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Building a Holistic Grid Simulation Ecosystem

Evaluating Innovative Grid Design Approaches

September 30th, 2016

Executive Summary

- **<u>Challenge</u>: Renewables and DERs are readily being evaluated for grid integration, but more work could examine innovations in fundamental grid design principles**
  - The grid landscape is changing quickly, and fundamentally new capabilities exist
  - Individual grid models are too narrow to enable evaluation of holistic grid design
  - Talented engineers are on the sidelines due to lack access to models and data

- **<u>Objective</u>: Build a *Holistic Grid Simulation Ecosystem* to facilitate investigation of innovative grid design approaches**
  - Investigate whether innovative grid designs <u>*can*</u> be done (e.g. technical)
  - Investigate whether innovative grid designs <u>*should*</u> be done (e.g. economic)

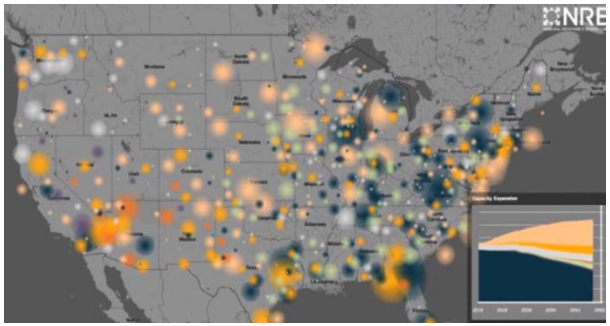
Building an Model Ecosystem

Identifying Objective Functions

Evaluating Hypotheses

Many grid system analyses are evaluating renewables and complex grid integration scenarios

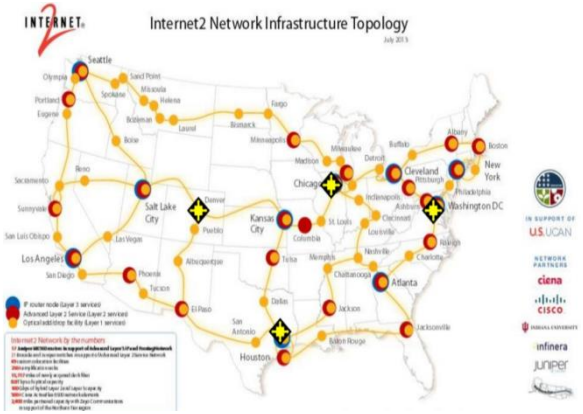
DOE "Quadrennial Energy Review" & NREL ReEDS

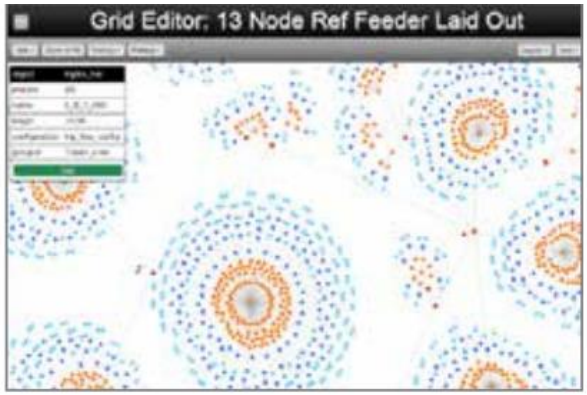


National Renewable Energy Laboratory (Renewable Energy Deployment System, ReEDS)

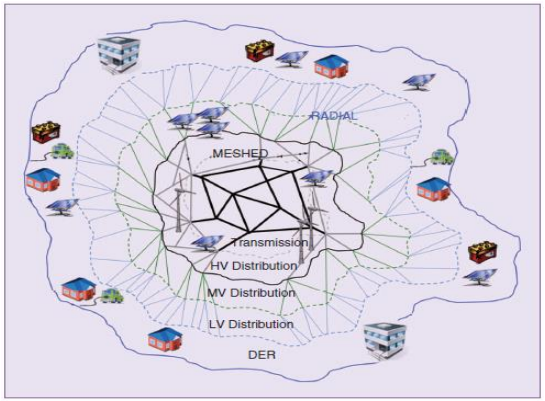
- Electricity generation capacity expansion model
- Outputs include transmission capacity expansion, generation, electricity costs, etc.

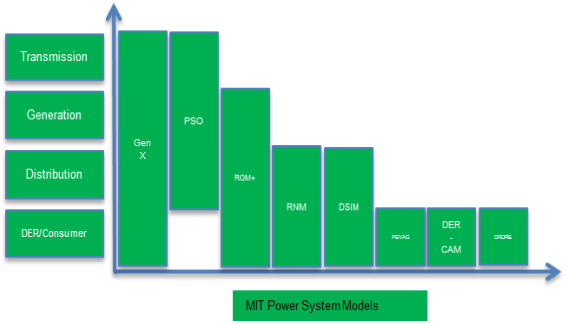
NRECA "Open Modeling Framework" & GridLAB-D





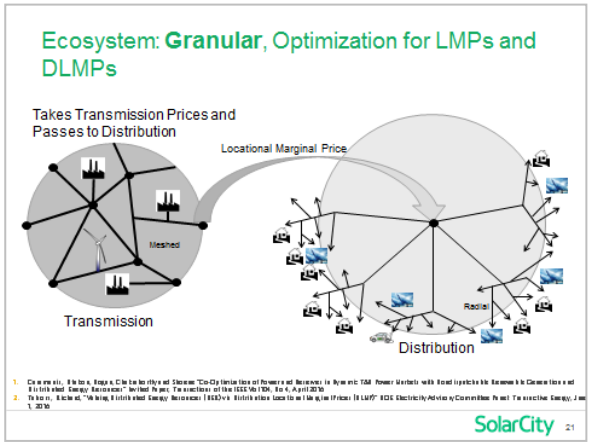
MIT "Utility of the Future"



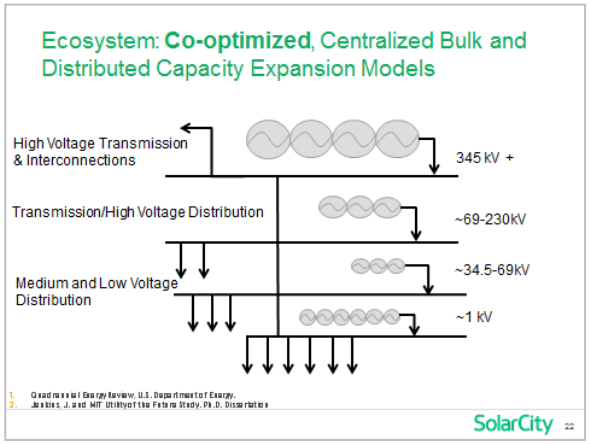


However, distributed resources are still challenging to model alongside bulk-level grid design changes

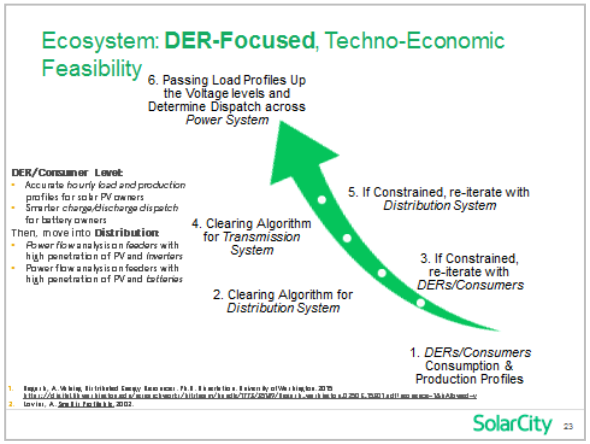
1 **Bulk Optimization**



2 **Co-Optimized**



3 **DER-Focused**



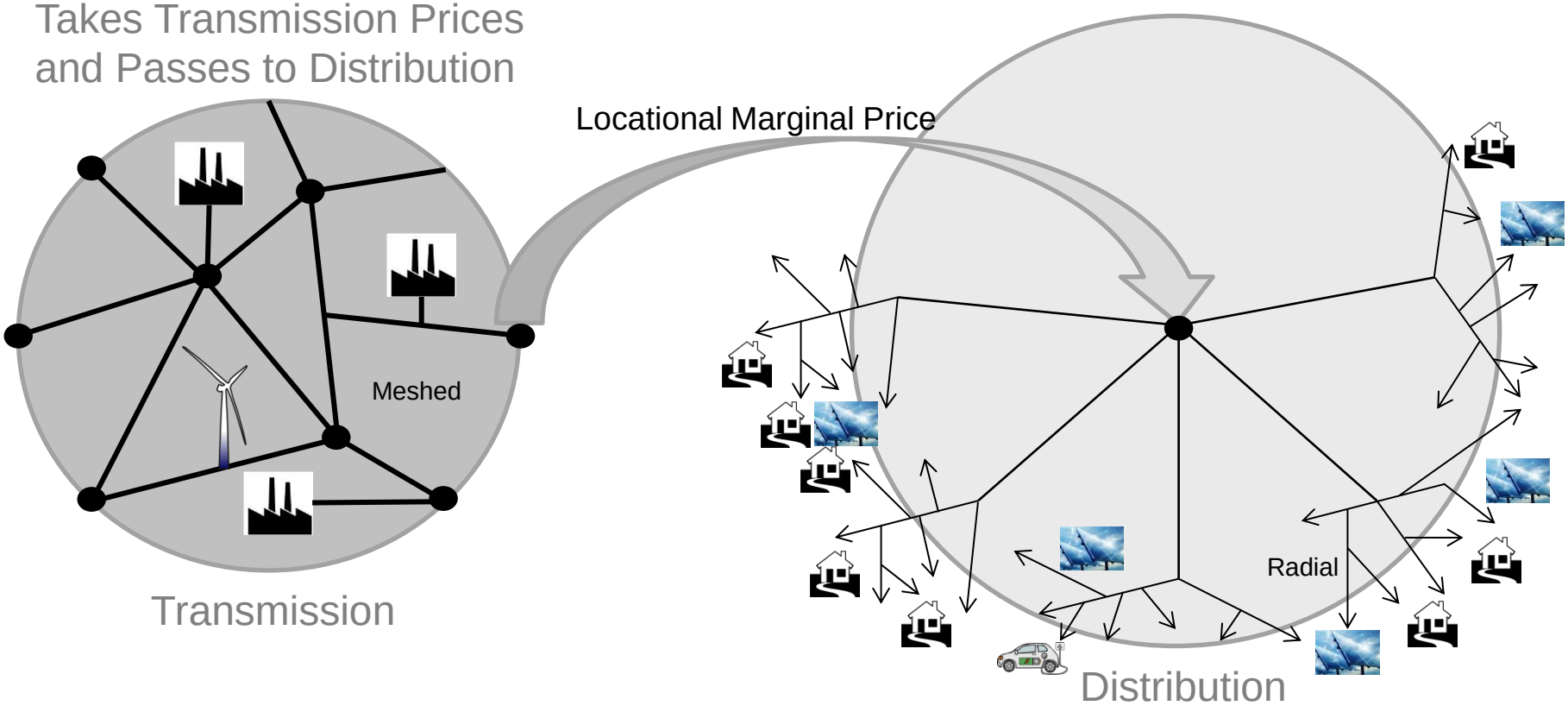
Passive distribution design, with DERs responding to bulk level signals

DERs and Distribution at the forefront, but computationally challenging

1

Bulk Optimization signals LMPs and DLMPs

Takes Transmission Prices and Passes to Distribution



1. Caramanis, Ntakou, Hogan, Chakrabortty and Shoene "Co-Optimization of Power and Reserves in Dynamic T&D Power Markets with Nondispatchable Renewable Generation and Distributed Energy Resources" Invited Paper, Transactions of the IEEE Vol 104, No 4, April 2016
2. Tabors, Richard, "Valuing Distributed Energy Resources (DER) via Distribution Locational Marginal Prices (DLMP)" DOE Electricity Advisory Committee Panel: Transactive Energy, June 1, 2016

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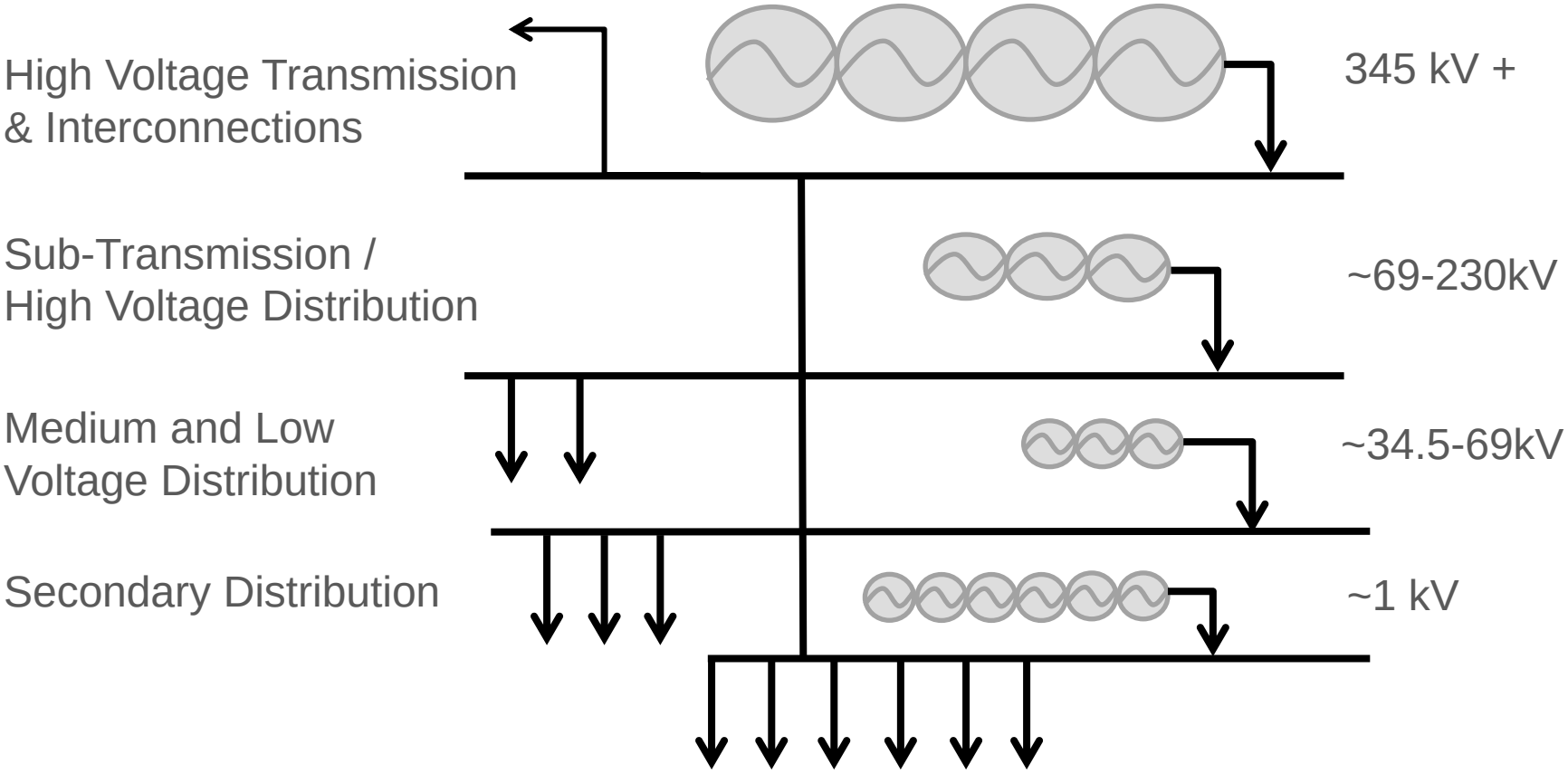
2

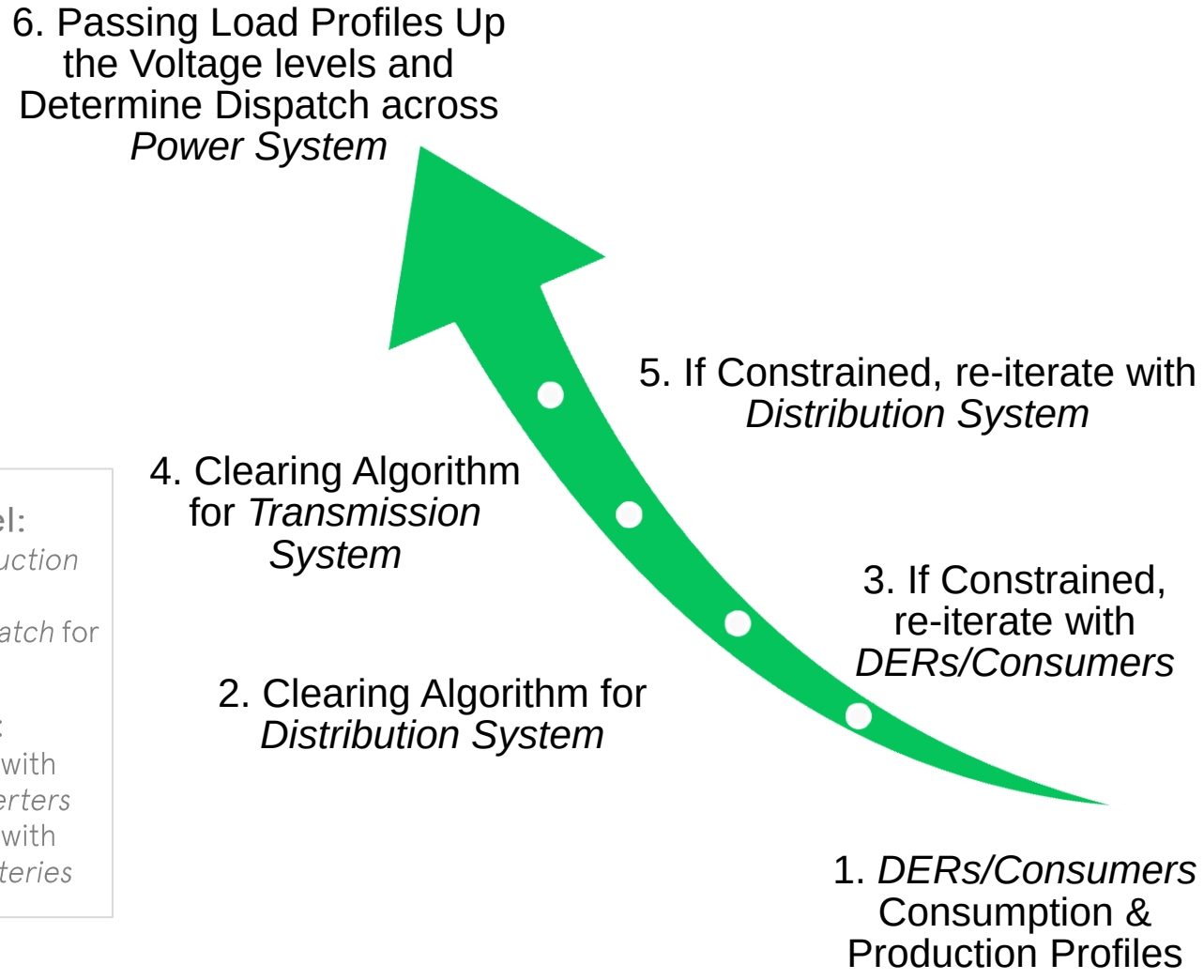
Co-Optimized, Centralized Bulk and Distributed Capacity Expansion Models



1. Quadrennial Energy Review, U.S. Department of Energy.
2. Jenkins, J. and MIT Utility of the Future Study. Ph.D. Dissertation

3

DER-Focused, Techno-Economic Feasibility



Start at **DER/Consumer Level**:

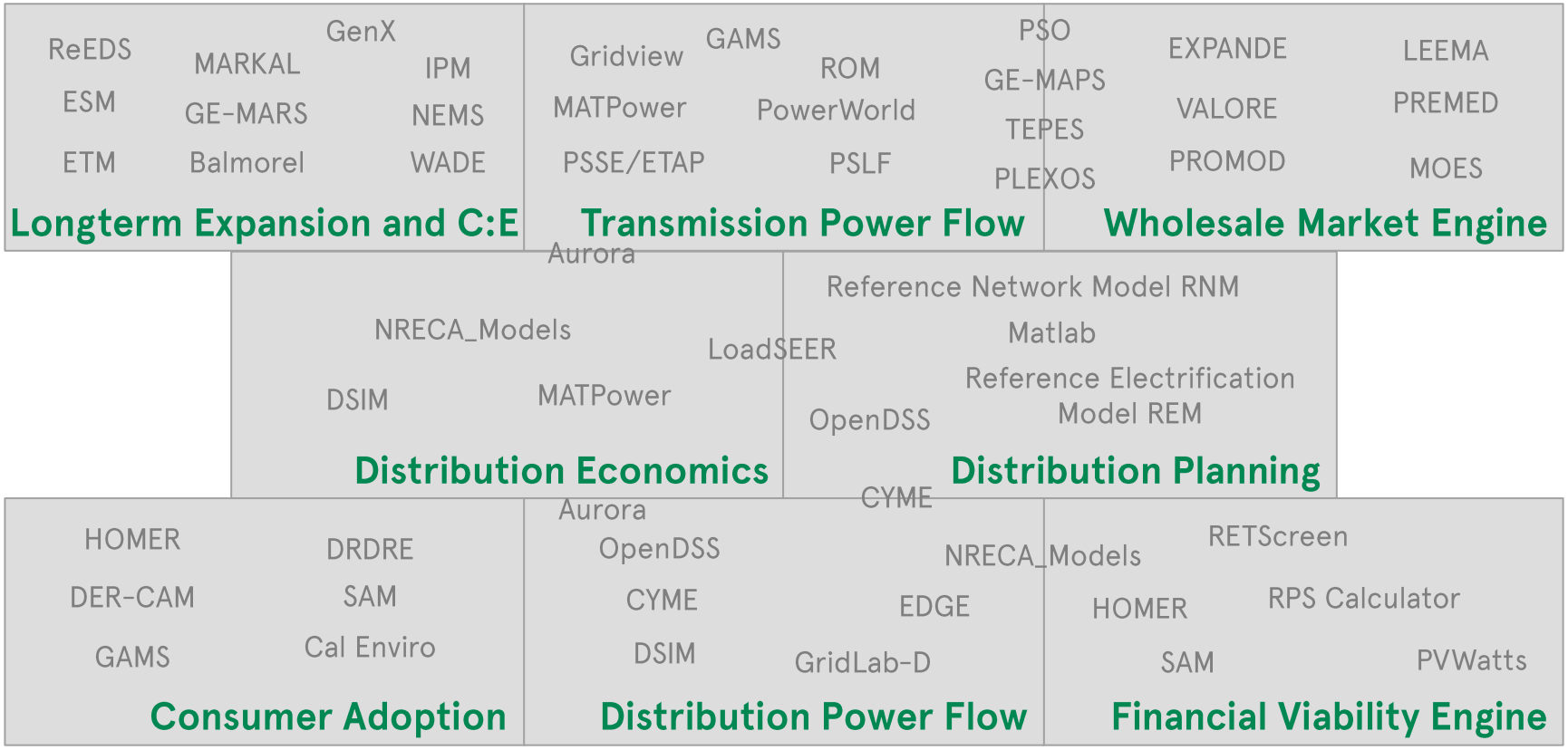
- Accurate *hourly load and production* profiles for solar PV owners
- Smarter *charge/discharge dispatch* for battery owners

Then, move into **Distribution**:

- *Power flow* analysis on *feeders* with high penetration of PV and *Inverters*
- Power flow analysis on feeders with high penetration of PV and *batteries*

1. Negash, A. Valuing Distributed Energy Resources. Ph.D. Dissertation. University of Washington. 2015 https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/35189/Negash_washington_0250E_15301.pdf?sequence=1&isAllowed=y
2. Lovins, A. "Small is Profitable". 2002.

Modeling building blocks exist at every level of the power system, but holistic ecosystems do not

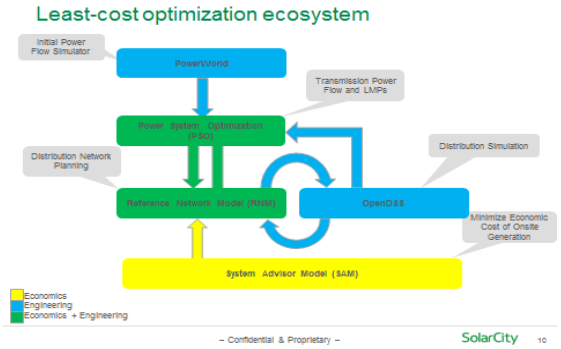


Solvers	GUROBI	AIMMS	CPLEX	Xpress

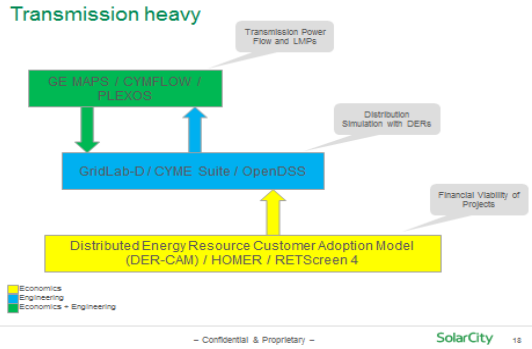
Other Engines	Natural Gas	Transportation	Atmospheric	Buildings	Cyber-Security

Ecosystems can be built with existing tools, but refinement is needed to make them readily usable

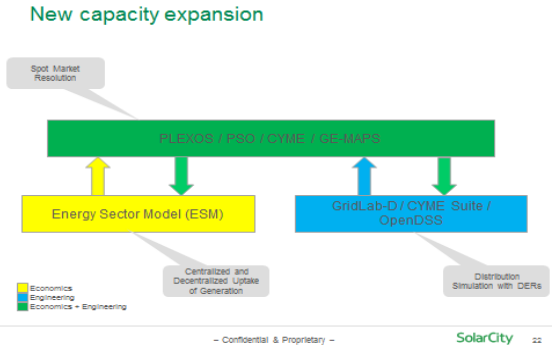
Least-Cost Co-Optimized



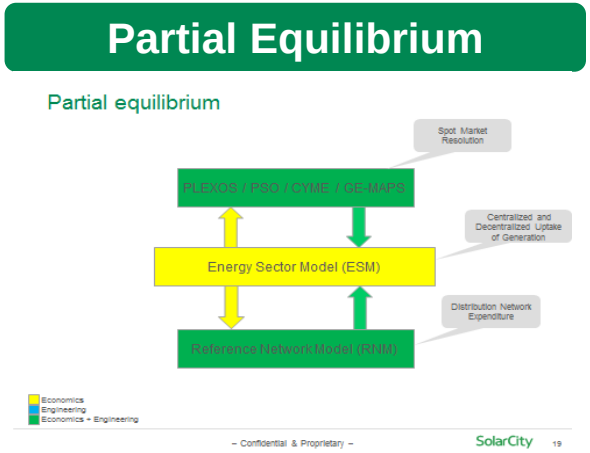
Transmission Heavy



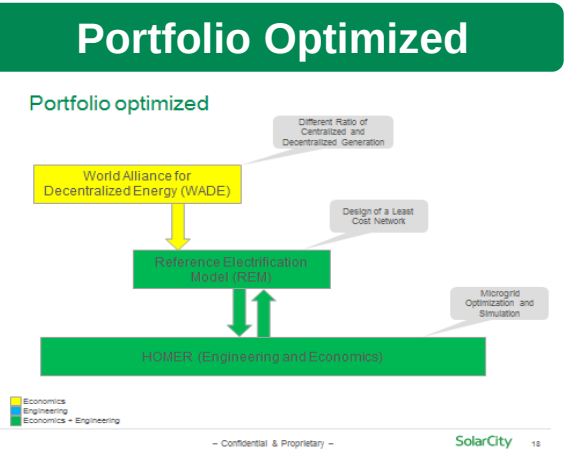
New Capacity Expansion



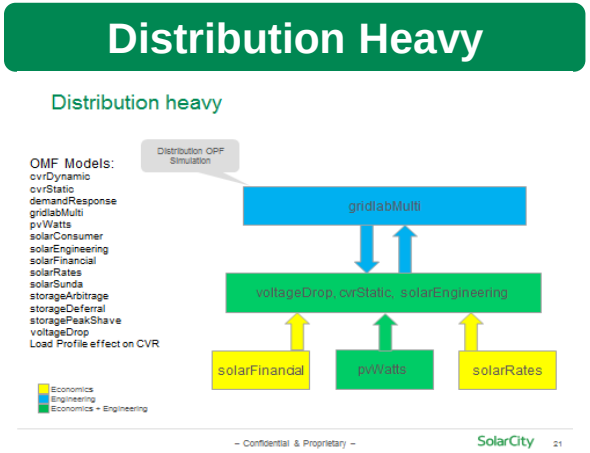
Partial Equilibrium



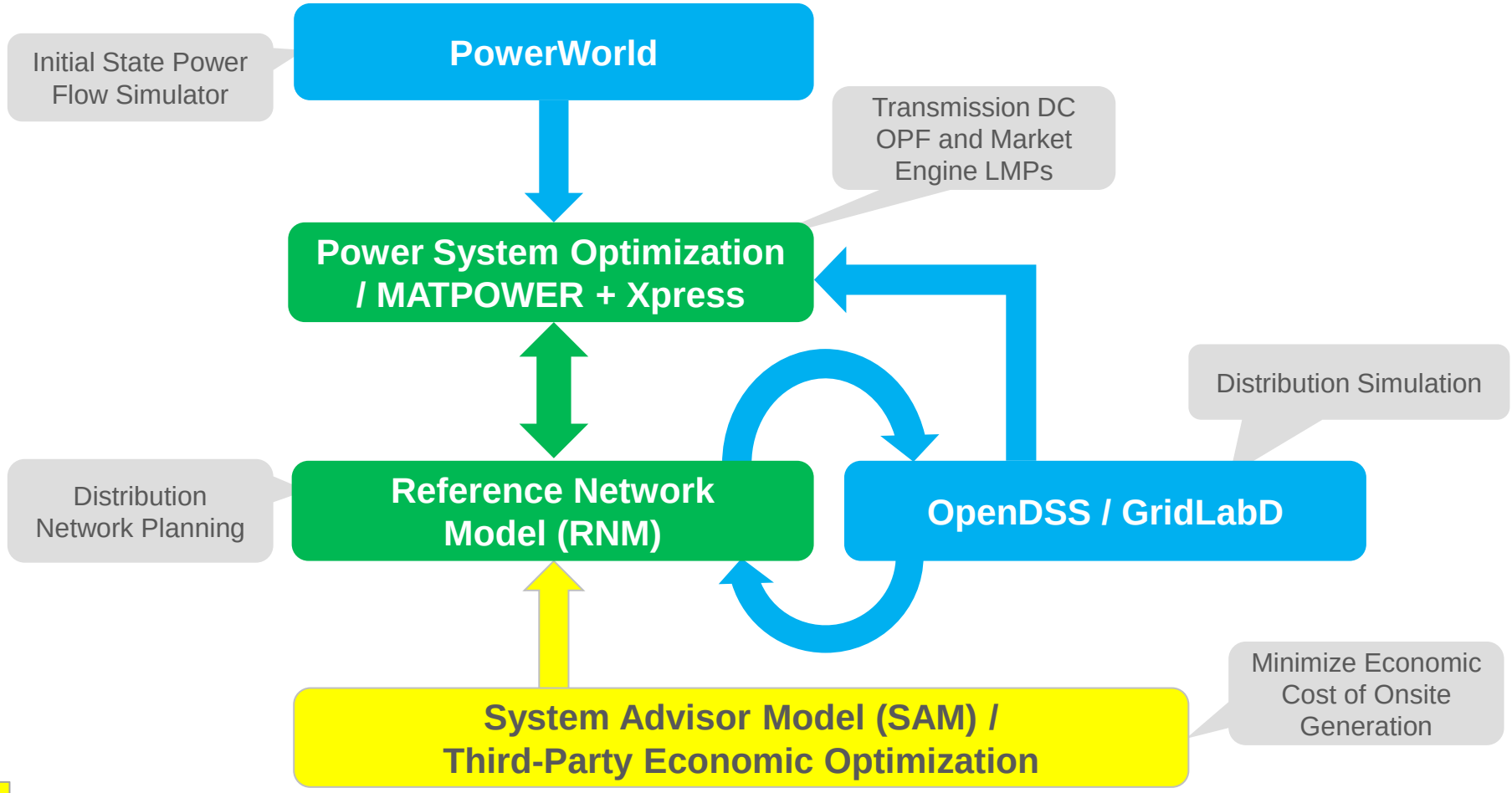
Portfolio Optimized



Distribution Heavy



Example: “Least-Cost Co-Optimized” Ecosystem



Pros and Cons of Sample Ecosystems

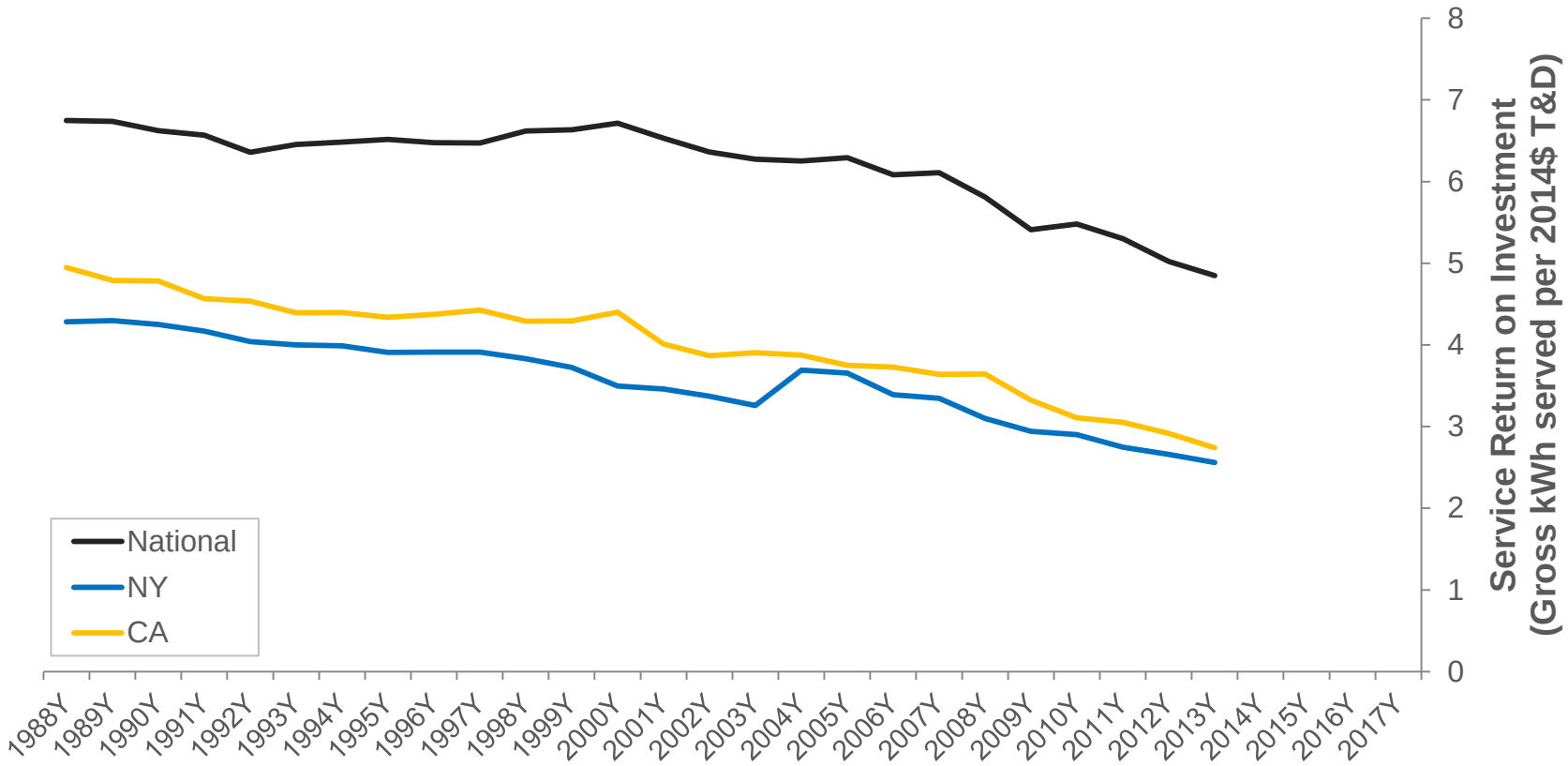
	Ecosystem	Models	Pros	Cons
1	**Least Cost Co-Optimized**	PSO, PLEXOS, CYME, SAM, PowerWorld, OpenDSS, RNM	High spot market/ transmission system resolution	Most computationally intensive, transmission informing distribution
2	**Transmission Heavy**	PLEXOS, GE-MAPS, DERCAM, Gridlab-D	Detailed transmission and distribution simulation	Lack of planning distribution system optimization
3	**Capacity Expansion**	ReEDS, ESM, Gridlab-D	Single model, long-term equilibrium	Abstracts away complexity, lacking detailed economic optimization at DER and distribution levels
4	**Partial Equilibrium**	ESM, RNM, PLEXOS, CYME	Long-term economic model with transportation included	Intensive inputs for data at distribution and DER levels
5	**Portfolio Optimized**	WADE, REM, HOMER	Ratio of centralized to decentralized resources	Lacks spot market resolution and transmission simulation
6	**Distribution Heavy**	gridlacMulti, voltageDrop, solarFinancial, solarRates	Comprehensive financial and distribution simulation model	Lacks spot market resolution and transmission simulation

Building an Model Ecosystem

Identifying Objective Functions

Evaluating Hypotheses

Potential objective function: How do we increase grid system utilization?



Source: Regulated Electric Companies FERC Form 1 Annual Filings
Period: 1988 – 2013; Accessed March 2015 via SNL
All numbers are estimated in real terms. $ are adjusted for inflation. Kwh of service are adjusted for EE and DG.

Other Potential Objective Functions

- Evaluate approaches to increase system utilization
- Evaluate approaches to integrate high levels of renewables
- Evaluate approaches to increase resiliency and security of supply
- Evaluate convergence of electric ecosystem with other industries (e.g. transportation, IT and communications, etc)

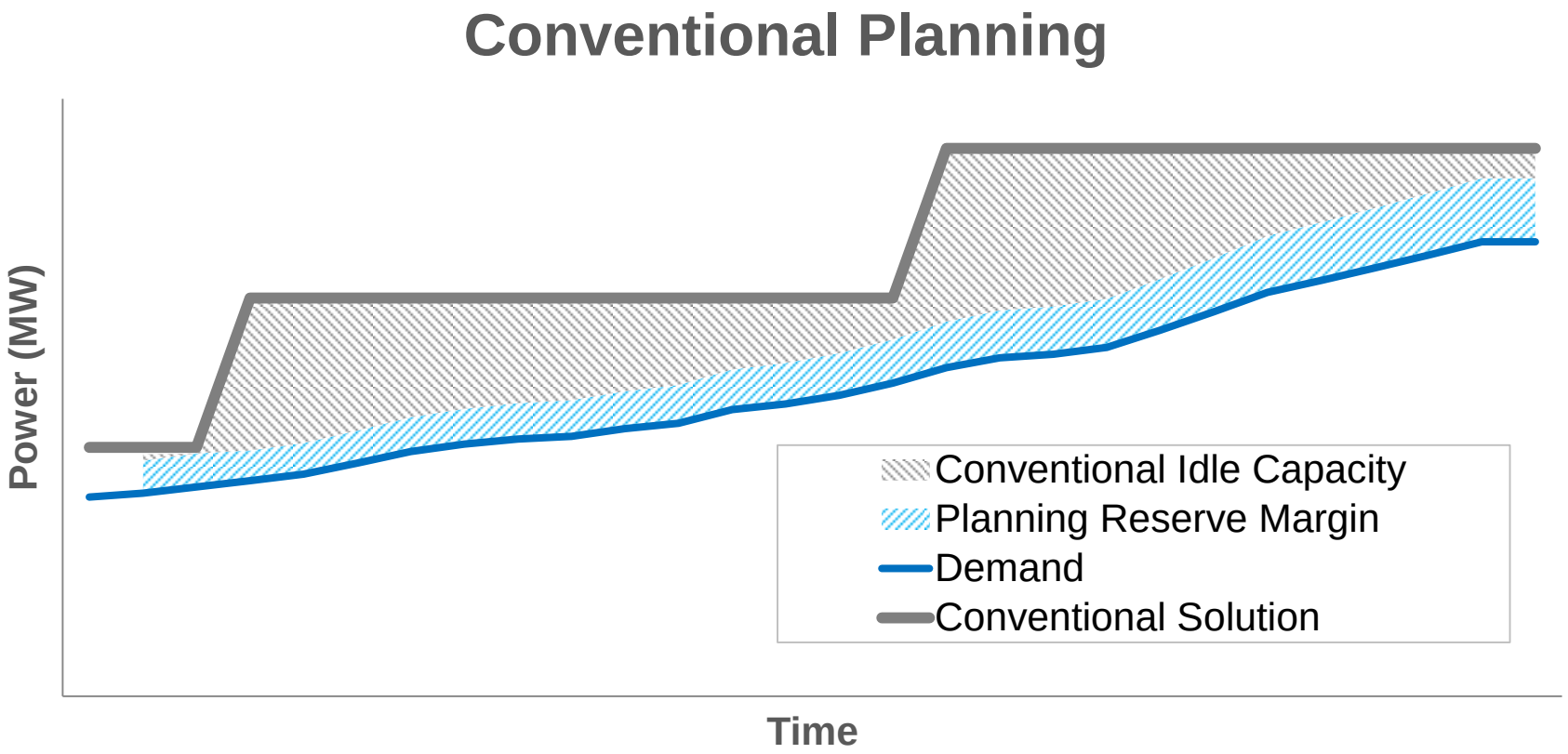
Building an Model Ecosystem

Identifying Objective Functions

Evaluating Hypotheses

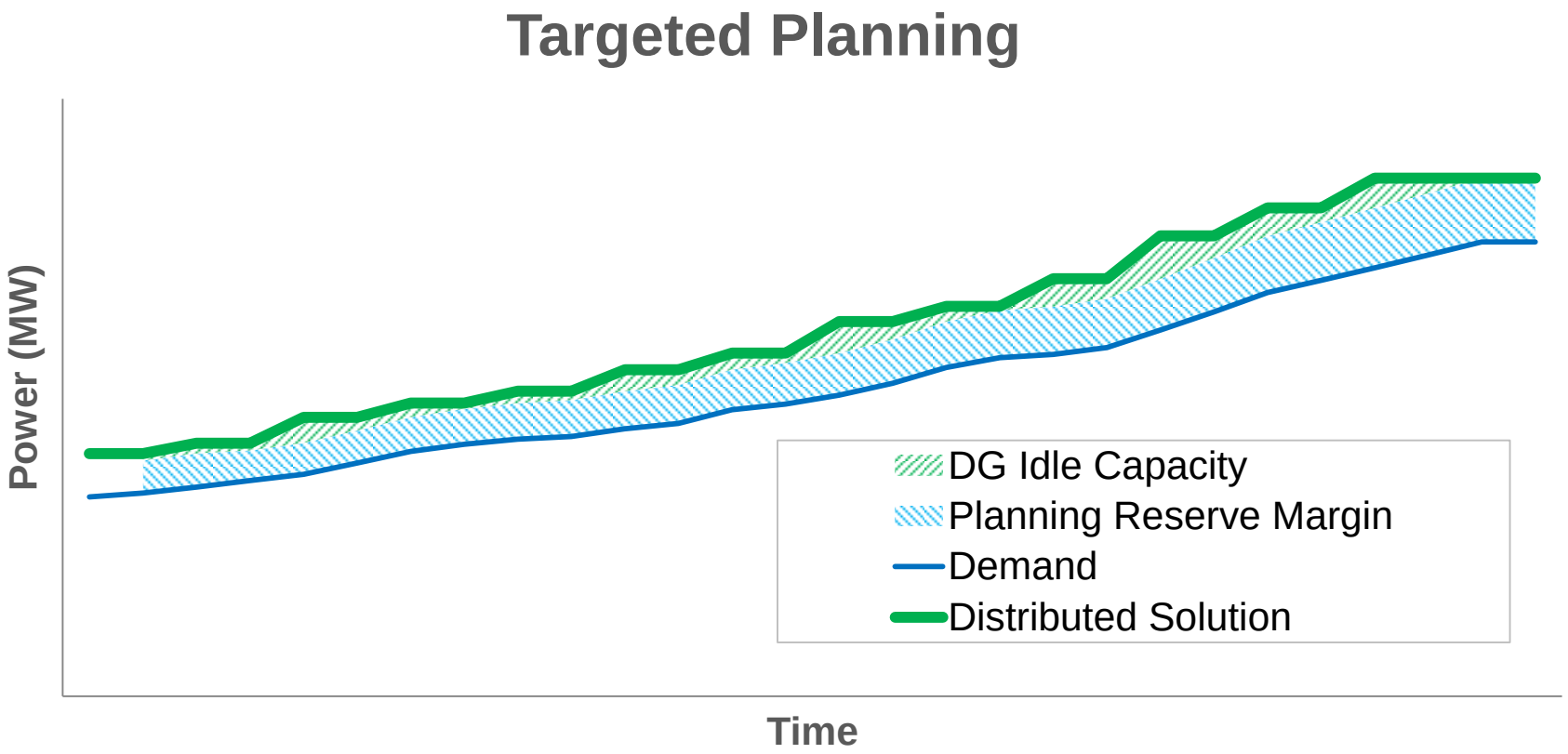
Hypothesis: Decentralized Could be Better

Conventional planning is bulky



Hypothesis: Decentralized Could be Better

Targeted, distributed deployments increase utilization



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Power forever.

Thank you!

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Grid Engineering Solutions
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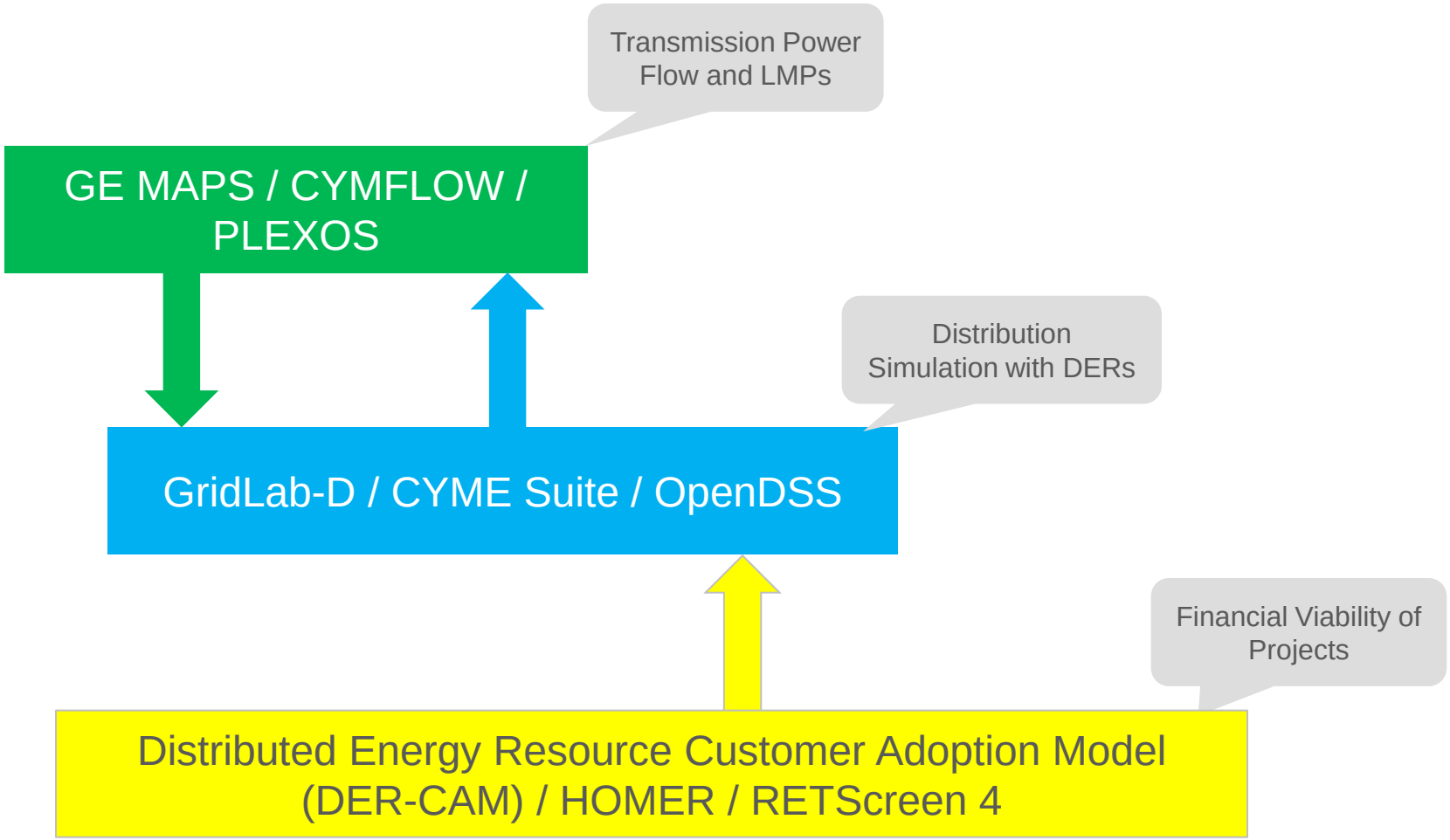
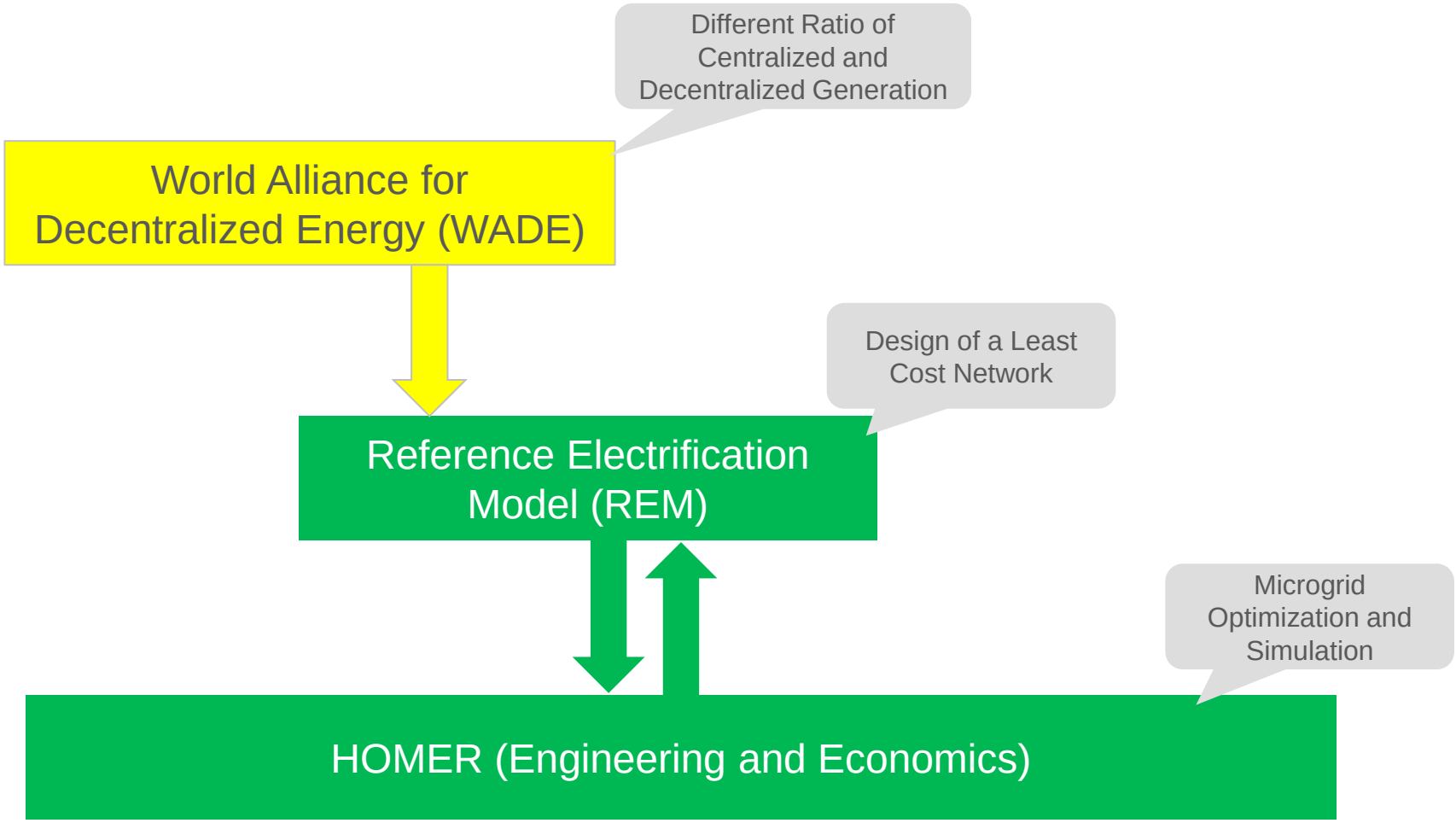
Transmission Heavy



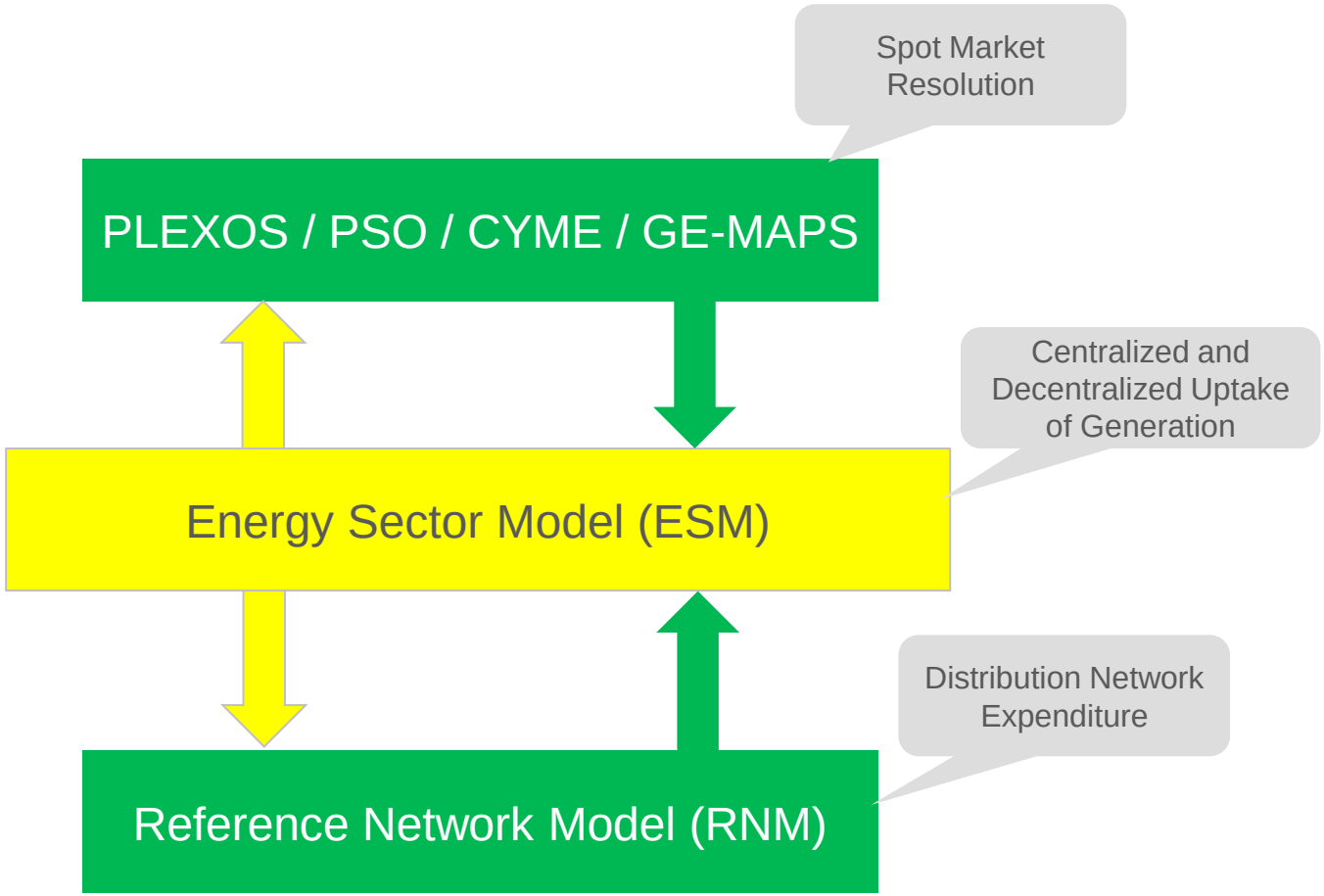
Economics
Engineering
Economics + Engineering

Portfolio Optimized



Economics
Engineering
Economics + Engineering

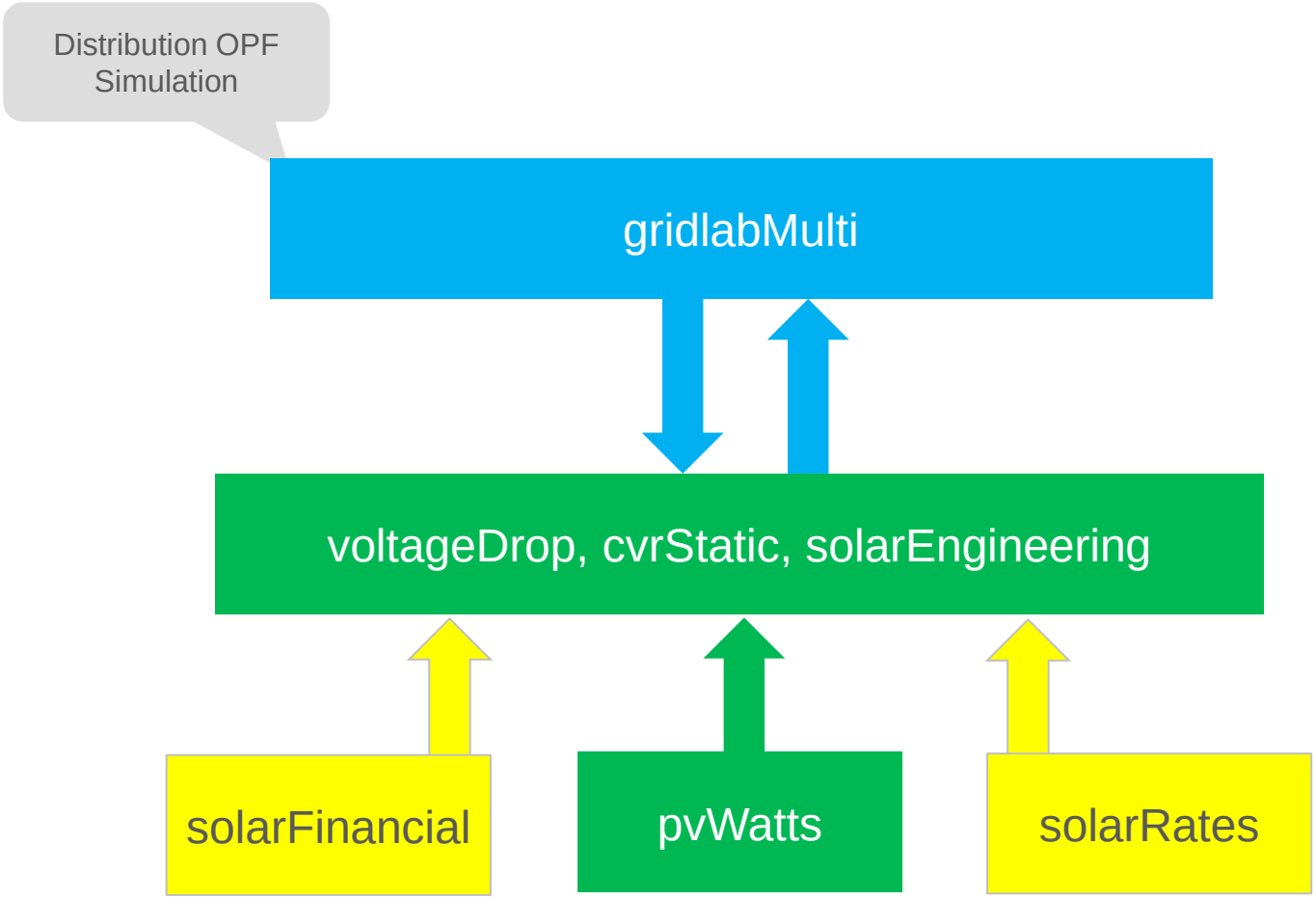
Partial Equilibrium



Economics
Engineering
Economics + Engineering

Distribution Heavy

OMF Models:
cvrDynamic
cvrStatic
demandResponse
gridlabMulti
pvWatts
solarConsumer
solarEngineering
solarFinancial
solarRates
solarSunda
storageArbitrage
storageDeferral
storagePeakShave
voltageDrop
Load Profile effect on CVR



Economics
Engineering
Economics + Engineering

New Capacity Expansion