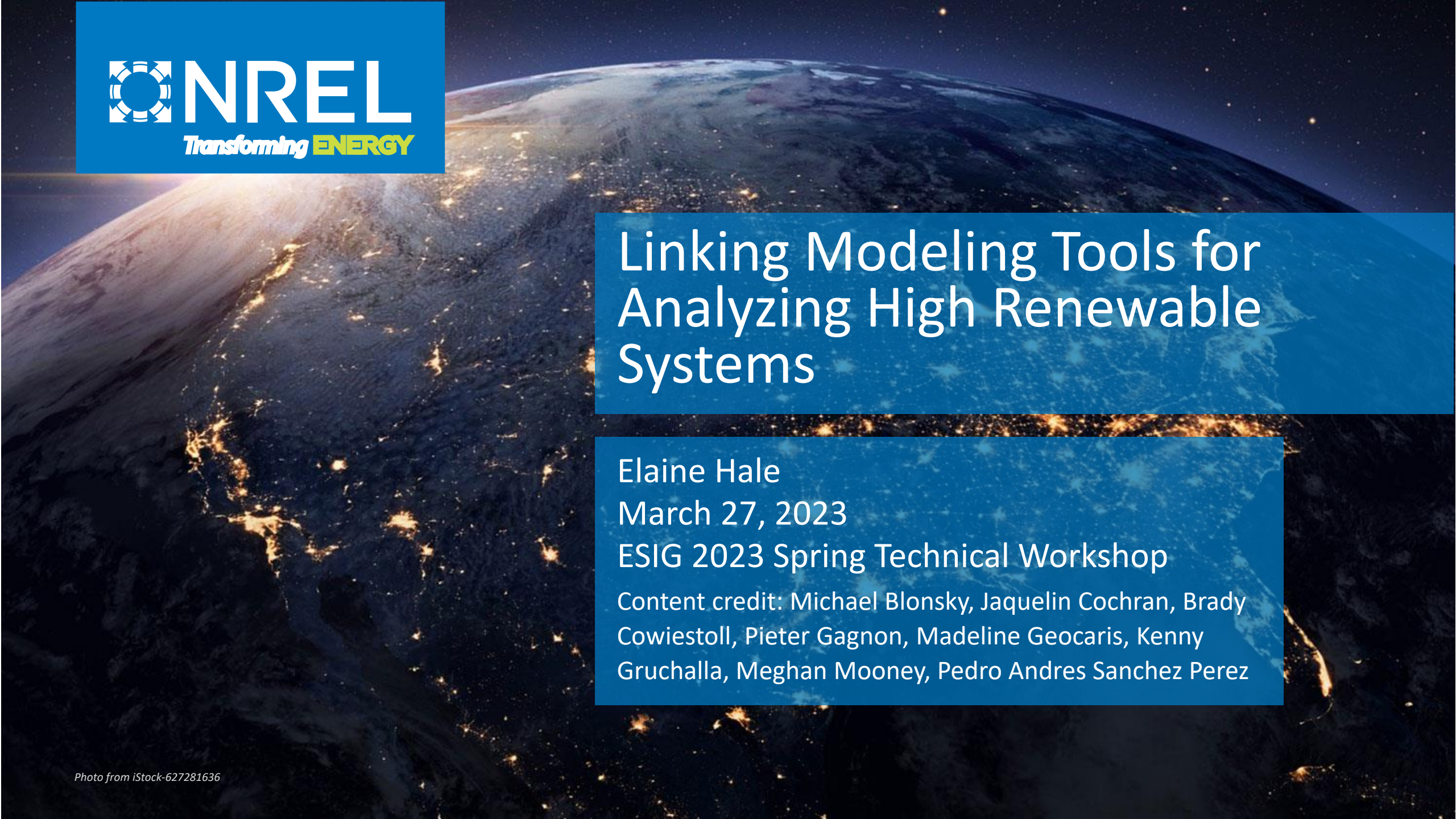


# Linking Modeling Tools for Analyzing High Renewable Systems

Elaine Hale

March 27, 2023

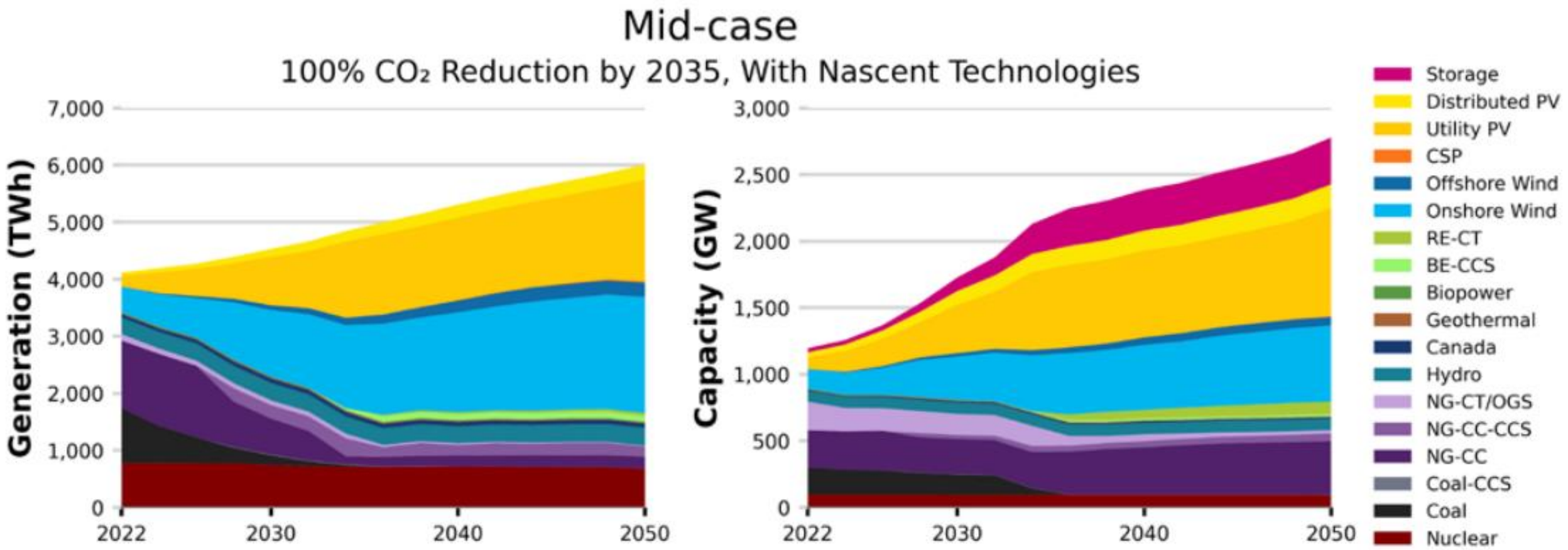
ESIG 2023 Spring Technical Workshop

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

*Photo from iStock-627281636*

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

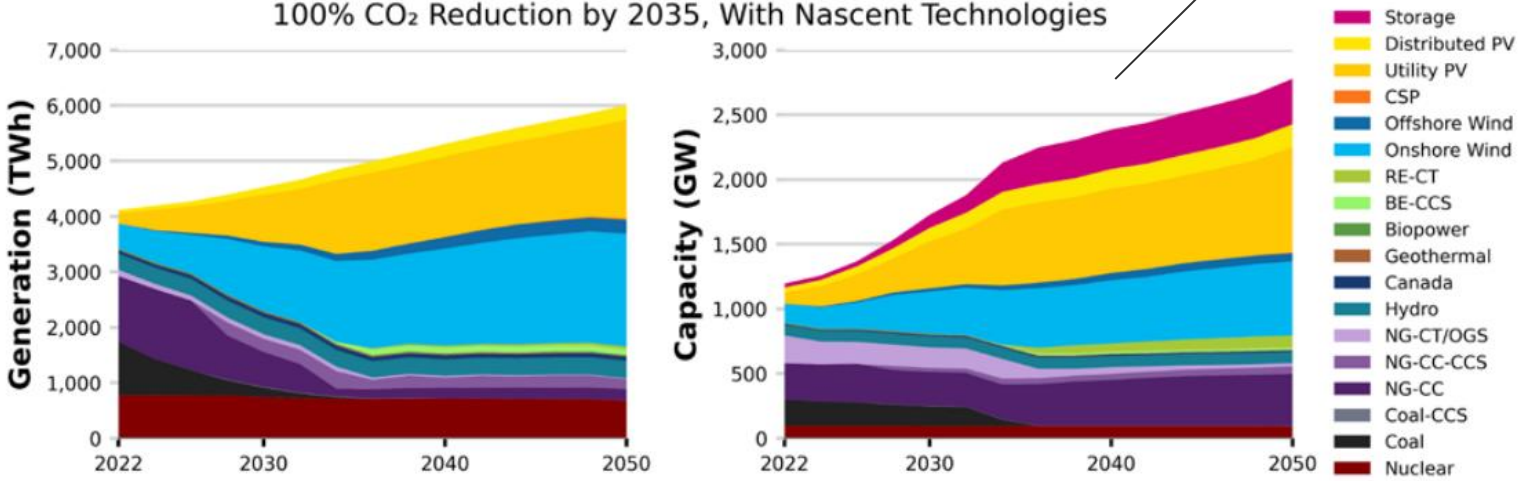
**2022 Standard Scenarios (Gagnon et al.)**




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.)**
https://www.nrel.gov/docs/fy23osti/84327.pdf



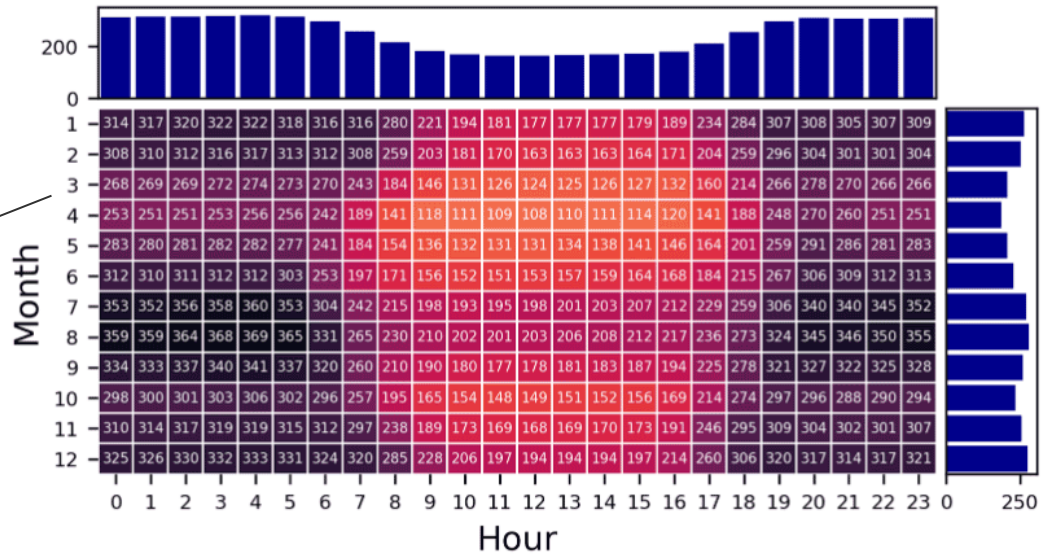

ReEDS : capacity expansion / utility investments

dGen : 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

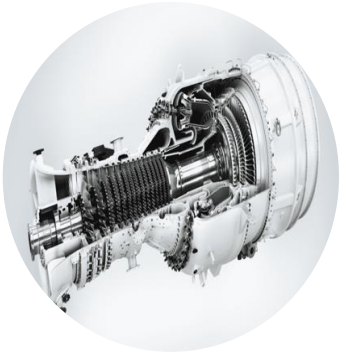
Renewable
Energy

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

Storage
(including coupled with solar)

+ >2,700 MW

Distribution,
Transmission



Renewably Fueled
Combustion
Turbines

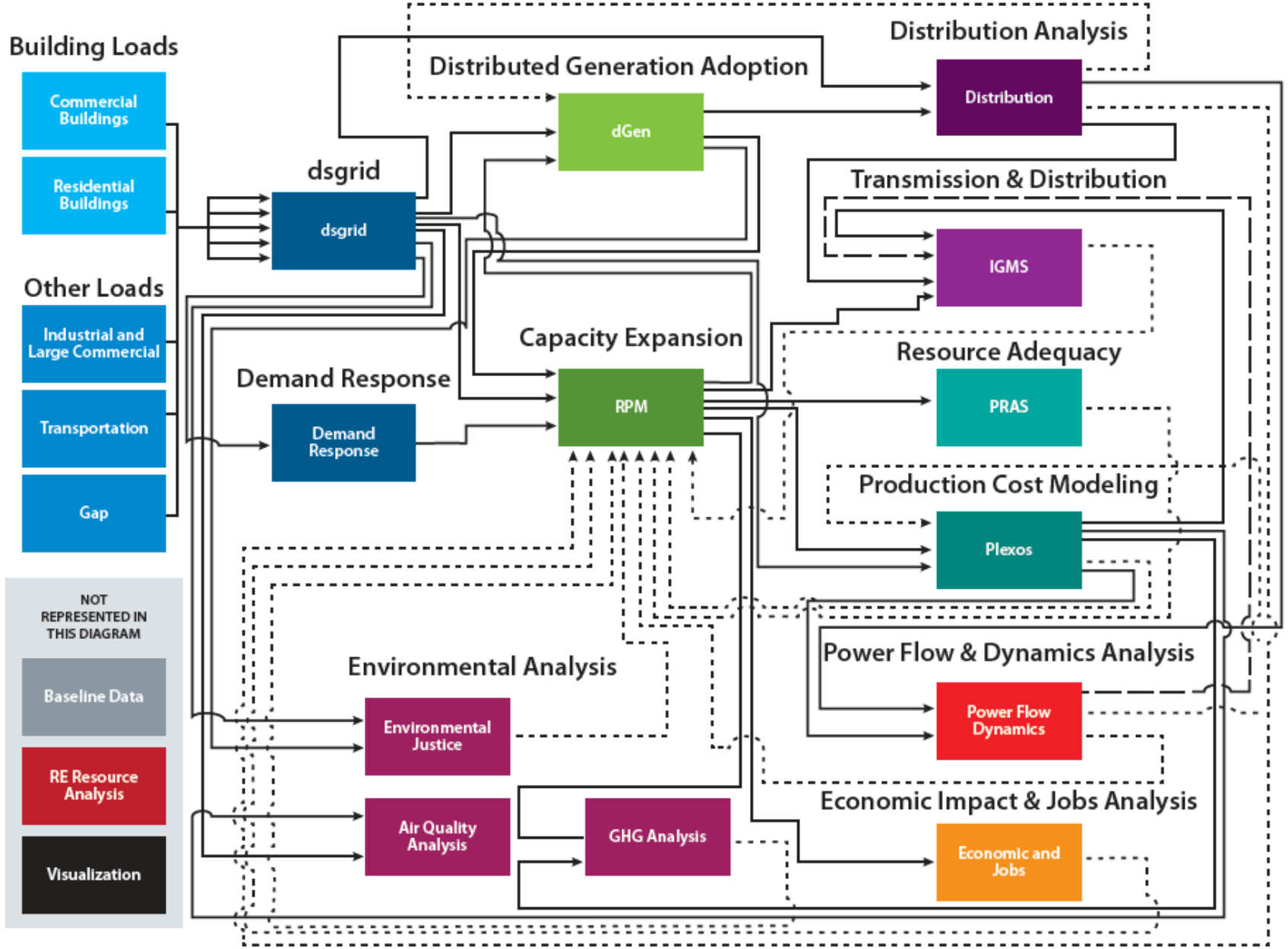
+>2,600 MW
(in basin)

**Much More**

**New**

| Natural gas → Biofuel/ hydrogen |
|---|
| **Today:** Daily |
| **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

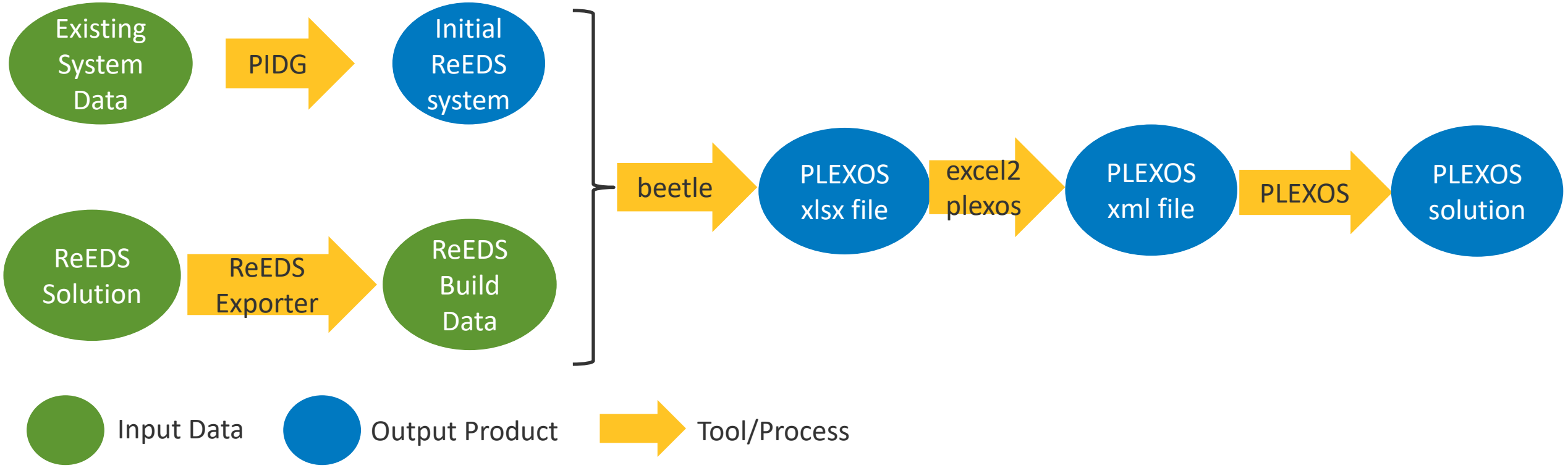
# ReEDS 2 PLEXOS enables detailed descriptions of how realistic future power systems would operate

**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

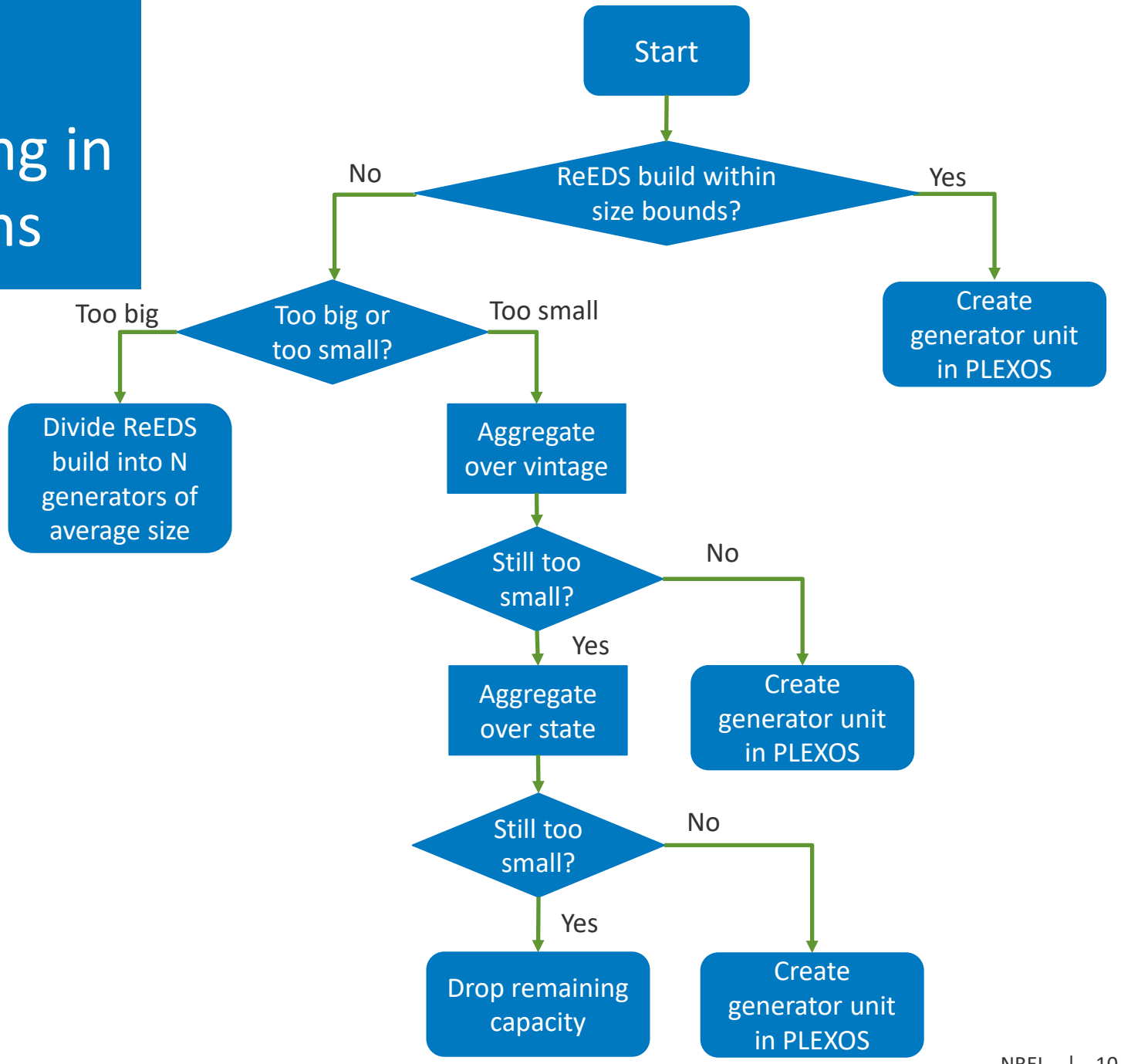



**Capacity Expansion Model**
single scenario, selected year

**Production Cost Model**
single scenario, single year

# ReEDS 2 PLEXOS
## Requires aligning and filling in data; Specific algorithms

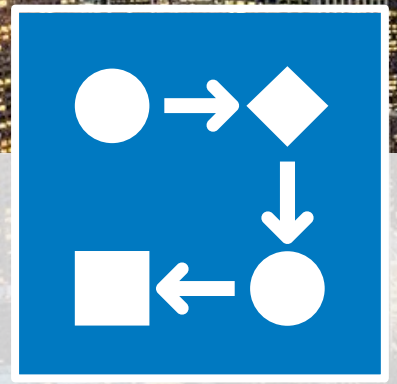
| Property | Data Source |
|---|---|
| Emission rate | **ReEDS** |
| Fuel cost | **ReEDS** |
| Heat rate | **ReEDS** |
| Hydropower energy | **ReEDS,** modified |
| Minimum stable level | **ReEDS;** ERGIS |
| Minimum up and down time | NARIS |
| Outage duration | NARIS |
| Outage rate | **ReEDS** |
| 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

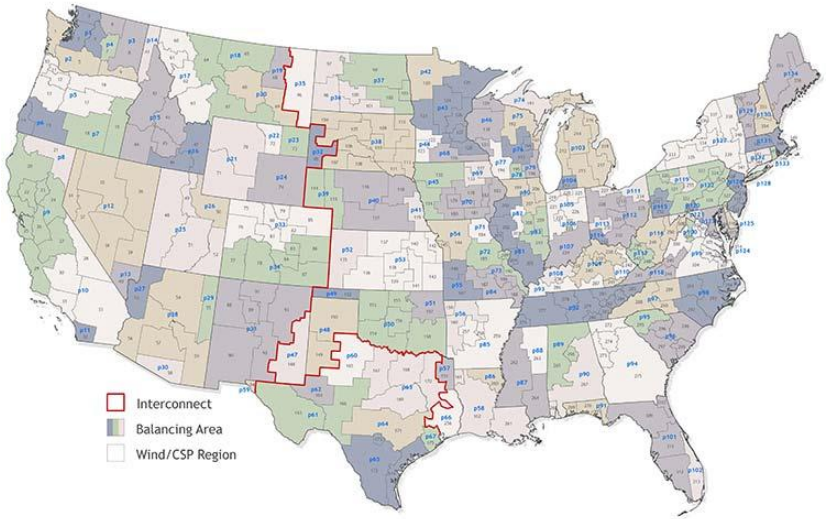
## Project Planning

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

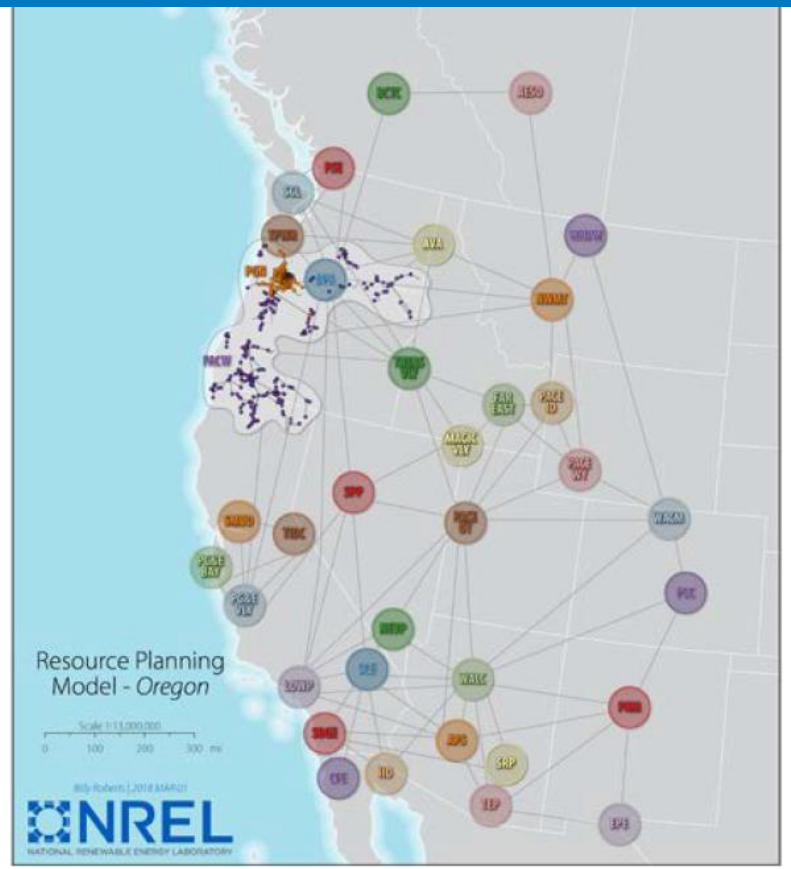
- Unit testing and error handling
- Simplify workflow for users of ReEDS 2 PLEXOS
- Prepare for R2X (e.g., other production cost models like SIIP)
- Code optimization
- Robust compatibility tracker with ReEDS version tags
- Improve maintainability of the main repo and adjacent repositories
- Generalize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

# Long-term, we would like to enable this capability across multiple scales




**National-scale**

- Balancing authorities
- Aggregated generators
- Pipe-flow transmission




**Regional-scale**

- Nodal-zonal structure
- Linear power flow within the focus region
- Limited validation


**Community-scale**

- Highly validated
- Additional reliability constraints (e.g., deliverability of reserves)

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

Existing System

GridDB

Load Projections

dsgrid
Demand-Side Grid Toolkit

Renewable Resource

rev

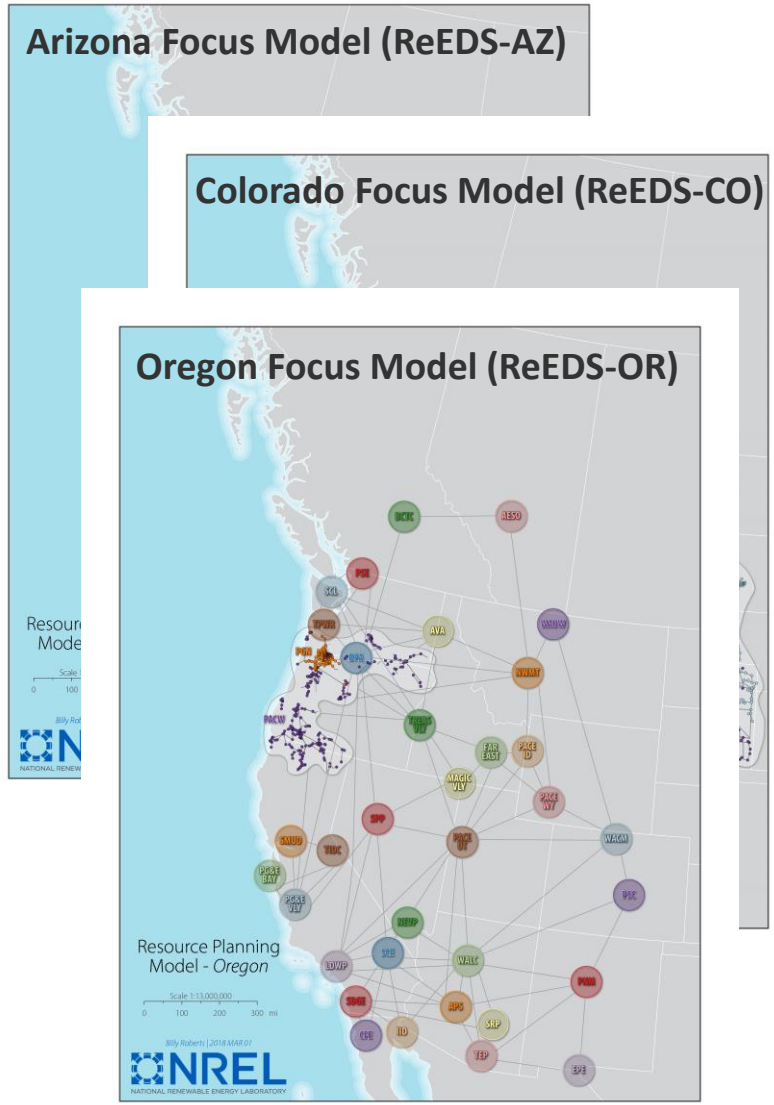
Filter by Geography

Aggregate Neighboring Systems' Data

Unit-level and Nodal Data for Focus State

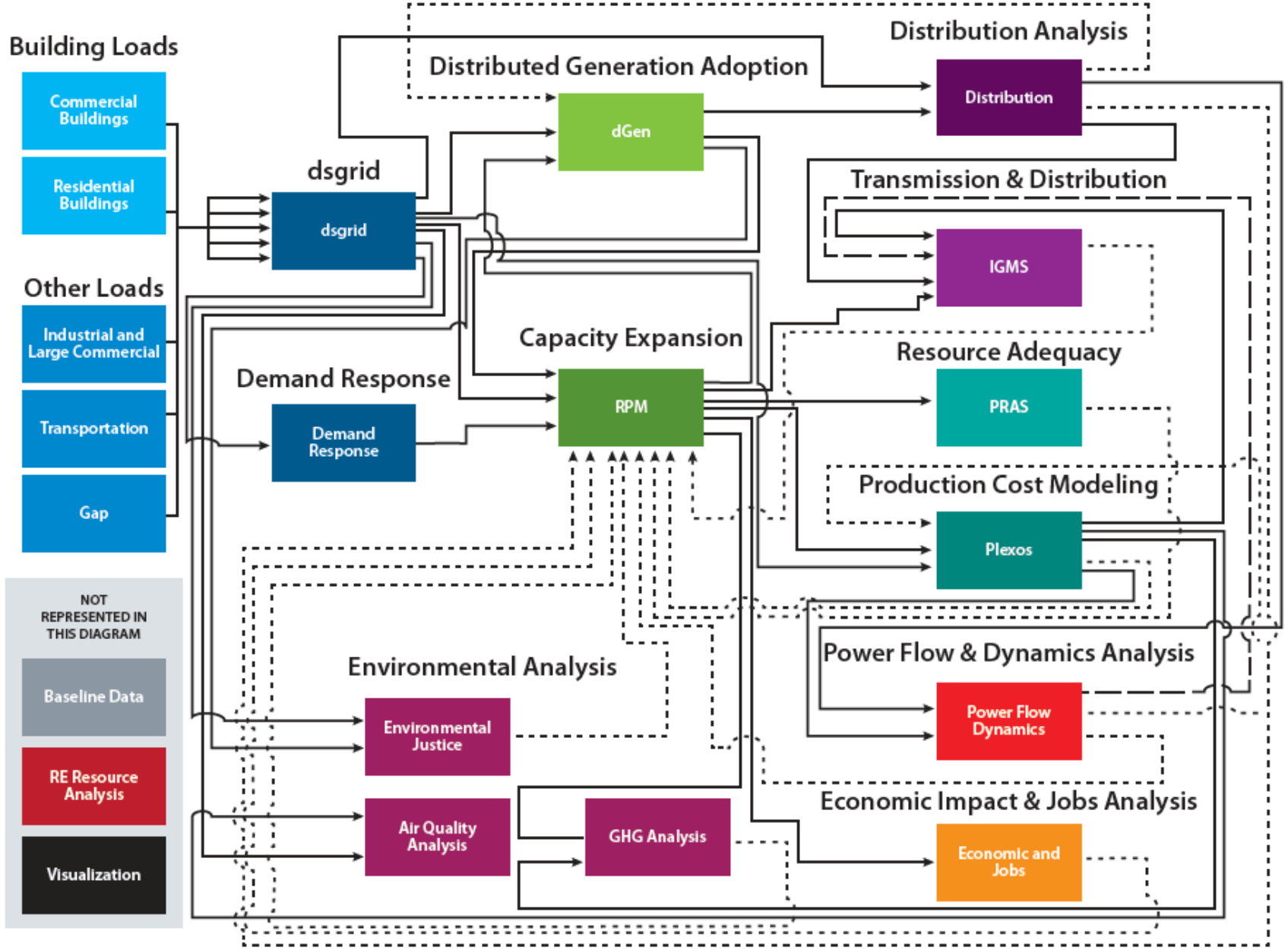
?

(Aspirational)



# LA100

# Establishing confidence at all levels of a power system is challenging




**Over 100 million simulations**


High 2045
Net Loads
25 kWh
0 kWh
Bakersfield
Tehachapi
California City
Lancaster
Palmdale
Victorville
Santa Clarita
Santa Paula
Simi Valley
Oxnard
Thousand Oaks
Los Angeles
Santa Monica
El Monte
West Covina
Chino
Fontana
Corona
Anaheim
Santa Ana
Irvine
Long Beach
Rolling Hills Estates
LAX
LGB
ONT
CNO
NTD
VCV
mapbox
©Mapbox, ©OpenStreetMap


Fri 08/10 06:00
Load (GW)
0
1
2
3
4
5
6
7
8
08/10 00:00
08/10 06:00
08/10 12:00
08/10 18:00
08/11 00:00
08/11 06:00
08/11 12:00
08/11 18:00
08/12 00:00
08/12 06:00
08/12 12:00
08/12 18:00
08/13

# 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 fo**
**handoffs MU**

**Note that PST i**
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**:**

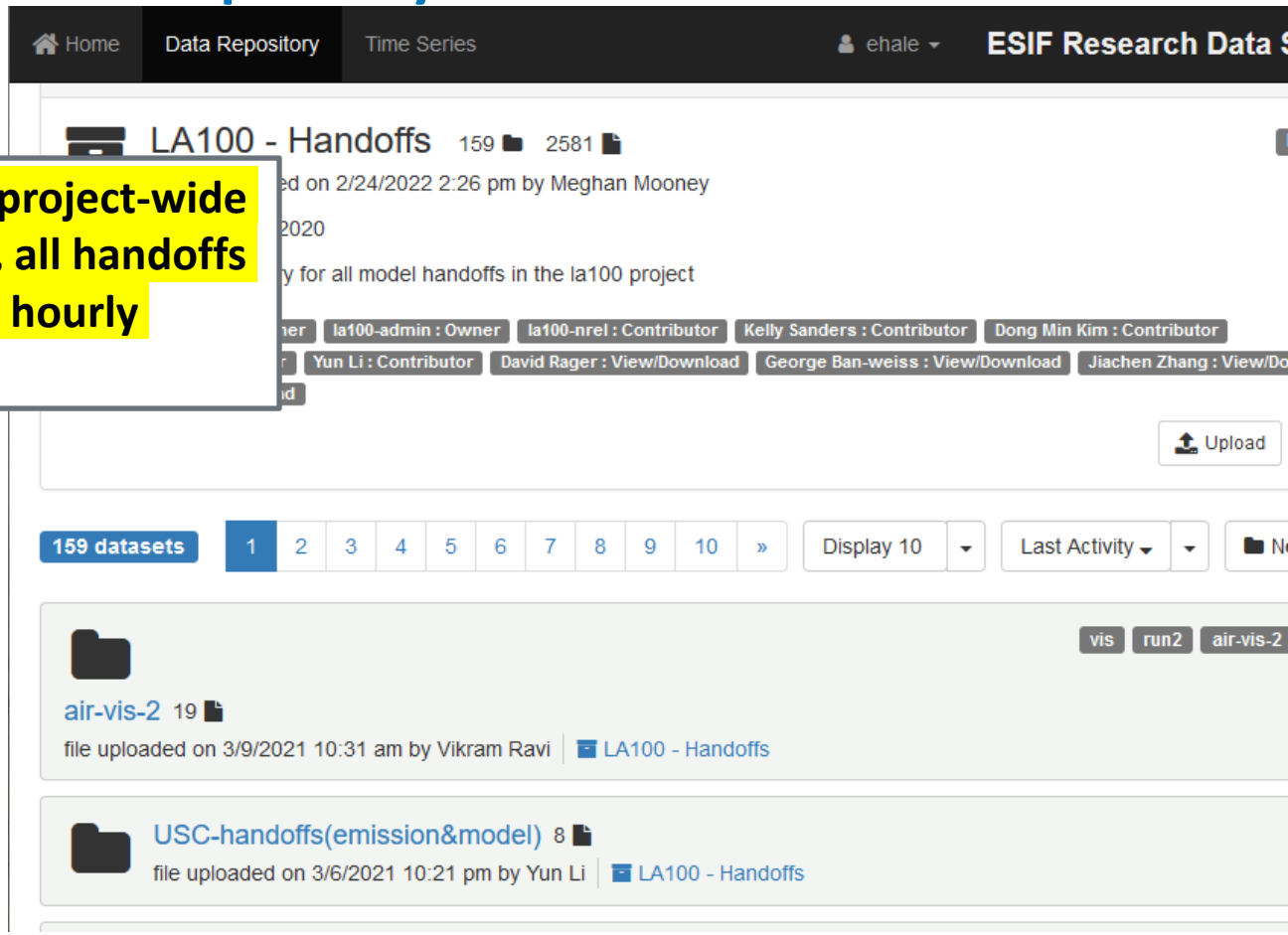
I need every member of this team doing technical work (leads/analysts/coders) to reply to this email (or respond in a separate email) saying that you:

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.

**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).**

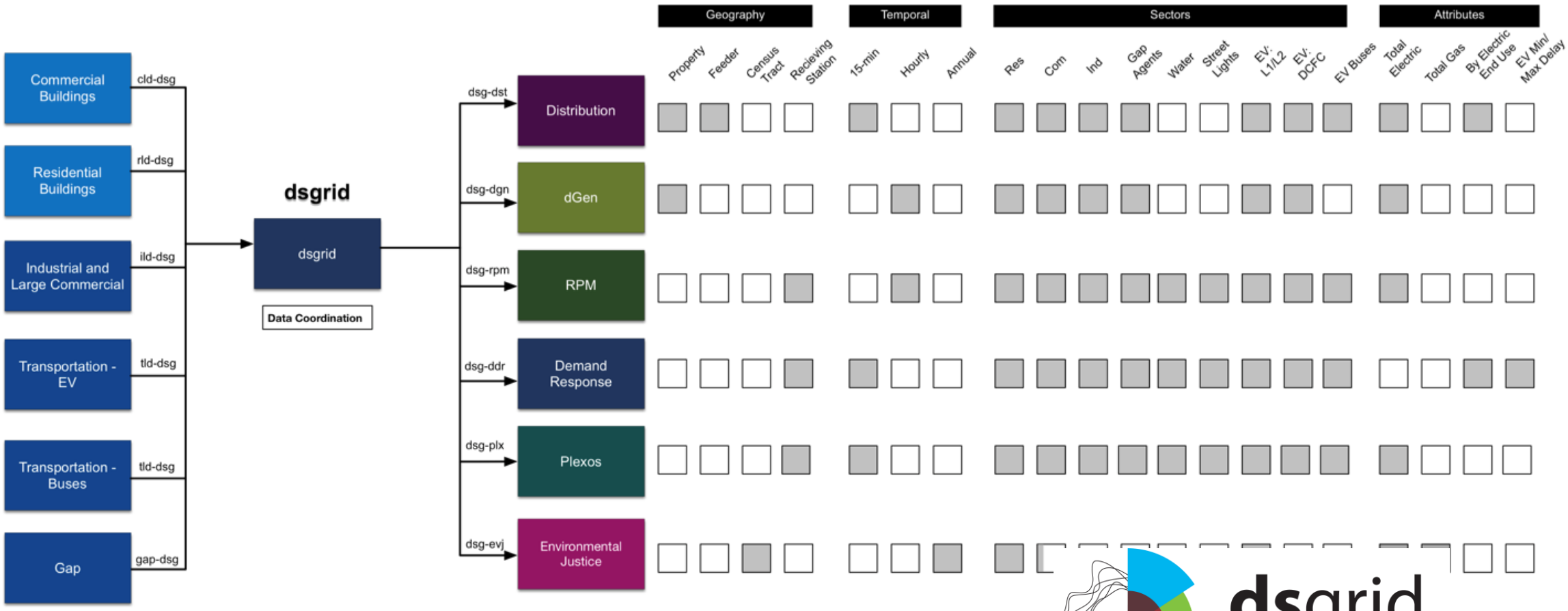
## Data repository for internal data hand-offs




## 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

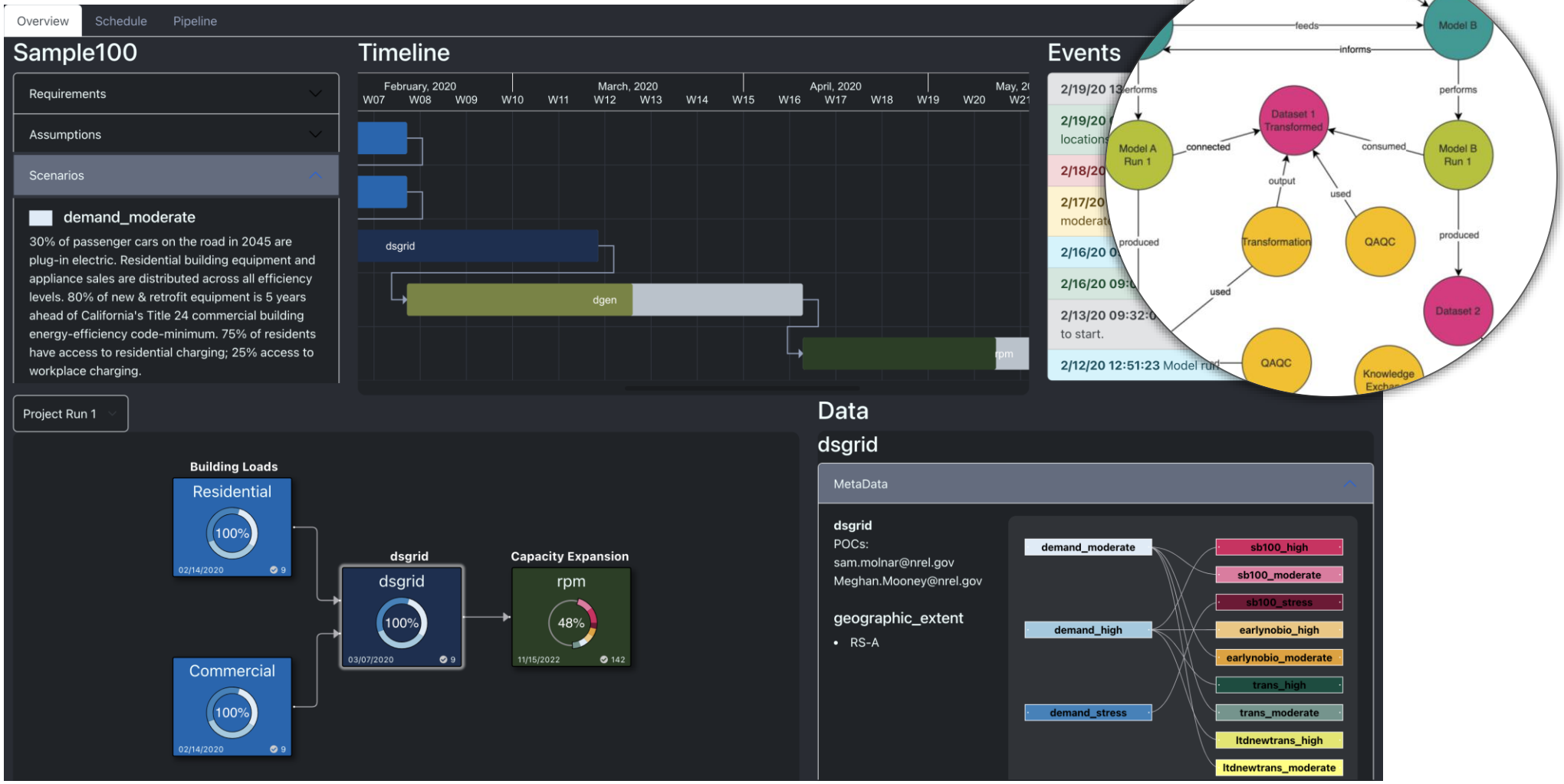
https://www.nrel.gov/analysis/dsgrid.html

# 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

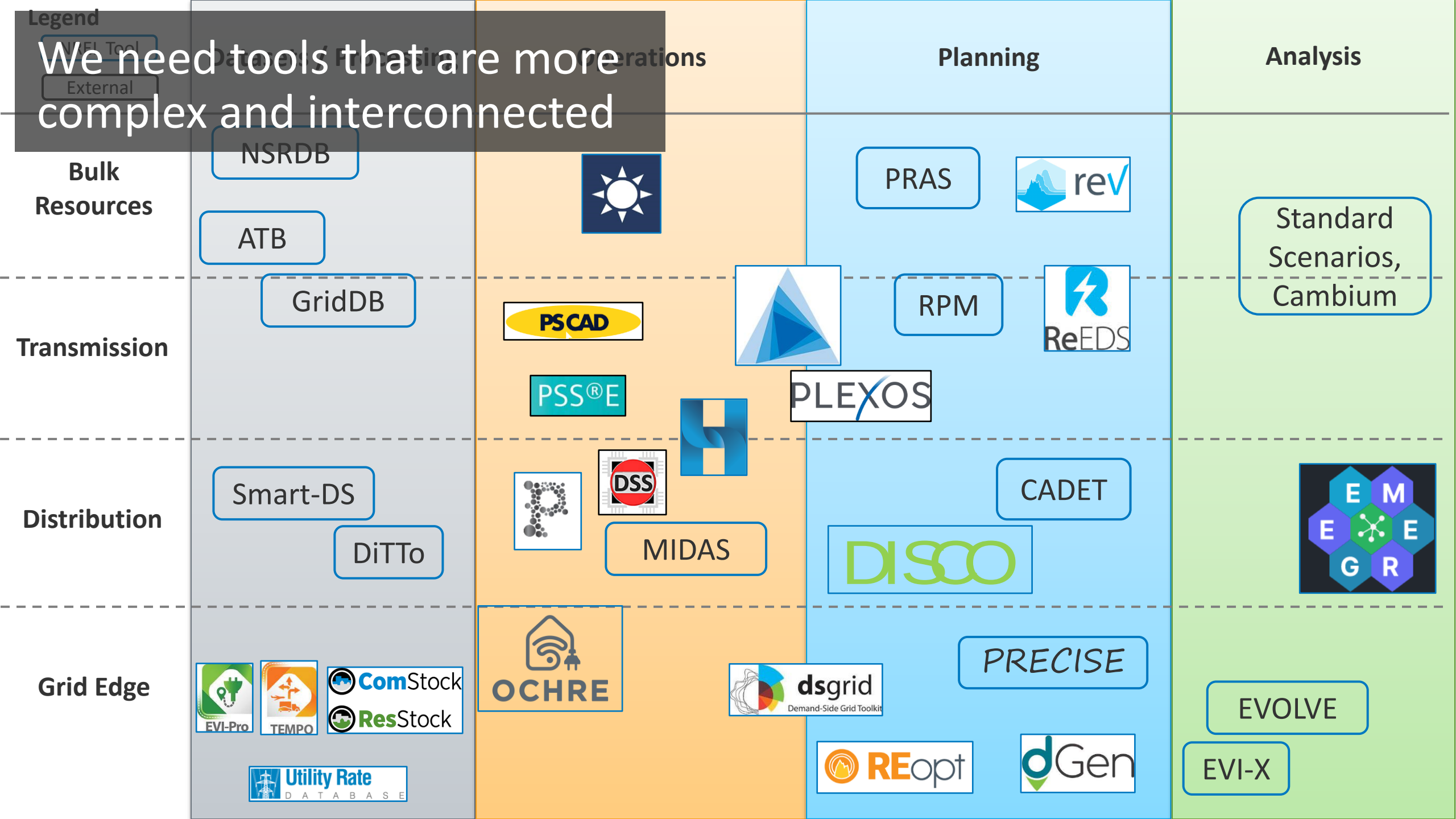
# There are a lot of things we didn't talk about today

- 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
FOR RENT
314
3 BEDROOMS


Legend
NREL Tool
External
Data and Preprocessing
Operations
Planning
Analysis
We need tools that are more complex and interconnected
Bulk Resources
Transmission
Distribution
Grid Edge
NSRDB
ATB
GridDB
Smart-DS
DiTTo
PRAS
rev
Standard Scenarios, Cambium
RPM
ReEDS
PSCAD
PSS®E
PLEXOS
DSS
MIDAS
CADET
DISCO
EMEGR
OCHRE
dsgrid
Demand-Side Grid Toolkit
PRECISE
EVOLVE
EVI-X
REopt
dGen
EVI-Pro
TEMPO
ComStock
ResStock
Utility Rate DATABASE

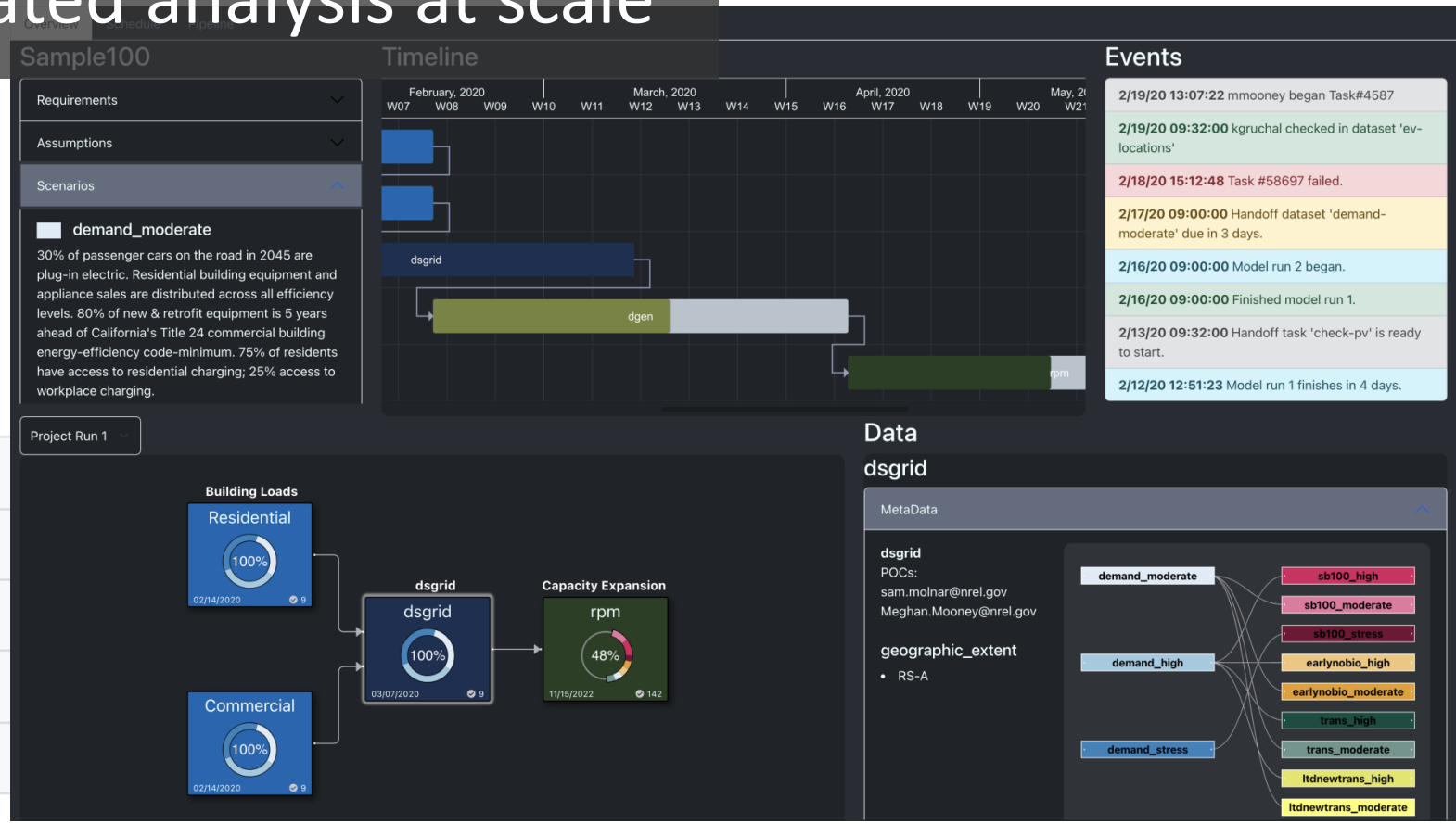
# And we need curated datasets, interfaces, testing, data management layers, and other processes to enable integrated analysis at scale

## 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.**