Sustainable energy in de Veenkoloniën

Communicating rooftop solar potential

Commissioners:
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GRS 60312 - Remote Sensing and GIS Integration

ANALYSIS REPORT

Energie bureau VEENKOLONIËN

KENNISwerkplaats Veenkoloniën

Energy Consultancy Team

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Summary

As public and political forces are winding around the issue of sustainable energy in the area of Gasselternijveenschemond there is a strong need for clear communication of the potential of these energy sources for individual villagers. We propose the development and publication of a Web-Map Application to be used by the Energy Team and the village council both online and in the information PR Van.

Goals of application
The application's primary function is to (a) visualize and (b) communicate the potential for Photovoltaic (PV) panels within Gasselternijveenschemond. It accomplishes this by providing users an overview of their zoning plot within which the application will show the following information:

- Estimated total suitable roof area available for PV Panels
- Estimation of number of panels
- Estimated Initial costs of installation
- Estimated yearly return
- Estimated break-even point

Viewable data layers:

- Solar potential layer (focussing on sustainability)
- break-even point layer (focussing on monetary output)
- Base map (Searchable)

Auxiliary data:

- Prices of energy measures

This analysis report will cover the data requirements, details for implementation (publishing) and an evaluation of data sources, data quality and geospatial techniques.

Contents

1. Introduction

Though energy production has long been an important economic driver in the area of the Veenkoloniën, currently public opinions are highly divergent. *Energie Bureau Veenkoloniën* started a pilot in 2013 to aid in the processes of creating awareness and to form a stronger civic society. Its primary model of achieving this is by public participation with the villagers in the area in collaboration with *Kenniswerkplaats Veenkoloniën,* a joint knowledge platform consisting of students and project teams of *AOC Terra, Van Hall Larenstein and Wageningen University and Research Center.* Among the combined activities are the setup of an Energy plan *(Dorpsenergieplan)* for the village of Gasselternijveenschemond (in collaboration with *Dorps Energie Team*), regular public meetings including a touch table meeting in which villagers could visualize sustainable energy potential, and the plan to create a PR Van to inform villagers on the benefits of sustainable energy solutions.

This project is framed on the lessons learned during meetings and aims to form the first step towards a greater public awareness in local energy production opportunities. The application builds on the idea that by providing users an easy to understand interface the interest in starting energy production by photovoltaic panels mounted on the roofs will become tangible and clear. With this tool, able to use in the PR Van, people are able to see and evaluate the potential of their roofs for solar panels without the need of deeper knowledge about technical aspects.

Problem Definition

Within the village council meetings a strong desire to create awareness on matters concerning energy consumption reduction and sustainable production has been expressed and several initiatives have been set out. More specifically they aim to reduce energy consumption in the area by combining reductive measures with local sustainable production methods. These desires, stems primarily from the notion that the area has always played a big part within the Dutch energy production network. The village council and Energie Bureau expressed the ambition of becoming a public example of community participation leading to measurable changes in energy consumption patterns. Parallel to the issue of reduction of energy consumption at the individual villager's level the province is invested in several large scale energy production projects in the form of the development of wind turbines. Based on the commissioner's reporting this leads to a negative public opinion in sustainable energy. In other words *"Nimby"* processes are strongly at play here. The problem is thus defined as follows:

> *In aid of generating public support there is a lack of conveying geospatial representations of energy reduction options in the Veenkoloniën area.*

Concerning the use of geospatial data for communication of sustainability measures the touch surface project was successful. Due to its physical properties it failed to reach a large audience though. It is our opinion that the basic premise of visualizing the opportunities for sustainable energy solutions is the correct way to enthuse and inform users. If a bigger audience is to be reached, local functioning should be assured so that it can be used at any time and place at the user's convenience.

Objective

Since the village council's problem is well defined and no moral or scientific objections can be raised, the main objective of this project is to aid in their goal of communicating energy reduction potential in conformity with their request. By using a web application to visualize and communicate potential for energy reduction and production within a user's own living area the options become not only more tangible, the first step towards actually implementing them is then already made. In addition to the development of the web application the quality and implications of the required data layers and geospatial techniques will be analyzed. The ArcGis Models that were used for data (pre-) processing will also be delivered in order to have a repeatable outcome for future use.

Project Team

The Energy Consultancy Team is composed of four first year Master Geo-Information Science students. Because of their different backgrounds, their knowledge and skills are diverse, ranging from social and environmental sciences, to mapmaking, and energy infrastructure.

Jeroen Schilleman	*(Project manager)* Is a BSc in Human Geography & Urban Planning. Highly interested in 3D/GIS visualizations, analyses, and mapmaking of the built environment.
Georgios Anastasiou	*(Secretary)* Is an MSc in “Environmental and Ecological Engineering” and BSc in “Structural/Civil Engineering”. Highly interested in constructions' environmental impact, renewable energy and GIS visualization.
Samantha Martín del Campo Muñoz	*(Operator)* Is a BSc in Environmental Engineering. Highly interested in GIS visualization, map making, web app development, and renewable energies.
Hans Nienhuis	*(Project worker)* Is a BSc in Soil, Water, Atmosphere. Grew up at a farm in the Veenkoloniën, known with the area and local culture. Interested in technical and organizational aspects of energy grids.

2. Application

Development of Web-Map

Functionality

This application is intended to work as a communication tool for the solar potential of the area and consist of two parts: a tutorial where it functionality is explained and an interactive part where PV panels potential are evaluated. Figure 1 shows a diagram of its principal components.

Figure 1. Application functionality

The tutorial consist of five steps, including a welcome window, directions for address search, clickable buildings, and layer selection, the final window redirects to the interactive part and contact information. Interactive elements retrieve information using SQL, clicking on a house. This way the user can get information for a specific roof. Building data can be assessed in two layers: roof potential, and break-even time, these map layers can be switched on and off. Roof potential layer shows building divided in classes according to their suitability for PV panels (based on incoming radiation). Classes are defined as low, medium and high potential. The Break-even time layer displays buildings according to their estimated investment payback in years. Both layers contain information on: Annual MWh production, annual yield at high and low scenarios, break-even point, PV panels surface area, number of panels, and their installation costs. Building polygons were constructed based on the AHN2 data with an accuracy of 0.25 m^2 and cadastral data.

Cross platform functionality

The application is browser based so it runs on all platforms, desktop, tablet, and mobile phones. The tutorial however does not run well on mobile phones due to the size of the interface elements. The application has been tested to work on these platforms:

Desktop/Laptop[1]

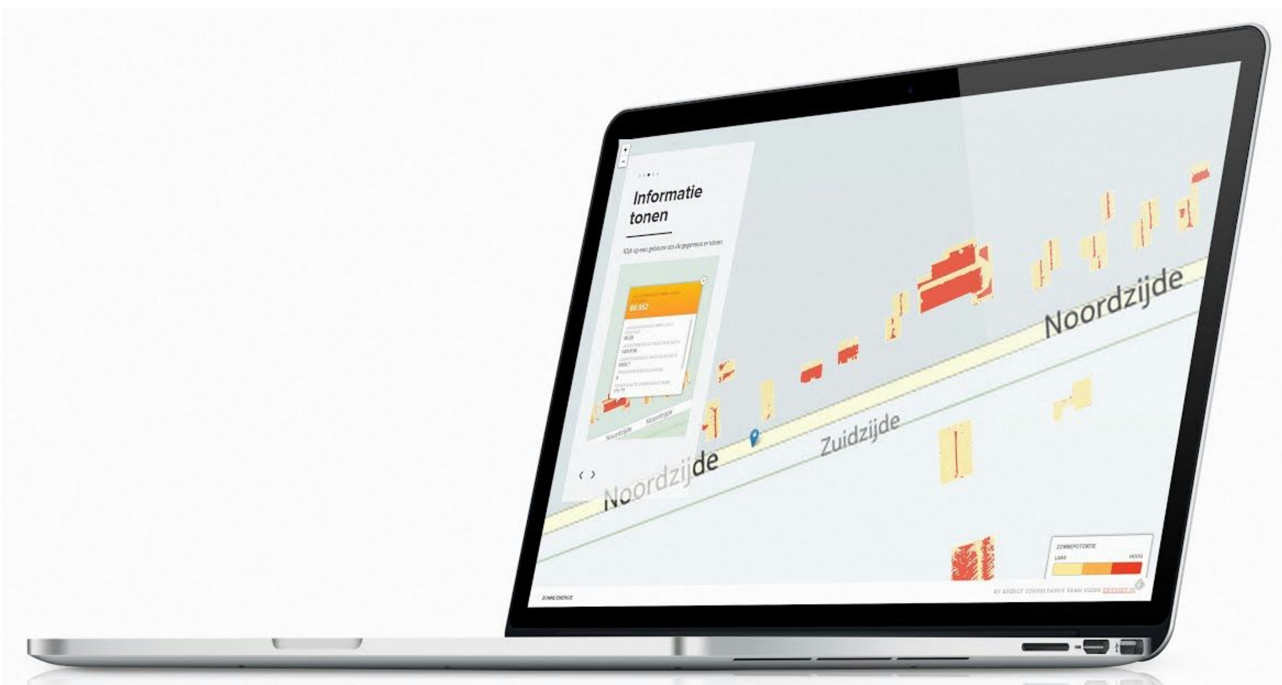

Figure 2. Tutorial running on a laptop (mockup)

Tablet[2]

[1] Google chrome, Internet Explorer and Firefox tested
[2] Android and iOS tested

Figure 3. Application running on an Google Nexus 9 (mockup)

Mobile[3]

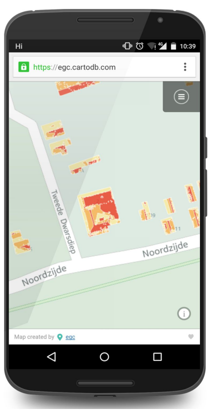

Figure 4. Application in a mobile

[3] Android and iOS tested

Web map publishing benchmark

Before choosing a publishing service several services have been tested for suitability within this project. In this paragraph a short overview of these services will be provided as well as a short description of the pro's and con's per service.

Main requirements of the web-mapping service are defined as follows:

- Free or inexpensive (€0-500,-/yr)
- User friendly environment on the admin side (uploading and editing of data and visualization relatively simple)
- Good looking graphics/visualizations on the user's side
- Low/no maintenance and future proof

ESRI ArcGIS Online

ESRI's ArcGIS Online was the first web-publishing service that was tried. Though this application suite allows nice mapmaking and contains easy to use storytelling tools. Using it might be quite simple for Wageningen University's students, since they get provided with a free academic, one year, licence. Although, for purposes outside university the terms are totally different and there is the need for planning ahead of the costs for the service and the hosting. A very important variable, the pricing plans with their unclear credit system, are the main reason to opt-out of this package.

Mangomap

Mangomaps was the first alternative to ArcGIS Online in our research. Though it looked promising the pricing lead us to search further. There are many integrated maps and datasets by region that can be used in combination with almost any datasets you have. The services it provides are quite good and it is relatively cheap to maintain your content.

Mapbox

Mapbox is a web mapping service. It is scalable, cheap, and open source. However, it is not as fully fledged as CartoDB, and thus it will need to be combined with other services in order to have the functionality necessary for this project. It lacks some of the more powerful data management and analysis tools that are essential. The framework is limited in that it only contains basemaps. The integration with other packages is possible but it is also complicated and more prone to errors. Given the limited time provided for the project, there was the need decided to move on and try an other solution.

CartoDB (used in combination with Odyssey.js)

CartoDB is a web-based environment and features a geospatial database. The components are handled by PostGIS (spatial database extender for open source PostgreSQL object-relational database) in the cloud, while the collaboration, visualization and analysis aspects can be presented simply and attractive in a web interface. The easy to use and nearly complete interface is what it provides. The key features are:

- It allows a fully integrated data management and mapmaking environment
- No costs are involved in the process. There is, a 50mb for free, limit which is plenty enough for this project. Only 5mb of data are in use currently.
- Odyssey.js was used to create the attractive and dynamic tutorial part with a quite .
- Future visualization are allowed, even with interactive graphs. This integration can be done with plotly/vizion.js.
- For the moment the only shortcoming was the inability of importing raster data.

Because of these features and the less important or lack of shortcomings, CartoDB was the choice for this web map Application.

3. Data and processing

Our goal was to create a generalized methodology to calculate the solar potential for each roof for the Gasselternijveenschemond village, based on panels specifications (SolarNRG, 2015 and CanadianSolar, 2015). Calculations try to obtain the highest accuracy possible beside generalization. Figure 5 represent an overview of the methodology used.

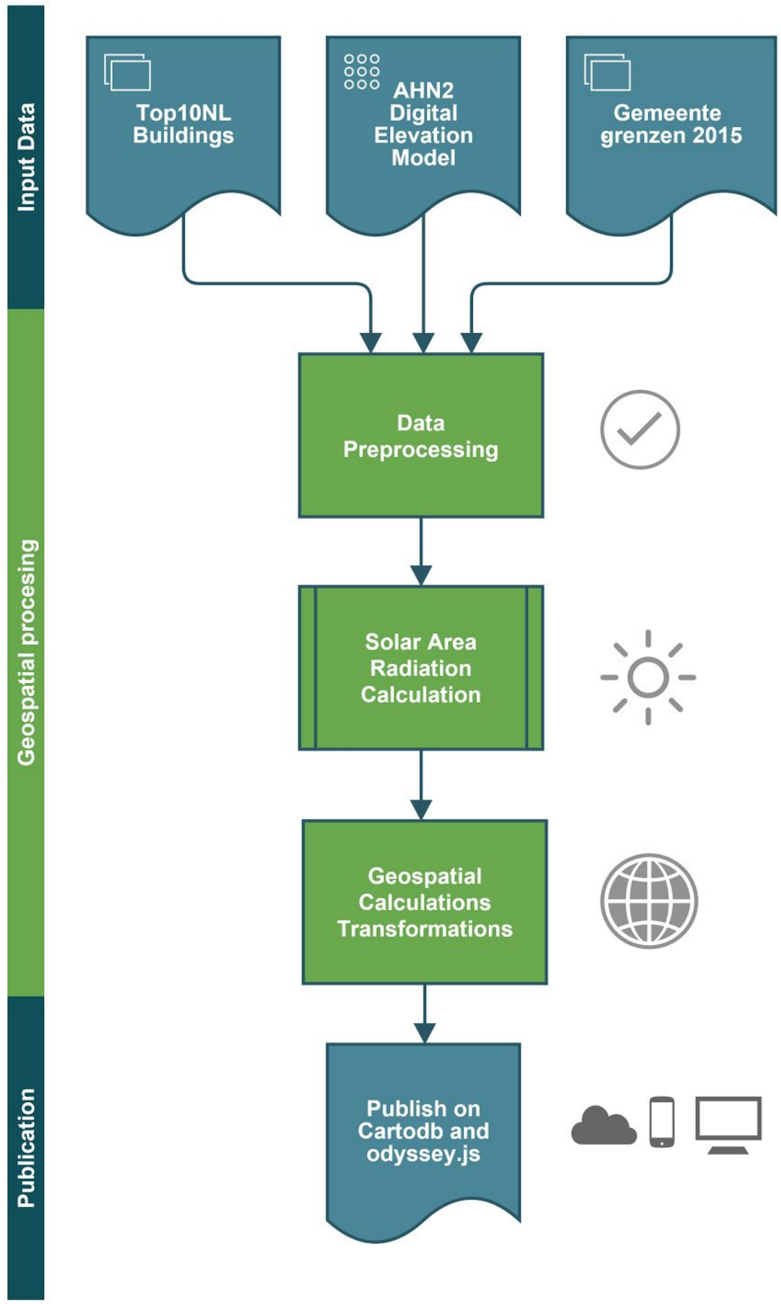

Figure 5. Overview of complete workflow

Geospatial Data Layers

Algemeen Hoogtebestand Nederland versie 2 (AHN2)
The *Actueel Hoogtebestand Nederland* (AHN) is a highly accurate elevation map which covers the complete area of The Netherlands. Since 2014 height data is available as open source and can be download via PDOK and can be used without any restrictions. Elevation data is produced through laser altimetry, a laser beam scan a surface from a plane and measures height. Dataset is obtained as a raster with a pixel resolution of 0.5 m.

Type	point cloud
Resolution	0.5 m
Extent	whole Netherlands
Coordinate System	RD New
Actuality and release	march 05, 2014
Contact information	beheerPDOK@kadaster.nl
Metadata contact	beheerPDOK@kadaster.nl
User restrictions	Free for public use and also for application in commercial use.
Licence	Public domain, licensed via a Creative Commons CC0 license.

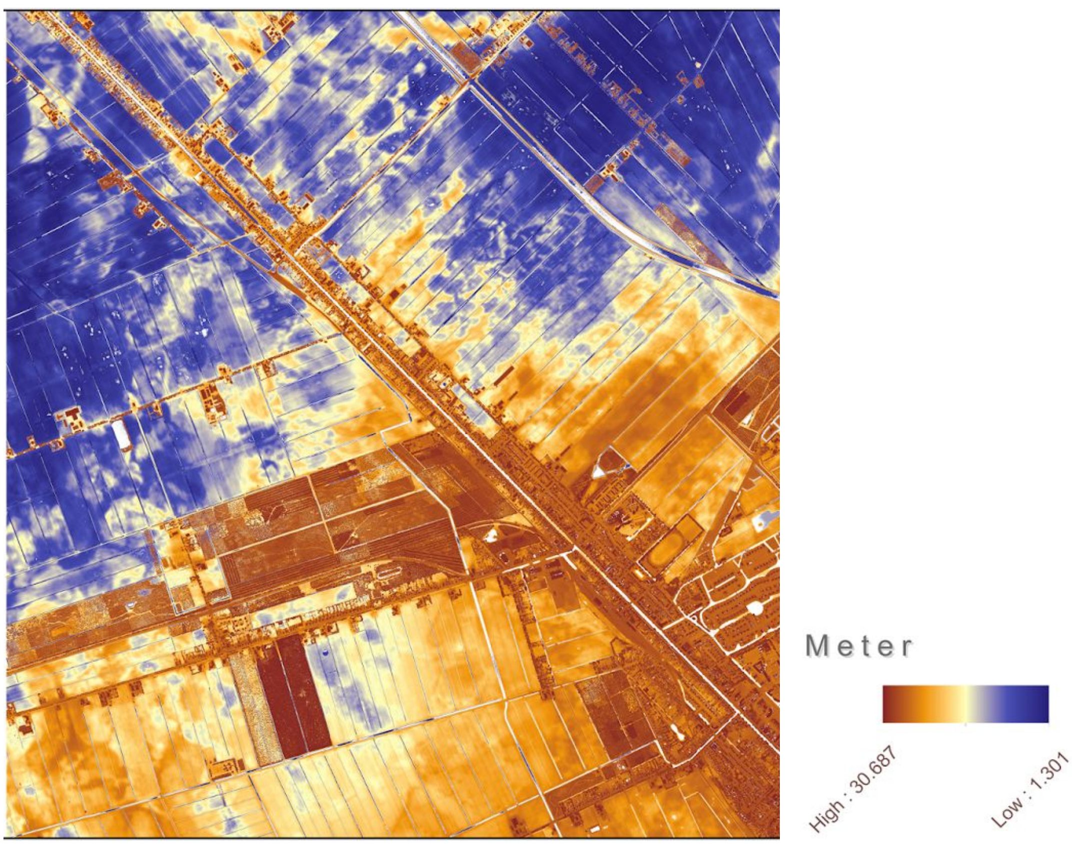

Figure 6. AHN2 DEM of Gasselternijveenschemond and surroundings

Top10NL

The digital topographic dataset, generated by *Kadaster*, was developed from aerial photographs, field measurements and external information. TOP10NL is available at scales between 1:5,000 and 1:25,000, covers the complete area of The Netherlands and includes anthropogenic objects, registrative, geographical and functional areas. Buildings of the habitational zone of Gasselternijveenschemond (Gebouw Polygon dataset), were used in the application.
The dataset is an open data and was download via PDOK.

Type	Vector
Resolution	vector (use-interval between 1:5000 and 1:50.000)
Extent	whole Netherlands
Coordinate System	RD New
Actuality and release	april 01, 2015 (most recent version)
Contact information	kcc@kadaster.nl
Metadata contact	kcc@kadaster.nl
User restrictions	Free for public use and also for application in commercial use.
Licence	Public domain, licensed via a Creative Commons CC0 license.

Gemeentegrenzen 2015

The Gemeentegrenzen 2015 file is a layer file showing all municipal borders in the Netherlands as they were at January 01, 2015. The layer is made by ESRI by using open data of the Kadaster, ImerGIS and CBS and can be downloaded and used in both desktop- and online GIS-tools and applications. It is important to note, that since the file is created by using open data, it can not be legal guaranteed that all borders are completely correct.

Type	Feature Service layer
Resolution	(vector)
Extent	Whole Netherlands
Coordinate System	RD New
Actuality and release	January 01, 2015
Contact information	content@ESRI.nl
Metadata contact	content@ESRI.nl
User restrictions	Free for public use and indicative use in other applications.
Licence	Public domain, licensed via a Creative Commons 3.0

Data preprocessing

Data preprocessing has been performed with ESRI's ArcMAP version 12.2.1. For repeatability the applied tools and procedures are described here.

ArcGIS models have three main components (Figure 7):

Blue ellipses correspond to project datasets or features, previously stored in a connected folder.
Yellow boxes represent tools, which modify data or generate derived data.
Green ellipses represent derived data, the result of a tool.

Figure 7. ArcGIS diagram properties

Data layers have different extent and coordinate system, in order to reduce computation time and projection errors all data sets were clipped to Gasselternijveenschemond and projected to RD New.

Model 1 (Figure 8, p.14) was used to modify the Coordinate System of AHN units to RD NEW. The polygon that defines Gasselternijveenschemond extent was selected and intersected with the AHN units to obtain only the unit that contain information about the community. Gebouw Polygon data was selected from the TOP10NL, and cropped to Gasselternijveenschemond boundaries. Model 2 (Figure 9, p.15) was used to reduce AHN2 extent to Gasselternijveenschemond boundaries.

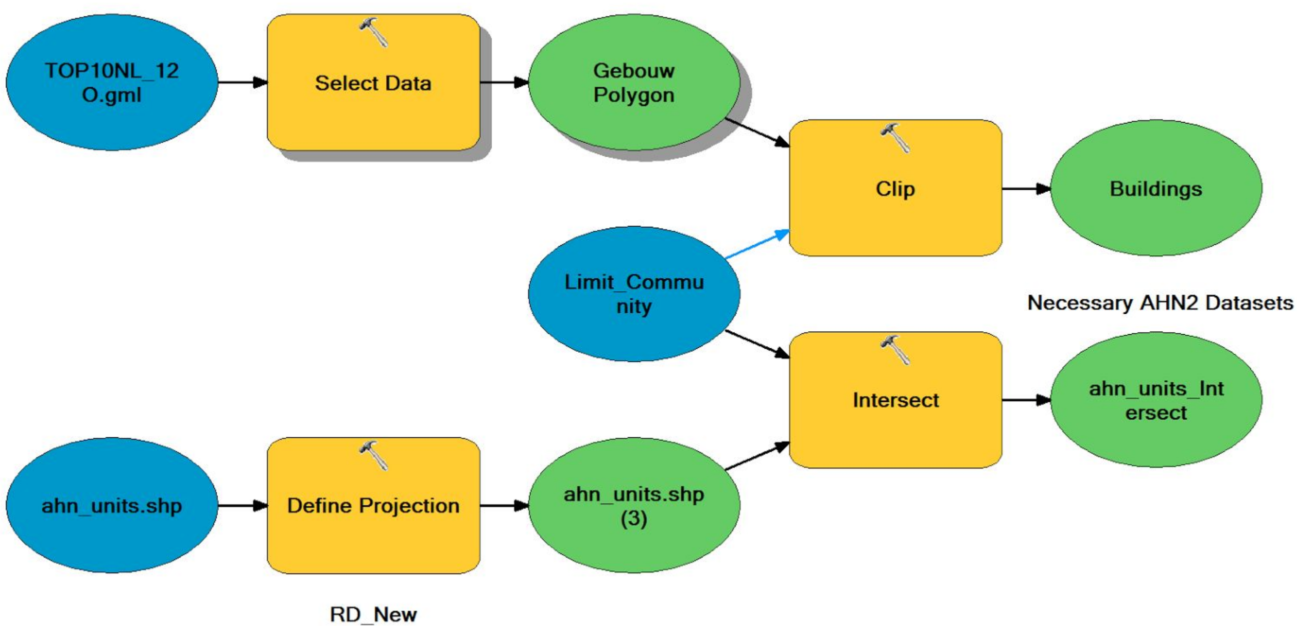

Figure 8.ArcGIS Model 1: Select area of interest

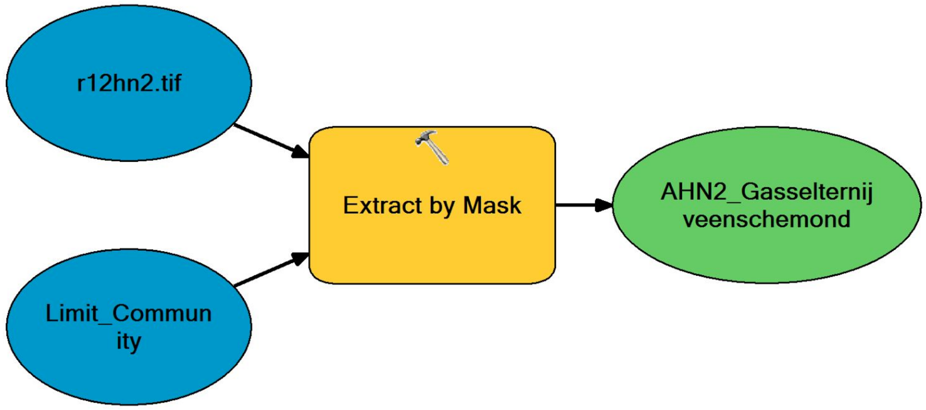

Figure 9. ArcGIS Model 2: Clip data to required extent

Geospatial transformations and techniques

Solar area calculation

Knowledge of the expected incoming energy is important in calculating the theoretical maximum yield of solar panels. Radiation consists of direct and diffuse radiation, which together add up to the total shortwave radiation budget. The solar angle relative to the facing side of the intercepting object depends primarily on astronomical parameters such as latitude and time of day. It is complicated by obstruction and diffusion of radiation by objects such as hills, trees, and buildings, and meteorological variables like clouds and snow cover (Fu and Rich, 2000). The sum of both diffuse and direct shortwave radiation form the total energy that can be used by solar panels to produce electricity. In calculating the yield of solar panels, technical specifications and limitations of the panels have to be combined with the calculation of incoming solar radiation. To calculate incoming solar radiation the ArcGIS tool area solar radiation is applied to the AHN2 DEM.

The Area Solar Radiation tool requires a set of inputs in order to calculate the sum radiation in a mathematical way given a certain time step length. A georeferenced Digital Elevation Model (DEM) as a raster file is taken as input to take slope and aspect relative to the north-south into account. To this raster the calculation is applied. Essential are the astronomical parameters latitude, time and day of the year. Time step resolution and the duration of the period of interest is set to obtain results like sum, average and trend. The albedo of the surrounding landscape and the transmissivity of the atmosphere are set and finally, the ratio between direct and diffuse radiation is given in.
Table 1 and Figure 10 give an overview of the most important parameters (and their units) that need to be set in order to calculate the incoming radiation.

Table 1. Overview of the most important parameters for the area solar radiation tool

Input parameter	Unit	Short description
Latitude	Degree	Latitude on the Earth surface relative to the equator
Sky factor	-	Part of the sky hemisphere expected suitable as radiation source
Time and date	Year, day, hour	Duration of the period for which the calculation goes
Calculation direction	Discrete	Number of positions from where the incoming radiation is traced
Diffusivity	Fraction	Ratio between direct and diffuse radiation
Transmissivity	Fraction	Part of the radiation passing through the atmosphere
Diffuse model	Choice	Choose between a proposed clear sky or an overcast sky

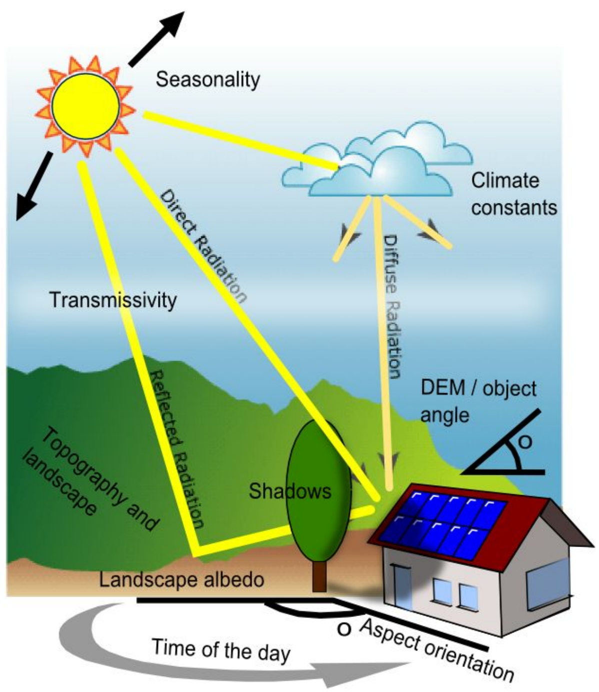

Figure 10. Overview of all radiation fluxes taken into account in the solar area calculation

The calculation method consists of ray tracing, for each pixel the sun's radiation is determined. Processing time is limited by computer calculation power and influenced by DEM and temporal resolution. The grid cell size of the OHN2 DEM, used as input, is 0.5 meter. For purposes like calculating suitable roof area and yield, 0.5 meter is sufficient. A more coarse resolution like 1.5 or 2.0 meters would result in erroneous cells at the borders of the roofs. A finer resolution, for example 0,25 m, would multiply the calculation time with a factor of four. In any case sufficient calculation power is necessary to stay within reasonable limits. The resolution of 0.5m allows to identify relatively small buildings and (to some extent) roof inclination, aspect, and shape and is thus sufficient.

The accuracy of this calculation is lowered by trees casting shadows over the roofs. The AHN2 DEM is made by using full waveform LiDARs (Kwaliteitsdocument AHN versie 1.3, 2013), but in order to reduce data size and processing, it is primarily delivered as a single value per pixel grid. Trees and other partial transparent objects such as greenhouses, pylons and bridges are considered as opaque. In reality, a tree is partially transparent to sunlight depending on the tree species and (in deciduous trees) also the seasonality. In this calculations, this transparency is not taken into account. Raster data is produced as output of the tool, with units of Wh/m2.
Finally radiation was computed based on the complete DEM (Gasselternijveenschemond extent) to avoid interference of vegetation and other anthropogenic structures. Table 2 indicate specified parameters used for Area Solar Radiation tool.

Table 2. Overview of the Solar area tool parameters using ArcGIS 10.2

Parameter	Setting	Remarks
Modeltime	One year	
Interval	0.5 hour	
DEM resolution	0.5 m	
Geographical area	~1.5 km2	According to the zoning plan
CPU used	Intel i5 3570k	
Processing time	~ 72 hours	

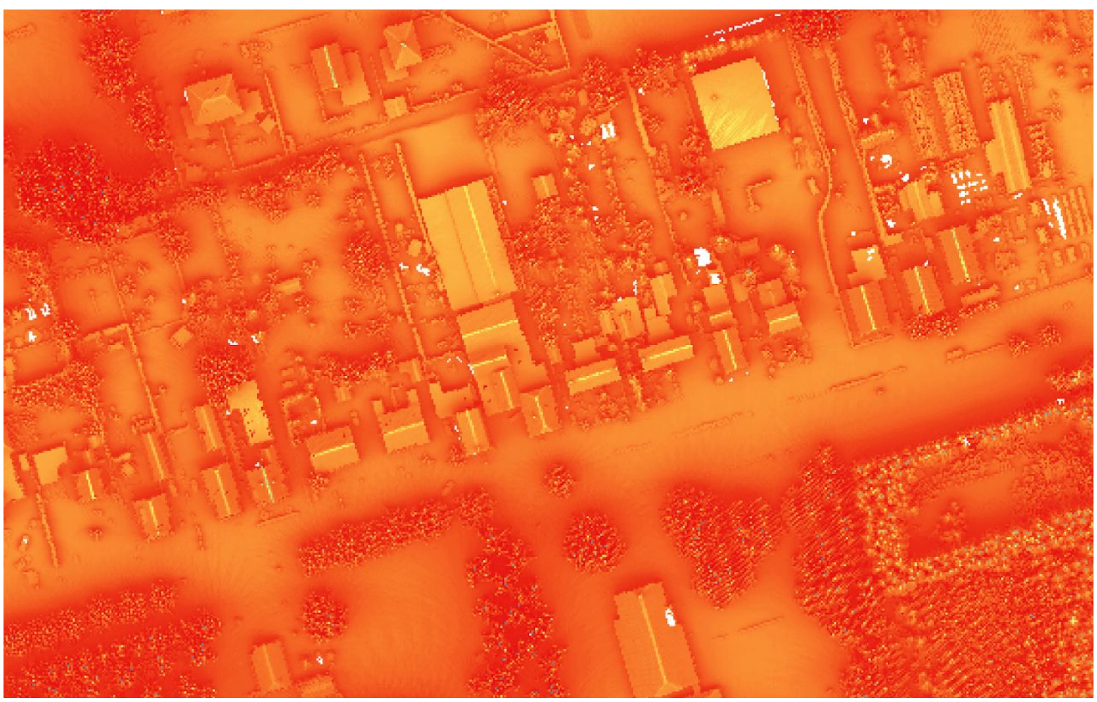

Figure 11. Solar area calculation results for Gasselternijveenschemond

Roof area calculation

Model 4 (Figure 12) uses the AHN2 DEM and the building polygon from TOP10NL. From the AHN2 DEM the buildings were clipped (extract by mask). Then Roof slopes are calculated. This delivers the slope of each roof, calculated as an average value for each individual building. As there are no negative value of slope values, a gabled roof can be assumed (Figure 13). The assigned value represents the average slope from its sides. Model result was stored as Building_Slope dataset.

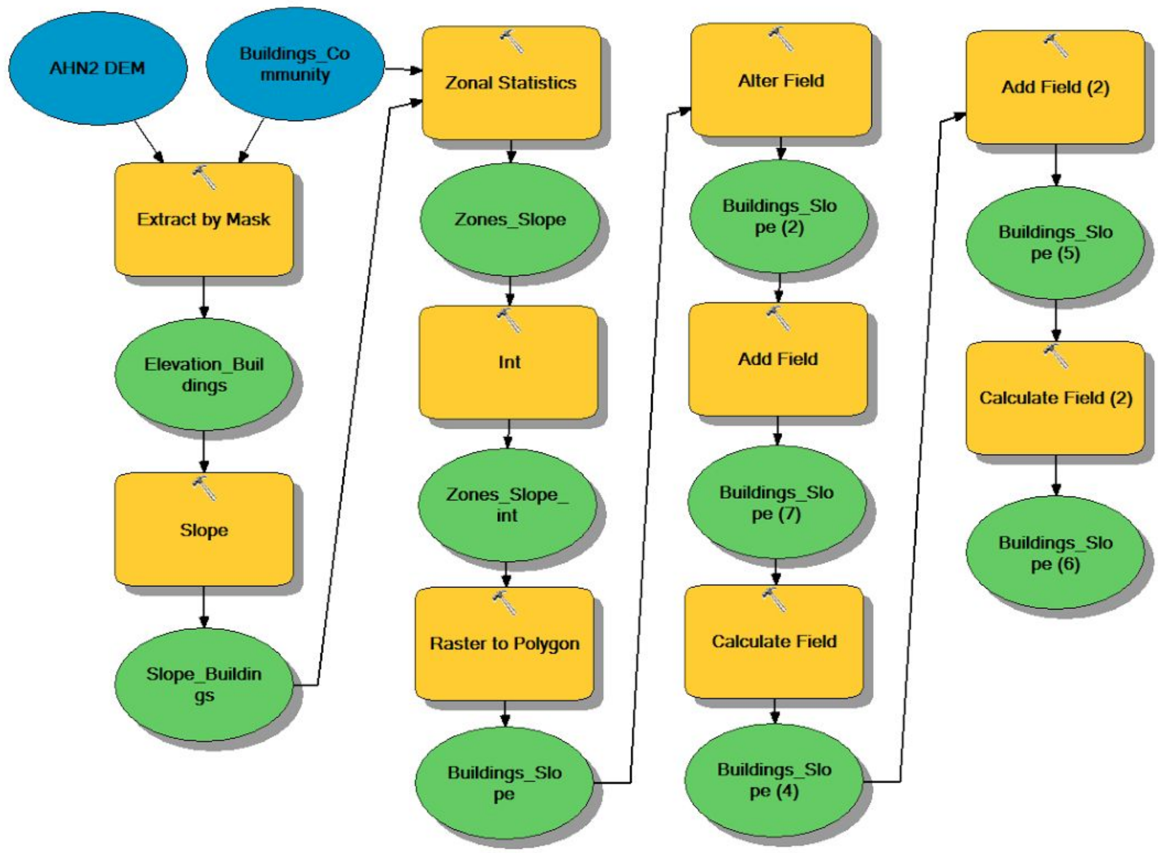

Figure 12. ArcGIS Model 4: Calculation of sloped roof area

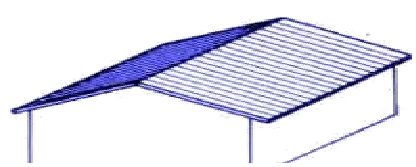

Figure 13. Gabled roof

Then by transforming the type of the data the calculations can be continued. In order to calculate the sloped area of the roofs, we normalize the available horizontal area into a perfect square so that the sides are known and can be used for the calculation. Now that the whole of the sloped area of the roof is available, it can be divided by two in order to use the one side, which is better oriented to the sun, for mounting the solar panels. Finally there is the resulting area has been lowered by a factor of 0.8 to account for the following factors: a) panels can not be mounted across the roof edge; b) there can be chimneys or other obstacles on the roof; c) complex roof shapes lead to less accurate results.

Solar potential per building calculation

Model 5 and Model 6 select solar potential and potential areas for PV panels installation. Areas with a yearly solar radiation equal or higher than the median value (750124.566 Wh/m2) were considered as potential areas for PV panels.
Model 5 uses as input the Global Radiation Raster and Buildings_Slope. Radiation data was clipped to buildings and cells with a value minor than median were assigned to NoData, remaining pixels were added per building to obtain potential radiation at rooftop. Units were modified to MWh/m2, those values were used to calculate number of panels, yearly yield, cost and effectiveness at different scenarios. Data were transformed to vector.
Model 6 was used to detect potential areas for PV panels, those areas correspond to potential radiation selected at Model 5. This model quantifies the number of cells per building that are above the median, from Rad_areas dataset and converts it into vector data. Number of pixel were scaled to m^2, taking into account the roof slope.
Model 7 joins in a single dataset results obtained from Models 4, 5, 6 and external calculations of number of PV panels, cost, and yearly yield. This dataset is used for the web map application.

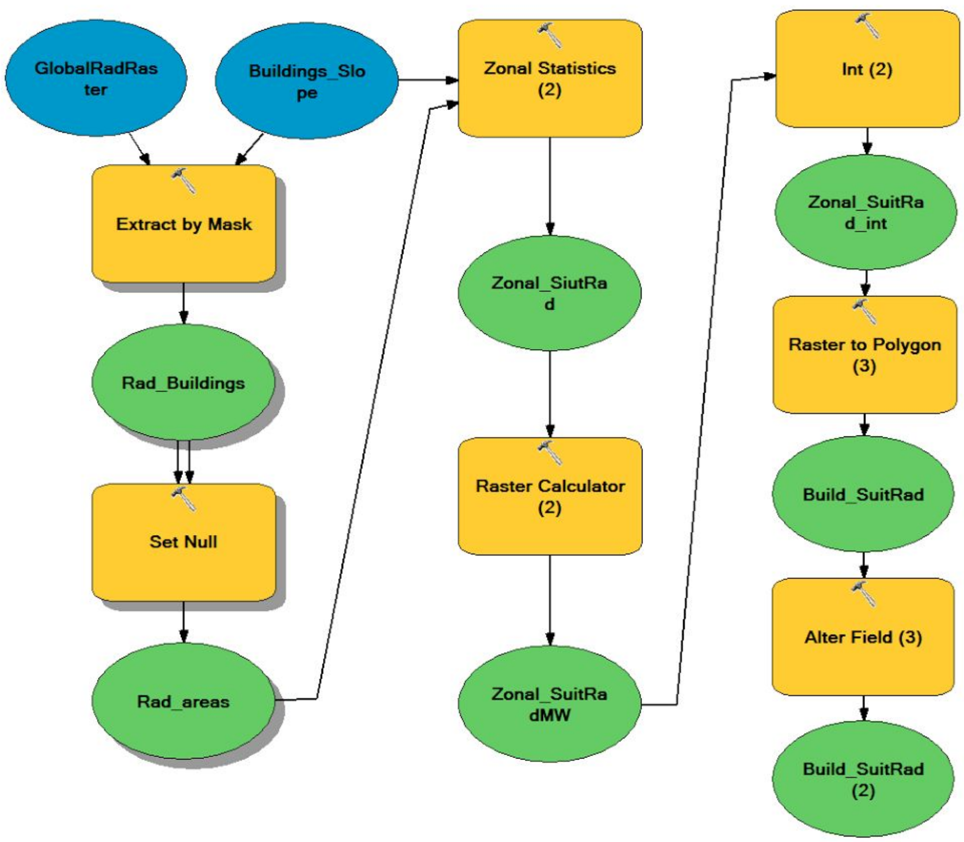

Figure 14.ArcGIS Model 5: Calculation of solar potential per building

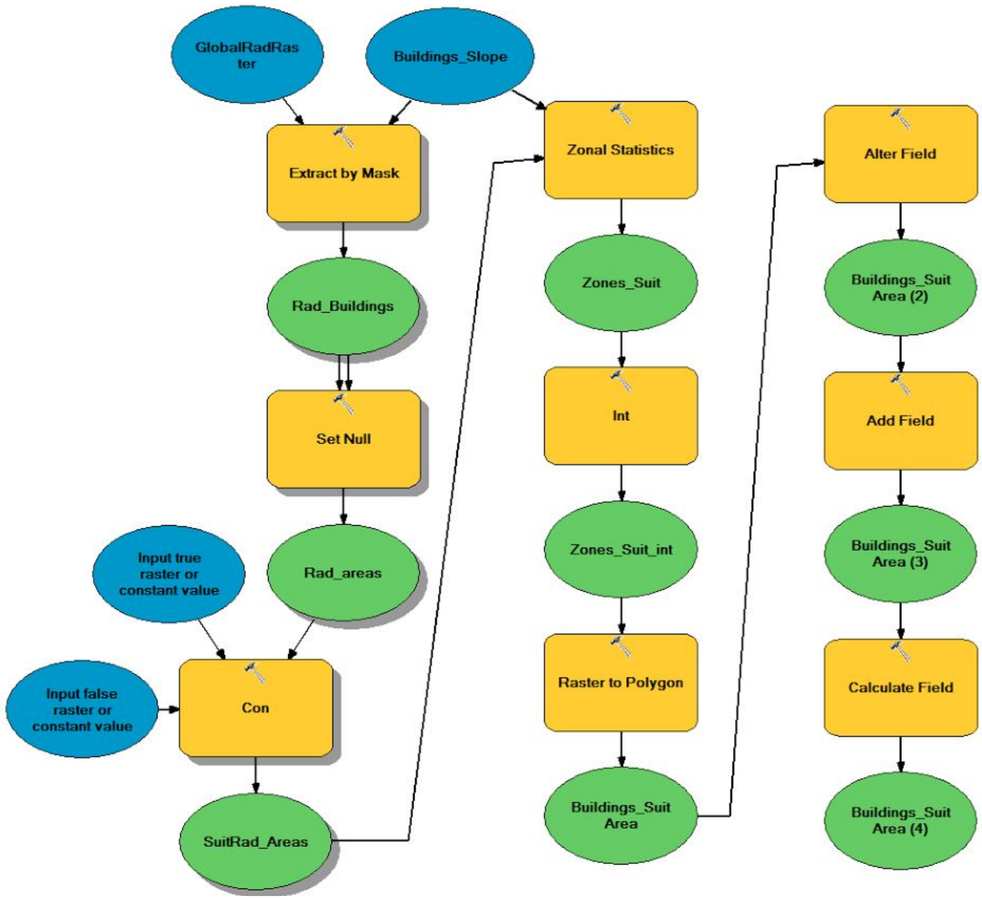

Figure 15. ArcGIS Model 6: Calculation of potential area per building

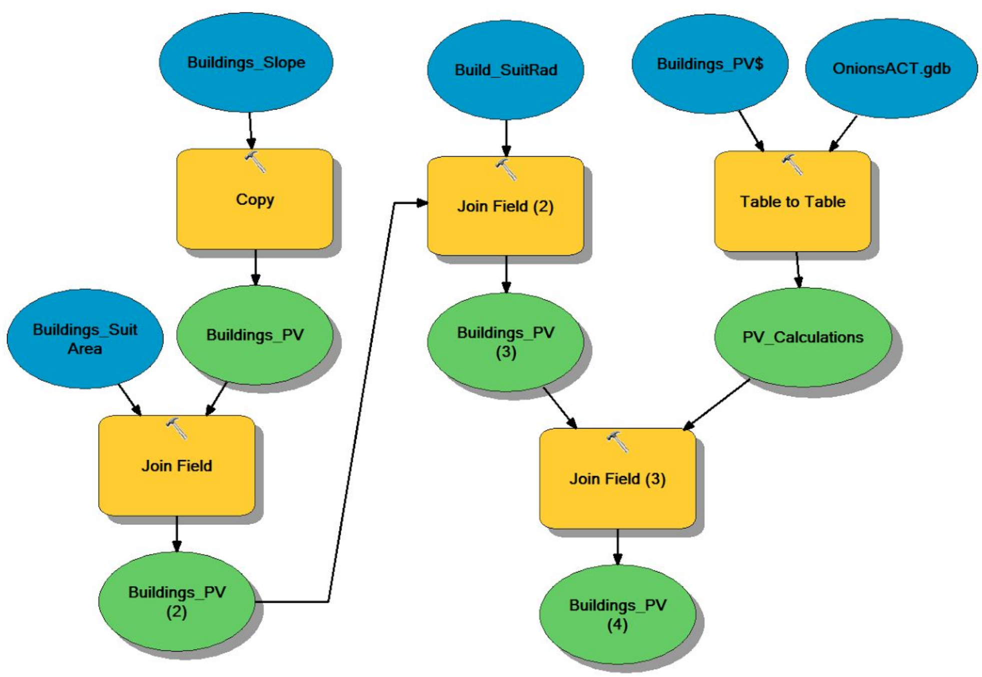

Figure 16. ArcGIS Model 7: Join of different calculations in one data set

Model 8 classifies buildings roofs in three suitable factors. Data were transformed to vector data. The output of this model contain information regarding Solar Potential and Potential areas, and is included at the web map application.
Classes were defined according their received yearly radiation:

- Low Factor (0): > 695682 Wh/m,
- Medium Factor (1): 695682-794358 Wh/m2,
- High Factor (2): >794358.5504 Wh/m2.

A single building can have any combination of factor types. This classification was realized to indicate areas where is suitable install PV panels. These zones have a higher area than the areas defined in Models 5 and 6, but with a lower efficiency. These areas can be considered as recommended areas.

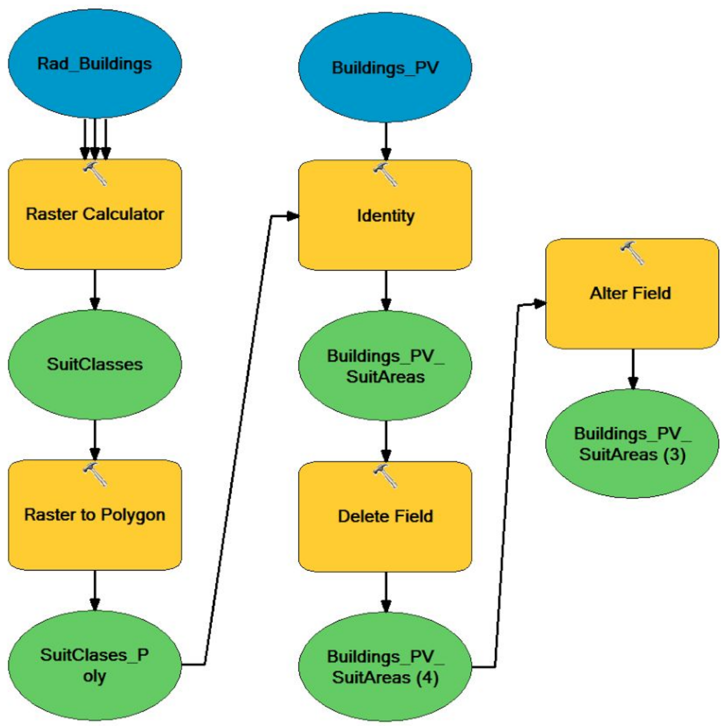

Figure 17. ArcGIS Model 8: Calculation of solar potential areas

PV Data

PV Panel Power Estimation
Three major factors are of influence in Photovoltaic (PV) panel power generation. Firstly the panel's efficiency determines the amount of incoming radiation that is converted into electricity. Depending on the year of production this measure lies between 10% (for older panels) and 16% (for modern panels) in commercial products (Alsema, 2010). Secondly panel degradation causes a yield loss over time of between 0.2% and 4.2% per panel per year (Jordan & Kurtz, 2012). Finally apart from the total incoming radiation, partial shading of the panel by natural or human built objects influence the power generation. Due to the panels internal wiring (in series) a 5% shaded area can lead to a drop in performance of almost 25%. More recently parallel wired panels have come to the market which reduce this problem to negligible loss rates; 5% shading leads to 5.2% less performance (Gao, et. al., 2009). When estimating the time it takes for a panel to balance its energy yield versus its purchase price, the energy payback time, the development of the national energy prices should also be taken into account (Bankier & Gale, 2006). Due to the unpredictability of this measure, especially over long time periods this measure will not be taken into account. Energy payback times will thus be calculated for current energy prices. The price of energy in the Netherlands is currently €0.23 per kWh/m^2 on average, most of which are energy taxes (Milieu Centraal, 2015).

PV Panel Energy payback time - Scenarios
From the radiance map several estimations on the yield and energy payback time per m^2 of panel will be calculated. Because the yield of a solar panel is highly dependent on the variables described a generalization in three scenarios will take place. These scenario's are described below:

Table 3. Estimation variables

Panel variables	High estimation (%)	Low estimation (%)
Panel Efficiency	16	12
Panel degradation	0.5	2
Partial shading efficiency	5	25

Table 4. Costs (derived from SolarNRG (2015) website)

	Price / Cost (€)
Per panel	350
Labor per panel	50
Connection to the grid	300
Of energy per kWh	0.23

The Suitable Area of the roof has been calculated from the suitable pixels (>750.125 kWh yearly incoming radiation) of each roof (output of Model 5 and 6), in order to have a good efficiency on the proposed system (the more output for the least number of panels used). This area was then transformed from horizontal area into slope area by multiplying it with the cosine of the roof that it was calculated earlier from Model 5.

It is assumed that for this application, PV panels of 250 Wh output were used, with an average of 1.635 m^2 area needed when mounted on to the roof for each. The number of the panels used in each roof was calculated by dividing the suitable surface area of the roof by the the area occupied by one panel. Example panel: CanadianSolar, module CS6P-P. (CanadianSolar, 2015)

The yearly yield was calculated from the total yearly incoming radiation on the roof, after lowering it by multiplying with factors of panel efficiency and the loss in efficiency from shading (Gao, et. al., 2009). For the yearly yield the total yearly incoming radiation had to be converted into kWh (multiplied by 1000) and to be then multiplied by the the price of the energy per kWh.

To calculate finally the break-even point for paying back the cost of the system it was taken into account the yearly yield multiplied with the average loss factor from panel degradation, degradation was considered for the next 25 years.. This was then used as the dividend of the total cost of the system in order to calculate the years needed for paying back the system. Average loss factor for 0.5%/year panel degradation, was calculated 0.942238%, and for 2%/year degradation, 0.793071%.

Table 5. Suitable areas

Suitable roof area example (m2)	Number of panels	PV panels cost	Installation costs (each panel installation + connection cost)	Yearly Power Output (kWh) Low estimation High estimation	Yearly Monetary output (€) Low estimation High estimation	break-even point for paying the system back (Years)
10	6	€ 2100	€ 600	765 1140	175 262	19 11
30	18	€ 6300	€ 1200	2295 3420	527 786	18 10
40	24	€ 8400	€ 1500	3060 4560	703 1048	18 10
60	36	€ 12600	€ 2100	4590 6840	1055 1573	18 10
80	48	€ 16800	€ 2700	6120 9120	1407 2097	17 10

Concluding remarks

As the objective of this project and the application's requirements from a usability and functionality standpoint were clear, the development of the application was generally straightforward. Still challenges in processing time have let to some changes to the initial plan, i.e. not the whole region of de Veenkoloniën has been processed, but just Gasselternijveenschemond. This report aims to leave the option for future larger scale processing open (see "*Additional villages/areas*") by providing the necessary workflow to accomplish this. Another area that is of interest is the PV panel variability. As technology is constantly changing and different manufactures have panels that vary in efficiency, panel degradation, cost, and size most of the outcomes used in the final application are highly generalized. The original data is provided so that adjustments can be made should future technologies emerge. The outcomes of this study provide the commissioners the unique opportunity to compare scientific estimations with actual real world yields, break-even points, and installation costs. We hope the projects to further set the agenda on the topic of sustainable energy in the region. More precise that this project contributes to actual investments in these types of energy or at least create some awareness into the here-and-now potential of solar energy.

Opportunities for future development

Visualization and graphs
The use of graphs could lead to more insight in the data and more powerful visualization. For example the yield could be plotted against the initial investment thereby showing the return of investment over time. There are possibilities for integrating the web-graphing solution plotly into CartoDB using SQL however the integration is not yet fully complete and requires higher level programming skills.

Additional villages/areas
Within this project's time and with the computer power available it was only possible to calculate rooftop potential for the village of Gasselternijveenschemond, other villages should be calculated individually. For the village of Gasselternijveenschemond computation of the solar area raster took about 72 hours, processing time needs to be taken into account for future developments.

Appendix A. Stakeholder Analysis

Inhabitants
Inhabitants of the village of Gasselternijveenschemond and (in the future) also other villages in the Veenkoloniën. The village energy plan highly depends on cooperation of interested villagers who see both a chance and a value in participation. Inhabitants are planned to become the most important stakeholders when the project gains momentum.

Energiebureau Veenkoloniën
Initiative to share knowledge about energy projects. The Energiebureau functions as a knowledge platform and they form the link between inhabitants, students, experts, companies and governments. Key concept of the Energiebureau is to be the central organisation, reachable for everyone and being driven bottom-up.

Kenniswerkplaats Veenkoloniën
The Kenniswerkplaats, to be considered as joint knowledge workgroup, is a cooperation between three education institutions AOC Terra (secondary school), Van Hall Larenstein (higher education) and the Wageningen University. The aim is to improve and stimulate innovation in the Veenkoloniën area. Sustainable energy and local initiatives are two of the main topics in this.

Aa en Hunze municipality (*Gemeente Aa en Hunze*)
The municipality is the primary owner of public land and responsible for spatial planning, permissions and procedures at local level. The municipality also has some legal power to control, permit or block processes and they form the link between higher governances and the inhabitants of the village of Gasselternijveenschemond.

Village council (*dorpsraad)*
The village council represents the village and is concerned with all processes and things happening in the village, in order to improve quality of life.

Village Energy Team
Organizes activities and support in the village to create and deploy enthusiasm in the inhabitants for joining the project. Also responsible for small projects and the agenda for long-term aspects of the project.

Enexis
The local grid operator for electricity and gas in this area of the Netherlands. Enexis does not produce or sell energy themselve, but they are responsible for maintaining the energy grids and their role concerns the technical aspect in monitoring the consumption and production of energy on local individual level. This stakeholder is the only one not yet involved today.

Appendix B. References

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