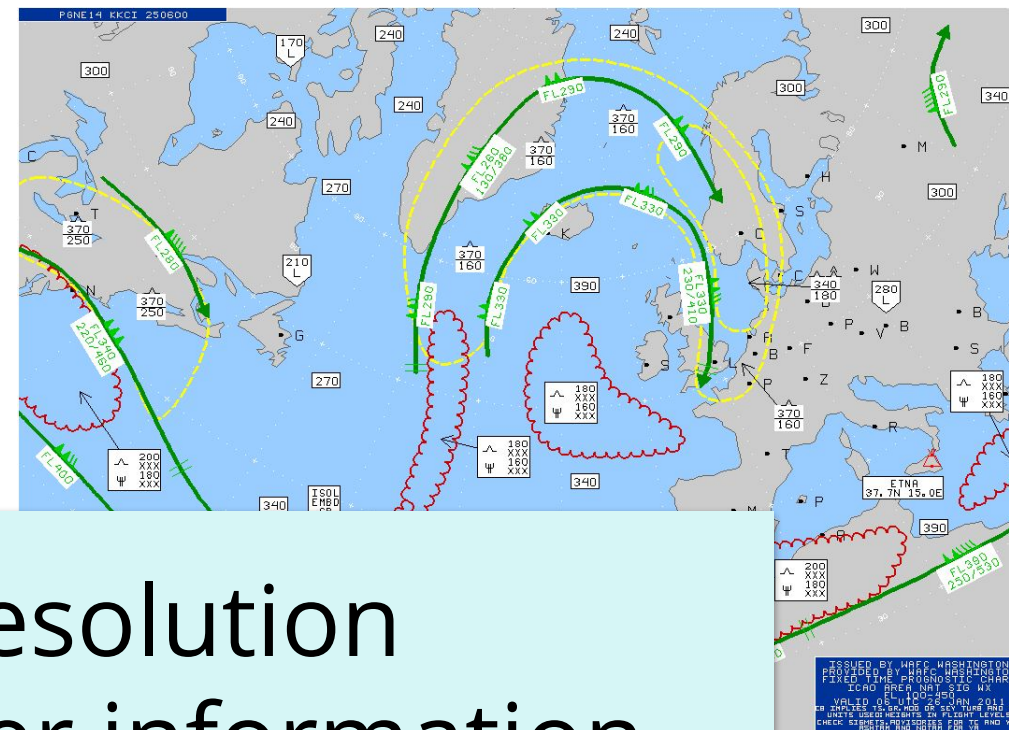


- 1 Data for low carbon energy transition
- 2 The EERAdata project
- 3 Status: Data, databases, metadata
- 4 To do: Advancing metadata

Data for the low carbon energy transition

New actors
invest in the
energy market.



High resolution
weather information
is needed. On-side
conditions matter.



Digital twins
are designed
and used.

Consumers
are metered.



Buildings get
energy passports.



Digital reporting &
compliance is starting.

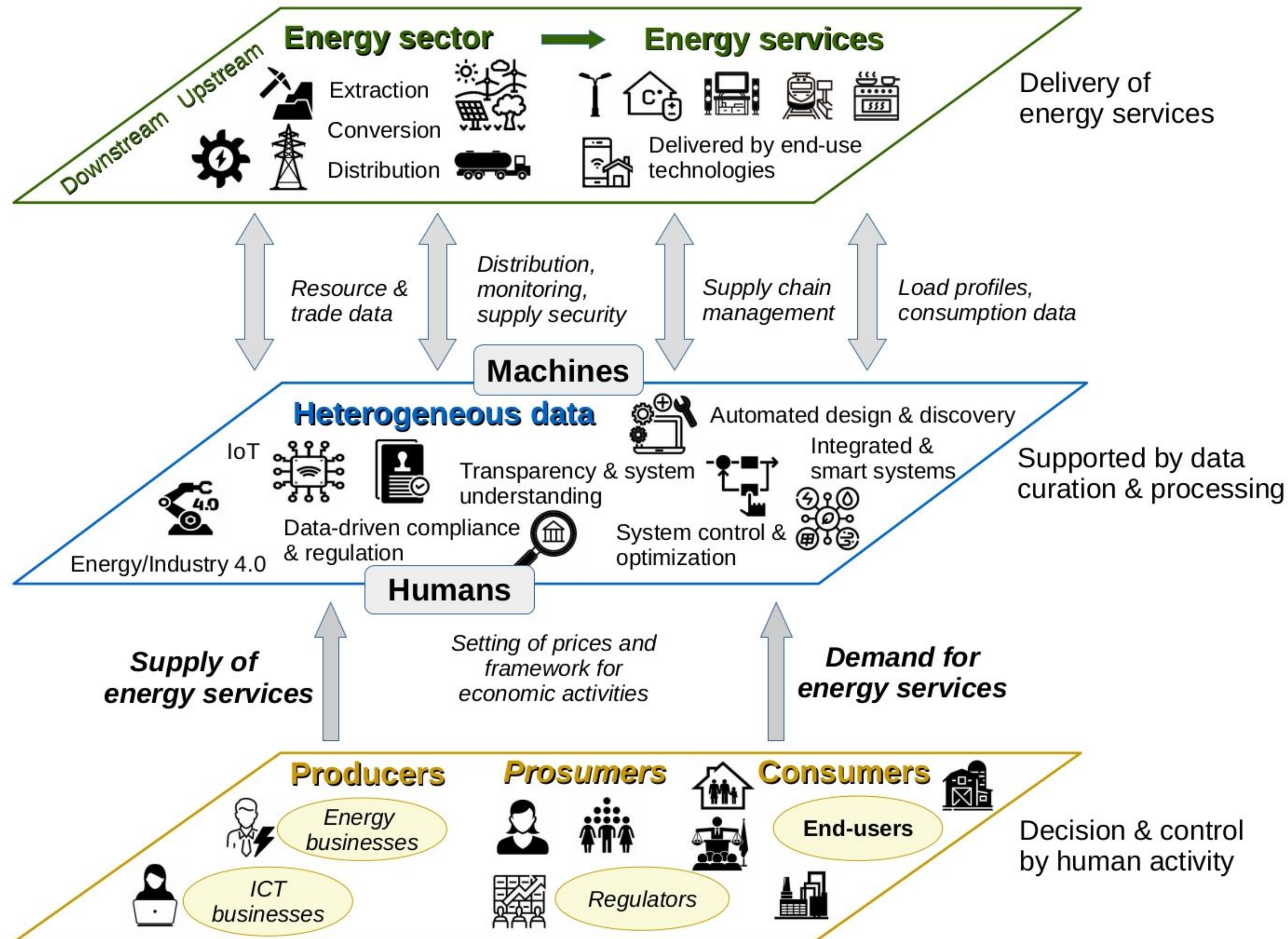


Equipment is
monitored.



Source of photos: see Appendix

Data for the low carbon energy transition



- Energy systems is a highly complex system of machines and humans.
- Due to the many different components, very heterogeneous data are exchanged.
- Low carbon energy demands and liberalization increase number of actors and complexity of technologies and interactions.

Towards FAIR and open low carbon energy data

- Horizon 2020 project, 03/2020-02/2023, <https://www.eeradata.eu/>
- Develop a joint understanding of how to approach FAIR/O energy data,
- Provide best-practices and recommendations on FAIR/O practices, connecting to EOSC and other initiatives,
- **Suggest a draft for metadata for the energy domain**, building on and linking with existing work in the field,
- Conduct a series of **community workshops** to advance 4 use cases
- Build a community for FAIR and open energy data
- Build a **FAIR and open energy data hub** (federated database)

EERAdata use cases: 1) Building efficiency, 2) Power transmission and & distribution networks, 3) Materials for low carbon energy, 4) Energy efficiency and low carbon energy policies



Community workshops building on HLEG 2018

First Year *Define*

Concepts

Workshop I

FAIR & Open Energy Data
June 2020. Community building.

Workshop II

Metadata concept
30.11.-7.12. 2020.

Second Year *Implement*

Ecosystem, culture, skills

Workshop III

FAIRification put into practice
Characterization of data and
development of workflows.

Workshop IV

Supporting technologies
Fair & open energy data
infrastructure.

Third Year *Embed & Sustain*

Incentives

Workshop V

Sustainable models
From licensing to business m.

Workshop VI

*New trends in open science &
steps beyond EERAdata*

Community workshop II - FAIR & open metadata

- 3 elements: Prep workshop, Online hackathon to write a metadata community paper, Use case workshops

Preparatory workshop (05.11.2020: 10-12)

- Lecture input & discussion: Advancing metadata standards for low carbon energy research
- Briefing for EERAdata paper writing workshop (Who? How? When? What?)

Hackathon “Metadata community paper” (Monday, 30/11/2020 and Monday, 7/12/2020, 10-16)

- Participants are co-authors
- DAY 1: Builds on read & watch aheads from preparatory workshop. Starts with a discussion of the proposed structure of the **community paper** (1st draft). Continues with **writing teams organized in break out groups**. Ends with a reporting back from writing teams.
- FINAL DAY: Starts with an **input from use cases**, continues with writing teams in break out groups. Ends with a presentation and discussion of work/open issues.
- Output: Reviewed and extended draft, to be finalized by the group by end of December.



Use case workshops. Spread across Tuesday-Friday, 1/12/2020-4/12/2020.

Discuss metadata from use case perspective. Collaboration across use cases. Specific dates on website.

- Building efficiency:
- Power transmission and distribution networks:
- Materials for low carbon energy:
- Energy efficiency and low carbon energy policies:



Community workshop II - FAIR & open metadata

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You are cordially invited to join!

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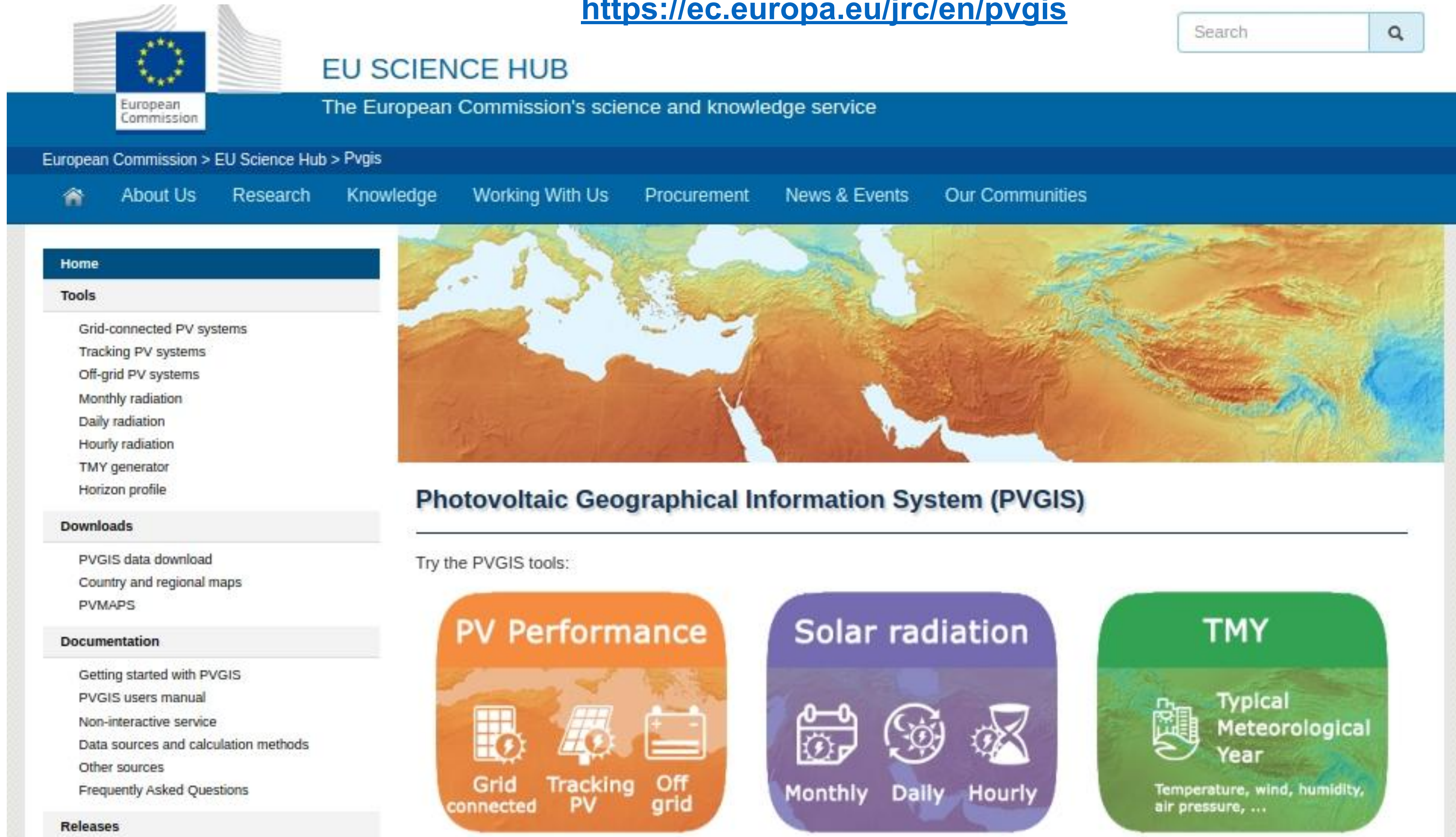


- Building efficiency:
- Power transmission and & distribution networks:
- Materials for low carbon energy:
- Energy efficiency and low carbon energy policies:



Databases for low carbon energy and metadata

<https://ec.europa.eu/jrc/en/pvgis>



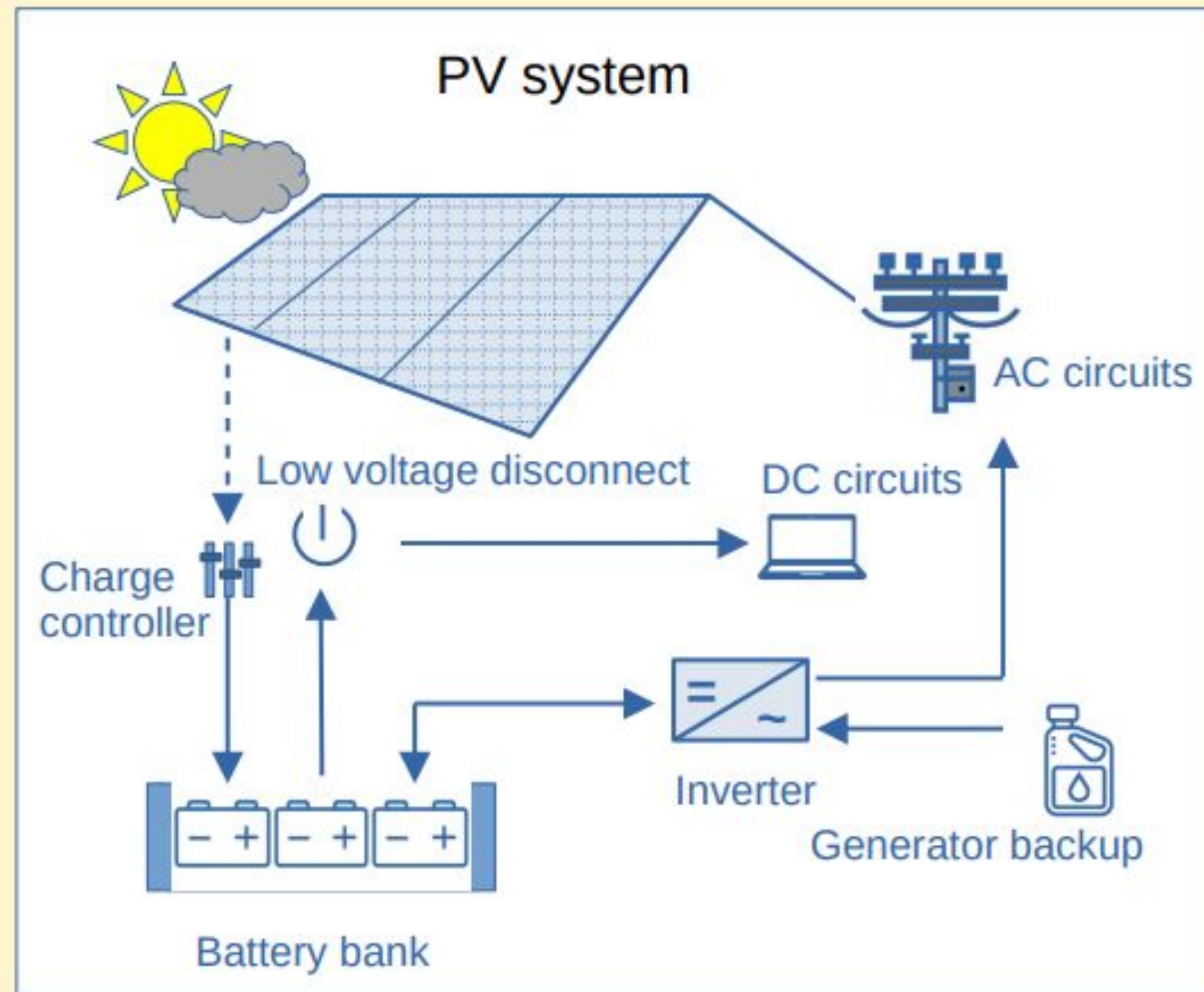
The screenshot shows the EU Science Hub website, specifically the Photovoltaic Geographical Information System (PVGIS) page. The header includes the European Commission logo and the text "EU SCIENCE HUB" and "The European Commission's science and knowledge service". A search bar is located in the top right corner. The main navigation bar lists various sections: Home, About Us, Research, Knowledge, Working With Us, Procurement, News & Events, and Our Communities. The left sidebar contains a "Tools" section with links to Grid-connected PV systems, Tracking PV systems, Off-grid PV systems, Monthly radiation, Daily radiation, Hourly radiation, TMY generator, and Horizon profile. Below this is a "Downloads" section with links to PVGIS data download, Country and regional maps, and PVMAPS. The "Documentation" section includes links to Getting started with PVGIS, PVGIS users manual, Non-interactive service, Data sources and calculation methods, Other sources, and Frequently Asked Questions. The "Releases" section is also present. The main content area features a large map of Europe and the Mediterranean region, followed by the title "Photovoltaic Geographical Information System (PVGIS)". Below the title, it says "Try the PVGIS tools:" and displays three large buttons: "PV Performance" (with icons for Grid connected, Tracking PV, and Off grid), "Solar radiation" (with icons for Monthly, Daily, and Hourly), and "TMY" (with an icon for Typical Meteorological Year and text "Temperature, wind, humidity, air pressure, ...").

PV data system - an example of a research workflow

PV system monitoring

Input data

Weather
Location
Type of module
Orientation of roof
...



Output data

Electricity to grid
Solar irradiance
Efficiency
Use profiles
...

PVGIS data output: example for information in csv file

Input section

Latitude (decimal degrees):	51.95								
Longitude (decimal degrees):	14.711								
Radiation database:	PVGIS-SARAH								
Nominal power of the PV system (c-Si) (kWp):	1								
System losses(%):	14								
Fixed slope of modules (deg.):	35								
Orientation (azimuth) of modules (deg.):	0								

Output section

Fixed angle									
Month		E_d	E_m	H(i)_d	H(i)_m	SD_m			
1		0.98	30.37	1.14	35.33	6.54			
2		1.69	47.38	1.95	54.47	16.48			
3		2.73	84.55	3.25	100.84	18.18			
4		4.06	121.83	5.01	150.23	21.45			
5		4.13	127.89	5.22	161.83	19.78			
6		4.21	126.22	5.42	162.53	9.68			
7		4.15	128.61	5.42	168.15	16.14			
8		3.93	121.68	5.05	156.57	14.51			
9		3.44	103.09	4.3	128.97	17			
10		2.31	71.5	2.8	86.71	16.17			
11		1.26	37.85	1.5	45.01	13.49			
12		0.95	29.42	1.11	34.37	6.23			
Year		2.82	85.87	3.52	107.08	5.52			
		AOI loss (%)	Spectral effects (%)	Temperature and low irradiance loss (%)	Combined loss (%)				
Fixed angle:		-3.05	1.82	-5.54	-19.82				

Variable description

E_d: Average daily energy production from the given system (kWh/d)
E_m: Average monthly energy production from the given system (kWh/mo)
H(i)_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2/d)
H(i)_m: Average monthly sum of global irradiation per square meter received by the modules of the given system (kWh/m2/mo)
SD_m: Standard deviation of the monthly energy production due to year-to-year variation (kWh)

PVGIS (c) European Communities, 2001-2020

PVGIS data output: example for information in json-ld file

Data

```
{"inputs": {"location": {"latitude": 51.95, "longitude": 14.71, "elevation": 44.0}, "meteo_data": {"radiation_db": "PVGIS-SARAH", "meteo_db": "ERA-Interim", "year_min": 2005, "year_max": 2016, "use_horizon": true, "horizon_db": "DEM-calculated"}, "mounting_system": {"fixed": {"slope": {"value": 35, "optimal": false}, "azimuth": {"value": 0, "optimal": false}, "type": "free-standing"}}, "pv_module": {"technology": "c-Si", "peak_power": 1.0, "system_loss": 14.0}, "economic_data": {"system_cost": null, "interest": null, "lifetime": null}}, "outputs": {"monthly": {"fixed": [{"month": 1, "E_d": 0.98, "E_m": 30.37, "H(i)_d": 1.14, "H(i)_m": 35.33, "SD_m": 6.54}, {"month": 2, "E_d": 1.69, "E_m":
```

Metadata

```
-----
"meta": {"inputs": {"location": {"description": "Selected location", "variables": {"latitude": {"description": "Latitude", "units": "decimal degree"}, "longitude": {"description": "Longitude", "units": "decimal degree"}, "elevation": {"description": "Elevation", "units": "m"}}}}, "meteo_data":
-----
"outputs": {"monthly": {"type": "time series", "timestamp": "monthly averages", "variables": {"E_d": {"description": "Average daily energy production from the given system", "units": "kWh/d"}, "E_m": {"description": "Average monthly energy production from the given system", "units": "kWh/mo"}, "H(i)_d": {"description": "Average daily sum of global irradiation per square meter received by the modules of the given system", "units": "kWh/m2/d"}, "H(i)_m": {"description":
-----|
"%"}, "l_spec": {"description": "Spectral loss", "units": "%"}, "l_tg": {"description": "Temperature and irradiance loss", "units": "%"}, "l_total": {"description": "Total loss", "units": "%}}}}}}}
```

PVGIS metadata - pros and cons

Pros:

- contains all relevant scientific context
- uses json-ld as format
- contains description on variables and units
- contains human description on variables
- ...

Cons:

- Variable names are not linked to a unique standards
- Units are not linked to unique standards
- No links to input databases
- Some administrative metadata is missing and could be implemented using Dublin core
- ...

Asking the practitioners: Questionnaire on metadata etc.

GUIDELINES FOR THE MONITORING OF PV SYSTEMS

Summary of questionnaire



COST ACTION PEARL PV: CA16235

Working Group 1, Task 1.1

Basant Raj Paudyal, Anne Gerd Imenes (University of Agder)

Date: 9 May 2019

Quality Control: In terms of quality control, most respondents require that instrumentation/sensor accuracy should be specified, data quality control processes should be in place, and a minimum requirement for data accuracy should be set.

File Format: Most respondents prefer “csv” file format, with missing datapoints reported as “NaN” and using 1-second time stamp resolution (YYYY-MM-DDTHH:MM:SS). Two respondents require sub-second resolution data (SS.ssss), indicating special applications such as grid interaction analysis. Reporting of missing datapoints (e.g. number or time period of datapoints missing) is desired, not required.

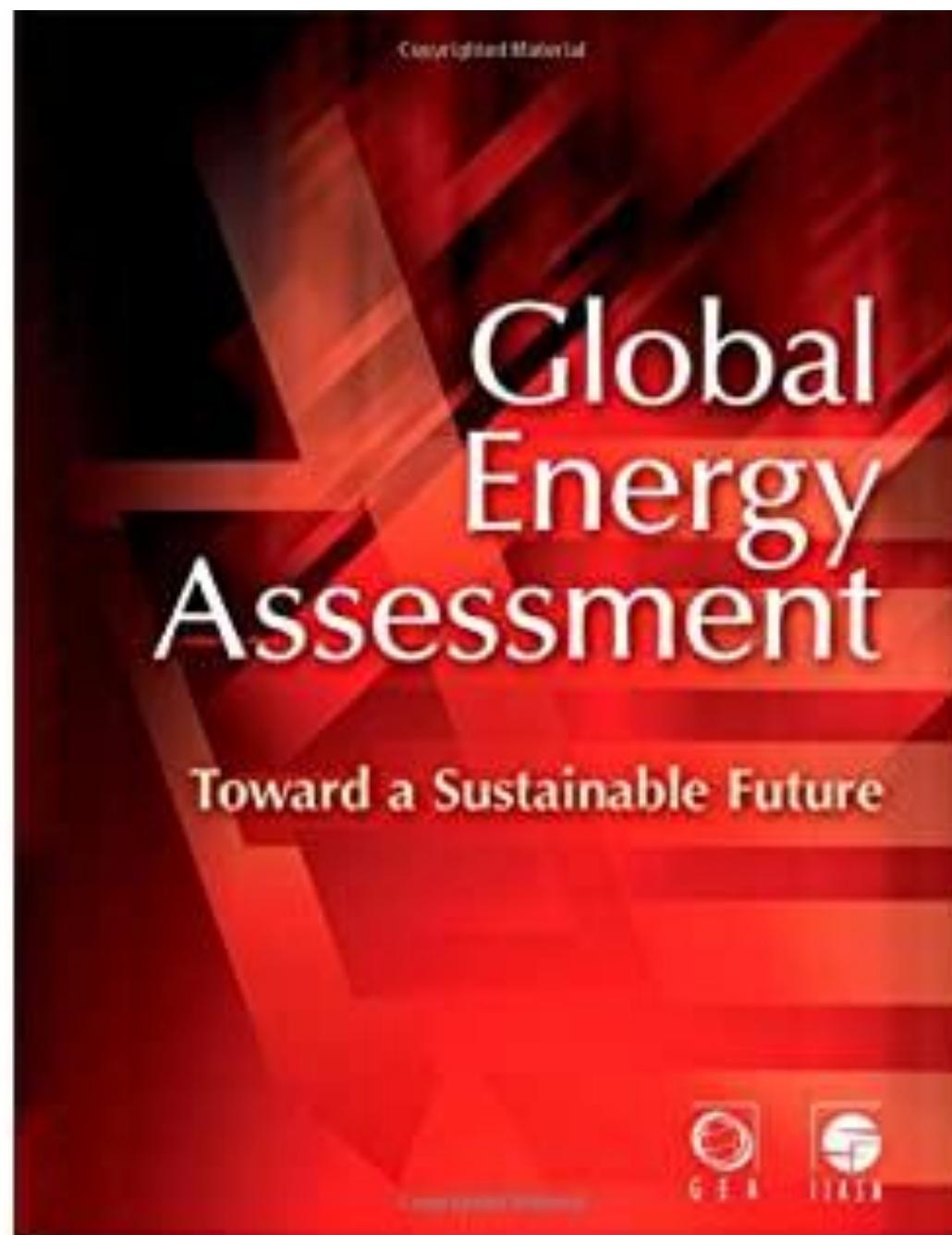
Metadata - PV system and components: Generally, respondents agree that a relatively large amount of metadata should be made available to adequately document the system and technology used. Required information is: Site name and GPS coordinates, type of PV installation (fixed, tracking, BAPV/BIPV, roof/façade, etc), type of PV module technology, PV module characteristics (Imp, Vmp, Isc, Voc, Pmp, temperature coefficients), string design (number of modules, number of strings, connections to each inverter), shading (no shading), type of inverter technology (central, string, micro, transformerless, etc), inverter specifications (AC/DC power, frequency, rated efficiency, number of phases, reactive power, number of independent MPP's, total number of inverters, communication protocols). When applicable, the following BOS-components should be specified: Battery-system and own developed hardware/software. Information about other parts of the BOS is desired, not required.

taken from:

COST ACTION PEARL PV: CA16235, Working Group 1, Task 1.1, Authors: Basant Raj Paudyal, Anne Gerd Imenes (University of Agder)

Multidisciplinarity and interdisciplinarity in energy science

Global energy assessment, index on non-engineering solar energy issues:



- case study
- economics
- installed capacity
- market developments
- occupational health
- potential
- sustainability
- technology roadmap
- transitions management
- buildings
- forecasting
- health risks
- historical trends
- innovation policies

However:

Not every detail is needed in interdisciplinary studies.

Therefore, clean modularity of concepts & variables are needed.

Metadata - The babylonian confusion of tongues



Pieter Bruegel the Elder - The Tower of Babel. Source: Wikimedia Commons

Towards common understanding of concepts in energy science

Existing taxonomies/ontologies in energy science

- PV-TONS ontology (literature, Oxford solar house)
- IRPWind taxonomy (scientific literature, expert elicitation)
- SEMANCO - Semantic tools for Carbon Reduction in Urban Planning (standards, use cases, activity descriptions)
- energy accounting of statistical offices (e.g. Eurostat)
- Energistics: Energy Industry Profile of ISO 19115-1:2014
- Open Energy Ontology (community initiative)
- ...

Other options for (semi-)automatized sourcing of ontologies

- Textbooks and exam questions
- Wikipedia articles
- Models and simulation activities on aspects of the energy system

However:

Many unrelated ontologies and islands of codified knowledge.

Alignment and linking is needed.

Support for navigation & visualization required.

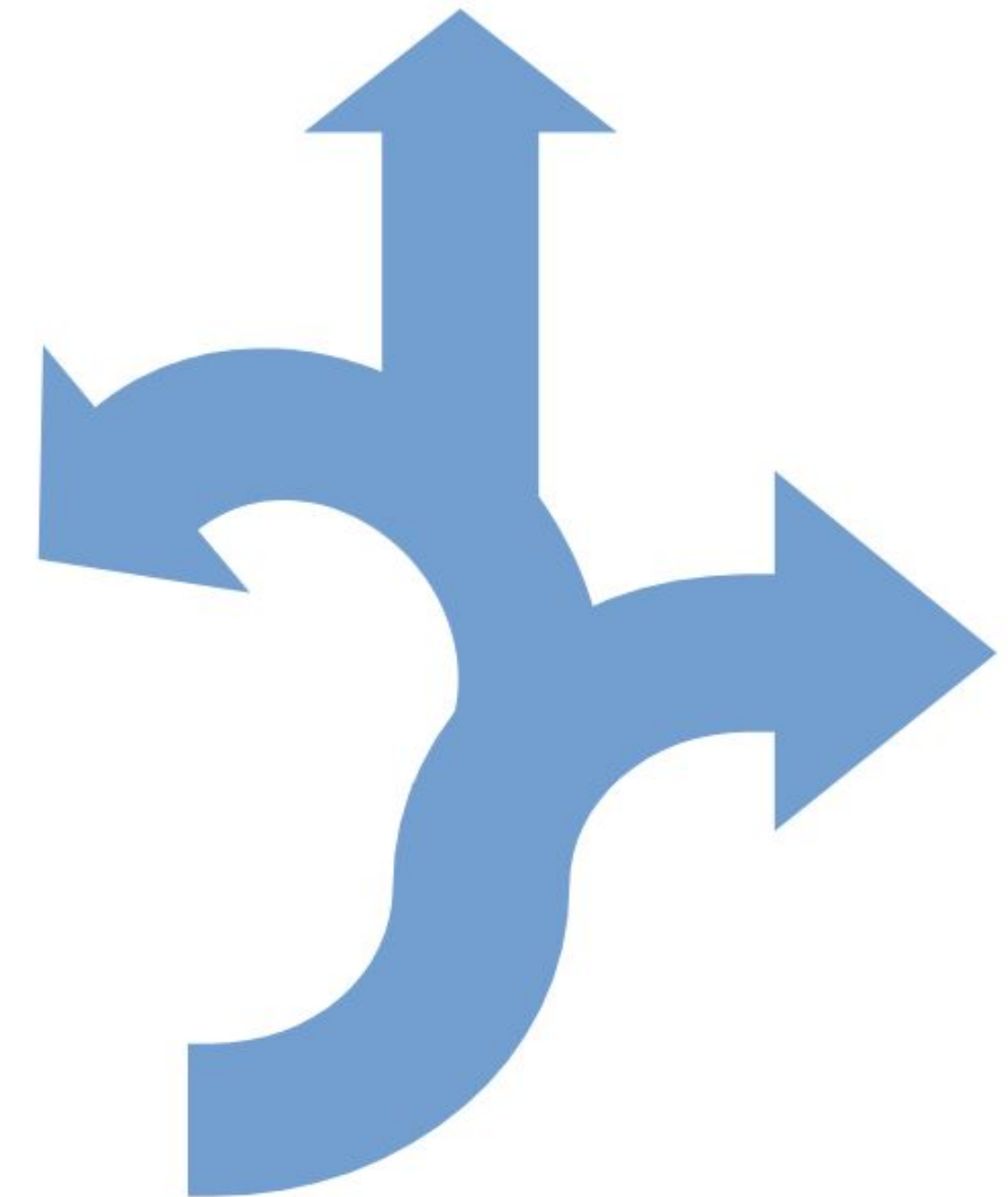
Bringing things together?

Convergence to a common metadata model

VS.

Interoperation among many metadata models

taken from: RDA Metadata Principles and their Use



Conclusions

- Need of data governance and data harmonization in the energy sector: Unleash synergies to support the transition to a low carbon energy system
- FAIR principles seen as important design principles
- Cooperation on data only possible if rich metadata are provided (and metadata are updated along the scientific workflow).
- Competing interest by various research interests:
 - very detailed information needed by specialist
 - only aggregated information needed by interdisciplinary projects
- Many ontologies already existing, of various detail, typical unlinked and with non-standardized terms/vocabulary
- The energy system may serve as a overarching concept to align and match ontologies
- Standardization may be fostered by metadata suggestion cards similar to suggested keywords, e.g. in the upload process



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 883823.

www.eeradata.eu

Credits & sources

https://commons.wikimedia.org/wiki/File:Aviation_weather_forecast_chart.png

https://commons.wikimedia.org/wiki/File:Halberton,_electricity_transformer_station_-_geograph.org.uk_-_151077.jpg

[https://en.wikipedia.org/wiki/File:Windmills_D1-D4_\(Thornton_Bank\).jpg](https://en.wikipedia.org/wiki/File:Windmills_D1-D4_(Thornton_Bank).jpg)

https://commons.wikimedia.org/wiki/File:Libro-sistemas-scada-3ra-ed-mecatronica-automatizacion-22680-MLM20234441553_012015-F.jpg

https://commons.wikimedia.org/wiki/File:Intelligenter_zaeher- Smart_meter.jpg

<https://www.nps.gov/goga/learn/management/energy-efficiency.htm>



TOWARDS A FAIR AND OPEN DATA
ECOSYSTEM IN THE LOW-CARBON
ENERGY RESEARCH COMMUNITY