

Linking Modeling Tools for Analyzing High Renewable Systems

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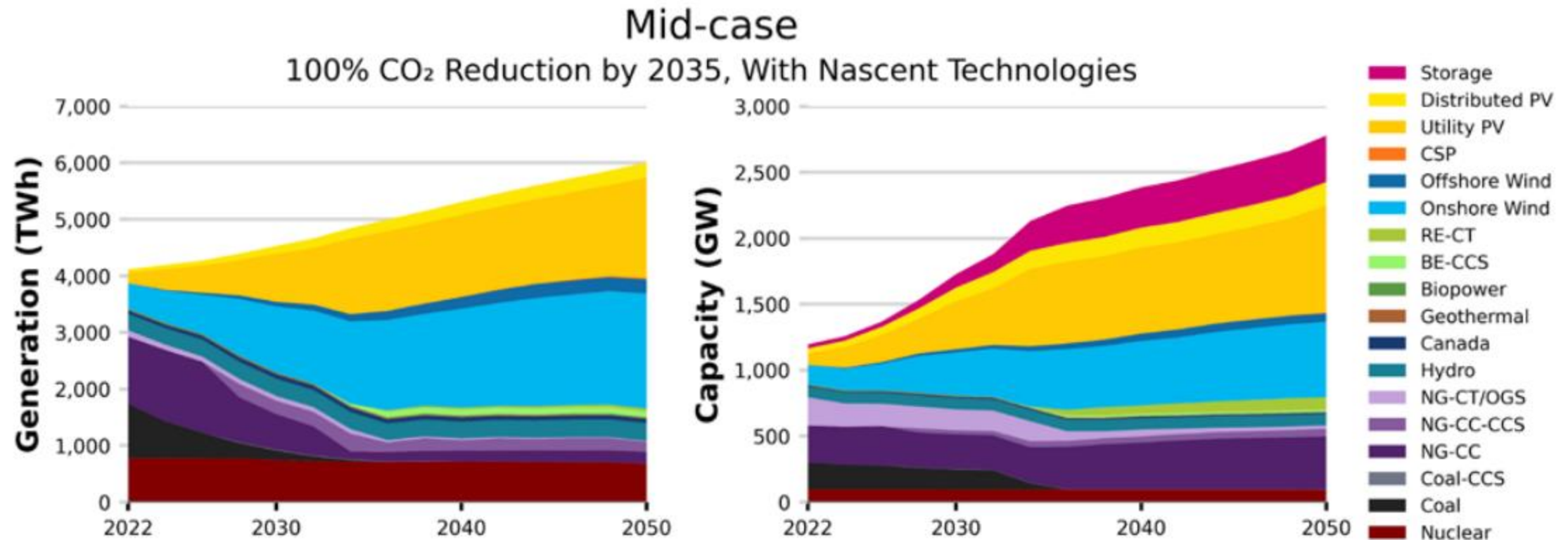
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ESIG 2023 Spring Technical Workshop

Content credit: Michael Blonsky, Jaquelin Cochran, Brady Cowiestoll, Pieter Gagnon, Madeline Geocaris, Kenny Gruchalla, Meghan Mooney, Pedro Andres Sanchez Perez

We analyze high-renewables systems and communicate the results to foster vision

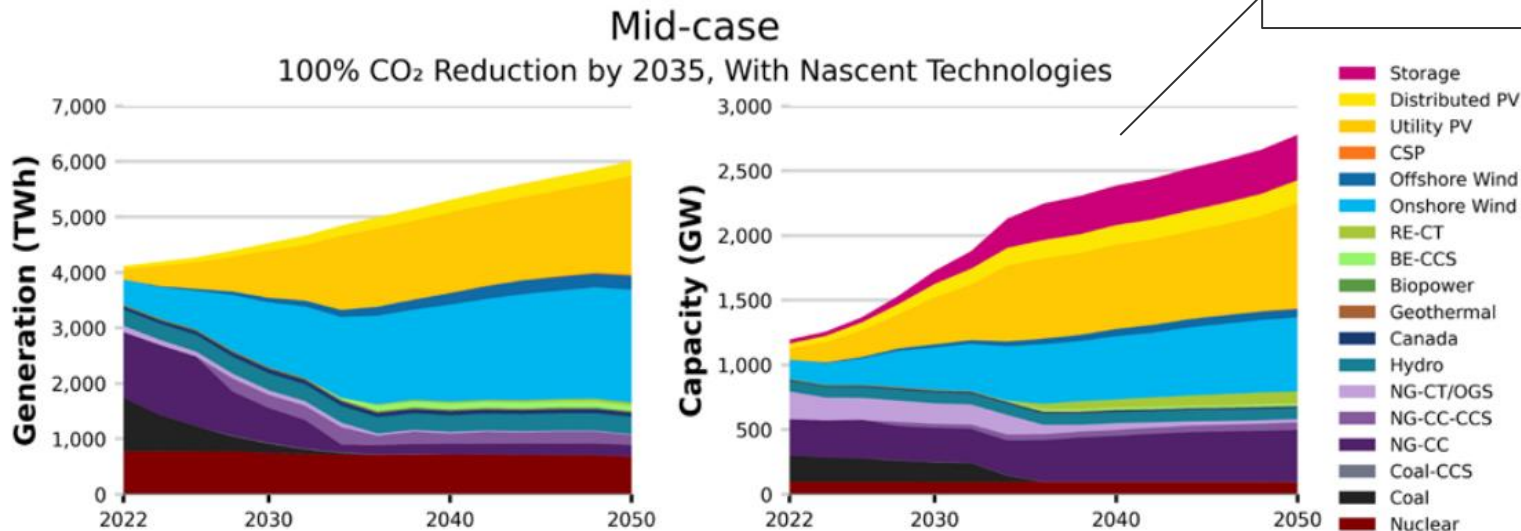
2022 Standard Scenarios (Gagnon et al.)



<https://www.nrel.gov/docs/fy23osti/84327.pdf>

Linking tools lets us answer multiple questions and cover multiple scopes

2022 Standard Scenarios (Gagnon et al.)
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capacity expansion /
utility investments

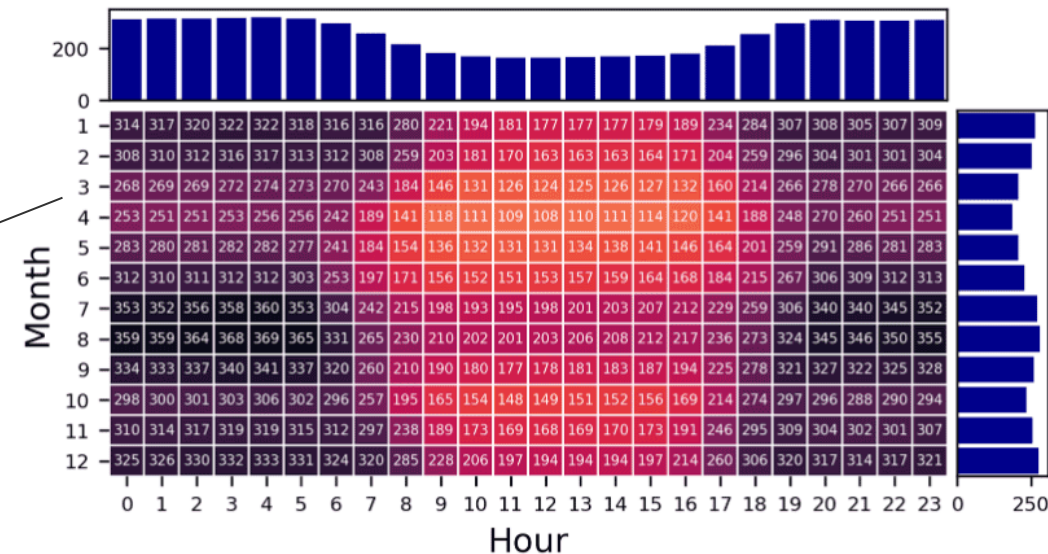


agent-based
customer investments

PLEXOS: production cost /
grid operations

Cambium: data processing /
8760 value metrics

Cambium Long-run Marginal Emission Rates
<https://www.nrel.gov/analysis/cambium.html>



We analyze high-renewables systems and communicate the results to support planning and foster confidence

Across all Los Angeles 100% Renewable Energy Study (LA100) Scenarios



Electrification
Efficiency
Flexible Load



Customer
Rooftop Solar



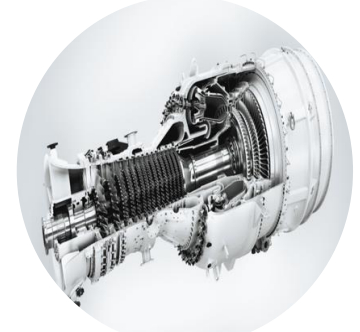
Renewable
Energy



Storage
(including coupled
with solar)



Distribution,
Transmission



Renewably Fueled
Combustion
Turbines

+>2,600 MW
(in basin)

Solar: + >5,700 MW
Wind: + >4,300 MW

+ >2,700 MW

Much More

New

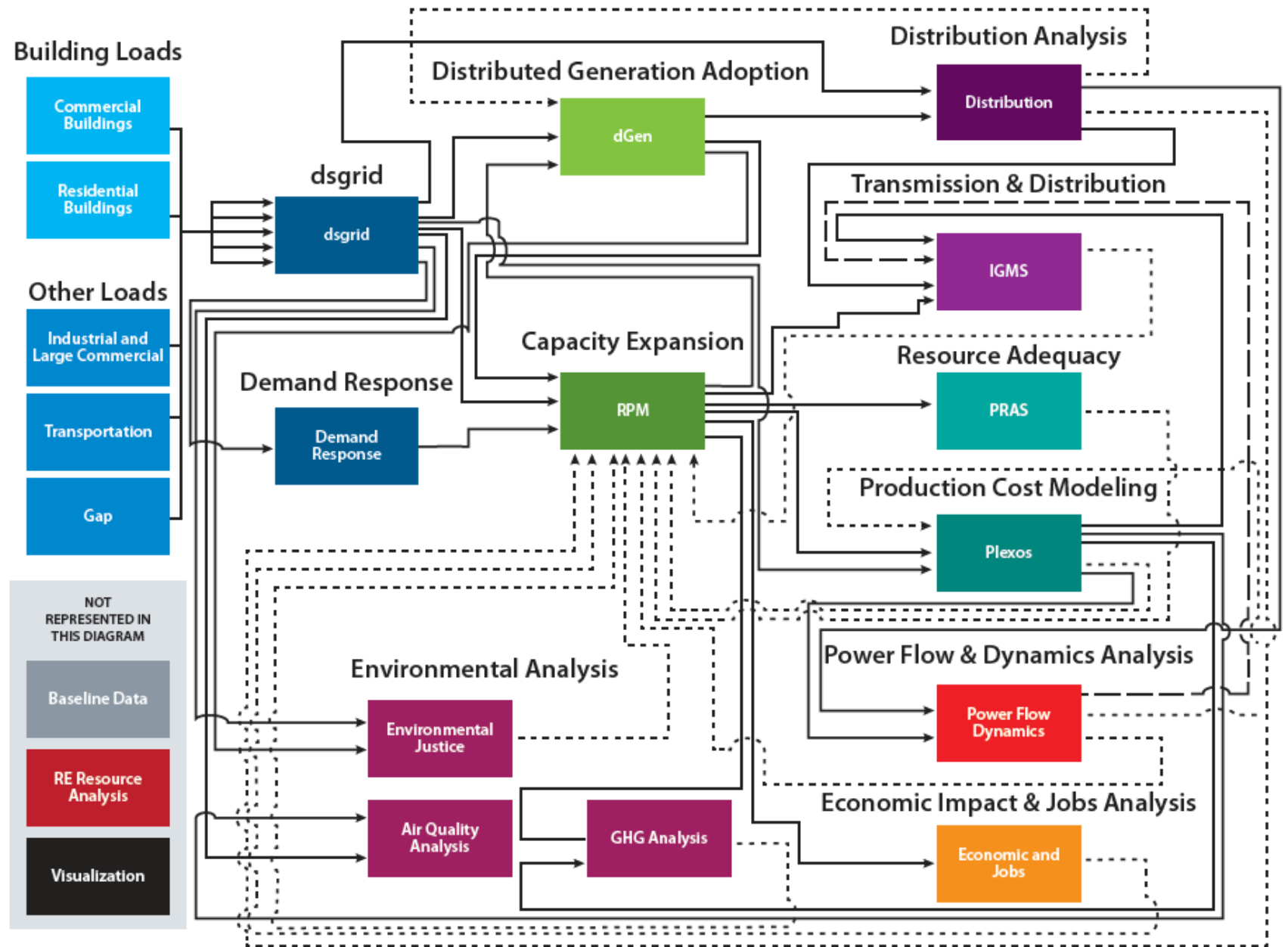
Natural gas

Today:
Daily

Biofuel/ hydrogen

Future:
Infrequently

Establishing confidence at all levels of a power system is challenging



Over 100 million simulations

Today's Talk

Case Studies

- ReEDS 2 PLEXOS: The process that enables Cambium (and much more)
- LA100: The Los Angeles 100% Renewable Energy Study

Questions Addressed

- What do model linkages look like under the hood?
- Why are model linkages hard to do well?
- How can we improve the model linkages we need to analyze more-connected energy systems?

ReEDS to PLEXOS

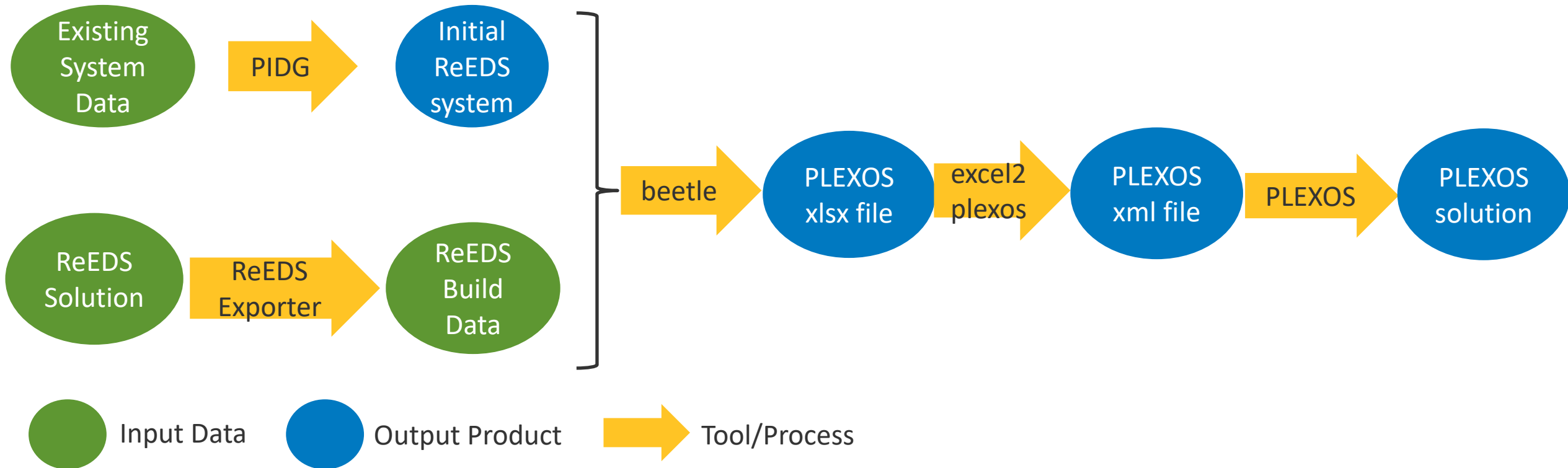
ReEDS 2 PLEXOS enables detailed descriptions of how realistic future power systems would operate

Example Studies

- [The Technical and Economic Potential of the H2@Scale Concept with the United States](#) – Economic potential of hydrogen across 9 applications and 3 production processes
- [The North American Renewable Integration Study \(NARIS\)](#) – Detailed, continent-wide analysis with planning scenarios of transmission, generation, and demand to reach continent-wide carbon reductions up to 80%
- [Standard Scenarios](#) – Suite of forward-looking scenarios for the U.S. power sector that are updated annually and have included hourly (Cambium) results since 2021
- [Solar Futures Study](#) – Detailed power-sector modeling to evaluate three scenarios: Reference, Decarbonization, and Decarbonization with Electrification

How ReEDS 2 PLEXOS works

Four semi-automated processes, plus the models themselves



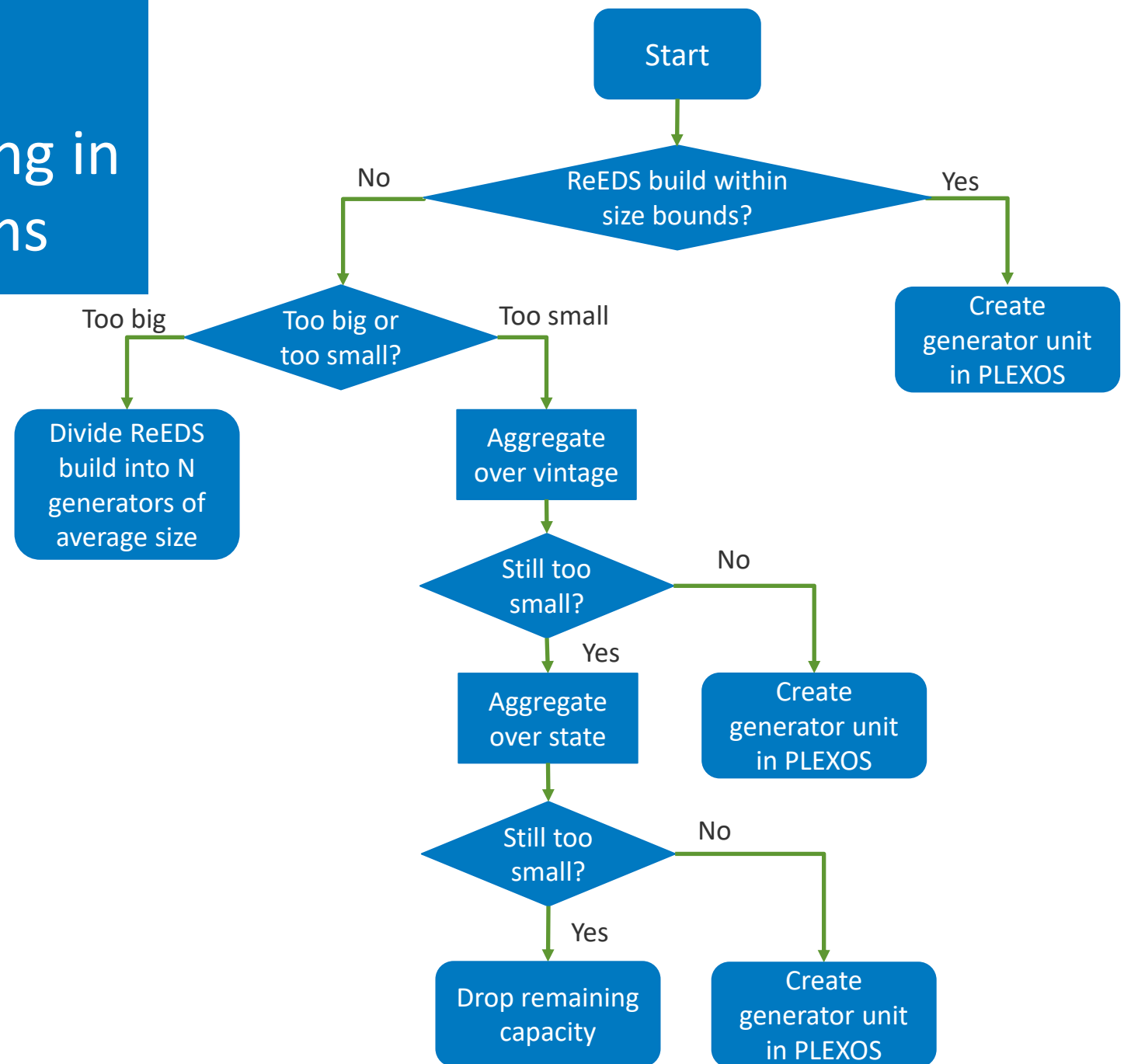
Capacity Expansion Model
single scenario, selected year

Production Cost Model
single scenario, single year

ReEDS 2 PLEXOS

Requires aligning and filling in data; Specific algorithms

Property	Data Source
Emission rate	ReEDS
Fuel cost	ReEDS
Heat rate	ReEDS
Hydropower energy	ReEDS, modified
Minimum stable level	ReEDS; ERGIS
Minimum up and down time	NARIS
Outage duration	NARIS
Outage rate	ReEDS
Ramp rate	NARIS
Start cost	NARIS
Storage efficiency	ReEDS
Transmission loss rates	ReEDS
VO&M cost	ReEDS
Variable renewable energy profiles	reV

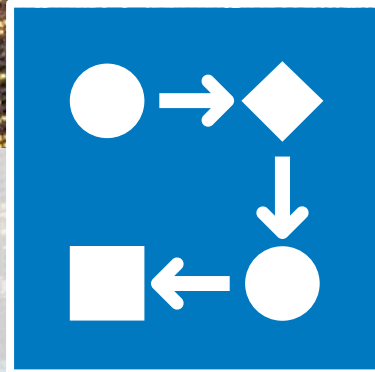


This critical
capability has been
hard to maintain.
Why?



Data

Different types and resolutions of data; mapping between zonal and nodal data can be ad hoc per project



Interfaces

Linkages are easier to maintain if connection points like input data, output data, and software APIs are stable and versioned



Quality Control

Software and datasets, like papers, need review; Review culture and resources must be established



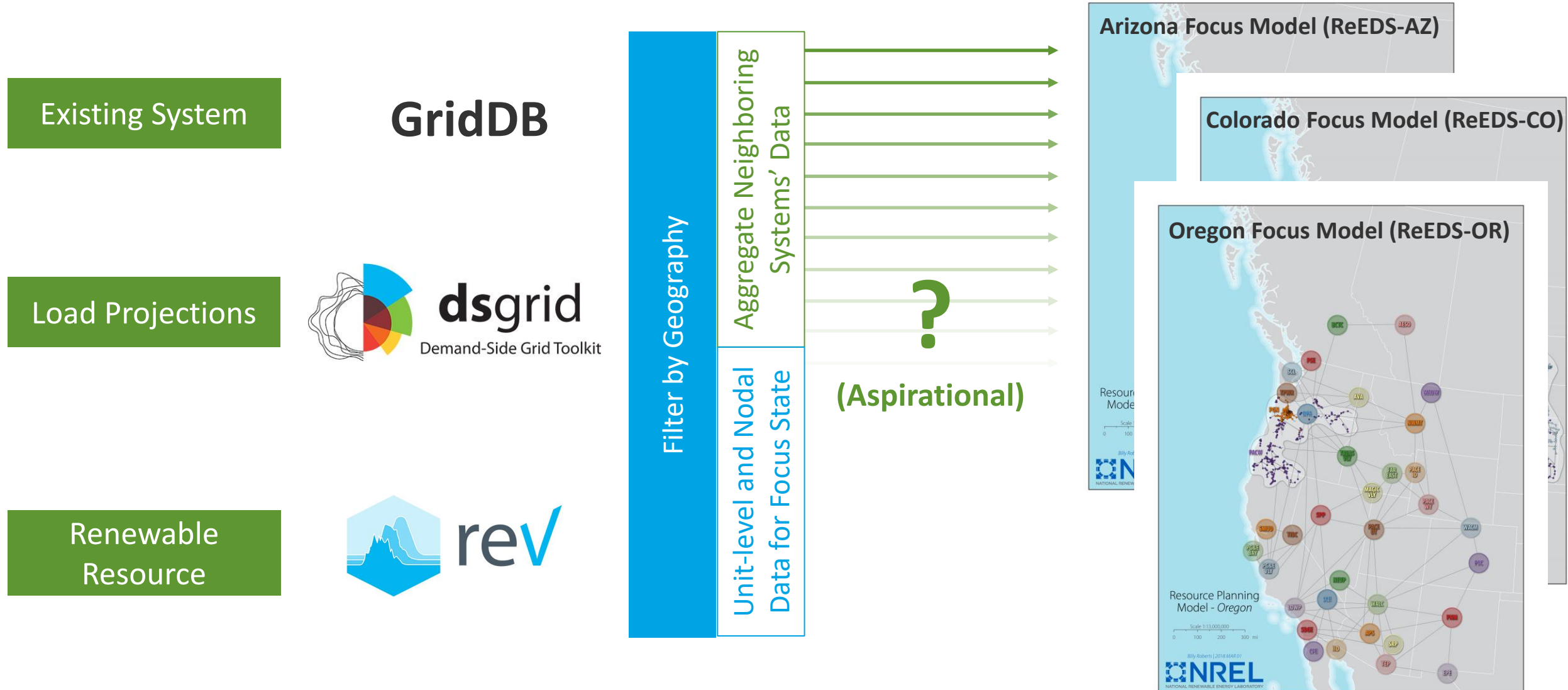
Project Planning

Model linkages might not be recognized as a distinct task; Developing robust, long-term links costs more up front

Punchlist identified to improve this capability in the near-term

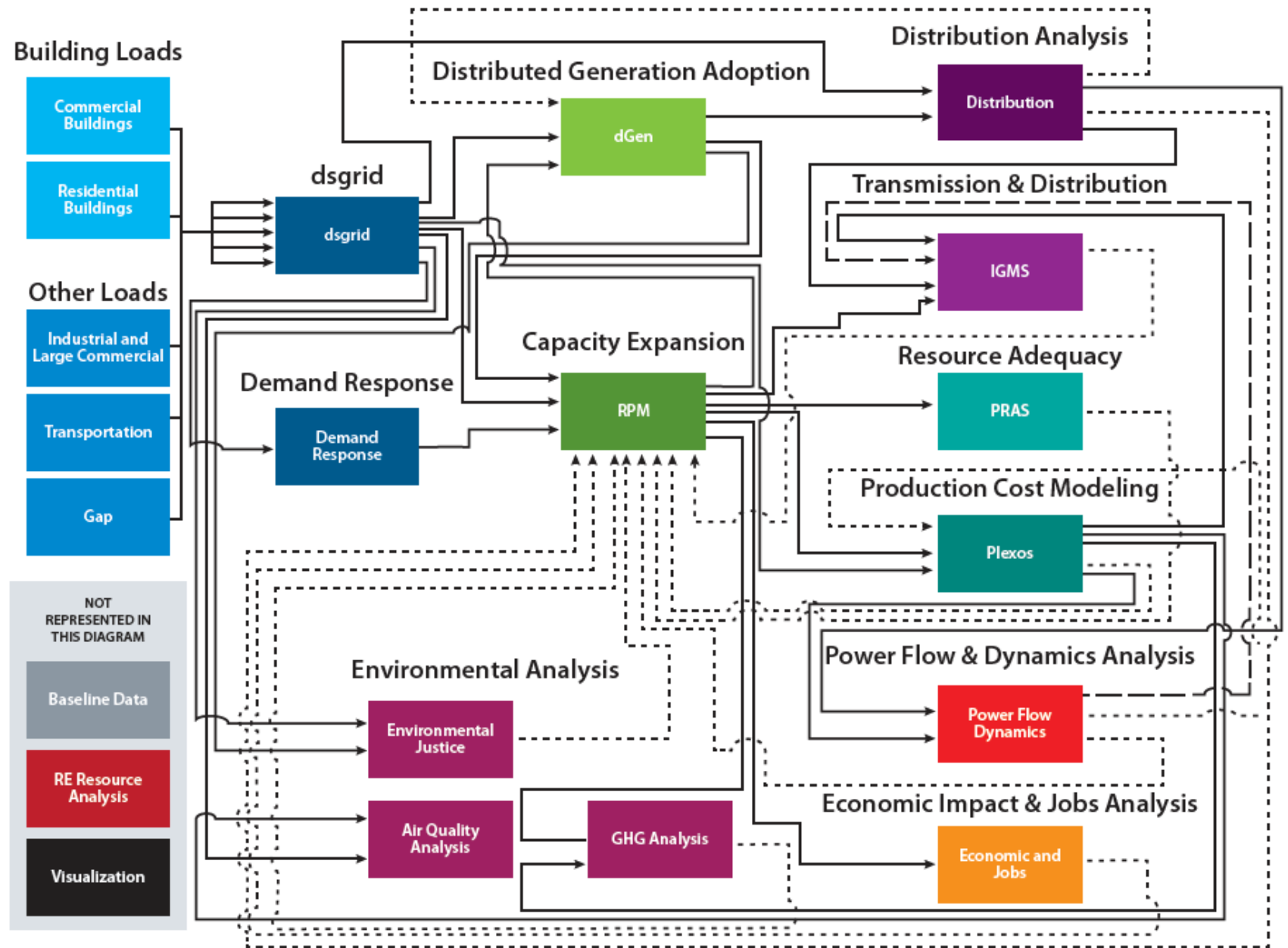
- Unit testing and error handling
- Simplify workflow for users of ReEDS 2 PLEXOS
- Prepare for R2X (e.g., other production cost models like [SIIP](#))
- Code optimization
- Robust compatibility tracker with ReEDS version tags
- Improve maintainability of the main repo and adjacent repositories
- Generalize process to other ReEDS adaptations (e.g., India)

Selecting scope and linking models should be easier if multiple models get data from the same sources

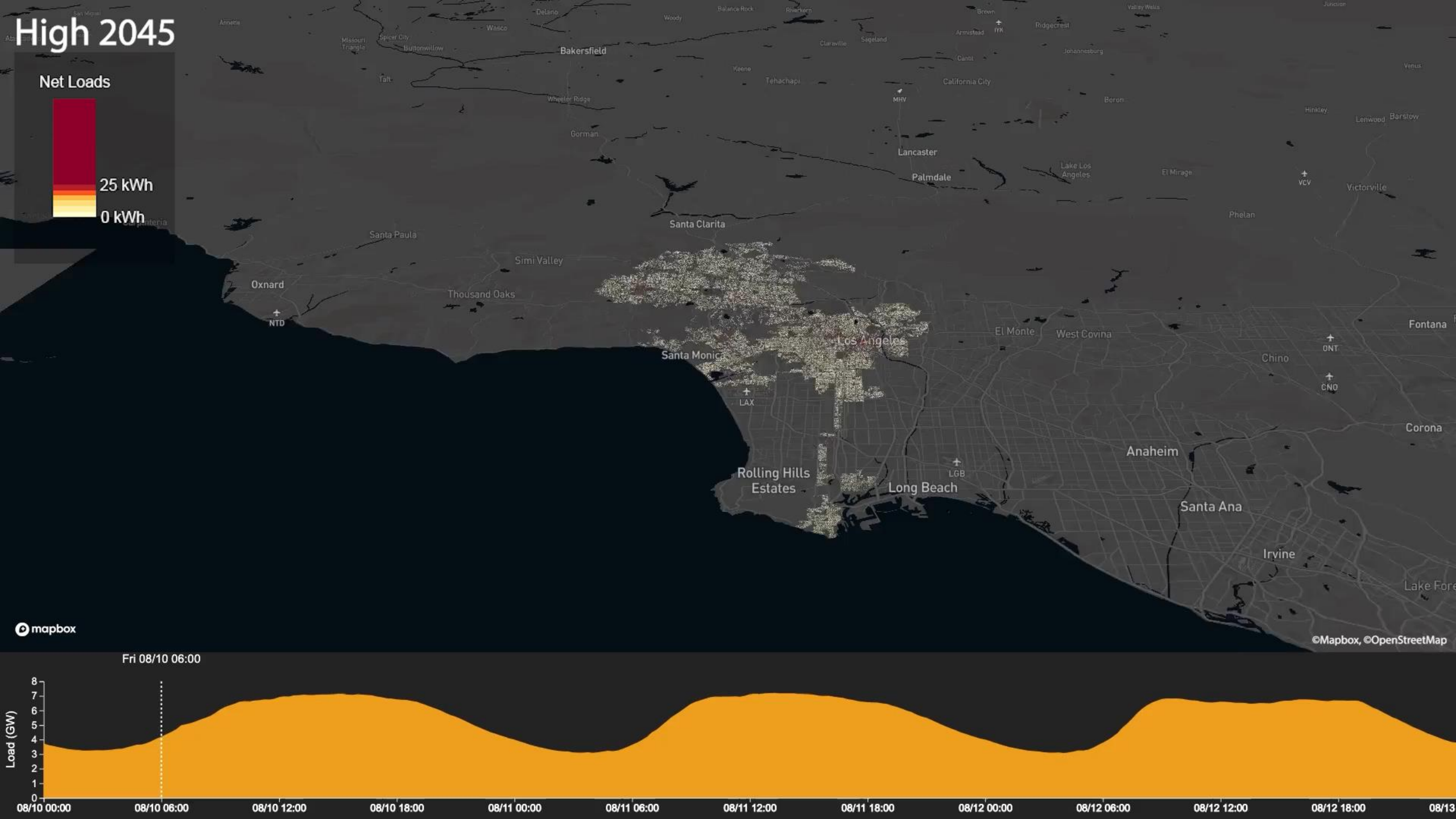


LA100

Establishing confidence at all levels of a power system is challenging



Over 100 million simulations



Unprecedented up-front effort on data coordination made LA100 possible

Timeseries data alignment

Hi LA100 Team:

One major data-related issue we might run into on this project is having misaligned timeseries data across the modeling groups. This is a surprisingly common problem that has resulted in hundreds of thousands of dollars wasted on past projects. Because of the rigid timeline and multi-team/multi-model complex

To account for this, we are enforcing a standard la100 project-wide timeseries format for all handoff datasets. Specifically, all handoffs MUST be in a PST, with an hour-beginning format (e.g. hourly timestamps of 1:00 refers to 1:00-1:59).

Note that PST is light savings is

Now, this does you must (at the very least) set up your models with a converter that converts the PST, hour-beginning la100 format to your model's specific requirements, and upon exporting handoffs, that you make the conversions back to PST, hour-beginning. Basically, everything coming in and out of your models and being passed around between groups needs to be in this la100 standard format.

In addition, because 2012 (our baseline resource/load year) is a leap year, all 8760 data must drop 12/31 from the end to fit the year into the 8760. The same logic should also be applied for any 8760 data transfers for any other leap year.

Finally, the start of any 8760 (index 0) should be at 00:00 (12:00 AM) in PST.

****Your Immediate Action Items**:**

I need every member of this team doing technical work (leads/analysts/coders) to reply to this email (or respond in a separate email) saying that you:

1. You understand that we are using a la100 project-wide timeseries format for the LA100 project,
2. You understand the requirements of the format which are that all model handoffs and data transfers be in PST, hour-beginning format, and if it is an 8760, that 12/31 be dropped for all leap years and the first index value (index 0) be set to 00:00 (12:00 AM) PST, and
3. You promise to adhere to this LA100 project wide format for all handoffs and movement of timeseries data from one LA100-subteam to another.

In addition, please include in your email response your answer to the following: "Do you think there might be DST shifts hiding in your data currently?". If yes, please say where they might be. If no, please explain how your timeseries data is handled for your current model. If you do not know, please respond saying what your uncertainties are/might be. We will document these so we can address these uncertainties.

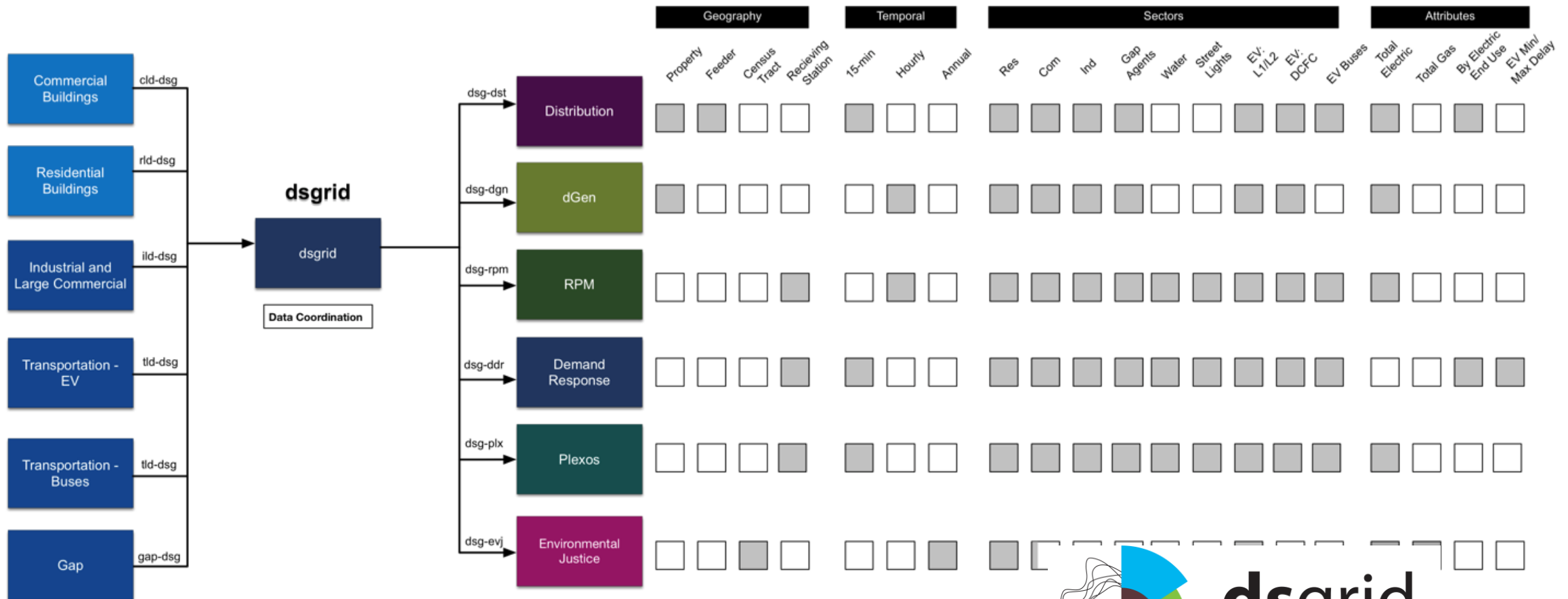
Data repository for internal data hand-offs

The screenshot shows a SharePoint site titled "LA100 - Handoffs" with 159 datasets and 2581 files. The site is part of the "ESIF Research Data" collection. The interface includes a navigation bar with "Home", "Data Repository", and "Time Series" tabs. Below the navigation bar, there is a list of contributors: la100-admin (Owner), la100-nrel (Contributor), Kelly Sanders (Contributor), Dong Min Kim (Contributor), Yun Li (Contributor), David Rager (View/Download), George Ban-weiss (View/Download), and Jiachen Zhang (View/Download). The main content area displays a list of datasets, including "air-vis-2" (19 files) and "USC-handoffs(emission&model)" (8 files). Each dataset entry shows the file upload date and time, and the user who uploaded it. The "air-vis-2" dataset was uploaded on 3/9/2021 at 10:31 am by Vikram Ravi. The "USC-handoffs(emission&model)" dataset was uploaded on 3/6/2021 at 10:21 pm by Yun Li. The site also features a "Display 10" dropdown menu and a "Last Activity" dropdown menu.

SharePoint site and tracking spreadsheets for utility data requests and hand-offs

New dsgrid software designed in response to LA100 challenges including data size and time representation

Accept datasets in native resolution and performs queries to return desired resolution



Proactive choice of big-data technology (Apache Spark)

Formal declaration and automatic conversion of time formats



dsgrid

Demand-Side Grid Toolkit

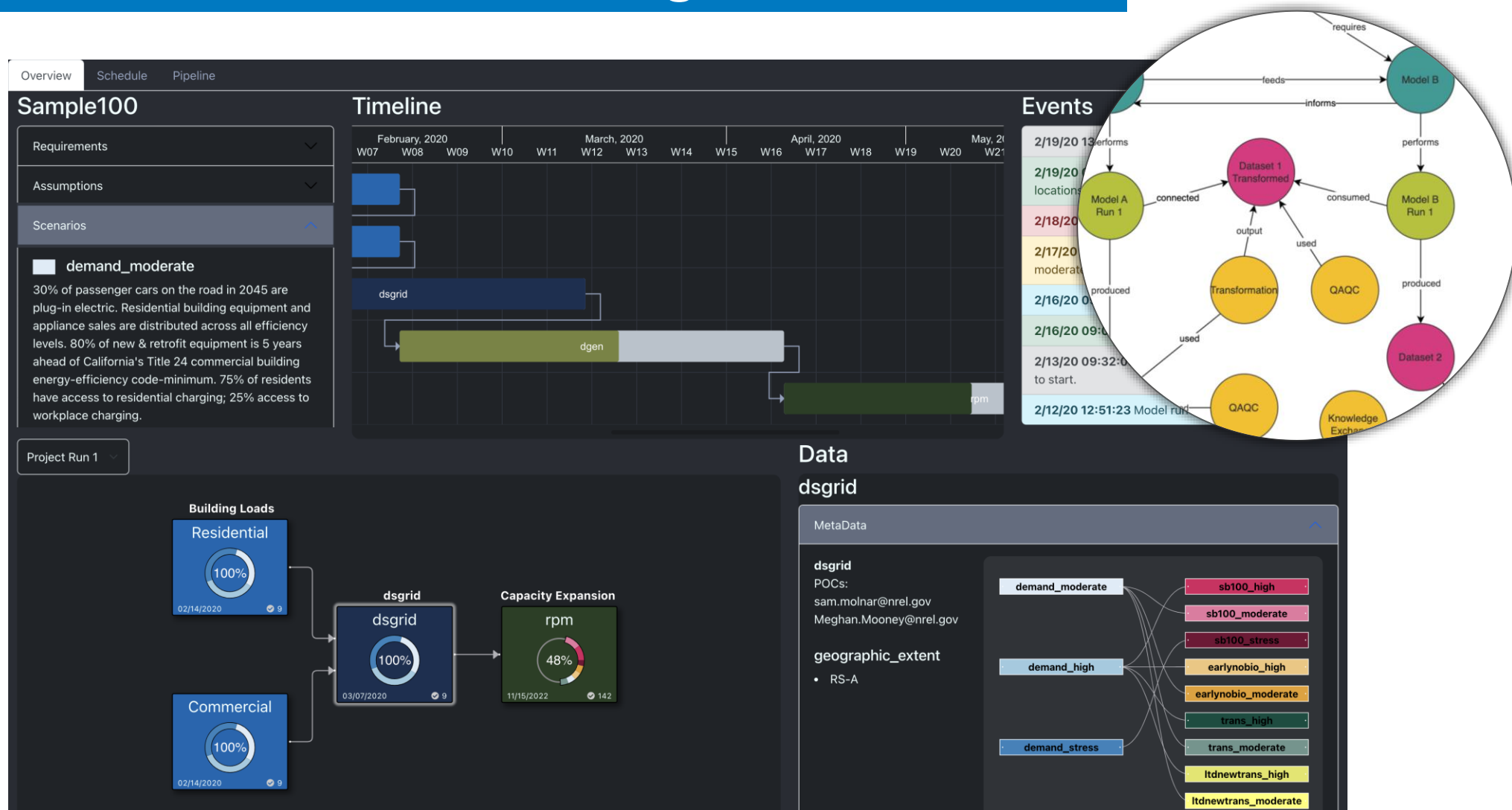
<https://www.nrel.gov/analysis/dsgrid.html>

A centralized data repository was too rigid for fast iteration between modeling teams



The Pipeline for Integrated Projects in Energy Systems (PIPES):

- project management
 - data management
 - workflow management
- thin layer on top of existing workflows to enable scalable integrated modeling



Backend: Graph Database (Amazon Neptune), Metadata Catalog (GDC), PIPES API

Front End: GUI and CLI

Conclusion

There are a lot of things we didn't talk about today

- Co-simulation
- Strategic behavior
- Agent-based modeling
- General equilibrium modeling
- Open-source tools
- Data standards
- Communication standards
- Resource adequacy
- Dynamic contingency analysis
- Distribution system modeling
- Other energy carriers
- Fuel markets
- Integrated assessment models
- Macro- and micro-economics

As we envision energy systems that
are more complex and interconnected



Legend

We need tools that are more complex and interconnected

Bulk Resources

NSRDB

ATB

GridDB



Planning

PRAS



RPM



PLEXOS

Standard Scenarios, Cambium

PSCAD

PSS®E



Smart-DS

DiTTo



MIDAS

CADET

DISCO



Grid Edge



PRECISE



EVOLVE

EVI-X

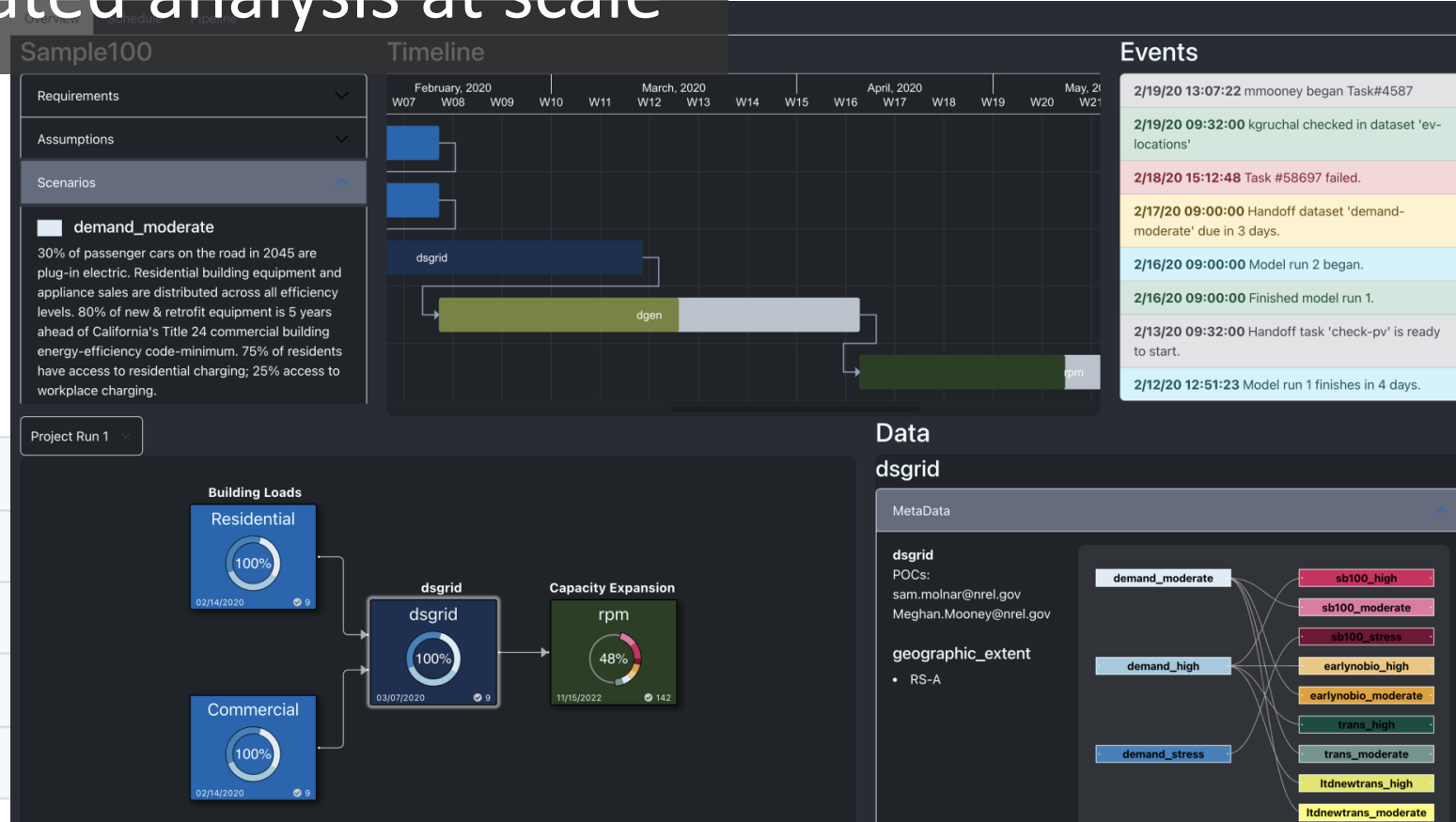
And we need curated datasets, interfaces, testing, data management layers, and other processes to enable integrated analysis at scale

Codecov Report

Patch coverage: 99.24 % and project coverage change: +3.45 🎉

✓ All checks have passed
5 successful checks

- ✓ Lint / black_lint (pull_request) Successful in 13s
- ✓ Lint / black_lint (push) Successful in 17s
- ✓ Pytests / build (ubuntu-latest, 3.10) (pull_request) Successful in 6m
- ✓ Lint / flake8 Lint (pull_request) Successful in 14s
- ✓ Lint / flake8 Lint (push) Successful in 12s



Analysis models are the hardware for envisioning, pre-testing, and communicating the clean energy future—like hardware, they require development, maintenance, and interconnection.