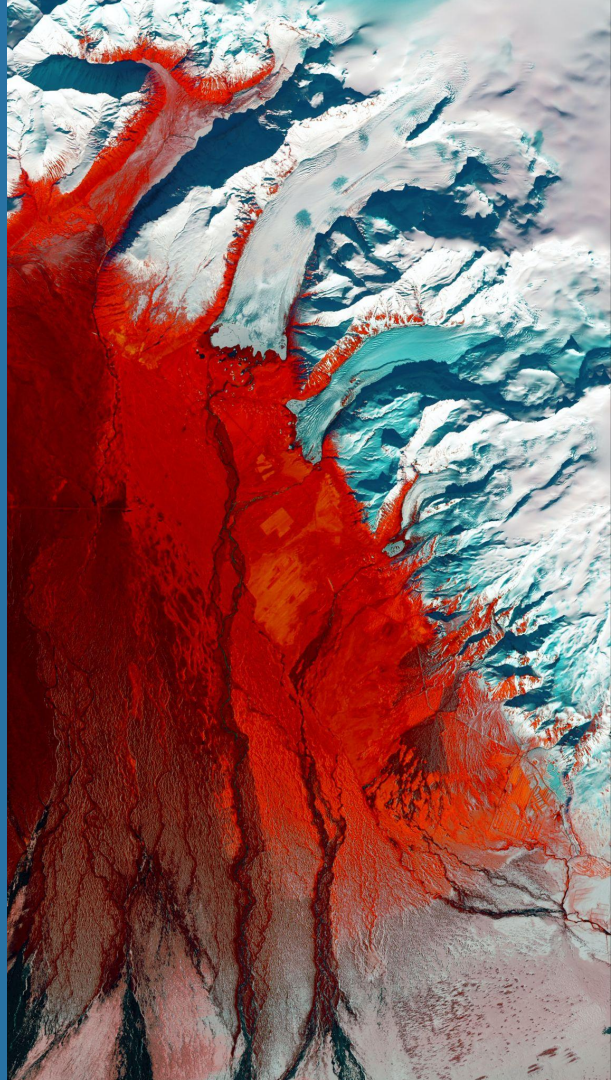
Digitalisation of Power Curves

An introduction to the schema for the upcoming IEC 61400-16 standard and our experiences developing it.

2024 Drivetrain Reliability Collaborative Workshop, Argonne National Laboratory, Chicago.

Tom Clark
CEO, Octue
14 March 2024



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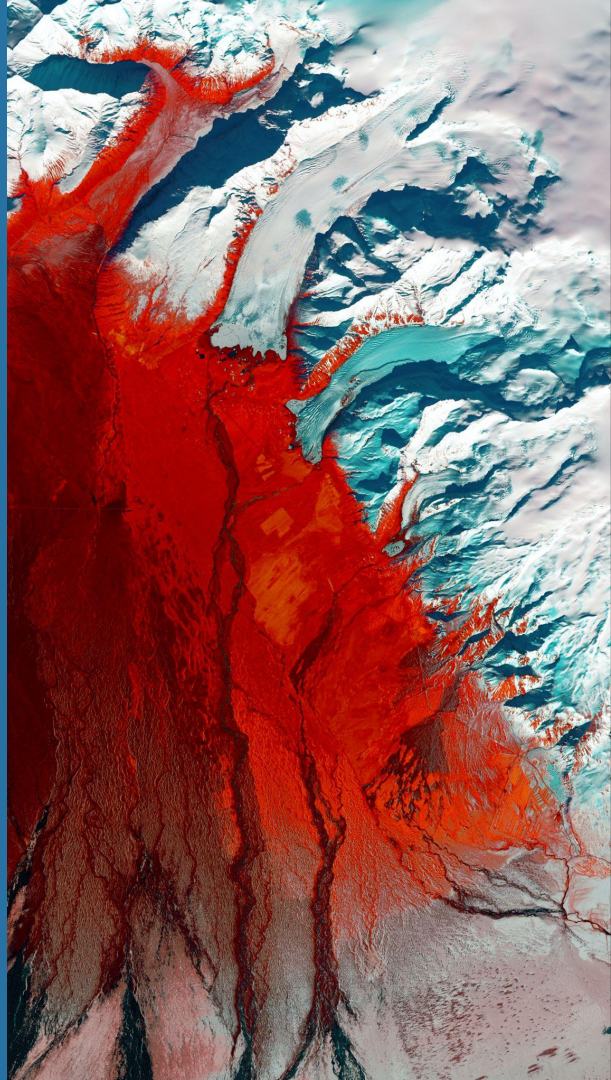
Our mission: Help scientists and engineers work more effectively with data

Octue is a solutions provider:

- we develop open-source tools
- we provide consultancy on data engineering and application development



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Today

Introduction to the schema and its status

The schema, what it's for and where we're at with it. We'll look at motivations, key features and the process of becoming a standard.

Tools and Ecosystem

A look at some of the possibilities: webforms for data entry, QC processes, plotting tools, databases and report generators.

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Aims and Motivation

To create a common format to be used by all OEMs for the sharing of power curves and associated key information that serves multiple stakeholders using an agreed machine-readable format and common terminology to minimize errors and to reduce the turnaround time for Energy and Turbine Suitability Analysis.

Digitalization of power curves, especially seamless data exchange, will enable reduction in:

- **time-to-market** for new wind turbine sales (eg by accelerating turnaround for OEMs' local sales teams)
- **time-to-financial-close** for new wind farms
- **workflow friction** between internal and external teams
- **technical, commercial and reputational risk** (eg from human error in EYA and other processes)
- **exposure of sensitive information** beyond the intended audience and duration

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Just quickly: What is a schema?

A schema is a way of describing data and its structure.

It's possible to include conditional logic, cross references, and deeply nested data items… but here's a simple excerpt of schema and matching data

```
"manufacturer_name": {
    "type": "string",
    "title": "Manufacturer name",
    "description": "Full name of the manufacturer",
    "minLength": 1,
    "examples": [
          "Generic Turbines (US) Inc.",
          “Megacorp GMBH”
    ]
}
```

```
"manufacturer_name": “Tom’s Turbines Ltd”
```

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Status and Resources

Schema will be usable (with pinned version) from April 1st.

Join us by collaborating on GitHub. Comments and questions are welcome!

github.com/octue/power-curve-schema

- Underlying schema has now had 3+ years in production, covering (to-date) 112 curves over 15 different manufacturers
- We (WindPioneers and Octue) open-sourced the schema in 2023 as a basis for the IEC 61400-16.
- Panel of experts and occasional input from members in other groups (IEA Wind Task 43, TIMWind)
- About 2 weeks away from releasing the first draft candidate for the standard.
- There will be a subsequent round of changes following standard review process.

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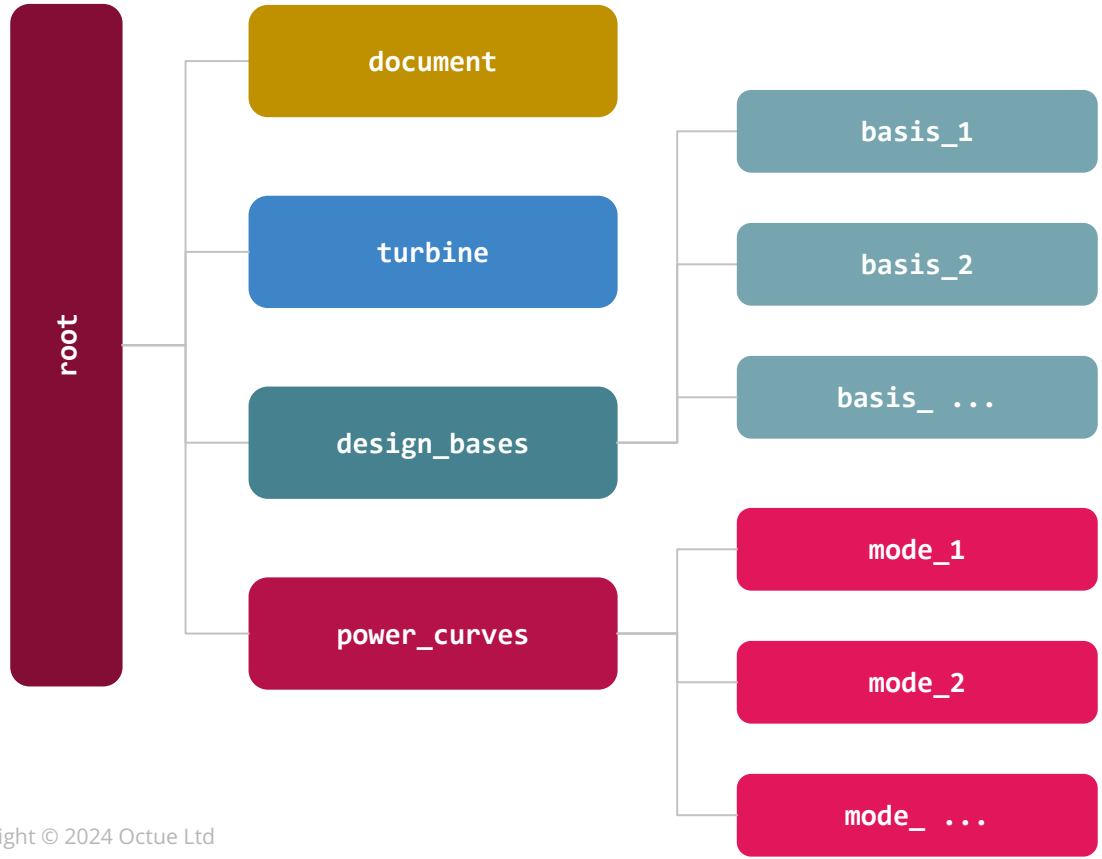
Root level structure



Data is split into four key areas

- `document` contains information about the document itself such as author, identifiers, provenance etc.
- `turbine` contains information about the turbine for which the power curve data is produced.
- `design_bases` is a specification of the conditions under which the power curve(s) are valid.
- `power_curves` comprises a list of the different operating modes available, each containing a power curve. Each mode contains informational metadata (eg the name and purpose of the mode) and power/thrust curves.

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Killer Features

In no particular order…

- **DCMI Compatible metadata**
- **Fields added to facilitate web app development**
  - Such as `manufacturer_short_name` vs `manufacturer_name`
- **Custom or predefined environmental classes**
  - Allows simple specification eg “IEC Class 2” all the way to full environmental conditions under which a power curve is valid
- **Power, thrust and acoustic emissions**
  - Parameterisable by stability, turbulence, shear, veer, wind direction, wind speed, air density
- **Mode-specific overrides**
  - To allow for edge cases in certain modes - fewer available hub heights, rated power, etc
- **Thermal derating**

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Tools and ecosystem

A JSONSchema allows quick development of a rich set of tools and integrations around the schema. Here are a few of the tools that have been built on top.

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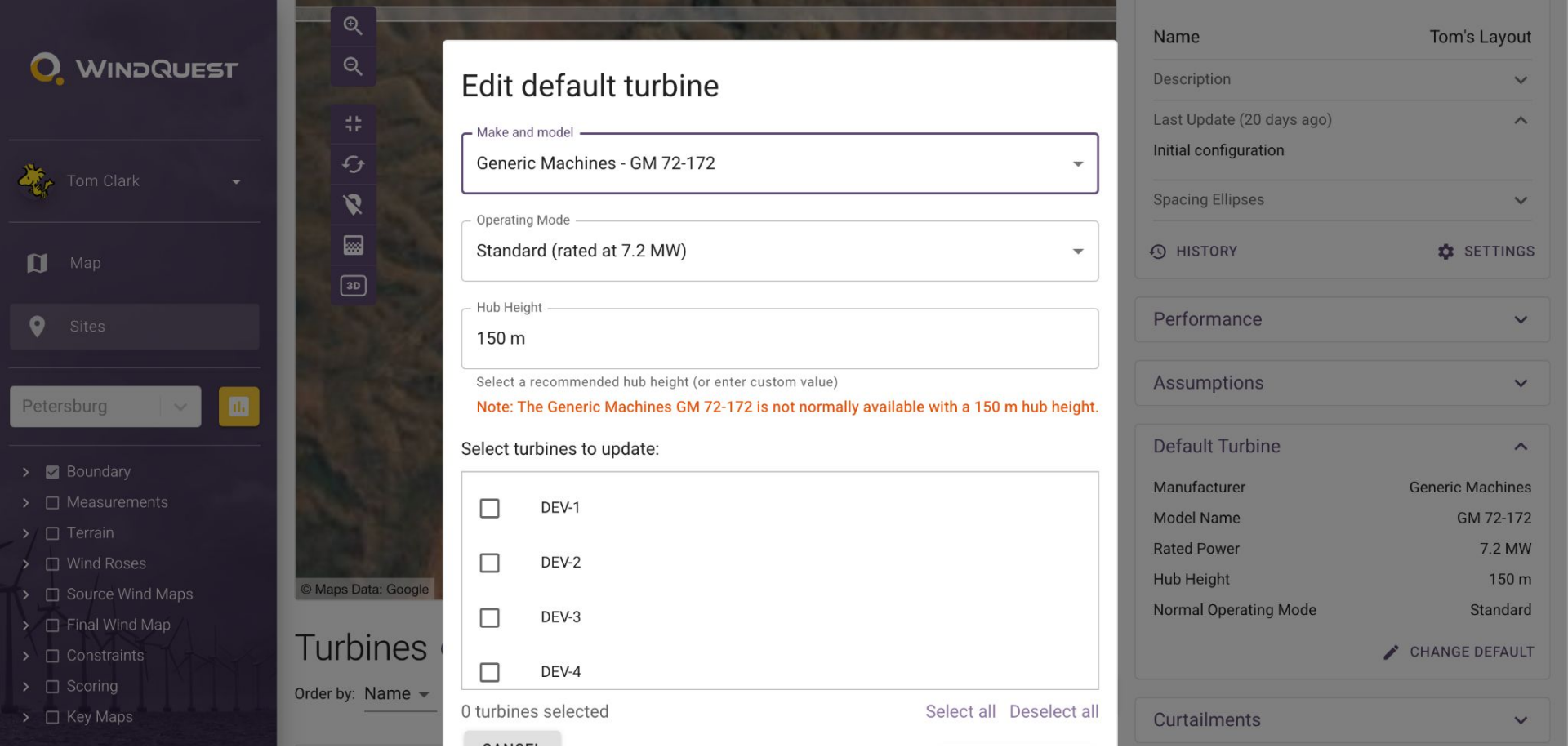
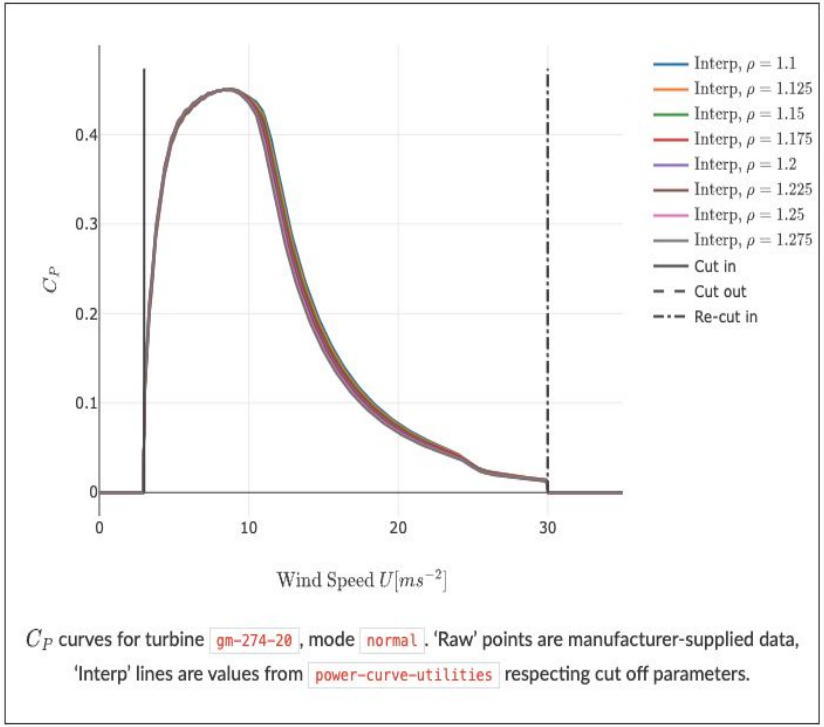
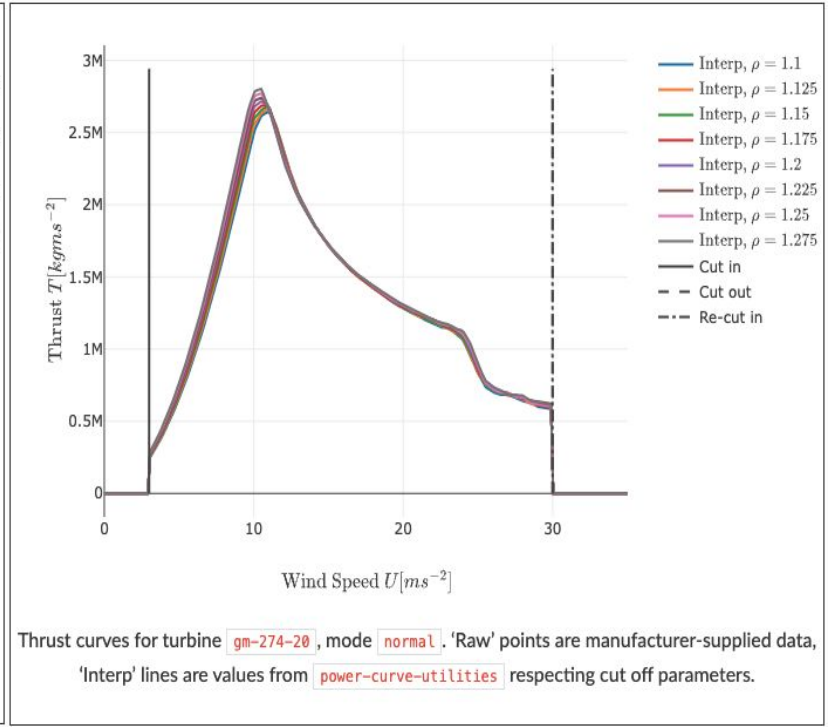


"Orders of magnitude improvement in capability of the team" (quote from WindPioneers' CEO) from rapid iterative design of wind farms. Consistent schema allows to switch and compare turbines in the context of true economic value, as well as raising warnings around performance and configuration.



C_P curves for turbine `gm-274-20`, mode `normal`. 'Raw' points are manufacturer-supplied data, 'Interp' lines are values from `power-curve-utilities` respecting cut off parameters.



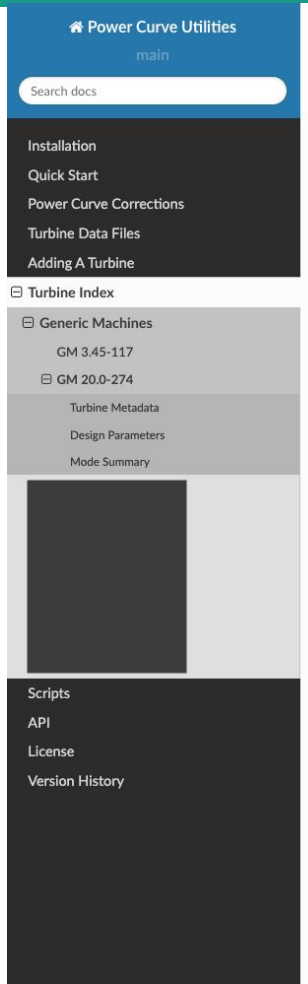
Thrust curves for turbine `gm-274-20`, mode `normal`. 'Raw' points are manufacturer-supplied data, 'Interp' lines are values from `power-curve-utilities` respecting cut off parameters.

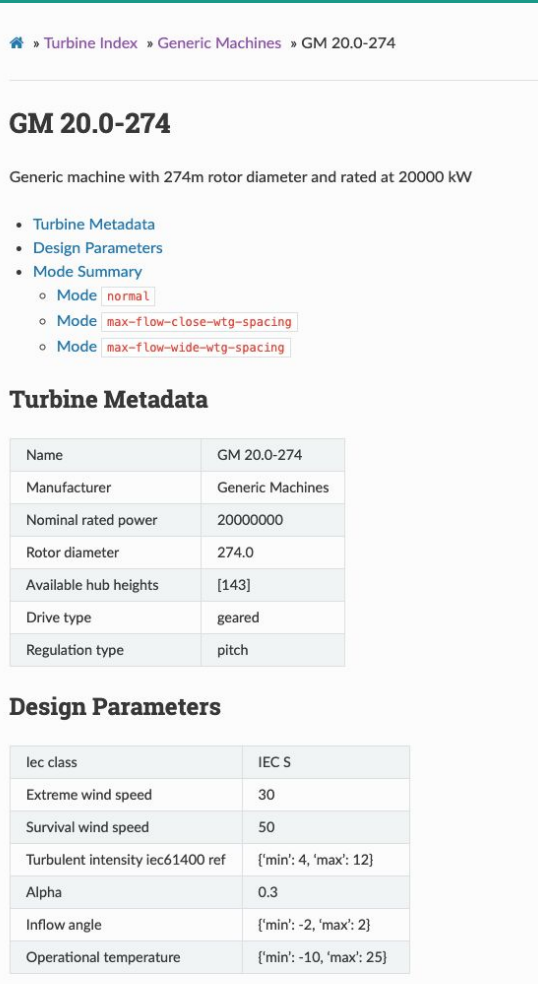
CP, T charts expressed in plotly-compliant JSON, interactively viewable in browser. This is very useful for QC checks as well as inspection of turbine performance characteristics.

Automated reports

Reports can be generated from the data (we use the sphinx rendering engine to generate static HTML and PDFs).

An overview of the metadata and design parameters sections for a generic turbine.





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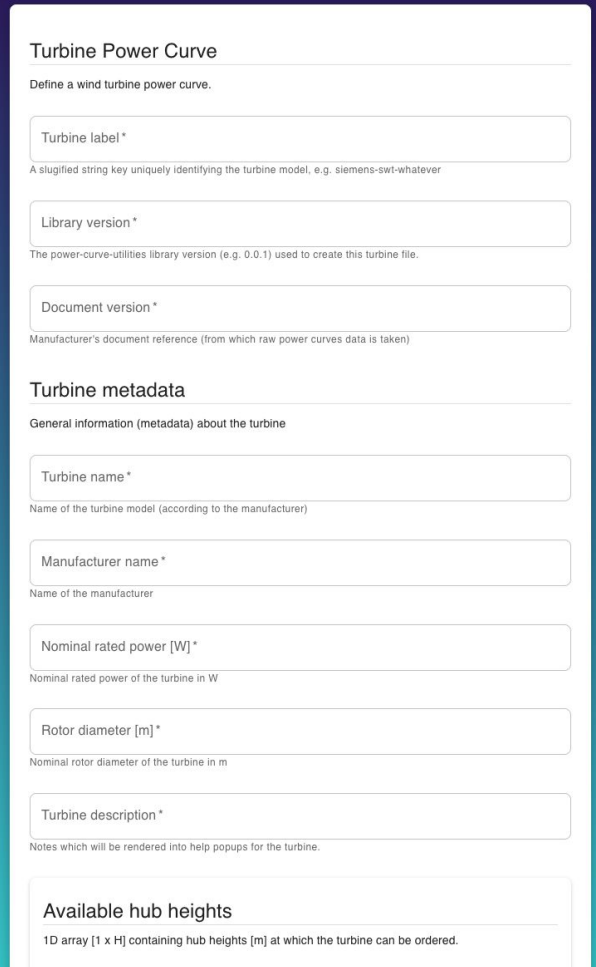
Input Forms

JSONSchema can be used to quickly generate web forms for data entry. The default table fields are not really suitable for multidimensional data but could be made fit for purpose.

https://9pl493.csb.app/

SCAN ME



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Read the poster

- It describes the method we used to build it

  https://doi.org/10.5281/zenodo.7940068

- Broadly:
  - Now 3 years in production of which >18 months stable (no breaking changes to the schema)
  - Used for > 112 turbines from 15 manufacturers

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Thank you to WindPioneers for willingly open-sourcing!

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There will be many more resources coming in the following months...

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