
    "power_pv" float
)
WITH (
    OIDS=FALSE
);

```

```

CREATE TABLE "pir"
(
    "amount_pvpanels" integer,
    "known_adresses" integer,
    "pc4" integer,
    "pc6" character(6),
    "max_capacity_pv_kwp" float,

```

```
        "power_pv_kwh" integer,  
        "obtained_year" integer  
    )  
WITH (  
    OIDS=TRUE  
);
```

APPENDIX G - PEER+ TABLE SQL SCRIPT

```
DROP TABLE IF EXISTS tempnrpvae;
DROP TABLE IF EXISTS tempnrpvexnine;
DROP TABLE IF EXISTS tempnrpvpir;
```

```
DROP TABLE IF EXISTS tempaerial;
DROP TABLE IF EXISTS pvaerial;
DROP TABLE IF EXISTS pvexnine;
DROP TABLE IF EXISTS pvpir;
```

```
DROP TABLE IF EXISTS tempcapaae;
DROP TABLE IF EXISTS tempcapexnine;
DROP TABLE IF EXISTS tempcapapir;
```

```
DROP TABLE IF EXISTS temppowae;
DROP TABLE IF EXISTS tempowexnine;
DROP TABLE IF EXISTS tempowpir;
```

```
DROP TABLE IF EXISTS peerplus;
```

```
-----
-----
CREATE TEMPORARY TABLE tempnrpvae AS (
```

```
    SELECT districtboundaries.neighborhood, count(aerial.oid) AS
    pvtotal_aerial
    FROM aerial, districtboundaries
    WHERE aerial.pc6=districtboundaries.pc6
    GROUP BY districtboundaries.neighborhood
    ORDER BY districtboundaries.neighborhood
```

```
);
```

```
CREATE TEMPORARY TABLE tempnrpvexnine AS (
```

```
    SELECT districtboundaries.neighborhood,
    sum(existancenine.amount_pvpanels) AS pvtotal_exnine
    FROM existancenine, districtboundaries
    WHERE existancenine.pc6=districtboundaries.pc6
    GROUP BY districtboundaries.neighborhood, districtboundaries.pc4
    ORDER BY districtboundaries.neighborhood
```

```
);
```

```
CREATE TEMPORARY TABLE tempnrpvpir AS (
```

```
    SELECT districtboundaries.neighborhood, sum(pir.amount_pvpanels) AS
    pvtotal_pir
    FROM pir, districtboundaries
    WHERE pir.pc6=districtboundaries.pc6
    GROUP BY districtboundaries.neighborhood, districtboundaries.pc4
    ORDER BY districtboundaries.neighborhood
```

```
);
```

```
-----
-----
CREATE TEMPORARY TABLE tempaerial AS (
```

```

SELECT districtboundaries.municip_name, districtboundaries.district,
districtboundaries.neighborhood, districtboundaries.pc4,
aerial.pandid, aerial.amount_households
FROM aerial, districtboundaries
WHERE aerial.pc6=districtboundaries.pc6
GROUP BY districtboundaries.municip_name,
districtboundaries.district, districtboundaries.neighborhood,
districtboundaries.pc4, aerial.pandid, aerial.amount_households
ORDER BY districtboundaries.neighborhood

);

CREATE TEMPORARY TABLE pvaerial AS (

SELECT municip_name, district, neighborhood, pc4,
SUM(amount_households) AS householdstotal_aerial
FROM tempaerial
GROUP BY municip_name, district, neighborhood, pc4

);

CREATE TEMPORARY TABLE pvexnine AS (

SELECT districtboundaries.neighborhood, districtboundaries.pc4,
SUM(ex.known_adresses) AS householdstotal_existancenine
FROM existancenine AS ex, districtboundaries
WHERE ex.pc6=districtboundaries.pc6
GROUP BY districtboundaries.neighborhood, districtboundaries.pc4
ORDER BY districtboundaries.neighborhood

);

CREATE TEMPORARY TABLE pvpir AS (

SELECT districtboundaries.neighborhood, districtboundaries.pc4,
SUM(pir.known_adresses) AS householdstotal_pir
FROM pir, districtboundaries
WHERE pir.pc6=districtboundaries.pc6
GROUP BY districtboundaries.neighborhood, districtboundaries.pc4
ORDER BY districtboundaries.neighborhood

);

-----
-----

CREATE TEMPORARY TABLE tempcapaae AS (

SELECT districtboundaries.neighborhood, SUM(aerial.max_capacity_kwp)
AS capacitytotal_aerialkwp
FROM aerial, districtboundaries
WHERE aerial.pc6=districtboundaries.pc6
GROUP BY districtboundaries.neighborhood
ORDER BY districtboundaries.neighborhood

);

CREATE TEMPORARY TABLE tempcapexnine AS (

SELECT districtboundaries.neighborhood,
SUM(existancenine.max_capacity_pv_kwp) AS capacitytotal_exninekwp
FROM existancenine, districtboundaries
WHERE existancenine.pc6=districtboundaries.pc6

```

```

GROUP BY districtboundaries.neighborhood, districtboundaries.pc4
ORDER BY districtboundaries.neighborhood

);

CREATE TEMPORARY TABLE tempcapapir AS (

SELECT districtboundaries.neighborhood, SUM(pir.max_capacity_pv_kwp)
AS capacitytotal_pirkwp
FROM pir, districtboundaries
WHERE pir.pc6=districtboundaries.pc6
GROUP BY districtboundaries.neighborhood, districtboundaries.pc4
ORDER BY districtboundaries.neighborhood

);

```

```

-----
-----

```

```

CREATE TEMPORARY TABLE temppowae AS (

SELECT districtboundaries.neighborhood, SUM(aerial.power_kwh) AS
powertotal_aerialkwh
FROM aerial, districtboundaries
WHERE aerial.pc6=districtboundaries.pc6
GROUP BY districtboundaries.neighborhood
ORDER BY districtboundaries.neighborhood

);

```

```

CREATE TEMPORARY TABLE tempowexnine AS (

SELECT districtboundaries.neighborhood,
SUM(existancenine.power_pv_kwh) AS powertotal_exninekwh
FROM existancenine, districtboundaries
WHERE existancenine.pc6=districtboundaries.pc6
GROUP BY districtboundaries.neighborhood, districtboundaries.pc4
ORDER BY districtboundaries.neighborhood

);

```

```

CREATE TEMPORARY TABLE tempowpir AS (

SELECT districtboundaries.neighborhood, SUM(pir.power_pv_kwh) AS
powertotal_pirkwh
FROM pir, districtboundaries
WHERE pir.pc6=districtboundaries.pc6
GROUP BY districtboundaries.neighborhood, districtboundaries.pc4
ORDER BY districtboundaries.neighborhood

);

```

```

-----
-----

```

```

SELECT

pvaerial.municip_name,
pvaerial.district,
pvaerial.neighborhood,

pvaerial.pc4,tempnrpvae.pvttotal_aerial,
tempnrpvexnine.pvttotal_exnine,

```

```

tempnrpvpir.pvttotal_pir,
ROUND((tempnrpvae.pvttotal_aerial-
tempnrpvexnine.pvttotal_exnine)*100/tempnrpvae.pvttotal_aerial::float)
as pvpercentage_not_ex9,
ROUND((tempnrpvae.pvttotal_aerial-
tempnrpvpir.pvttotal_pir)*100/tempnrpvae.pvttotal_aerial::float) as
pvpercentage_not_pir,

pvaerial.householdstotal_aerial,
pvexnine.householdstotal_existancenine,
pvpir.householdstotal_pir,
ROUND((pvaerial.householdstotal_aerial-
pvexnine.householdstotal_existancenine)*100/pvaerial.householdstotal_
aerial::float) as householdspercentage_not_ex9,
ROUND((pvaerial.householdstotal_aerialpvpir.householdstotal_pir)*100/
pvaerial.householdstotal_aerial::float) as
householdspercentage_not_pir,

ROUND(tempcapaae.capacitytotal_aerialkwp::NUMERIC,1) AS
capacitytotal_aerialkwp,ROUND(tempcapexnine.capacitytotal_exninekwp::
NUMERIC,1) AS capacitytotal_exninekwp,
ROUND(tempcapapir.capacitytotal_pirkwp::NUMERIC,1) AS
capacitytotal_pirkwp,
ROUND((tempcapaae.capacitytotal_aerialkwp-
tempcapexnine.capacitytotal_exninekwp)*100/tempcapaae.capacitytotal_a
erialkwp) as capacitypercentage_not_ex9,
ROUND((tempcapaae.capacitytotal_aerialkwp-
tempcapapir.capacitytotal_pirkwp)*100/tempcapaae.capacitytotal_aerial
kwp) as capacitypercentage_not_pir,

temppowae.powertotal_aerialkwh,
tempowexnine.powertotal_exninekwh,
temppowpir.powertotal_pirkwh,
ROUND((temppowae.powertotal_aerialkwh-
tempowexnine.powertotal_exninekwh)*100/temppowae.powertotal_aerialkwh
::float) as powerpercentage_not_ex9,
ROUND((temppowae.powertotal_aerialkwh-
temppowpir.powertotal_pirkwh)*100/temppowae.powertotal_aerialkwh::flo
at) as powerpercentage_not_pir

        INTO peerplus

```

FROM

```

pvaerial,
pvexnine,
pvpir,
tempnrpvae,
tempnrpvpir,
tempnrpvexnine,
tempcapaae,
tempcapexnine,
tempcapapir,
temppowae,
tempowexnine,
temppowpir

```

WHERE

```

pvaerial.neighborhood=pvexnine.neighborhood AND
pvaerial.neighborhood=pvpir.neighborhood AND
pvaerial.neighborhood=tempnrpvae.neighborhood AND

```

pvaerial.neighborhood=tempnrpvpir.neighborhood AND
pvaerial.neighborhood=tempnrpvexnine.neighborhood AND
pvaerial.neighborhood=tempcapaae.neighborhood AND
pvaerial.neighborhood=tempcapexnine.neighborhood AND
pvaerial.neighborhood=tempcapapir.neighborhood AND
pvaerial.neighborhood=temppowae.neighborhood AND
pvaerial.neighborhood=tempowexnine.neighborhood AND
pvaerial.neighborhood=temppowpir.neighborhood

APPENDIX H - MAP SCRIPT HTML

```
<!DOCTYPE html>
<html>
  <head>
    <style>
      #map-canvas { width:1000px; height:700px; }
      .layer-wizard-search-label { font-family: sans-serif };
    </style>
    <script type="text/javascript"
      src="http://maps.google.com/maps/api/js?sensor=false">
    </script>
    <script type="text/javascript">
      var map;
      var layer_0;
      var layer_1;
      function initialize() {
        map = new google.maps.Map(document.getElementById('map-
canvas'), {
          center: new google.maps.LatLng(52.15269346976416,
4.45181222557538),
          zoom: 18
        });
        var style = [
          {
            featureType: 'all',
            elementType: 'all',
            stylers: [
              { saturation: -80 }
            ]
          }
        ];
        var styledMapType = new google.maps.StyledMapType(style, {
          map: map,
          name: 'Styled Map'
        });
        map.mapTypes.set('map-style', styledMapType);
        map.setMapTypeId('map-style');
        layer_0 = new google.maps.FusionTablesLayer({
          query: {
            select: "col0",
            from: "1Q8BRR8_3e7VINQ3DpWE1x2C0nUFgpWlt6UHcoNWu"
          },
          map: map,
          styleId: 2,
          templateId: 2
        });
        layer_1 = new google.maps.FusionTablesLayer({
          query: {
            select: "col0",
            from: "1u6DyK0mgf330rVLQ1FtwjgMqbLgcpABpmbAZTQin"
          },
          map: map,
          styleId: 2,
          templateId: 2
        });
      }
    </script>
  </head>
  <body>
    <div id="map-canvas">
    </div>
  </body>
</html>
```

```
    google.maps.event.addDomListener(window, 'load', initialize);  
</script>  
</head>  
<body>  
  <div id="map-canvas"></div>  
</body>  
</html>
```