Assessing policy constraints and technical feasibility of energy developments in cities

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Abstract: GOMap (Geospatial Opportunity Map) was developed to support informed decisions concerning the siting of renewable energy systems in cities. It examined installing freestanding solar photovoltaic (PV) farms in Glasgow's Vacant and Derelict Land (VDL) and was implemented as an interactive Geographic Information System. In evaluating whether a site was suitable for renewable energy deployment, two sets of constraints were considered: technical factors which were imposed by the location on the achievable power level; policy factors which affected the likelihood of receiving planning permission. Two scoring methods were applied which generated different perceptions concerning the size of opportunity available, based on a 50x50 m grid across Glasgow. The stringent method applied the highest score for any individual layer as the combined score and resulted in 15.7 % of the VDL area as technically favourable and 7.8 % as politically possible; the recommended lenient method summed the individual factor scores and displayed 42.9 % as technically favourable and 46.8 % as politically possible. Focusing on the lenient method, it was found that 285 ha of suitable VDL could allow for 142,708 solar PV panels to be built, equating to an energy yield of 344.55 MWh/yr which could provide energy for ~70,000 dwellings.

Keywords: energy, renewables, geospatial, opportunity, map.

Introduction

As part of the Future City Glasgow demonstrator project on Energy Efficiency (Energy Efficiency Demonstrator, 2017), Glasgow City Council (GCC) had chosen to develop a process for producing Opportunity Maps for urban renewable energy schemes. This was intended to be a concrete example of how technology could help make life in the city smarter, safer and more sustainable. Opportunity Maps would become publicly available tools which would help to identify land where community renewables projects could most easily be developed, and to give a guide to the kinds of challenges which might apply there; this should avoid wasted effort during the normal technical development and planning control stages of a project.

GOMap was developed to be a reusable method to estimate energy yields, evaluate potential constraints and have these displayed on an interactive map. The methodology was established through considering the potential for deploying renewable technologies on vacant and derelict land (VDL). This is land that at one time had been used for housing or industry, and so would be classed as a priority for being put to productive use; renewable energy generation is one – though not the only - possible use. Beyond the household level, the Scottish Government has set a target of 500 megawatts of community and locally-owned renewable energy to be deployed by 2020 (Scottish Government: Renewable Energy for Communities, 2013).

When evaluating the suitability of a site for renewable energy generation, two different sets of potential issues must be considered. The first is technical with the constraints imposed by the location on the achievable power level. Assuming these can be managed, the policy constraints that might constrain or facilitate the likelihood of receiving planning permission to build at that location need to be understood by potential developers. With multiple possible factors affecting each of the technical and policy issues, a critical aspect of the method is to weight each factor appropriately to give a realistic screening of the resource. In addition, technical and policy evaluations can conflict, so in order to understand options for management, it is important to be able to identify the specific issues at play in any one location.

Various published papers investigated the deployment of renewable technologies using GIS software, however most only focused on the technical/environmental aspect such as the predicted amount of wind/sunlight etc. in a given location or how much energy can be produced if a wind turbine/solar PV panel was built on a hill (Watson et al, 2015; Mekonnen et al, 2015; Mellino et al, 2014; Tiba et al, 2010). Although incredibly useful, they do not show a 'realistic' possibility in terms of the technologies actually being built but rather answer: *this is what you can get if it is built*. Few papers actually combine both the technical/environmental aspect **AND** those concerning the political constraints which are primarily dealt with by the decision makers themselves who have the knowledge and data of determining whether such a technology can be built, this can be the local/regional council or indeed the Government themselves (Asdrubali et al, 2013; Grassi et al, 2012; Juárez et al, 2014).

The aim of this project was to develop an opportunity mapping tool which could be used to determine the suitability of areas in which to deploy renewable technologies in cities. Glasgow (Scotland, UK) was chosen as the urban settlement for this project, the principal reason being that the city has received substantial investment in order to increase sustainability. Because of this, various technologies were being investigated in order to implement low-carbon renewable deployment. Glasgow was also deemed "the UK's first green super city" ('All-Energy 2015 breaks records in Glasgow, Scotland', 2015). The renewable technology chosen for this project was solar Photovoltaic (PV).

Solar PV is most often deployed on roofs and integrated into the building's electricity supply, with generation power constrained by the available surface area. It has advantages in a city context: it is not unsightly, and can be installed without disruption. However, it is a relatively expensive technology so it is important to understand how to make the best use of it to minimise costs and maximise income.

The tool was designed to take into account both the technical factors, which encompass renewable energy generation and their corresponding efficiency; and the policy factors, which can determine sites' suitability. This tool, named "GOMap", was built in conjunction with the free, open-source Geographic Information System (GIS) software – Quantum GIS (QGIS). It would allow decision makers and planners to create, edit, visualise, analyse and publish geospatial information in various formats. This allowed users to not only calculate optimal areas for renewable deployment but also visualise them with dynamic colour gradients. GOMap was used to investigate the installation of solar PV farms on vacant and derelict land.

Methodology

A previous project examined developing an energy plan for the use of wind turbines in Caithness (Clarke et al, 1997). This procedure expands on the energy plan for Caithness and is summarised by the following points with focus on solar PV technology:

- Identified the factors which constrained power offtake or beneficial, economic return.
- Produced the base data to allow various areas to be effectively evaluated.
- Outlined the criteria where the policy and technical factors, at any location, would be assessed on a 3 or 4 point system.
- Scrutinised and allocated a score according to the data and criteria for a given location.
- Weighted and combined the individual factors which gave a combined score for both policy and technical factors.

For all policy-related data, a 4 score system was selected whereby each data layer was evaluated as one of '*Possible'*, '*Intermediate'*, '*Sensitive'* or '*Showstopper'*. The '*Showstopper'* score was used only in rare occasions where any kind of development would be deemed almost impossible, such as World Heritage Sites. For all technical-related data, a 3 score system was chosen whereby each data layer was evaluated as one of '*Favourable'*, '*Likely'* and '*Unlikely'*. A 3 or 4 score system was chosen as it allowed planners to easily distinguish between areas where justifications of improvement can be done or not. Increasing the score system would only cause bigger ambiguity between the scores. For example, it is easier to process '*good*', *'medium', 'bad'* than it is to process '*very good, good, medium, bad, very bad'.*

Each individual score was combined in order to deliver an overall evaluation for each of the policy and technical factors. Two scoring methods were formulated; each provided a different perspective, both mathematically and visually, of the area in question. These were known as the lenient and stringent methods:

- **Lenient (equal weighting)**: This method summed up the scores for each set of constraints. This method provided the most realistic opportunity maps as it indicated where the high difficulty areas lie but also encouraged development as much as possible.
- **Stringent (user-defined weighting)**: This method uses the highest score of any one factor as the combined overall score. In contrast to the lenient method, this provided the most pessimistic viewpoint in terms of opportunity available which ignored any possibilities of mitigation.

Policy constraints

Political constraints can greatly influence whether a renewable energy system can be developed on a site or not. Although many constraints can apply to most renewable technologies, some constraints are specifically tailored to address a particular energy system. For this thesis, the following factors were classified for freestanding solar PV:

- Environmental designation of land or buildings, such as sites containing special scientific interest.
- Land development zone such as housing.
- Glare which could constitute a safety risk to cars or aircraft.
- Possible presence of protected or endangered species, requiring surveys and mitigation plans.
- Visibility of the energy system from neighbouring housing.

Technical feasibility

These factors were considered generic as they would have been associated with many different renewable technologies and were identified as to their influence regarding building and installing solar PV arrays:

- Distance to the nearest 11 kV substation on the grid.
- Capacity of the circuits in each 11 kV substation to absorb new renewables generation.
- Overshadowing from nearby buildings.

Data processing

GOMap followed a strict procedure in order to calculate scores which determined how possible/impossible or likely/unlikely it was for a renewable technology such as solar PV farms to be built at a particular location based on specific constraints (e.g. conservation limitations, grid capacity etc.). To achieve this, a grid system at a pre-defined resolution was employed which covered the entire extent of the area.

Each polygon layer was *clipped* onto this grid and the resulting layer contained the exact same polygons broken up into grid cells with each cell becoming a polygon in itself. Therefore, if a layer overlaid another, their grid cells would also overlay perfectly. This overlap allowed for grid cells to be connected together which ultimately resulted in a single grid cell containing all of the overlapped data as shown in Figure 1.

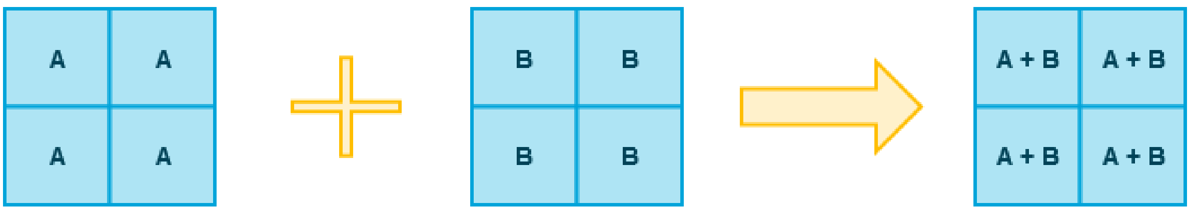

Figure 1. Grid system showing 2 sets of overlapping cells resulting in cells containing data from both.

GOMap

QGIS was used to build the interactive tool, GOMap. Geospatial and attribute data are stored in shapefiles and become “layers” when imported into GOMap. Layers can be combined, filtered and used in calculations; in Figure 2, a colour coding was used to show the geographical variation in scoring - darker shades represent increasing levels of difficulty.

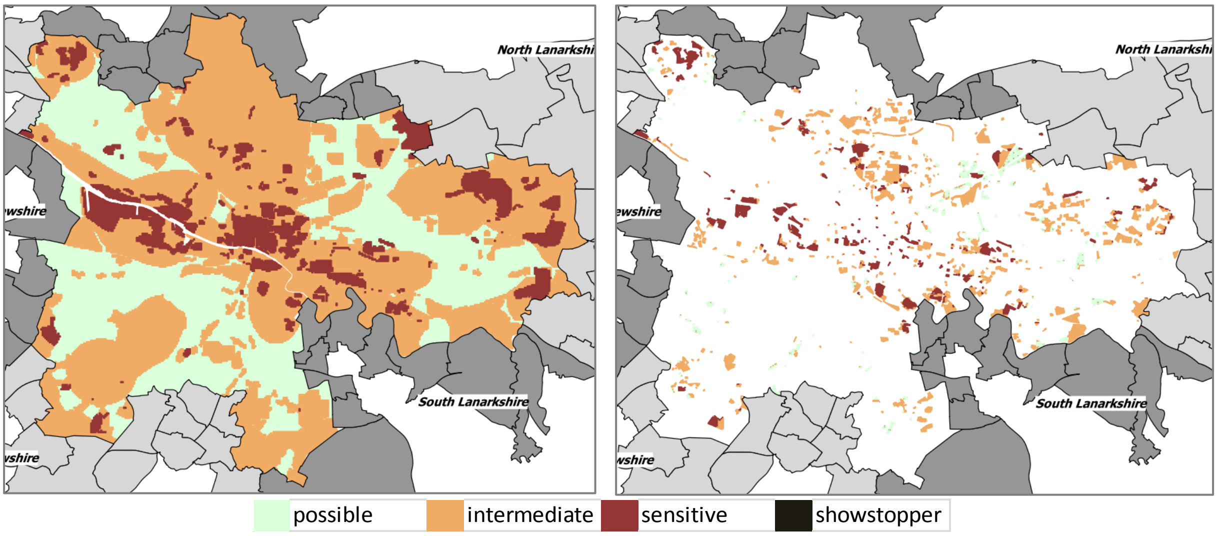

Figure 2. Layers showing development policy scoring across Glasgow and for VDL sites.

Interface

GOMap provides a dynamic interface allowing users to continuously update the opportunity map in real-time by switching any constraint layer on or off. Acreage and energy yield statistics are calculated based on the selected constraints and reported to the user:

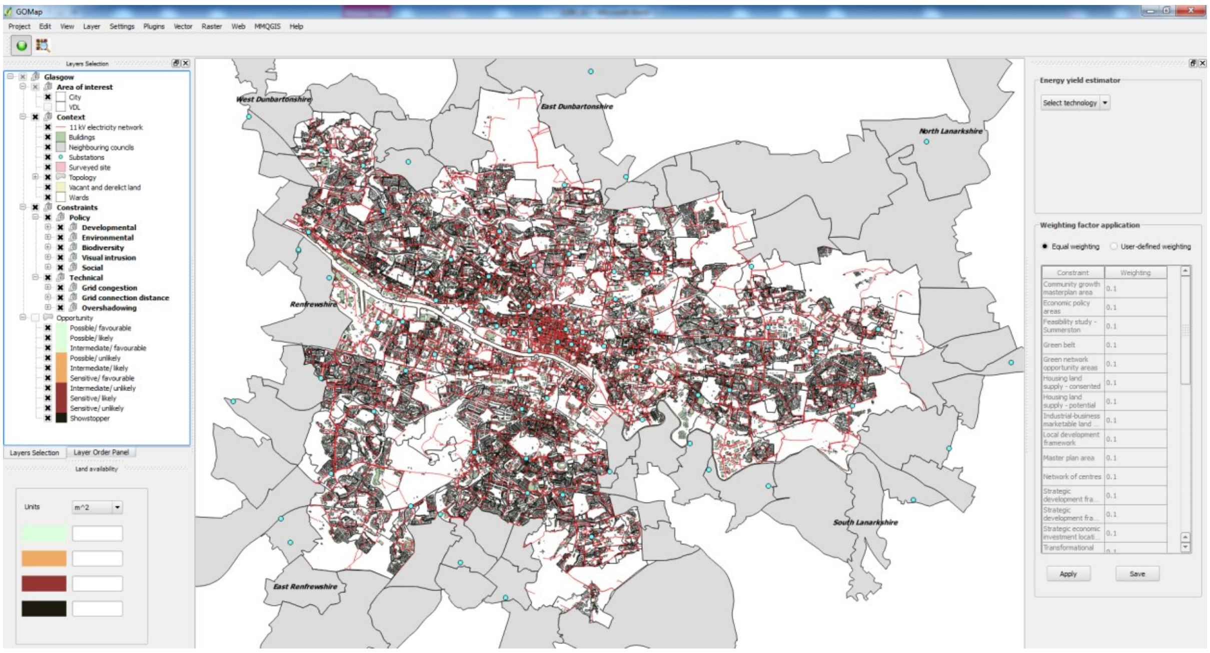

Figure 3. GOMap interface showing context layers for Glasgow.

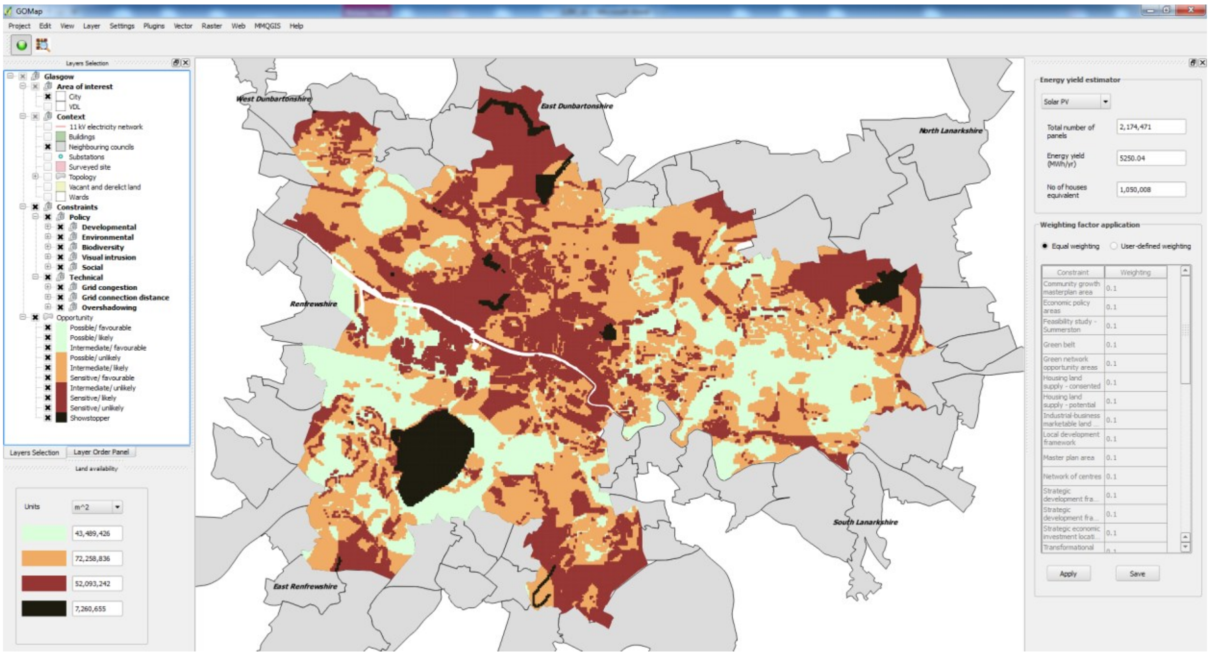

Figure 4. GOMap interface showing equal weighting opportunity for entire city.

Results

GOMap calculated the land availability and solar energy yield for Glasgow in terms of both citywide (Figure 4) and vacant and derelict land (Figure 5). It was shown that the amount of land dictated as being possible for solar PV deployment was 2.9 x10^6 m^2 or 285 ha. Using the lenient method and making the assumption that each solar panel has an area of 20 m^2 and the energy yield for one panel is 3018 kWh/yr, then the total number of panels and annual energy yield were found to be 142,708 and 344.55 MWh/yr respectively. Assuming the average house in Scotland consumes 5000 kWh/yr, the number of houses that could be supplied energy from the solar panels equates to 68,910.

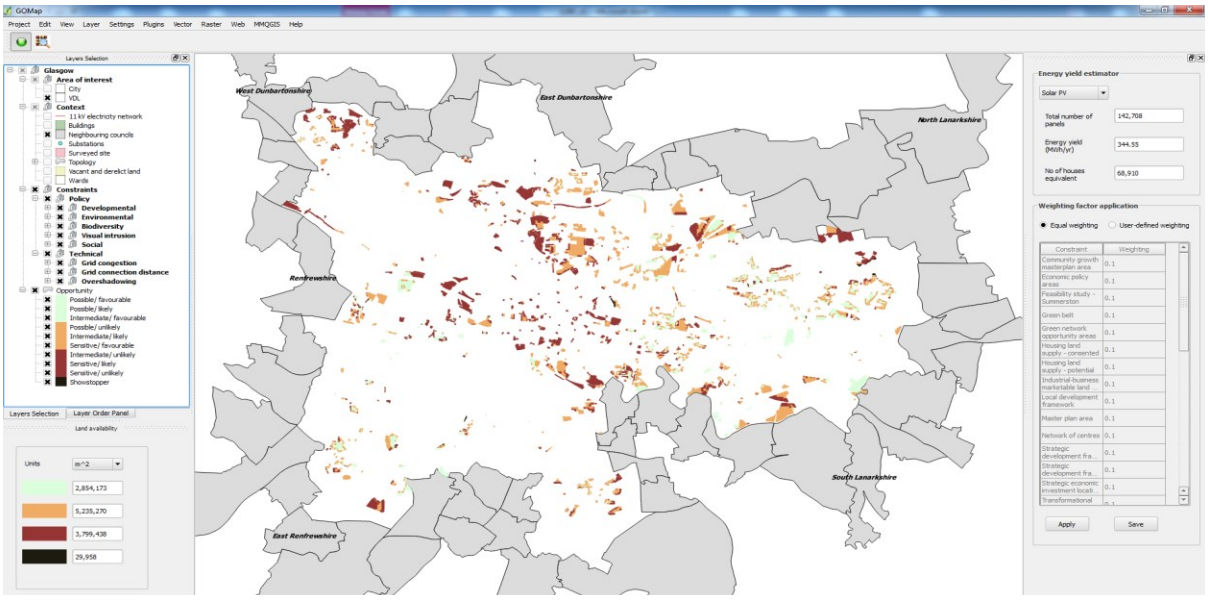

Figure 5. GOMap interface showing opportunity for vacant and derelict land.

The total area of vacant and derelict land in Glasgow was calculated as 1194 hectares. The calculations were performed using the area of each 50 m x 50 m grid square intersected by the VDL sites; this information was available in the attribute table for each grid cell. The deeper shades of colour indicated an increasing level of constraint. The main distinction in outcomes from using the different scoring methods can be seen in Table 1. When the lenient method was chosen, more land becomes readily available for renewable deployment in terms of both constraint types: with 46.8 % for policy and 43 % for technical. Conversely, the stringent method restricts much of the available land with only 7.8 % for policy and 15.7 % for technical. If the stringent scoring method was chosen, the level of difficulty appeared unpromising but alternative routes to bypass the apparent constraints may still exist.

Table 1. Comparison of proportion of VDL area scores by stringent and lenient methods.

	% VDL area	Stringent	Lenient
Policy			
	Possible	7.8 %	46.8 %
	Intermediate	49.0 %	46.0 %
	Sensitive	42.9 %	6.9 %
	Showstopper	0.3 %	0.3 %
Technical			
	Favourable	15.7 %	43.0 %
	Likely	36.1 %	29.7 %
	Unlikely	48.2 %	27.5 %

Conclusion

GOMap has been developed to support informed decisions concerning the siting of community scale renewable energy systems. The tool was developed for freestanding solar photovoltaic (PV) farms in Glasgow's Vacant and Derelict Land (VDL). GOMap was designed to accommodate other energy systems in other geographies. The development process for this project involved close collaboration between the planning experts in GCC providing greater credibility to GOMap. It was implemented as an interactive Geographic Information System, running on a freely open source application, QGIS.

The tool illustrated how individual and combined scores could vary spatially across Glasgow, which would allow the user to examine overall suitability of a site in question and be able to extract detailed information. Each individual factor and combined score was displayed in layers all of which were based on a 50 x 50 m grid across the city. For some issues, data existed in order for it to be mapped across Glasgow while others required a detailed survey of individual sites.

Different combination methods were applied which generated different perceptions concerning the size of the opportunity available. The stringent method applied the highest score for any individual layer as the combined score and resulted in 15.7 % of the VDL area as technically favourable and 7.8 % as politically possible; the recommended lenient method summed the individual factor scores and displayed 42.9 % as technically favourable and 46.8 % as politically possible. Both methods could be used depending on whether the user wishes to encourage maximum deployment of renewables or to minimise technology impact.

Regions of where the VDL areas are deemed politically possible and technically favourable were shown to have an accumulated area of 285 ha. As a result, 142,708 solar PV panels could be constructed with a potential annual energy yield of 344.55 MWh/yr, based on the assumptions discussed earlier. This could provide enough energy for just under 70,000 dwellings.

GOMap is an aid designed to calculate and provide opportunity maps for policy and decision makers and encourage collaboration with technology experts. GOMap can be transferable to other locations utilising other technologies. Technical constraints may be different for each technology but does not necessarily have to vary by location (i.e. the same technical constraints for solar PV in Glasgow could be applied to another city). However, each local authority or planning department will have their own approach to the policy constraints, so only the framework can be used elsewhere and appropriate evaluation criteria must be determined in each case. In other words, an opportunity map for Glasgow focusing on solar PV could have the same policy constraints as an opportunity map for Edinburgh focusing on CHP (combined heat and power) but the technical constraints may differ.

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