IRENA
International Renewable Energy Agency

Data quality for the Global Renewable Energy Atlas – Solar and Wind

Concept paper

GlobalAtlas
FOR RENEWABLE ENERGY

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.
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Acknowledgements

This report was prepared by the International Renewable Energy Agency (IRENA) in close collaboration with: Steve Ross (3Tier); Ivan Moya (CENER); Jake Badger and Ferhat Bingol (DTU Wind); Dave Renne (ISES); Carsten Hoyer-Klick (DLR); Hosni Ghedira and Taha Ouarda (Masdar Institute); Lionel Menard and Lucien Wald (MINES ParisTech); Paul Stackhouse (NASA); Daniel Getman (NREL); Johannes Sander (Sander & Partners); Richard Meyer (Suntrace); Gil Lizcano (Vortex).

Comments or questions about this report can be sent to potentials@irena.org.

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Highly detailed planet Earth at night© Anton Balazh/Shutterstock

PURPOSE

The Global Renewable Energy Atlas is providing access to a vast amount of solar and wind resource maps created using different methodologies, with different spatial coverage and resolutions. Several datasets can overlap over a territory, and users can choose among several data sources. This poses a dilemma for the end-user as to which data is adapted for its use, and what are the main strengths/weaknesses of the proposed datasets.

Currently, no synthetic information on the suitable use of the data is available to the users. The Global Renewable Energy Atlas website only links to existing literature, referencing the validation process of each solar and wind dataset, and consequently the Spatial Data Infrastructure (SDI) fails to provide information on *Data Quality.*

The notion of Data Quality is often confused with the quantification of uncertainty, and discussions are often limited to the definition of validation protocols. However, the concept of Data Quality shall be understood in a broader sense, *i.e.,* the purpose of characterising Data Quality is not to judge or rank data resources, but to describe the characteristics needed to be known in order for the user to decide whether he/she should use them (Group on Earth Observations (GEO) Data Sharing Working Group (DSWG), 2013).

Building on the outcomes of the Solar and Wind Energy Resource Assessment programme (SWERA) funded by the United Nations Environment Programme (UNEP), the recommendations of GEO, the definition of data quality established by the International Organisation for Standardisation (ISO), and the recommendations of data providers and end-users of the initial Global Solar and Wind Atlas, this concept paper puts forward a proposal to define a Data Quality Information Framework applicable to the datasets referenced by the Global Renewable Energy Atlas.

This framework is specific to solar and wind data. It is not intended to be transferred to other renewable energy resources, which will require their own dedicated strategies.

BACKGROUND

One of the focus areas of IRENA is to provide information on renewable energy potentials. The activity started with solar and wind in 2009 and developed in partnership with the Multilateral Working Group on Solar and Wind Energy Technologies of the Clean Energy Ministerial (CEM), led by Denmark, Germany and Spain. The Global Solar and Wind Atlas was released during the third Assembly of IRENA in January 2013.

Since then the initiative has continued to expand. There are currently 39 countries and more than 50 institutes and partners are contributing to the initiative; 45,000 visitors have used the interface and 600 users have registered on the system.

After the successful release of the portal, the ambition of the Global Solar and Wind Atlas programme was significantly revised, with the goal to create the Global Renewable Energy Atlas – the first ever platform with the ability to access geographic information on any renewable energy resource for any location in the world.

The Global Renewable Energy Atlas aims to close the gaps between those nations that have access to the necessary datasets, expertise and financial support to evaluate their national potentials, and those lacking such capacity. The initiative started with solar and wind, and is expanding progressively to include bioenergy and geothermal energy during the period 2013-2014, and hydropower and marine energies during 2014-2015.

THE GLOBAL ATLAS SPATIAL DATA INFRASTRUCTURE

The original objective was to facilitate access to information on solar and wind technical potentials (UNEP and IRENA, 2013). The Global Solar and Wind Atlas (now the Global Renewable Energy Atlas) is a SDI made of a geographic information system (GIS[1]) exploiting a catalogue.[2]

The GIS searches the catalogue and loads one of the 400 registered solar and wind resource datasets,

[1] GIS interface: http://irena.masdar.ac.ae

[2] Geocatalog: http://geocatalog.webservice-energy.org/geonetwork/srv/eng/main.home/

3d illustration/render of a global network© brave rabbit/Shutterstock hosted remotely. Each of the 400 catalogue entries provides a detailed description of the source of information, intellectual property restrictions and links to the originating website (metadata).[3]

The GIS allows for the superposing of information layers, performing basic estimates of the technical solar and wind potentials, and saving the resulting map under a personal profile.

The catalogue is compatible with standards of the Open Geospatial Consortium (OGC), which enables links to existing similar platforms, and allows third party applications to search and access the information (*e.g.*, esri ArcGIS, Quantum GIS).

By linking to existing relevant data collection initiatives, and referencing new sources previously unavailable in GIS format, the Global Atlas initiative is *de facto* creating a central repository for sharing and accessing GIS information on all renewable energy technologies. In itself, the creation of such repository has a large added value for the renewable energy community.

THE NEED FOR DATA QUALITY INFORMATION FRAMEWORK

The Global Renewable Energy Atlas is providing access to a considerable amounts of solar and wind maps created through different methodologies, with different spatial coverage and resolutions. It allows users to overlap several datasets over a single territory, and to choose from several data sources. The dilemma for users is which dataset can be identified as being most suitable for its intended use, and the main strengths/ weaknesses of the proposed datasets.

Currently, the website only links to the existing literature referencing the validation process, but does not provide a synthetic overview to the end-user. The Global Atlas SDI misses a crucial aspect of information, which is to characterise the *Data Quality*.

As discussed earlier, the purpose of characterising Data Quality is not to judge or rank data resources, but to describe the characteristics needed to be known in order for the user to decide whether they are suitable (GEO DSWG, 2013).

Building on past experiences, such as the international projects Management and Exploitation of Solar Resource Knowledge (MeSor) and UNEP-SWERA, it is proposed to develop a *data quality information framework* for the Global Atlas.

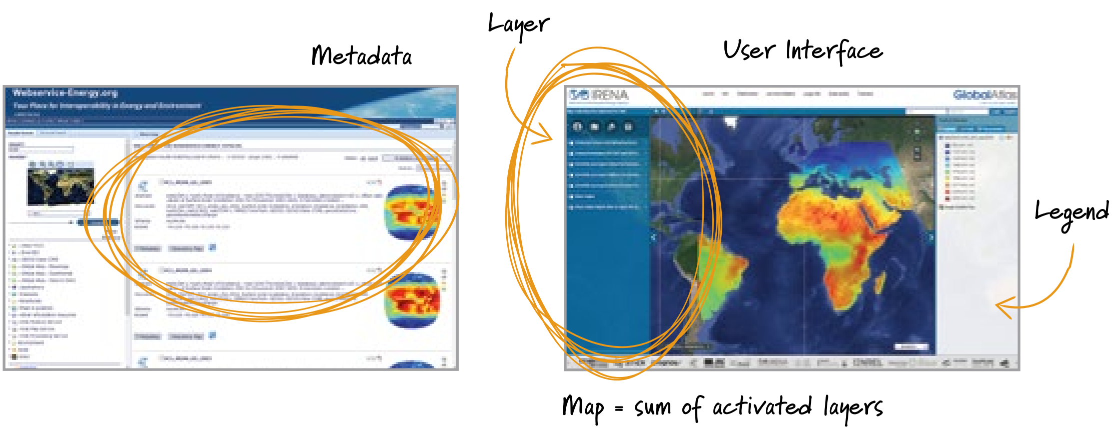


Figure 1: Definitions of the main terminology.

The data catalog (left) provides the title and description of each individual layer, which indicates, i.e., the data source, copyrights, and original website. The data catalogue is open access and interoperable using standards from OGC and similar major initiatives to share information. The GIS interface (right) enables a user to superpose information registered by the data catalogue. The full description of each individual layer is fully preserved from the data catalogue to the interface. A map is made of a superposition of such layers. A map is limited to a geographic extent defined by its author (world, continent, region, country…). A map is referenced by a title and description. The description can point out a specific method, provide restrictions of use, and other relevant information. A map has its own URL and can be accessed directly through the map gallery of the website. Every user of the Global Atlas can create a private account and save their own maps, although only IRENA can make those maps visible to the online map gallery.

[3] For a more detailed description of the Global Atlas GIS and catalogue, the reader may refer to the original website of the application: www.irena.org/GlobalAtlas

The particularities of the Global Renewable Energy Atlas partnership are listed below, these were taken into account while designing the data quality information framework:

» The Global Atlas is a large international partnership, with direct country participation. The participating countries make available information from their national institutes freely, and on a voluntary basis. The added value of this partnership is to share information broadly and to reference existing work. The participating institutes are not requesting the Global Atlas to provide feedback on the quality of the information, or to assess, benchmark or compare their work with others.

» The consortium involves private companies, sharing non-commercially sensitive information. While companies are eager to provide transparent information on the data quality, a level of confidentiality may remain on processing the data.

» The datasets referenced by the SDI have not been developed specifically for the purpose of the Global Atlas, as each project followed its own specifications. The Global Atlas shall therefore take into account the original purpose intended with the creation of those datasets, contextualising data of greatly varying types and quality accordingly (GEO DSWG, 2013).

» The ambition of this framework is not to be universal, and may not apply to topographic, landcover, population density, or data related to the infrastructures.

Taking these points into consideration, the following guidelines are proposed for the *data quality information framework*:

» The purpose of collecting information on data quality is not to rank datasets or discriminate between data providers, but to inform the end-users on the suitability, and the internal characteristics of the dataset. This work is not intended to create an absolute comparative basis for datasets.

» The data quality information will be requested as part of the future data sharing agreements linking IRENA to its data providers. It is proposed that the information should be provided on a declarative basis to IRENA, who cannot take responsibility for possible errors on the information provided.

» Several datasets referenced by the data catalogue are harvested from third parties projects. It may not be possible to collect all data quality information for all datasets at once. The information will therefore be collected and improved over time.

» For private-sector datasets, the framework aims to avoid collecting commercially-sensitive information.

» Although the framework shall include a level of detail relevant to experts, effective guidance shall also be provided to non-experts.

» The information on data quality shall be easily accessible from all components of the Global Atlas SDI

DATA QUALITY

Characterising data quality for geospatial data is an active field of research. Data Quality can be separated in two components: Internal Data Quality and External Data Quality, also called “Fitness for Use” (Devillers, Bédard and Jeansoulin (2005), Zabala, et al. (2013)).

The internal data quality describes internal characteristics of the dataset (data acquisition technology, data model, instrument and sensor). This information is oriented towards technical aspects, and requires expertise for being assessed and understood. Although internal data quality information is necessary to properly describe the information, Devillers, Bédard and Jeansoulin (2005) point out that such information usually remains unused by non-experts, and there is a need to provide synthetic information to the end-users.

The concept of fitness for use is referenced by ISO 9000:2000 (ISO, 2000) and revised ISO 9000:2005 (ISO, 2005). Quality is defined by the compliance to requirements specified by the client. According to Agumya and Hunter (1999), fitness for use is usually assessed by directly comparing actual data quality against a set of established standards.

The Solar and Wind Energy Resource Assessment (SWERA) programme has developed materials and concepts corresponding to the internal and external data quality (Annex 1 and 2). This information was readily available on the SWERA website, and is now referenced by OpenEI (SWERA, 2013).

The internal data quality parameters (Annex 1) are limited to solar information. They form a quorum of information, matching points (2) and (3)[4] of the GEOSS[5] Data Quality Guidelines (GEO DSWG, 2013), recommending to provide information in particular on the resources lineage (provenance), the quality of the data resources, and any quality assurance procedures.

One relevant recommendation from GEO DSWG (2013) that can be added to this list would be to specify the original purpose of the data, since most datasets referenced by the Global Atlas were created by third parties projects.

This indication is a key to contextualising the data creation, within which a given level of precision or accuracy was achieved.

An approach similar to the fitness for use was developed for the UNEP SWERA programme as an online guide. The guide was developed by the International Solar Energy Society (ISES), the German Aerospace Centre (DLR), the U.S. National Renewable Energy Laboratory (NREL) and the State University of New York at Albany. The guide is presented in Annex 2. It defines the minimum requirement and criteria for 12 parameters and 4 different categories with 15 sub-categories of solar data applications.

SWERA end-user and service definition	Global Atlas end-user and service definition
Policy makers: Solar and wind maps can help you estimate the renewable energy potential of your country and progress toward energy independence in a global context of the continuously rising prices of fossil fuels.	**Policy makers and public authorities** in charge of planning their energy future are looking for synthetic maps of technical and economic potentials.
Developers: Assessment maps, geographic analysis tools and optimisation models can help identify specific renewable energy technologies for specific regions leading to effective use of resources in siting studies and system design.	**Investors and developers:** For market screening and helping investors raise money for more detailed assessments by commercial service providers. In the initial phase, coarser data is sufficient. Annual averages are often enough for a first assessment of a project.
Investors: Renewable energy maps in combination with optimisation models provide a credible probability of success of a project to be estimated.	
Utilities: What energy resources are available and how can load balancing be achieved?	N/A
Educators: Knowledge of renewable energy technologies is critical to inform young, future consumers, and for educating future developers and leaders.	**Educators and the interested public:** May require basic information on wind and solar resources, this is particularly valuable in countries with little practical experience with renewables. The information in the Atlas would allow for the cross referencing of best practice examples, capacity-building initiatives or (micro-finance options, with online tools developed for demonstration purposes.
Consumers: What are the renewable energy alternatives for specific individuals and communities? In rural areas, off-grid solutions using solar, wind, small-hydro or biomass are often cost-effective.	

Table 1: Comparison of the scope of end-user and services for the SWERA and Global Atlas programmes, requiring to define a specific the *'fitness for use'* category of the Global Atlas.

[4] *" 2. Provide data resources lineage, also called provenance, recording the data collection and/or generation, including auxiliary information used, in detail sufficient to allow reproducibility. 3. Provide information about the quality of the data resources, and any quality assurance procedures followed in producing the data."*

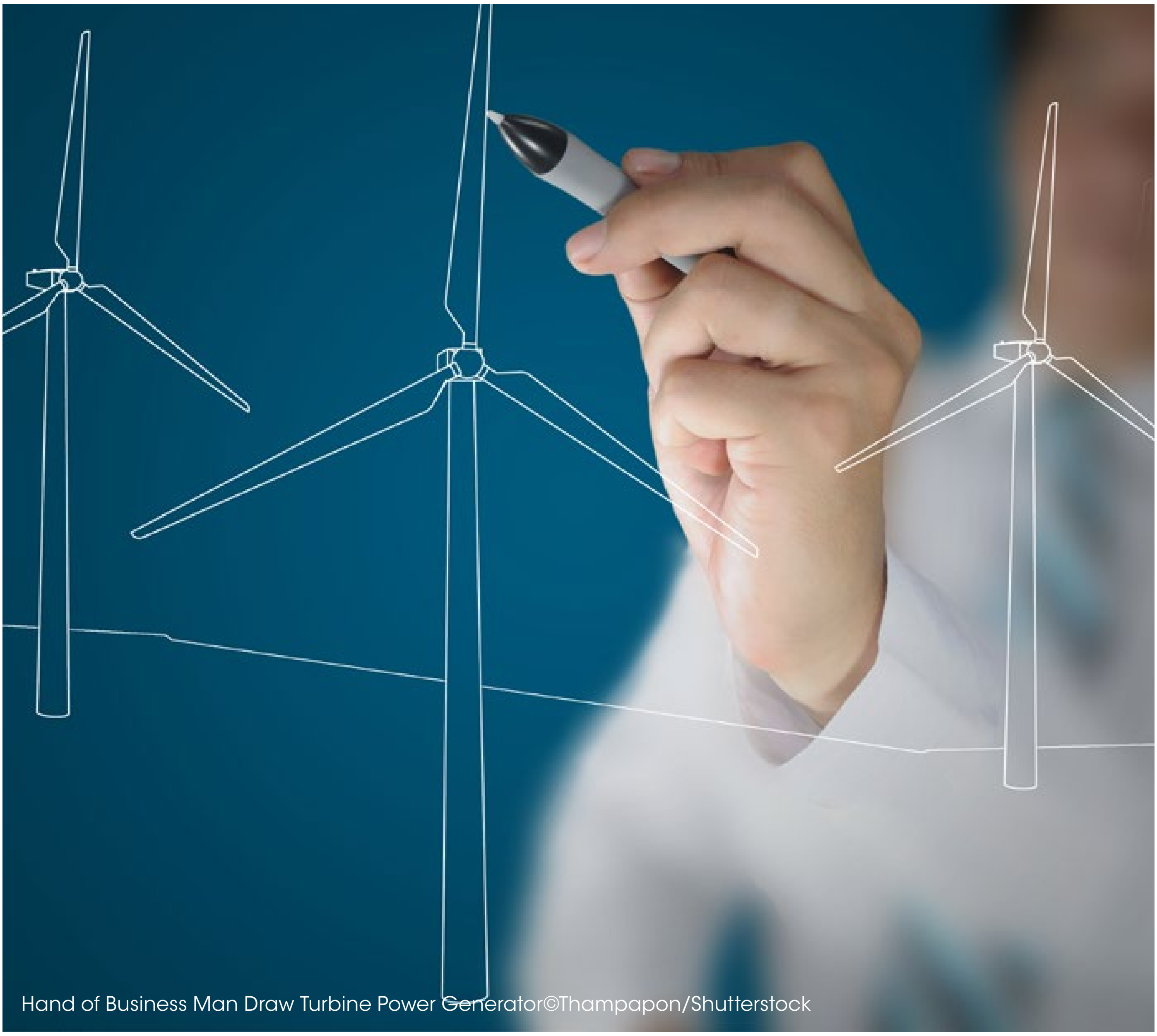
[5] Global Earth Observation System of Systems (GEOSS)

This characterisation was based on the range of stakeholders addressed by SWERA, requiring a large spectrum of information formats[6]. Table 1 compares the end-user categories of SWERA with the user categories of the Global Atlas, as defined by IRENA and CEM (2012).

The user categories defined by the Global Atlas, and the scope of services targeted by the initiative are narrower than SWERA, and a different categorisation is needed for the Global Atlas.

One major requirement communicated by the end-users of Global Atlas (IRENA, 2012) is to *'perform an initial analysis of the renewable energy potentials, and highlight the technical opportunities at different geographic scales (country, region), with a consistent and systematic approach. This initial analysis might highlight areas of particular interests, and provide a simple ranking of those areas, based on a number of simple and transparent parameters. The information should be sufficiently credible to attract interest from decision makers, and generate financing for ground measurement campaigns and detailed assessments. Ground measurement campaigns will be mandatory to refine and validate the initial analysis performed by the Atlas'.*

These requirements imply distinguishing between categories of data fit for the user categories and applications of the Atlas:


Hand of Business Man Draw Turbine Power Generator©Thampapon/Shutterstock

[6] http://en.openei.org/wiki/SWERA/Getting_Started

- datasets adapted to perform high-level analysis for the policy debate. This category of data is adapted to highlight areas of interest and perform market screening,
- datasets adapted to assess the technical potentials which is the overall aspirational objective of the Global Atlas,
- datasets exceeding the Global Atlas requirements, with a level of detail out of the original scope of work,
- datasets not reaching minimum requirements of the above categories, which can be used for activities not involving decision-making, *e.g.* education, awareness campaigns.

COMPONENTS OF THE DATA QUALITY INFORMATION FRAMEWORK

The *data quality information framework* for the Global Atlas is made of two distinct sections that deal separately with internal and external data quality.

Internal data quality – an identity card for the datasets

For the internal data quality, a number of parameters will be collected from the data providers by IRENA, on a declarative basis. This comprehensive information should be summarised as an 'identity card' of the dataset. The proposed parameters are listed in Annex3, and the concept will progressively be implemented through the data infrastructure.

External data quality – fitness for use

A set of six indicators is proposed in order to characterise the *fitness for use* of the information, summarised in four categories. Table 2 summarises the proposed approach, and provides the minimum requirements for each indicator under every category. The below categories are designed to provide guidance to the users of the Global Atlas on the appropriate use of the data they are manipulating:

- **EDUCATION:** datasets recommended for uses excluding decision-making, such as educational, or awareness raising activities.
- **POLICY:** datasets recommended for activities involving decision-making, but excluding financial commitments. Those datasets can be used to inform the high-level policy debate (identification of opportunity areas for further prospection, preliminary assessment of technical potentials), or to perform market screening (cross referencing the resource information with policy information).
- **POTENTIAL:** datasets recommended for activities involving decision-making, but excluding financial commitments. The information available through the Global Atlas SDI enables users to estimate the technical potentials.
- **BUSINESS:** This category complements the POLICY and POTENTIAL (*i.e.*, POLICY+BUSINESS, POTENTIAL+BUSINESS). The Atlas is likely to host only a sub-set of the full datasets in this category. The user is notified that the information he is manipulating is a sub-sample of a dataset of better spatial and/or temporal resolution than that available from the Global Atlas, and that of sufficient magnitude to initiate business-related activities, (*e.g.*,. kilometre (km) or less than a-kilometre, hourly data). In this case, detailed information can be supplied by the owner of the data. Commercial datasets are likely to fall in this category, but the denomination can also be proposed to non-commercial datasets extensively validated, of high spatial and temporal resolution and designed to be used for pre-feasibility studies (prospection).

Indicator/Minimum requirement per use	EDUCATION	POLICY	POTENTIAL	+BUSINESS
	Educational and awareness-raising activities	High level policy debate, (identification of opportunity areas) market screening	Assessment of technical potentials	Part of a larger dataset developed for commercial purposes. Also applies to public datasets of high quality / high resolution.
Is the dataset validated by ground measurements for more than a year, with publicly available documentation?	YES	YES	YES	YES
Is the dataset validated independently, or is the validation protocol publicly available?	NO	YES	YES	YES
Is the spatial resolution of the data 10 km or better?	NO	YES	YES	YES
Is the temporal coverage equal to or greater than 10 years?	NO	NO	YES	YES
Is the temporal distribution available through the Global Atlas? (monthly, seasonal, yearly values or statistical quantities)	NO	NO	YES	YES/NO[7] (depending on the data sharing agreement)
Is the dataset presented by the Global Atlas an extract of a larger dataset i.e., presenting better spatial and/or temporal resolution, and available by contacting the author of the data?	NO	NO	NO	YES

Table 2: proposal for data quality indicators and *fitness for use* for the Global Atlas - solar and wind components.

ACCESSING THE DATA QUALITY INFORMATION

IRENA would be charged with collecting the information on the internal data quality. IRENA would also make an initial assessment of the *fitness for use*, and propose a category of use to the data providers (EDUCATION, POLICY [+BUSINESS], POTENTIAL [+BUSINESS]), for review. The data provider can recommend a documented counter-proposal. Only agreed assessments of the *fitness for use* category would be communicated in the Global Atlas.

One technical challenge is the propagation of the information on data quality throughout the Global Atlas SDI, so that users have a direct access to it. The data catalogue of the Global Atlas would be the natural repository of the information. The metadata structure of the catalogue contains a specific section dedicated to data quality. With such solution, the GIS interface would be able to query, search and display the data quality information hosted by the catalogue, and so would any third-party application remotely accessing the Global Atlas catalogue.

[7] This depends on the Data Sharing agreement signed with the data provider.

The current procedure of the Global Atlas favours obtaining the description of the data provider resources via the core structure of their Web Services. The main advantage is that data providers do not have to manually describe their resources as ISO Metadata in existing forms in the Catalogue, which can be long and tedious. Once deployed and described on the GeoServer side, the information contained in Web Services (description, keywords, contact point, coverage…) are automatically translated into ISO 19139 Metadata when harvested by the catalogue.

The drawback of this approach is that there is no dedicated structure for describing Web Service quality information in the existing GeoServer forms.

A possible workaround that will allow internal and external quality to be easily described by data provider at the time they deploy their resources can be as follow:

- For internal data quality: Data providers would be invited to provide in the abstract section of a Web Service, a link to a document that precisely describes the internal data quality procedure assessment associated with the resource. A repository hosted and maintained by IRENA should be deployed and would host the "qualified" internal data quality documents. This will ease maintenance and consistency of this pool of documents.
- For external quality: End-users should be supplied with transparent information to identify the resources that best suit their needs according to the *fitness for use* classification. The categories can be highlighted through the data catalogue and the GIS interface by including keywords at the level of the Web Service description on the GeoServer.

The unique keywords would describe the state of the resources according to its *fitness for use*. Possible example of such unique keywords could be: GlobalAtlasEducation; GlobalAtlasPolicy; GlobalAtlasPotential; GlobalAtlasBusiness[8].

Adding these keywords in the Web Service description would allow the Catalogue harvester to reference these into the ISO Metadata description of each resource. On the catalogue side, it will be possible to classify these resources as new dedicated categories corresponding to the keyword element.

It will therefore be possible to access the keywords from the catalogue in the WebGIS client, and visualise the categories (*e.g.*, category tag, icons).

The approach describe above has the advantage of limiting the burden on the data providers, and to ensure consistency of the attributes through the entire data infrastructure, since the quality information is included at the resource level.

It is worth mentioning that such a keywords flag approach exists in GEOSS with the GEOSS Data CORE (GEO, 2013) able and has demonstrated its feasibility for the dissemination of such information in the GEOSS Common Infrastructure (GCI) for the benefit of data providers.

[8] The 'business' keyword comes in addition the Policy and Potential keywords.

ASSESSMENT OF THE GLOBAL ATLAS DATA QUALITY INFORMATION FRAMEWORK AGAINST GEOSS DATA QUALITY GUIDELINES

Table 3 and 4 compare the proposed data quality information framework for the Global Atlas to the recommendations of the GEO Data Sharing Working Group (DSWG) (GEO DSWG, 2013).

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GEOSS recommendations for Data Providers	Global Atlas Data Quality Framework
For instruments used to collect Earth observations identify, establish and exploit a "reference standard" as a means of evaluating performance or compliance for a particular activity. Ideally this should be undertaken as part of an internationally harmonised Quality Assurance procedure. For many data providers, who use commercial instruments, this may mean expressing the means by which the instruments are calibrated by the manufacturer, including the schedule followed for recalibrations.	N/A – the resource information referenced by the Global Atlas is already processed.
Provide data resources lineage, also called provenance, recording the data collection and/or generation, including auxiliary information used, in detail sufficient to allow reproducibility.	YES – As part of the internal data quality.
Provide information about the quality of the data resources, and any quality assurance procedures followed in producing the data.	YES – As part of the internal data quality.
Specify what purposes the data resource was collected or created for, or is known to be useful for, and any known caveats	YES – As part of the internal data quality.
Provide data quality assessments in a manner that ensures the quality information is supplied alongside the data resource itself, such as via associated metadata or documentation tightly coupled to the data.	YES – By linking from the metadata to a webpage referencing the internal data quality, and including a keyword in the metadata for the *fitness for use.*
Provide quality control information at product level, taking into account instrument characteristics, environmental characteristics at the time the observation is made, and any algorithmic and ancillary data characteristics.	N/A – This information is more relevant at data source level, while the Atlas is hosting processed products.
Address the multiple dimensions of quality. The purpose is not to judge or rank data resources, but to describe the characteristics needed to be known in order for the user to decide whether he/she should use them.	YES – As part of the external data quality – *fitness for use.*

Table 3: Comparison of the elements of the Global Atlas Data Quality Framework to the GEOSS recommendations listed by GEO DSWG (2013)

GEOSS recommendations for core metadata and quality tags for fitness-for-purpose assessment include	Global Atlas fitness for use indicator
Coverage, includes both spatial and temporal dimensions	Temporal only. The spatial coverage does not directly influence the use of the dataset, although it will naturally restrict the analysis to a specific territory. The Atlas hosts information with different geographic extents.
Consistency, including long-term consistency	This information is indicated as part of the internal data quality.
Uncertainties estimated and documented, including both spatial and temporal dimensions	Part of the internal data quality, not used as an indicator for *fitness for use*. Although for the technical potentials, the uncertainty value may be propagated through the analysis.
Attribution of error sources	Not included.
Validation information, *i.e.*, how the data was assessed for uncertainties by comparison with alternative measurements	YES
Latency from time of observation	Not directly relevant, although the temporal coverage, and duration of the validation period is taken into account.
Resolution, including both spatial and temporal dimensions	YES
Usability, in the sense of being in form and content convenient to use for the specific purpose	YES – GIS format, accessible by web-mapping service.
Simplicity, such that the data and the underlying data model are not unnecessarily complicated or difficult to understand or manipulate.	N/A

Table 4: Comparison of the elements of the Global Atlas Data quality Framework to the GEOSS recommendations for *fitness for use* listed by GEO DSWG (2013).

ADDITIONAL ACTIONS

As mentioned in the introductory section, the purpose of characterising Data Quality, and of this concept paper, is not to judge or rank data resources, but to describe the characteristics needed in order for the user to decide whether he/she should use them (GEO DSWG, 2013). According to the experts consulted while developing this concept paper, two research activities have emerged for the future:

» to develop agreed protocols to assess the data uncertainty for wind and solar,

» to increase transparency on the performance of the datasets by carrying an independent validation and benchmarking exercise similar to the exercise carried by the EU-funded project MESOR (MESOR, 2010)

The added value of these activities would be to provide a comparable basis for end-users to assess data uncertainty. The experts would see in those activities an open field of research, required to increase transparency on the datasets currently in use.

Power plant using renewable solar energy with sun©Gencho Petkov/Shutterstock

REFERENCES

Agumya A. and G.J. Hunter (1999), "A Risk-Based Approach to Assessing the '*Fitness for Use*' of Spatial Data", URISA *(Urban and Regional Information Systems Association) Journal,* Vol. 11, No. 1, pp. 33-44.

Devillers, R., Y. Bédard and R. Jeansoulin (2005), "Multidimensional Management of Geospatial Data Quality Information for its Dynamic Use Within GIS", Photogrammetric Engineering and Remote Sensing, Vol. 71, No. 2, pp. 205–215. *www.asprs.org/a/publications/pers/2005journal/february/2005_feb_205-215.pdf*

Hoyer-Klick, Carsten and McIntosh, Jennifer and Moner-Girona, Magda and Renné, David and Perez, Richard and Puig, Daniel (2010), *"Developing a Guide for Non-experts to Determine the Most Appropriate Use of Solar Energy Resource Information".* Eurosun 2010, Sept 29th - Oct. 1st, 2010, Graz, Austria.

GEO (Group on Earth Observations) Data Sharing Working Group (DSWG) (2013), "GEOSS (Global Earth Observation System of Systems) Data Quality Guidelines", *www.earthobservations.org/documents/dsp/GEOSS_Data_Quality_Guidelines.pdf.*

GEO (2013), "Data Sharing Principle Implementation", *www.earthobservations.org/geoss_dsp.shtml*

IRENA (International Renewable Energy Agency) (2012), "Global Solar and Wind Atlas – gathering the end-user community", Summary of the IRENA/CEM (Clean Energy Ministerial) workshop of the Global Atlas end-users, Abu Dhabi, 13 January 2012, *www.irena.org/DocumentDownloads/events/GlobalAtlasEnd-userworkshop/summary.pdf.*

IRENA and CEM Multilateral Solar and Wind working group (2012), "Implementation Strategy for a Global Solar and Wind Atlas", *www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=240.*

ISO (International Organisation for Standardisation) (2000), "ISO 9000:2000, Quality management systems - Fundamentals and vocabulary".

ISO (2005), "ISO 9000:2005, Quality management systems - Fundamentals and vocabulary".

MESOR (Management and Exploitation of Solar Resource Knowledge) (2010). "Benchmarking". *www.mesor.net/benchmarking.html*

SWERA (Solar and Wind Energy Resource Assessment) (2013), *http://en.openei.org/wiki/SWERA/Data*

UNEP (United Nations Environment Programme) and IRENA (2013), "Insights from Interviews, a Survey, and a Workshop with Potential End-Users of the Global Atlas for Solar and Wind Energy", *www.irena.org/GlobalAtlas/publications*

World Meteorological Organization (WMO) (2011), "Guide to climatological practices", WMO-N 100. ISBN 978-92-63-10100-6, *www.wmo.int/pages/prog/wcp/ccl/documents/WMO_100_en.pdf*

Zabala, A., *et al.* (2013), "Rubric-Q: Adding Quality-Related Elements to the GEOSS Clearinghouse Datasets", *Journal of Applied Earth Observations and Remote Sensing,* IEEE (Institute of Electrical and Electronics Engineers), Vol. 6, No. 3, pp. 1939-1404.

Wind turbine farm with rays of light at sunset© Johan Swanepoel/Shutterstock

ANNEX 1: SOLAR AND WIND ENERGY RESOURCE ASSESSMENT'S (SWERA) INTERNAL DATA QUALITY ELEMENTS

Organisation providing the data.
Geographical coverage
Source of data: geostationary satellites, or a combination of geostationary satellites and ground stations.
Spatial resolution: the minimun distance between two adjacent features or the minimum size of a feature that can be detected by a remote sensing system (units in km).
Temporal resolution: refers to the frequency with which images of a given geographic location can be acquired (15 min, 30 min, hourly, daily, monthly, annual…).
Time coverage. Period of time the data have been acquired (including start and end periods).
Component: The solar components contained in the dataset, *i.e.* GHI, DNI, TPI, DFI, PAR, Diffuse, Global Tilt.
Validation information available - published articles, preferably, peer-viewed & third party (primary) authored, providing RMSE & MBE results with documented methodology, and using IEA/SHC Task 36 and/or MESoR benchmarks.
Validation Type - none provided, conference paper, or third party authored peer reviewed using IEA/SHC Task 36 and/or MESoR benchmarks.
Low Mean Bias Error (MBE): low difference between an estimator's expectation and the true value of the solar parameter being estimated. Considered Low when: <5% GHI, <10% DNI.
Low root mean square error (RMSE): The root mean square error measures the differences between values predicted by a model and the values actually observed. Considered Low when: <120W/sqm hourly GHI<160W/sqm hourly DNI.
Frequency distirbution metrics, *e.g.* KSI, OVER, available? If yes, values and link should be provided.
Current data available / Near real time data.
Availability: Free data sets or for sale.
Website (where available).

Powerplant with photovoltaic panels and eolic turbine© taraki/Shutterstock

ANNEX 2: SOLAR AND WIND ENERGY RESOURCE ASSESSMENT'S (SWERA) INTERNAL EXTERNAL DATA QUALITY ASSESSMENT – FITNESS FOR USE

See below for expanation of input and changes (km)	Minimum spatial resolution (km) note 1 degree equals to 100km	Minimum temporal resolution	Minimum time coverage (years)	Solar radiation components	peer-reviewed or third party validated?
Investment Decision					
Site selection	10	annual long-term (map)	10	GHI or DNI	yes
Pre feasibility	100	annual long-term	5	GHI or DNI	yes
Feasibility	10	hourly	10	DHI or DNI	yes
PV offgrid systems (4)	10	hourly	10	GHI	yes
PV Small systems	10	monthly	5	GHI	yes
PV Medium sized systems	10	hourly	5	GHI+DNI, in	yes
PV Large systems	10	hourly	10	GHI+DNI, in	yes
Tracking/concentrating PV	10	hourly	10	GHI+DNI,i n	yes
Solar hot water	100	monthly	5	GHI	yes
Solar cooling	100	monthly	5	GHI	yes
CSP	10	hourly	10	DNI	yes
Daylighting		hourly	5	Illuminance	yes
Solar Process Heat	10	hourly	10	GHI	yes
Due diligence	10	hourly	10	GHI+DNI	yes
Commissioning/System Acceptance	10	hourly	10	GHI+DNI	yes
Operation					
Performance monitoring (does the system work correctly?)	10	hourly	n/a	GHI+DNI	yes
Performance improvement (how to improve system performance)	10	hourly	n/a	GHI+DNI	yes
Forecasting	10	hourly	n/a	GHI	yes
Energy policy					
Potential assessment	10	annual long-term (map)	5	GHI	yes
Design of support instruments, e.g. levels of tariffs, incentives,	10	annual long-term (map)	10	GHI	yes
Climate policy					
Climate models	25	daily	VARIABLE	GHI	yes
Impact assessment models	10	daily	10	GHI+DNI	yes
Climate monitoring	25	annual	20	GHI+DNI	yes
Science					
Energy system analysis (Systems, components)	10	hourly	n/a	GHI+DNI (5)	yes
System simulations	10	hourly	n/a	GHI+DNI (5)	yes
Grid integration studies	10	hourly	5	GHI	yes

Database has been bench-marked according to IEA Task 36	Low Bias (<5% for GHI and <10% for DNI) (1)	Low root mean square error (<125 W/m² for hourly GHI and <160W/m² for hourly DNI) (1)	Frequency distribution metrics, e.g., KSI, OVER, available? (1)	Use of multiple independent data source	On site measurement	Current data available/Near real time data
				recommended always	**recommended always**	**No with the accuracy needed**
no	yes	n/a	n/a	yes	no	no
no	yes	no	no	yes	no	no
yes	yes	no	no	yes	no	no
yes	yes	no	yes	yes	yes	yes
no	yes	no	no	no	no	no
yes	yes	no	yes	yes	yes	yes/no
yes	yes	no	yes	yes	yes	yes
yes	yes	no	yes	yes	yes	yes
no	yes	no	no	no	no	no
no	yes	no	no	no	no	no
yes	yes	no	yes	yes	yes	yes
no	yes	no	no	no	no	no
yes	yes	no	yes	yes	yes	yes
yes	yes	no	yes	yes	yes	yes
yes	yes	no	yes	yes	yes	yes
				recommended always	**recommended always**	**No with the accuracy needed**
	yes	yes	less important	no	no	yes
	yes	yes	less important	no	no	yes
	yes	yes	less important	no	no	yes
				recommended always	recommended always	YES
yes	yes	n/a	n/a	yes	no	no
yes	yes	n/a	n/a	yes	no	no
				recommended always	**recommended always**	**No with the accuracy needed**
yes	yes	no	no	no	no	no
yes	yes	no	no	no	no	no
yes	yes	no	no	yes	yes	yes
				recommended always	**recommended always**	**No with the accuracy needed**
yes	yes	no	yes	no	no	no
yes	yes	yes	yes	no	no	no
yes	yes	yes	yes	no	no	no

ANNEX 3: INTERNAL DATA QUALITY FOR THE GLOBAL ATLAS

1. Author	» Organisation providing the data, or originating project » Original website » If required by the project - Acknowledgements to funders
2. Date of issue	Date and revision
3. Geographic coverage	Global, continent, country
4. Data source	Input data and/or model, ground measurement network (*i.e.*, number and type of instruments).
5. Spatial resolution (km)	For the dataset presented by the Atlas. If the dataset is a sub-set of a dataset of better resolution, please indicate also the best available spatial resolution.
6. Temporal resolution	» For the dataset presented by the Atlas (*e.g.*, annual average, monthly, daily), and in case of averaging the temporal resolution of the original data source. » If the dataset is a sub-set of a dataset of better resolution, please indicate also the best available temporal resolution.
7. Time coverage (time begin, time end)	Years (inter annual variability). Indicate data gaps. Indicate whether the dataset complies to the World Meteorologicl Organisation (WMO) definition of: provisional normal (any period), period averages (10 full years), climate normal (averages of at least 30 years), or climate standard normal (averages over 1961–1990) (World Meteorological Organisation, 2011).
8. Components	» Available through the Atlas - *e.g.*, yearly global irradiation on horizontal plane, yearly mean of irradiance on normal incidence, wind speed, Weibull A, Weibull k, power density (specify the altitude for wind). » Provide units (in the International System) » If the dataset is a sub-set of a dataset of better resolution, please indicate also the available parameters.
9. Validation type	» Internal, peer reviewed, third party authored, International Energy Agency (IEA) Task 36 standards/benchmarks. » Is the validation process publicly available (link or reference)?
10. Validation measures and time coverage	» For example, bias, Mean absolute error, root mean square error (RMSE), correlation coefficient. » Follow the ISO Guide on the Expression of Uncertainty in Measurement: first edition, International Organization for Standardization, Geneva, Switzerland, 1995 » Time coverage of the validation sample.
11.Number of validation points and their spatial repartition/ type of terrain	Gives an indication of the legitimacy of the validation for different locations or types of terrains. If available, indicate if the uncertainty varies with the geographic location.
12. Original dataset	If the dataset is a sub-set of a dataset of better resolution, please indicate how the full information can be accessed.
13. Is there a fee or any other constraints to access and use the full dataset?	If yes, indicate if a sample is available free of charge. Describe constraints of use.
14. Recommendations of use of the data	Does the dataset perform better in specific areas or locations? Is a map of uncertainty available?


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www.irena.org/GlobalAtlas

Potentials@irena.org

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IRENA
International Renewable Energy Agency

IRENA Headquarters
CI Tower, Khalidiyah
P.O. Box 236, Abu Dhabi
United Arab Emirates

www.irena.org