Solar Forecast Arbiter .org

An open source evaluation framework for solar forecasting

Will Holmgren

Tony Lorenzo

Department of Hydrology and Atmospheric Sciences

THE UNIVERSITY OF ARIZONA

Aidan Tuohy

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Grid Operations and Planning

Cliff Hansen

Photovoltaics and Distributed System Integration Department

Sandia National Laboratories

Justin Sharp

Principal and Owner

Sharply Focused
Understanding Renewable Resources

Tassos Golnas

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Project goal

Open-source framework for solar forecast evaluations that are impartial, repeatable, and auditable.

- Implement objective, consistent evaluation scenarios and metrics → better solar forecasts
- Develop user confidence in solar forecasts → system integration
- Standardize evaluations → reduce provider and user costs
- Easily extend to wind power and load forecasting

Three Key Tasks

Stakeholder Engagement

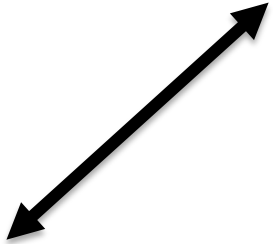
- Help define use cases
- Guide selection of benchmarks, metrics, data sets
- Contribute data
- Aid long-term planning

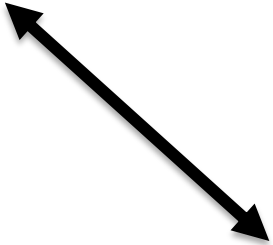
Support DOE Solar Forecast 2 Teams

- Define test data
- Provide evaluation services

Construct the Solar Forecast Arbiter

- Open source
- Thoroughly test, document, validate





THE UNIVERSITY OF ARIZONA | Sandia National Laboratories | U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY | EPRI ELECTRIC POWER RESEARCH INSTITUTE | Sharply Focused

Stakeholder Engagement

5 primary topics

- Use cases
- Data format/API
- Data policies
- Benchmark forecasts
- Evaluation metrics

Please join the Stakeholder Committee! (open to all)

solarforecastarbiter.org/stakeholdercommittee

Year 1 engagement process

Stakeholder Workshop

St. Paul, June 2018

→ Team discussions

Proposal documents

→ Stakeholder feedback

Revised documents

→ Stakeholder consensus

Final documents

Implement

Stakeholder Engagement: Year 1

5 primary topics

1. Use cases
2. Data format/API
3. Reference data & Data policies
4. Benchmark forecasts
5. Evaluation metrics

Please join the Stakeholder Committee! (open to all)
solarforecastarbiter.org

Use Cases

solarforecastarbiter.org/usecases

1.A. Compare a forecast to measurements

1.B. Compare a probabilistic forecast to measurements

1.E. Evaluate an event forecast

1.F. Conduct forecast trial

Use Cases: What is a forecast?

Consider the "Vendor A Solar Power Forecast"…

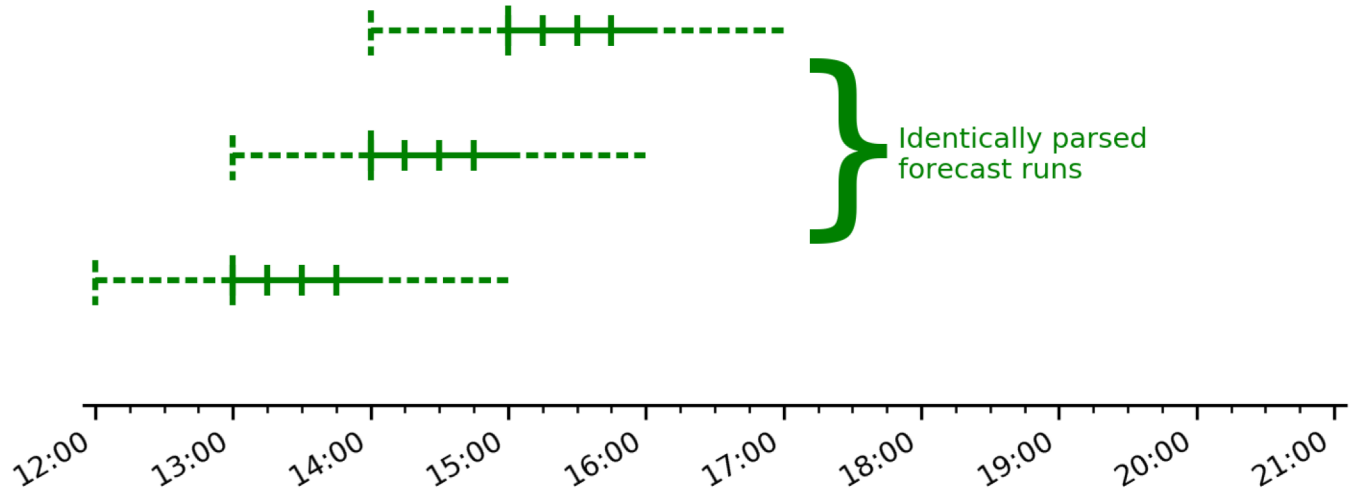
- New forecast each hour of each day
- Each forecast extends 48 hours
- Up to 47 forecasts valid at one time!
- Forecast for a specific power plant or aggregation of plants
- *To determine if the Vendor A solar forecast is a good forecast, we need to be more specific about the evaluation problem.*

The Solar Forecast Arbiter…

- *Encourages* the user to consider her application
- *Requires* the user to fully spec forecast definition, evaluation criteria

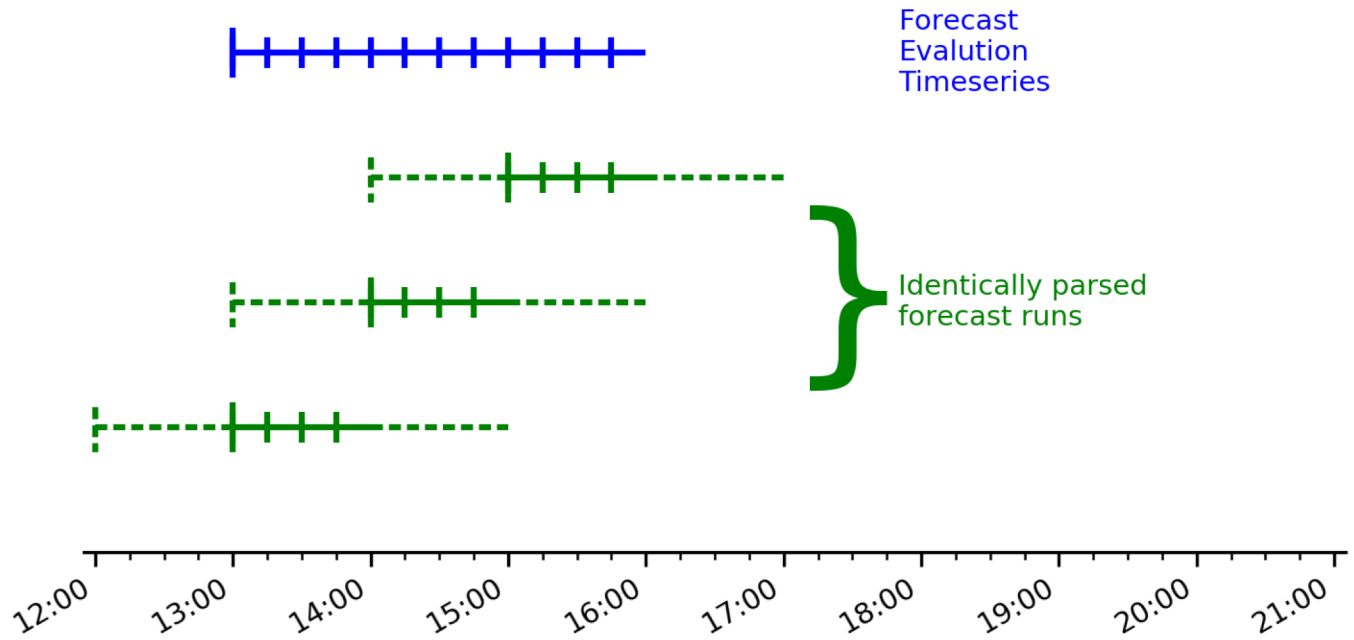
Forecast runs concatenated into a forecast evaluation timeseries

Application: short term market
Requirement: hour ahead forecast



Forecast runs concatenated into a forecast evaluation timeseries

Application: short term market
Requirement: hour ahead forecast

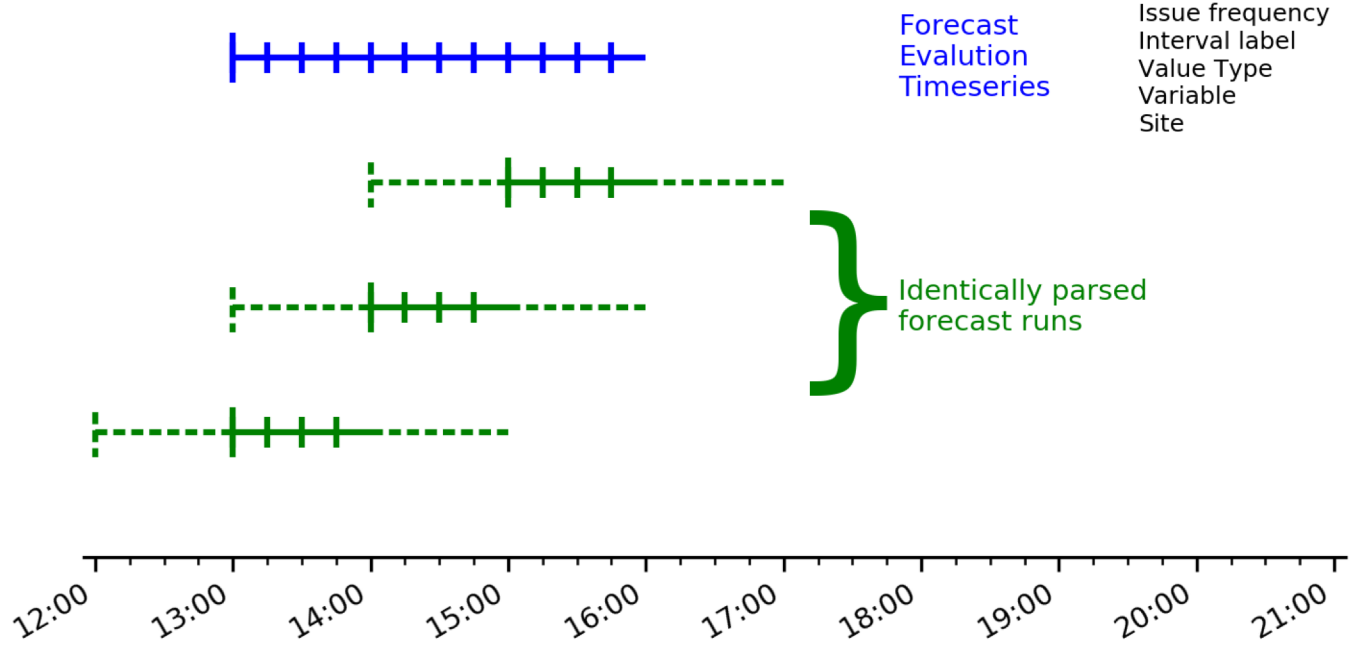


Forecast runs concatenated into a forecast evaluation timeseries

Application: short term market
Requirement: hour ahead forecast

Forecast taxonomy

Lead time to start	1h	1h
Interval duration	15min	15min
Intervals / sub.	4	12
Issue frequency	1h	1h
Interval label	left	left
Value Type	mean	mean
Variable	Power	Power
Site	Plant X	Plant X



Sketch of Forecast Trial Use Case

Solar Forecast Arbiter

- Website & API
- Reference databases
- Secure databases
- Data QA/QC
- Benchmark power fx
- Analysis engine

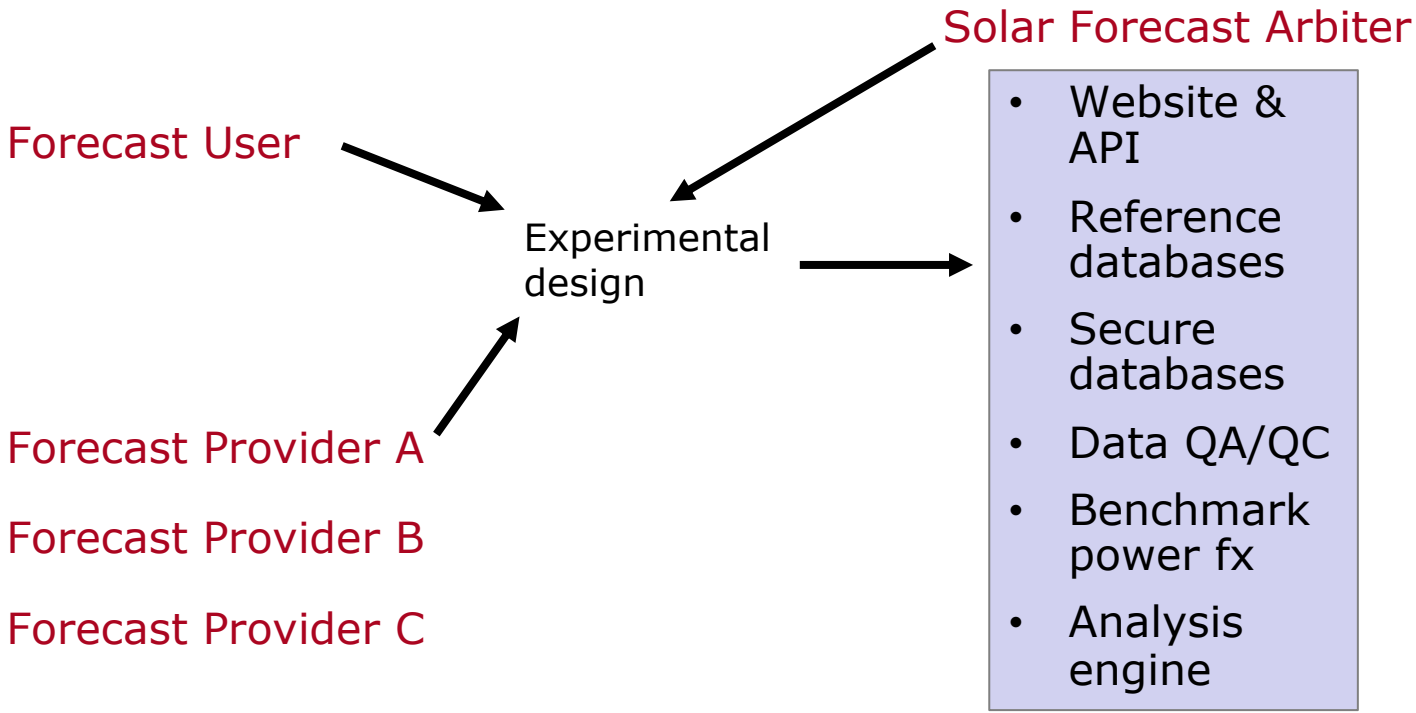
Forecast User

Forecast Provider A

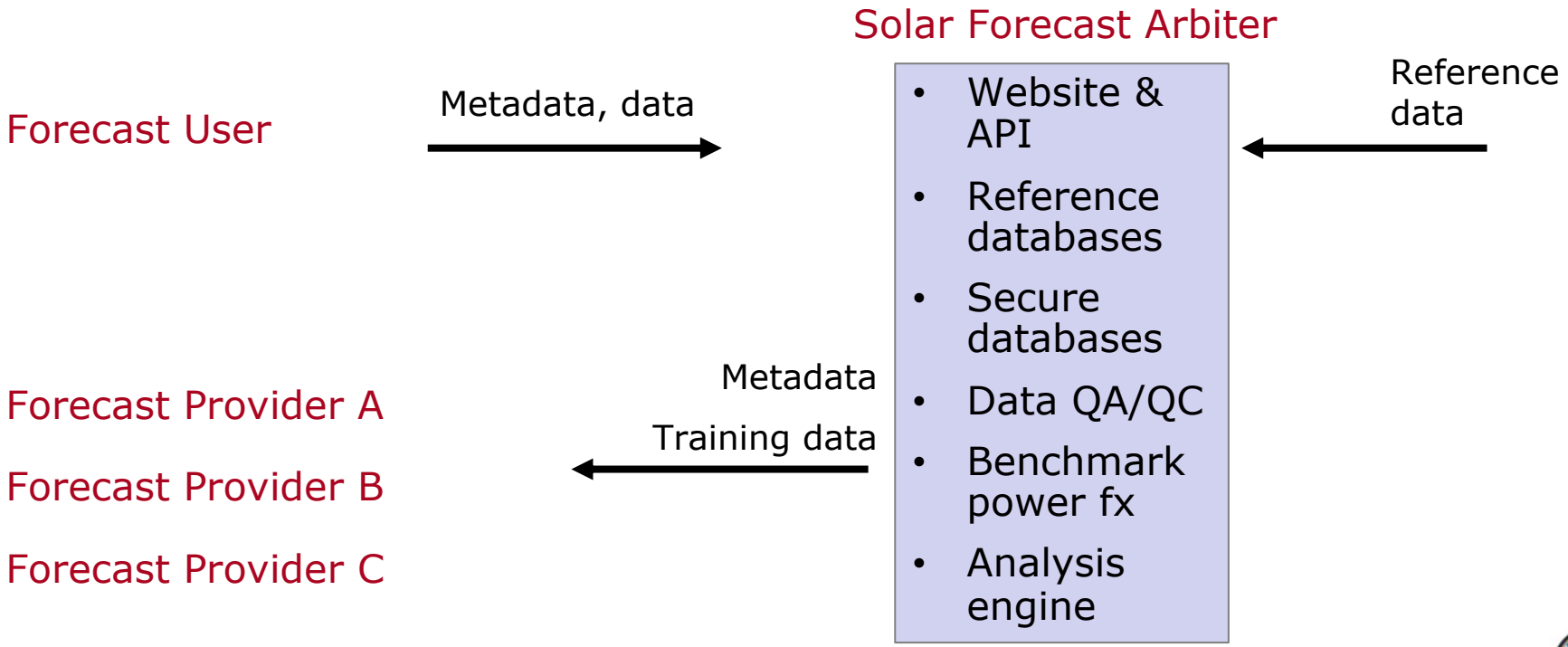
Forecast Provider B

Forecast Provider C

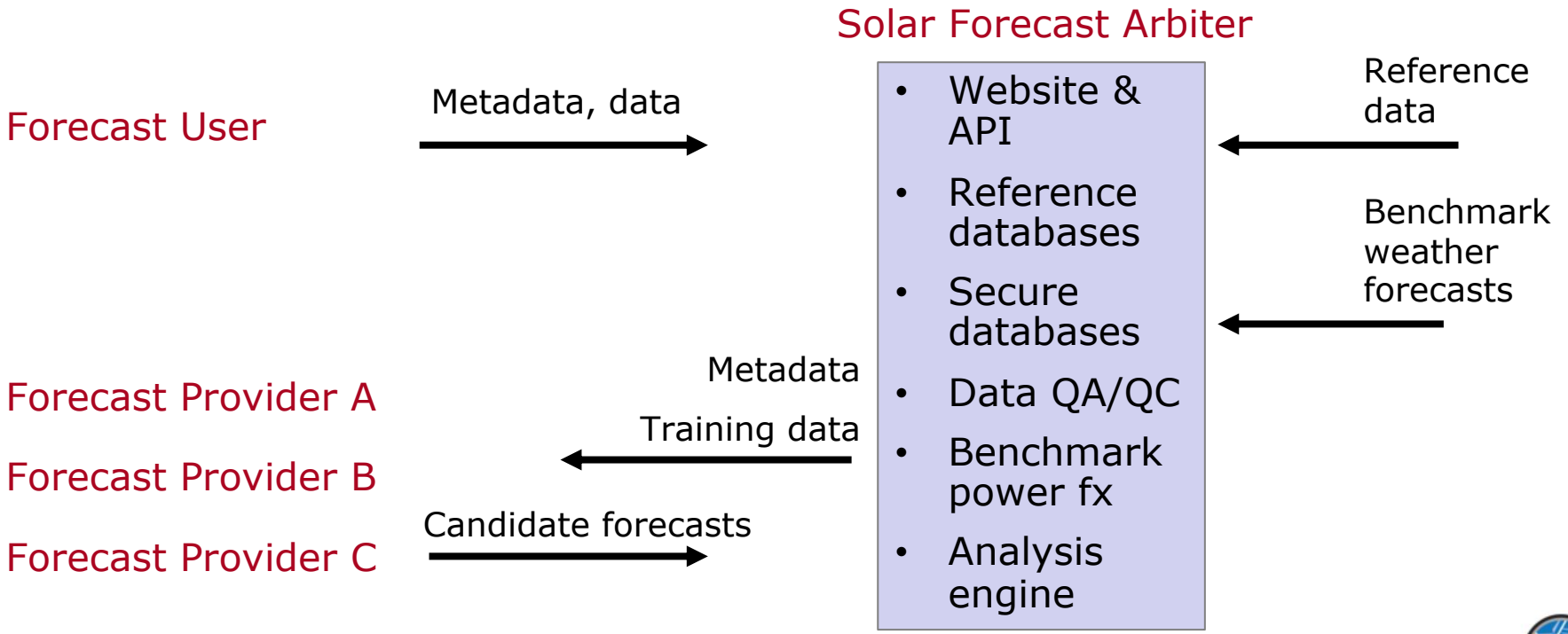
Sketch of Forecast Trial Use Case



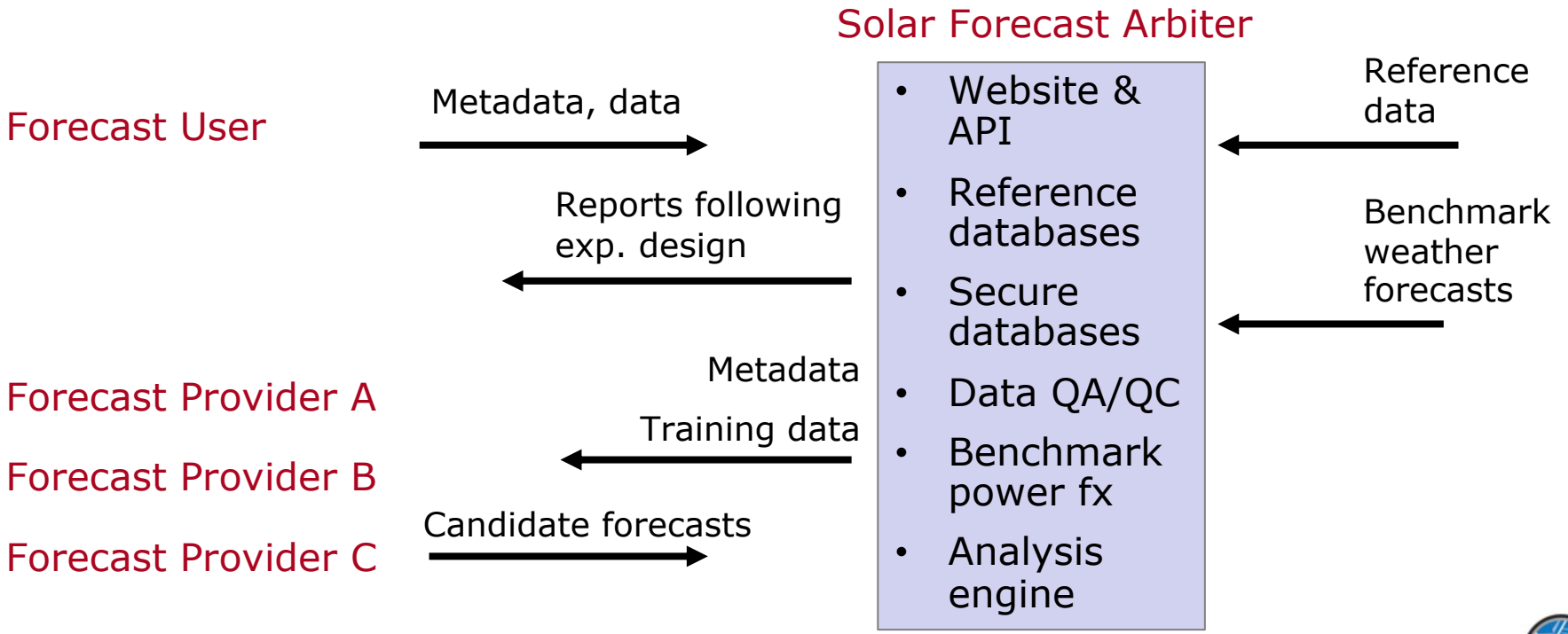
Sketch of Forecast Trial Use Case



Sketch of Forecast Trial Use Case



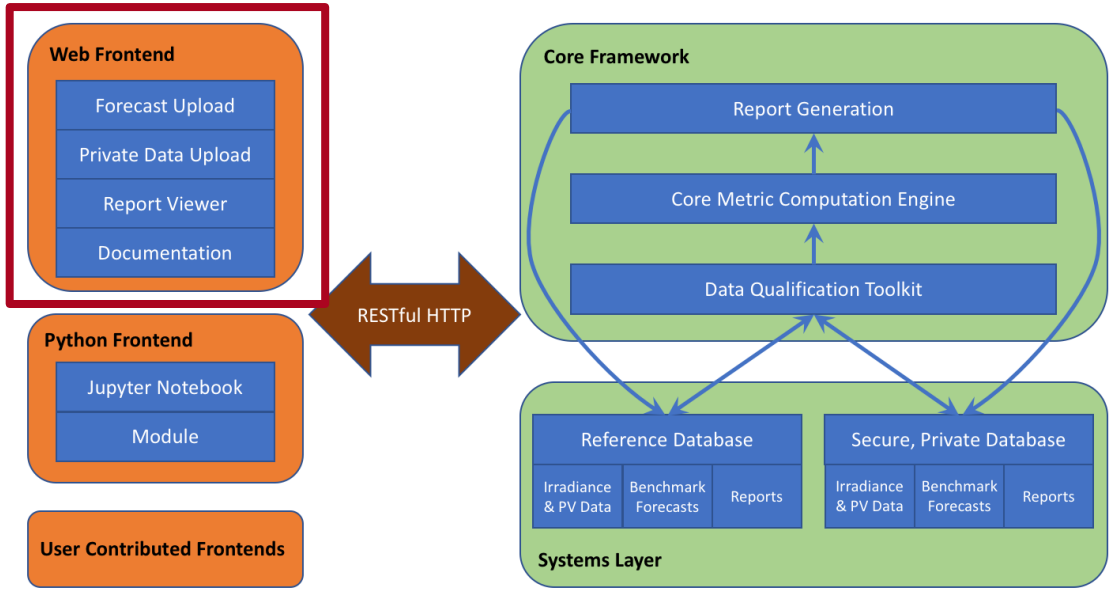
Sketch of Forecast Trial Use Case



Solar Forecast Arbiter Architecture

Web Portal and API

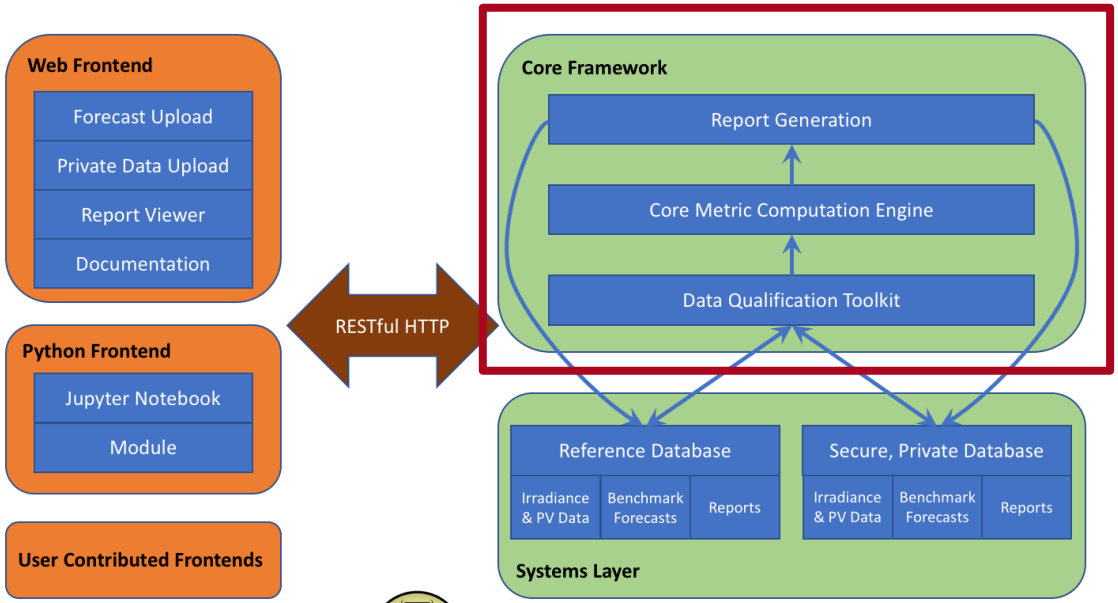
- Create Sites, Observations, Forecasts data objects
- Upload Obs/Fx timeseries data
- Download metadata/data
- Share metadata/data
- Run analyses, view reports
- Additional pages include:
  - Help
  - Metrics definitions, examples
  - How to contribute



Solar Forecast Arbiter Architecture

Core Framework

1. Accept point data of varying types and qualities
2. Calculate PV power from weather inputs and system metadata
3. Compare measurements, test forecasts, benchmark forecasts
4. Generate reports



NUMFOCUS
OPEN CODE = BETTER SCIENCE

PVPerformance MODELING COLLABORATIVE

Read the Docs
Create, host, and browse documentation.

THE UNIVERSITY OF ARIZONA

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

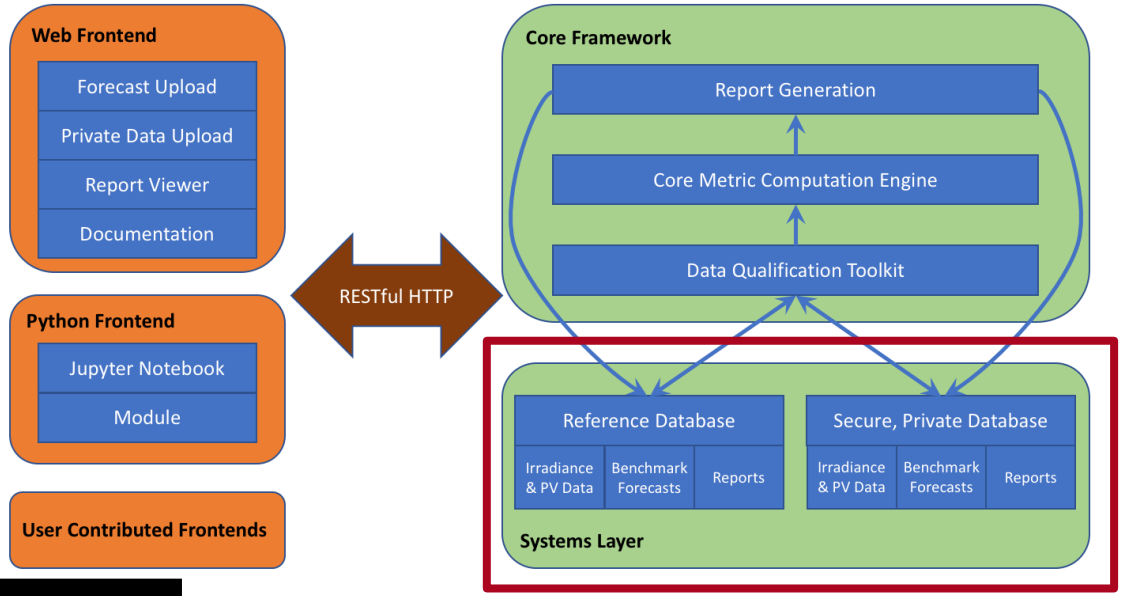
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Sharply Focused

Solar Forecast Arbiter Architecture

Systems Layer

- Operating system, web server, databases
- Built using Open Shift, virtual machines, and Vagrant files
- Enables users to install the entire framework on their own machines (private data not included)
- Architecture ensures that framework can be maintained beyond the initial funding period



CentOS Vagrant RED HAT OPENSHIFT

THE UNIVERSITY OF ARIZONA Sandia National Laboratories U.S. DEPARTMENT OF ENERGY Office of ENERGY EFFICIENCY & RENEWABLE ENERGY EPRI ELECTRIC POWER RESEARCH INSTITUTE Sharply Focused

Validation and Reference Data Sources

Reference Data

- NOAA SURFRAD
- Sandia
- NREL
- EPRI
- DOE RTC
- U. Oregon network

User Data

- Stakeholder supplied
- Owner controls access
- Commitments: TEP, Abengoa, Southern Co.
- **We need your help**

solarforecastarbiter.org/referencedata

THE UNIVERSITY OF ARIZONA | Sandia National Laboratories | U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY | EPRI ELECTRIC POWER RESEARCH INSTITUTE | Sharply Focused

Data Policies

solarforecastarbiter.org/datapolicies

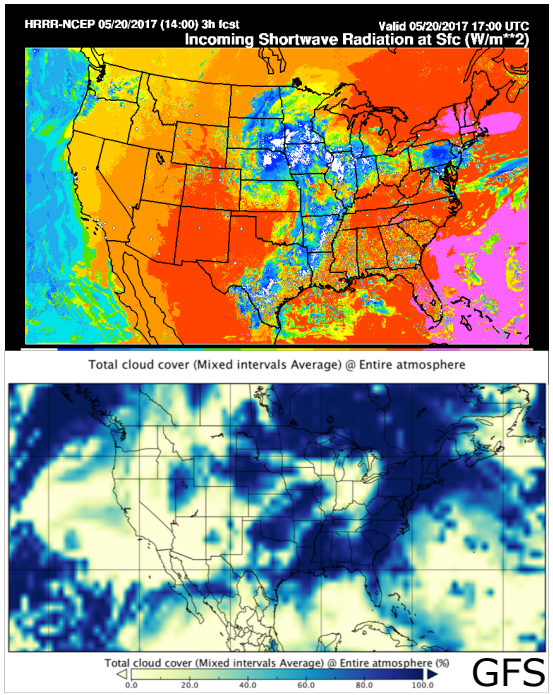
1. Organizations retain ownership of the data they upload to the framework.
2. Users upload data to the framework on behalf of organizations.
3. Users have complete control over how their data may be accessed by other users (public, NDA).
4. Users may delete data from the framework.
5. The framework will not sell data that it controls (e.g. statistics).
6. All non-public data will be securely deleted by the conclusion of the DOE funding period (June 30, 2021).

Poster Session Today!

Benchmark Forecasts

solarforecastarbiter.org/benchmarks

- For 1 hour – 7 day ahead and longer horizons:
  - NOAA operational models forecast irradiance, cloud cover, weather
  - Most operational NWP irradiance forecasts have known limitations
    a) Derive irradiance or PV power from cloud cover
    b) Bias correction
- For intrahour horizons:
  - Persistence, persistence of the clear sky index
  - ARMA model fitted to site-specific data
- For net load:
  - Net load = True load – BTM PV
  - Use regression w/weather obs for true load?
- Probabilistic? Aggregates?



Reports and Metrics

Reports

- Design templates with stakeholder input
- Framework uses templates to automatically generate custom reports

- Time series plots, scatter plots, reliability diagrams, etc.
- Standard and "advanced" error metrics
- Enable direct comparisons between anonymized vendors or researchers and benchmarks

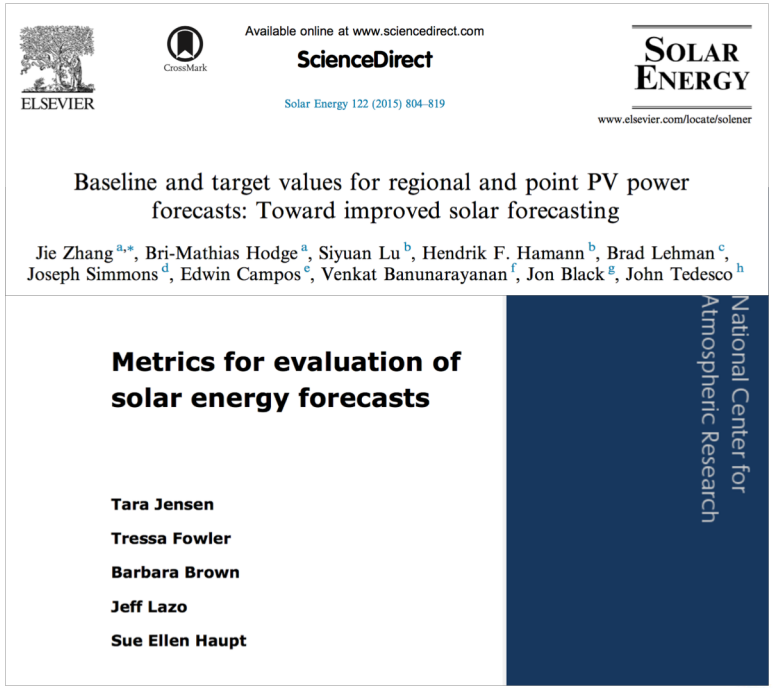
- Options for analysis based on conditions (time of day/year, events, etc.)

Reports and Metrics

Metrics

- Choose default metrics with stakeholder input
- Depending on use case, users have final control over metrics selection

- Build on DOE Solar Forecasting I metrics results
- Standard metrics (MAE, MAPE, RMSE, MBE)
- Advanced metrics (KSI, Renyi entropy)
- Probabilistic metrics (Brier, RPS)
- Forecast skill metrics to directly compare test and benchmark forecasts



Reports and Metrics

Cost metrics

1. User supplied fixed $/MW
2. User supplied time of day $/MW
3. User supplied time series of $/MW
4. User supplied time series of $/MW for predefined error bins
5. Costs related to ramps or variability (help needed)

Different complexity for different users

- How do you quantify cost of forecast errors without too much info?

- Report includes cost saved or incurred relative to benchmark forecasts

Project Timeline/Milestones

Year 1

Design, build, test and demonstrate the framework.

Year 2

Refine the framework and host two operational forecast competitions

Year 3

Support evaluations for Solar Forecasting II Topic 2 and Topic 3 awardees.

Transition framework to new operator.

Summary

- Open source, reproducible, transparent framework
- Stakeholder feedback guides project – need your help!
- Use cases tailored to needs of solar forecast stakeholders
- Reference datasets follow data policies
- Benchmark forecast capability
- Automated reports including bulk metrics, analysis filters
- Sign up for project updates, stakeholder committee at:

solar forecast arbiter . org