Using multi-criteria decision analysis to evaluate the feasibility of Renewable Energy Technologies and Sites - the Data4Sustain Web GIS decision support tool

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Summary

Developing renewable energy supplies face numerous barriers: finance; planning, viability constraints; many technologies; complexity of assessing feasibility; changing policy drivers. Therefore, a renewable energy decision-support tool is needed to systematically identify: constraints impeding / preventing development; feasible and / or priority technologies; integration with infrastructure.

Data4Sustain's Web GIS delineates potential resource and constraints to produce combined feasibility maps, integrating up to 100 data sets, using multi-criteria decision analysis. Resource, Constraint and Feasibility maps across multiple technologies (GSHP, WSHP, Solar Farms, Small and Large Wind, Small Hydro) are integrated into the Web GIS, from which users can export site reports.

KEYWORDS: renewable energy, feasibility mapping, multi-criteria decision analysis, infrastructure planning, decarbonisation

1. Introduction

Multi-criteria analysis (MCA) techniques are used to compliment traditional cost effectiveness analysis (CEA), and cost-benefit analysis (CBA) for environmental appraisal (Great Britain & Department for Communities and Local Government, 2009). Spatial MCDA methods have been used to facilitate renewable power plant deployments and assess their future impacts (e.g. Wanderer & Herle, 2015).

Renewable energy (RE) can contribute to addressing the energy trilemma (energy security, energy equity and environmental sustainability). Exploitation is impacted by natural resource availability and planning / physical constraints. Determining site feasibility for RE requires significant investment. Therefore, LQM, BGS, NEPes (with T4 Sustainability Ltd) and NGI have developed the Data4Sustain (D4S) decision support tool to help speed up site evaluation for seven RE technologies. Resource data layers for each renewable energy technology (e.g. ground source heat pumps, wind, solar) were scored by RE specialists and the scores combined using multi-criteria decision analysis (MCDA) to create a resource potential map. Other spatial variables which constrain each technology such as proximity to infrastructure (e.g. railways, airports) and physical factors (e.g. gradient, flood risk) were scored and combined using MCDA to create a constraints map. The resource and constraints map were combined to generate a feasibility map. The resulting decision support tool allows users to review and identify renewable energy technology site feasibility, and to drill down into the underlying data to better understand constraints. The tool is aimed at those evaluating sites and technology opportunities such as site owners, developers, but also policy makers, or vendors wishing to exploit or delineate suitable sites for each renewable technology. This paper describes the methodology developed and illustrative results for the pilot project study areas of Nottinghamshire, Derbyshire and the West Midlands.

2. Decision Support Ethos

Implementing a renewable energy technology on a site requires understanding of both resources and constraints. In highly populated nations like the UK, the development of many renewable energy technologies is also affected by planning regulations, proximity to infrastructure or buildings and areas of protected land (Areas of Outstanding Natural Beauty, SSSI or National Parks). In combination these make developing RE complex. Many factors are spatially controlled and thus perfect for assessment using Geographic Information Systems (GIS).

For of landowners seeking to make a return from their holding, independently assessing all of these criteria is a complex and potentially expensive operation. Thus there is a role for a GIS-based decision support system which synthesizes the available information, allowing both inappropriate technologies to be swiftly eliminated from consideration, and a desk-study assessment of the most appropriate technology to start to quantify the likely relative scale of resource to facilitate a more targeted site-survey. Supplying the information via a Web GIS makes it accessible via the internet and specialist access to GIS is not required.

3. Data & Geoprocessing Methodology

Multiple energy resource, environmental and planning datasets have been used in the study, including soil depth, solid and superficial geology, wind speed, rainfall, depth to groundwater and solar radiation, topography, and LiDAR/SAR data.

Geoprocessing to generate the resource and constraint maps presented multiple challenges. Input datasets for both technology resource and constraint maps were sourced from many organisations. Care was needed to check data suitability and licensing conditions. Geoprocessing methodologies were devised for each technology resource and constraint map in order to score the included input datasets and combine them into a single output map, whilst ensuring that the many input datasets (often over 50) could be processed reliably within a reasonable time frame. To achieve this, the input datasets were converted to raster formats (10m pixel resolution) and scored from 0 (representing an exclusion i.e. the technology could not be located at this site) upwards. These were multiplied together and normalised, thereby ensuring that a single exclusion score in the input datasets resulted in exclusion in the output map. Finally the geoprocessing methodologies were implemented using ESRI's ArcGIS™ software. For the more complicated methodologies e.g. constraint maps, Python code was developed, whilst for simpler methodologies such as resource maps for each technology ESRI's Model Builder™ was used.

A constraints map and resource map was produced for each technology. A feasibility map was then generated by multiplying elements of these arrays together (Figure 1). The resource, constraint and feasibility maps were then published to ESRI's ArcGIS Server™ to be incorporated into the Web GIS.

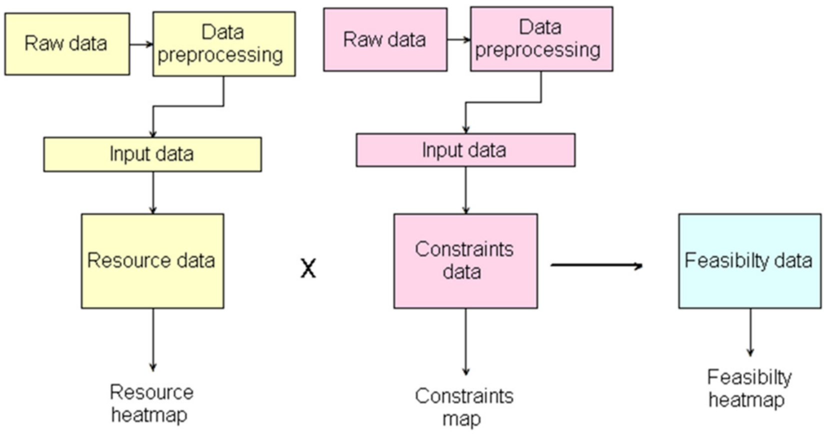


Figure 1 – links between Data4Sustain data and heatmap outputs

4. Data4Sustain Web GIS

Delivery of the technology resource, constraint and feasibility maps is performed via a web interface. Following wireframe prototyping of potential solutions using the Balsamiq rapid Mock-up tool (https://balsamiq.com/) a demonstration web solution was developed using AGILE software methodology and development Sprints. The ArcGIS API for JavaScript™ (https://developers.arcgis.com/javascript/) was used to implement mapping functionality. The website allows a user to select their site of interest by either drawing or uploading an ESRI Shapefile of the site boundary (Figure 2). Following site selection, the user sees an overview of the feasibility of each of the seven technologies based on the most favourable score for each technology within the selected site. The user can quickly identify which technologies have the most potential at the site. Users then open the Web GIS displaying detailed data for the technology of interest. This provides functionality to interrogate each of the resource, constraint and feasibility maps and returns information for each individual constraint, highlighting which constraints are present at the site and need to be investigated further.

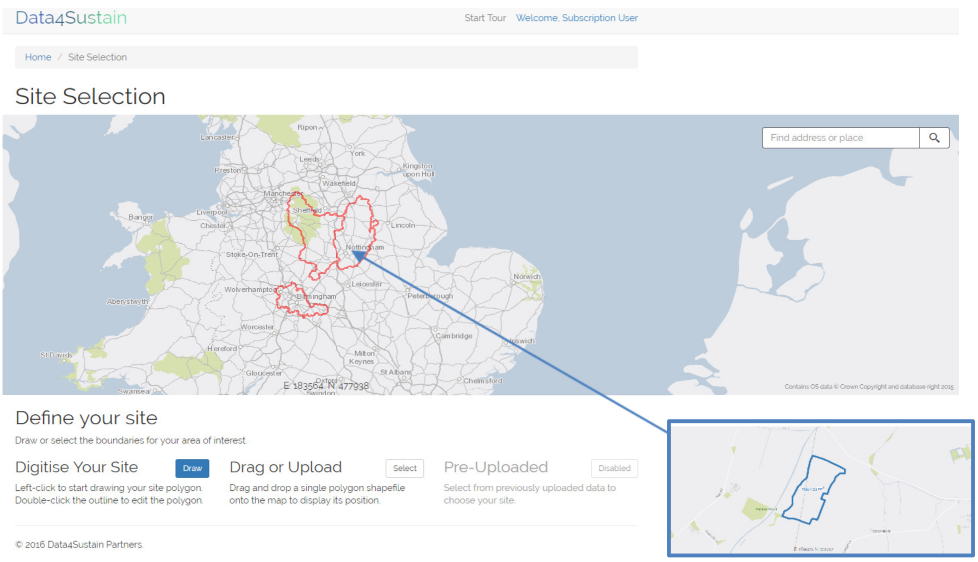
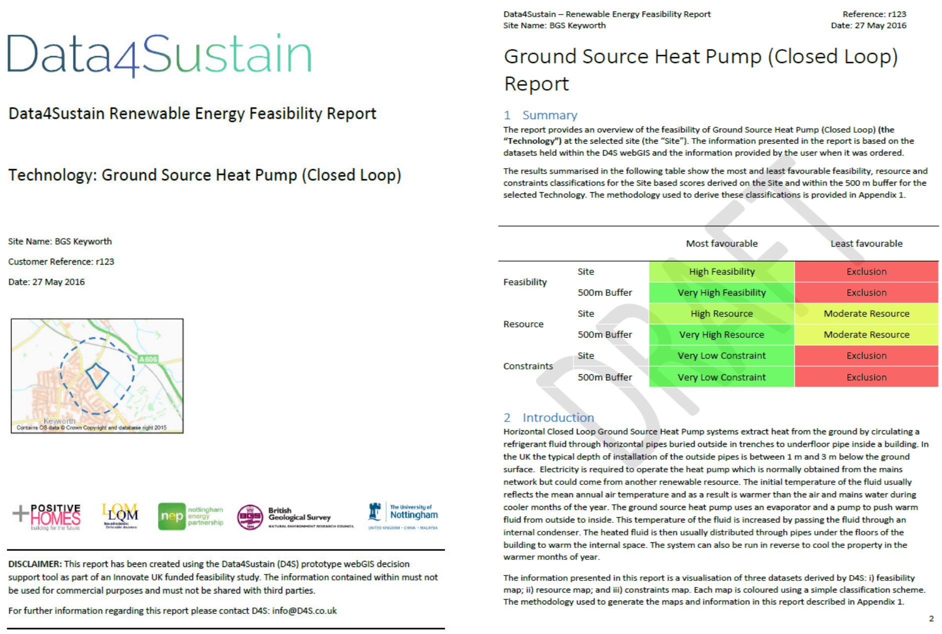


Figure 2 – Data4Sustain Web GIS Site Selection functionality

Additional functionality allows map annotation and upload of external point data via a shapefile or csv file (e.g. to display existing renewable sites to ground truth the D4S feasibility maps) and technology report generation. (Figure 3).



Data4Sustain

Data4Sustain Renewable Energy Feasibility Report

Technology: Ground Source Heat Pump (Closed Loop)

Site Name: BGS Keyworth

Customer Reference: r123

Date: 27 May 2016

Keyworth

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DISCLAIMER: This report has been created using the Data4Sustain (D4S) prototype webGIS decision support tool as part of an Innovate UK funded feasibility study. The information contained within must not be used for commercial purposes and must not be shared with third parties.

For further information regarding this report please contact D4S: info@D4S.co.uk

Data4Sustain – Renewable Energy Feasibility Report — Reference: r123

Site Name: BGS Keyworth — Date: 27 May 2016

Ground Source Heat Pump (Closed Loop) Report

1 Summary

The report provides an overview of the feasibility of Ground Source Heat Pump (Closed Loop) **(the "Technology")** at the selected site (the "Site"). The information presented in the report is based on the datasets held within the D4S webGIS and the information provided by the user when it was ordered.

The results summarised in the following table show the most and least favourable feasibility, resource and constraints classifications for the Site based scores derived on the Site and within the 500 m buffer for the selected Technology. The methodology used to derive these classifications is provided in Appendix 1.

		Most favourable	Least favourable
Feasibility	Site	High Feasibility	Exclusion
	500m Buffer	Very High Feasibility	Exclusion
Resource	Site	High Resource	Moderate Resource
	500m Buffer	Very High Resource	Moderate Resource
Constraints	Site	Very Low Constraint	Exclusion
	500m Buffer	Very Low Constraint	Exclusion

2 Introduction

Horizontal Closed Loop Ground Source Heat Pump systems extract heat from the ground by circulating a refrigerant fluid through horizontal pipes buried outside in trenches to underfloor pipe inside a building. In the UK the typical depth of installation of the outside pipes is between 1 m and 3 m below the ground surface. Electricity is required to operate the heat pump which is normally obtained from the mains network but could come from another renewable resource. The initial temperature of the fluid usually reflects the mean annual air temperature and as a result is warmer than the air and mains water during cooler months of the year. The ground source heat pump uses an evaporator and a pump to push warm fluid from outside to inside. This temperature of the fluid is increased by passing the fluid through an internal condenser. The heated fluid is then usually distributed through pipes under the floors of the building to warm the internal space. The system can also be run in reverse to cool the property in the warmer months of year.

The information presented in this report is a visualisation of three datasets derived by D4S: i) feasibility map; ii) resource map; and iii) constraints map. Each map is coloured using a simple classification scheme. The methodology used to generate the maps and information in this report described in Appendix 1.

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Figure 3 – Data4Sustain Web GIS Generated Report Functionality (sample extract)

5. Example Web GIS outputs and initial validation

Results from the Web GIS outputs were trialled for solar farms and large wind technologies, utilising sources such as the Renewable Energy Planning Database (BEIS, 2016).

As shown in Figure 4 and 5, respectively the Web GIS correctly identified locations which would fail or pass the critical feasibility criteria. This information could have saved pre-planning application effort involved in a wind farm project on the edge of the urban fringe (Nottingham), which was rejected by the Local Planning Authority. The Web GIS successfully identified that this site would clearly have failed a range of critical constraints despite good resource potential (Figure 4). A solar farm project was also successfully identified with excellent grid connectivity opportunity clearly identified (orange linear feature running north-south through the site, Figure 5). Additional nearby opportunity sites were subsequently identified by the non RE expert Web GIS user.

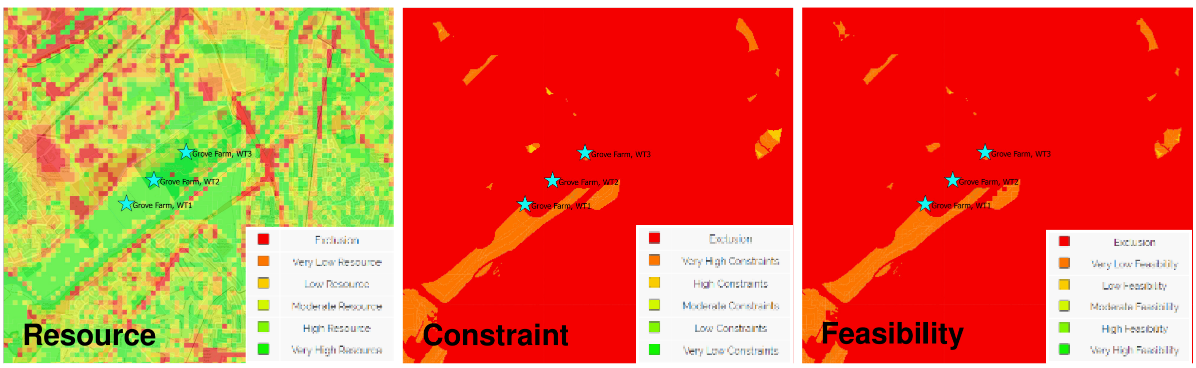

Figure 4 Failed wind turbine project (3 x 1MW) at Grove Farm, urban fringe Nottingham City, identified by the Data4Sustain Web GIS

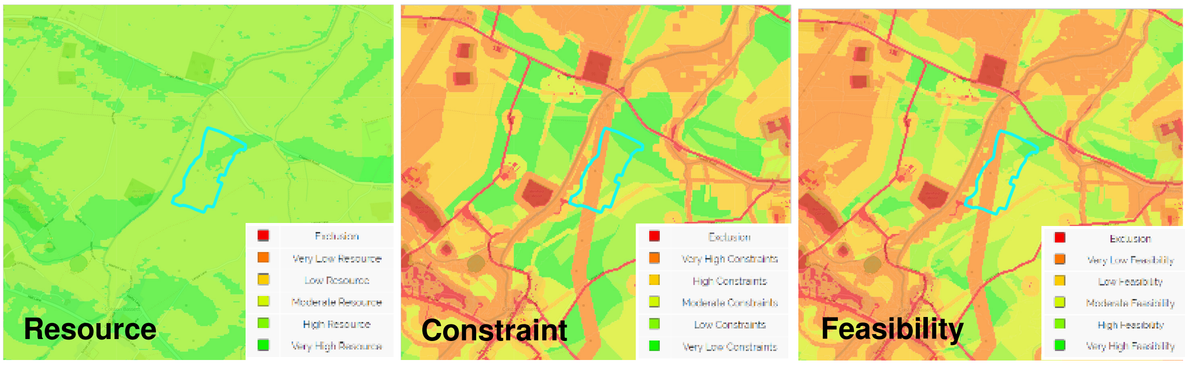

Figure 5 Successful solar farm project (5MW), Langar Lane, East Nottinghamshire, identified by the Data4Sustain Web GIS

6. Conclusions and impact

The Data4Sustain feasibility study and web GIS developed has demonstrated that multiple sources of large spatial data can successfully be integrated and modelled to inform reproducible decisions and identify opportunities for renewable energy. The availability of such a decision support tool is expected to assist development and integration of renewable energy technologies into major infrastructure projects and to support strategic decision making by individuals, communities, utilities, and all levels of government developing all sizes of project. This will help to meet local energy generation needs, enhance local sustainability, and reduce pressure on national transmission networks. This in turn will reduce the national need to import energy, and should ultimately help to address energy security and fuel poverty issues.

7. Acknowledgements

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8. Biography

Judith Nathanail (BSc, MSc) is Company Secretary & Project Manager (Land Quality Management Ltd) with over 20-years environmental consulting experience combining extensive field geology and contaminated land assessment experience with development of decision support tools (e.g. keyCSM, Data4Sustain). Research interests: geology; renewable energy; decision support tools; contaminated land.

Andy Gillett (BSc, MSc, PhD) is a Senior Environmental Scientist & Project Manager (Land Quality Management Ltd) with 4 years post-doc R&D (radioactive spatio-temporal modelling and decision support), and 17 years environmental consultancy experience. Research interests: GIS modelling environmental systems; contaminated land; environmental risk assessment; renewable energy.

Paul Nathanail (BA/MA, MSc, PhD, CGeol, EurGeol, SiLC) is Professor of Engineering Geology at the University of Nottingham and Managing Director of Land Quality Management Ltd. His research, teaching and consultancy interests span the spectrum of risk based contaminated land management and sustainable urban regeneration.

Andy Marchant (BSc, MSc) is Web GIS team leader (British Geological Survey) with over 19 years' experience project management & technical skills, specialising in Web & Desktop GIS development. Research interests: ESRI technology, inc. ArcGIS, ArcObjects & VB .NET, & WebGIS using ArcGIS Server, HTML & JavaScript.

Darren Beriro (BSc, MRES, PhD) is an inter-disciplinary geoscientist (British Geological Survey) with 8 years' experience in research, project management & consultancy in environmental projects. Research interests: risk-based land management; in-vitro lab research (bioaccessibility); data-driven modelling; innovation in modelling and geoscience product development.

Andrew Kingdon (BSc, MSc) is BGS Data Analytics Team Leader (British Geological Survey) managing science project delivery, with 25 years' experience as a petrophysicist studying subsurface rock properties, with 20 peer-review publications. Research interests: geological data management, subsurface properties distribution, dynamic process modelling & the UK's geothermal energy resources.

Steven Richardson (BSc, MSc) is an IT professional (British Geological Survey) with 8 years' experience in GIS systems, mobile, web and desktop software development for both industry & public sectors. Research interests: spatial solutions for environmental applications; cross-platform innovative data visualisation; virtual reality mapping.

John Beardmore (BA, MSc, CMIOSH, CEnv, MIEMA) former software engineer working in environmental sustainability sector since 2002, now Managing Director of T4 Sustainability Ltd. Research interests: environmental decision making; design and integration of renewable energy systems; promoting community renewable energy; open source control systems; electrical systems; grid connected energy storage.

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