

# Agent-Based Platforms for Electric Power Systems: Teaching, Training, and Research

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- ❑ What is **Agent-Based Modeling (ABM)** ?
- ❑ Three Illustrative ABM Platforms (Open Source, Java/Python/GLD)
  - **AMES V5.0 Platform**: An ABM platform for RTO/ISO-managed wholesale power markets
  - **ERCOT Test System**: Specialization of AMES V5.0 to Electric Reliability Council of Texas (ERCOT)
  - **ITD TES Platform**: An ABM platform for the study of Transactive Energy System (TES) designs implemented within Integrated Transmission and Distribution (ITD) systems
- ❑ Bridging the “Valley of Death” for Electric Power System Design
- ❑ Conclusion: Why ABM Platforms for Electric Power Systems?
- ❑ References & GitHub Code/Data Repositories

# What is Agent-Based Modeling (ABM) ? [1]

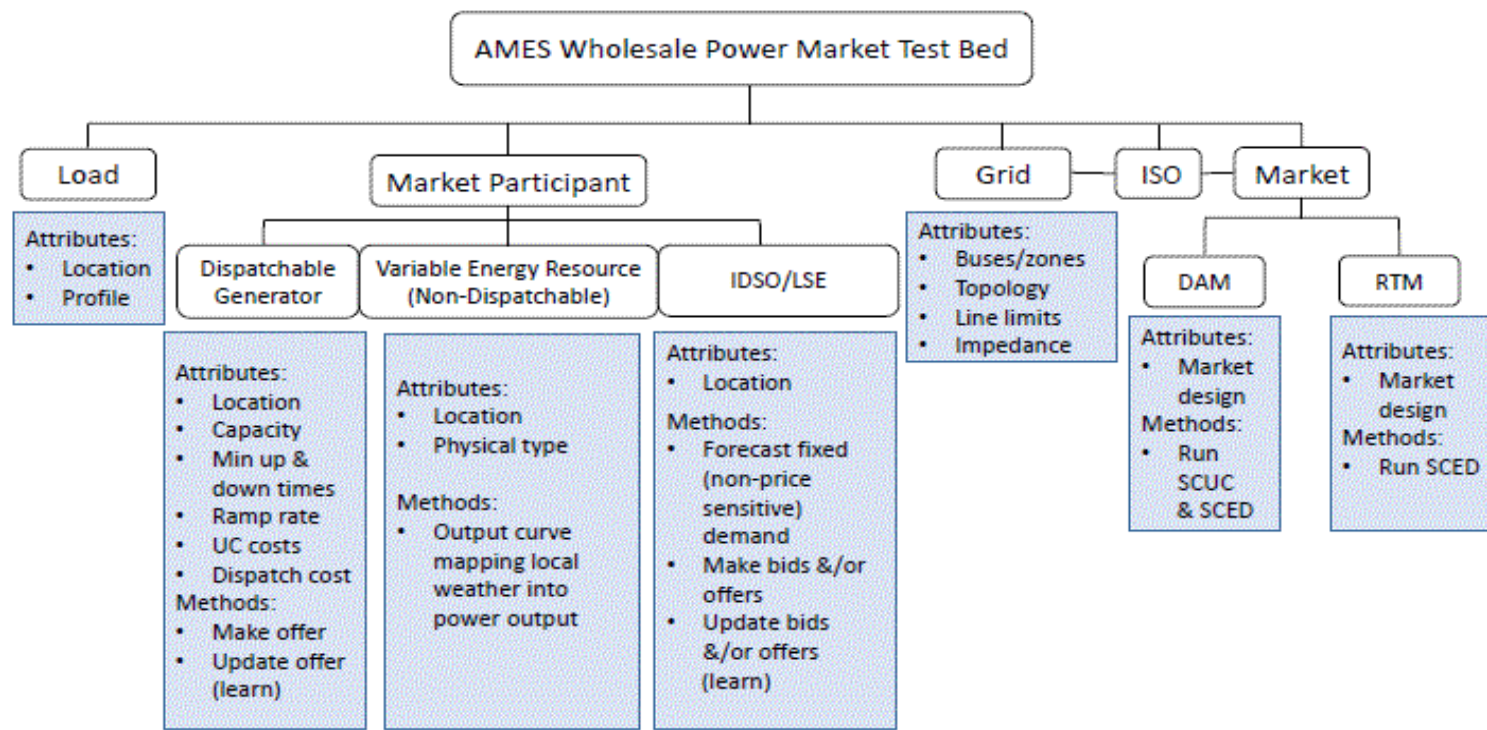
- Computational modeling of processes as open-ended dynamic systems of interacting agents
- An **agent** is a software entity within a computationally constructed world capable of acting on the basis of its own **state**, i.e., its own internal data, attributes, and methods.

## □ ABM Goals for the Modeling of Real-World Systems

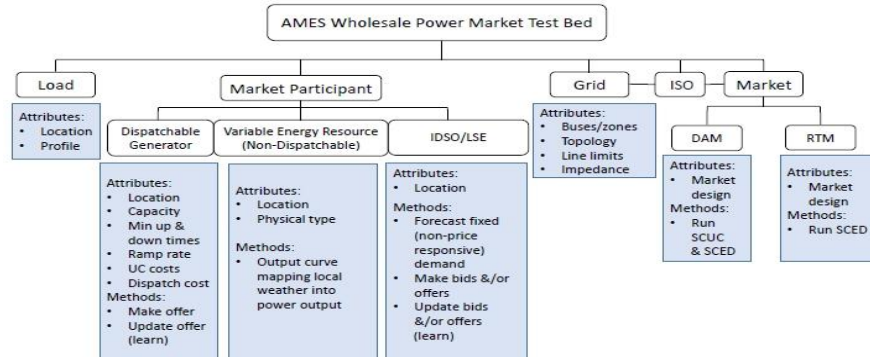
- Permit agents to be as free to act within their virtual ABM world as their empirical counterparts within the real world;
- Permit events to be fully driven by agent interactions, starting from user-set initial conditions (**culture-dish modeling**);
- Permit comprehensive empirical validation (**input validation; process validation; descriptive output validation; & predictive output validation**).

# AMES = Agent-Based Modeling of Electricity Systems [2]

## □ AMES V5.0 Platform (Java/Python): GitHub Repository [3]



## AMES V5.0 agents specialized to ERCOT



## AMES V5.0 constraints specialized to ERCOT

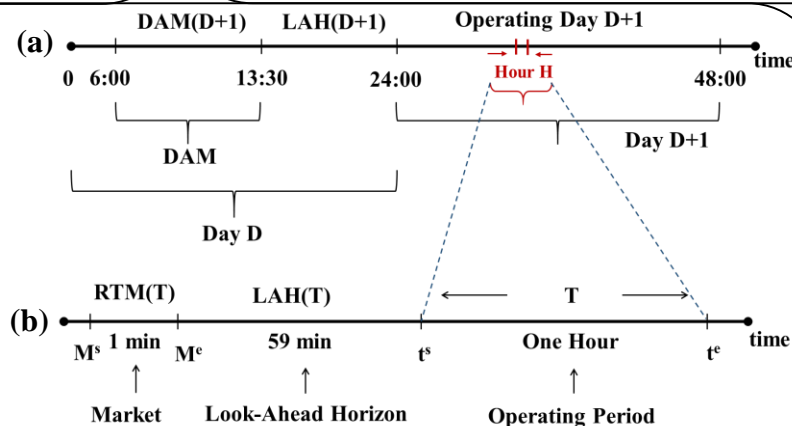
## System constraints for SCUC/SCED in DAM &amp; RTM

- Transmission line power flow limits
- Power balance constraints
- Generator capacity constraints
- Dispatchable generator ramp constraints for start-up, normal, and shutdown operating conditions
- Dispatchable generator min up/down-time constraints
- Dispatchable generator hot-start constraints
- System-wide reserve requirement constraints
- Zonal reserve requirement constraints

## AMES V5.0 market timing specialized to ERCOT

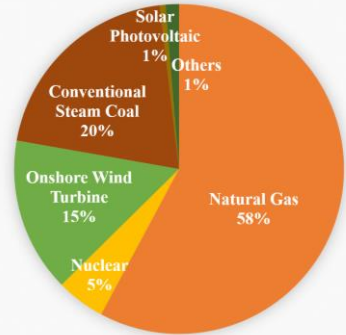
(a) ERCOT Test System timing configuration for a DAM conducted on day D to facilitate net load balancing during the following day D+1

(b) ERCOT Test System *default* timing configuration for an RTM whose purpose is to facilitate net load balancing for a near-term operating hour T

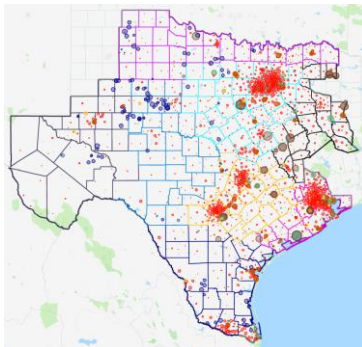


## Data

Fuel Types of Generators - ERCOT



ERCOT generation proportions by major fuel types (2016)



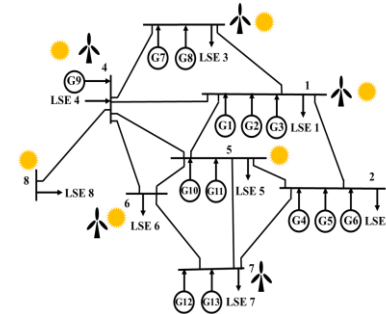
Initial load and generation nodes

## Grid Construction\*

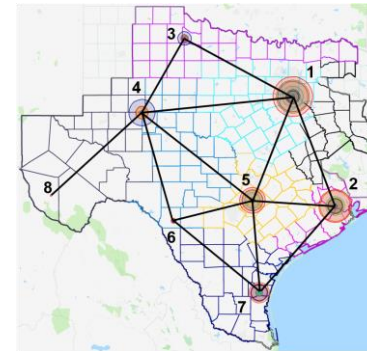
1. Specify the desired number of buses (NB)
2. Obtain ERCOT generation and load data
3. Use the ERCOT data to specify NN initial pure-load and pure-generation nodes, where  $NN \geq NB$
4. Use a hierarchical clustering algorithm to cluster these NN nodes into NB buses (node clusters).
5. Use a Delaunay Triangulation method plus ERCOT transmission line data to construct transmission lines connecting pairs of the NB buses formed in Step 4.
6. Prune the resulting grid to achieve greater empirical realism for the application at hand, e.g., remove lines that traverse areas outside the energy region of interest.

\* Synthetic grid construction method is adapted from:  
Overbye et al.: <https://electricgrids.engr.tamu.edu>

## Grid Illustration

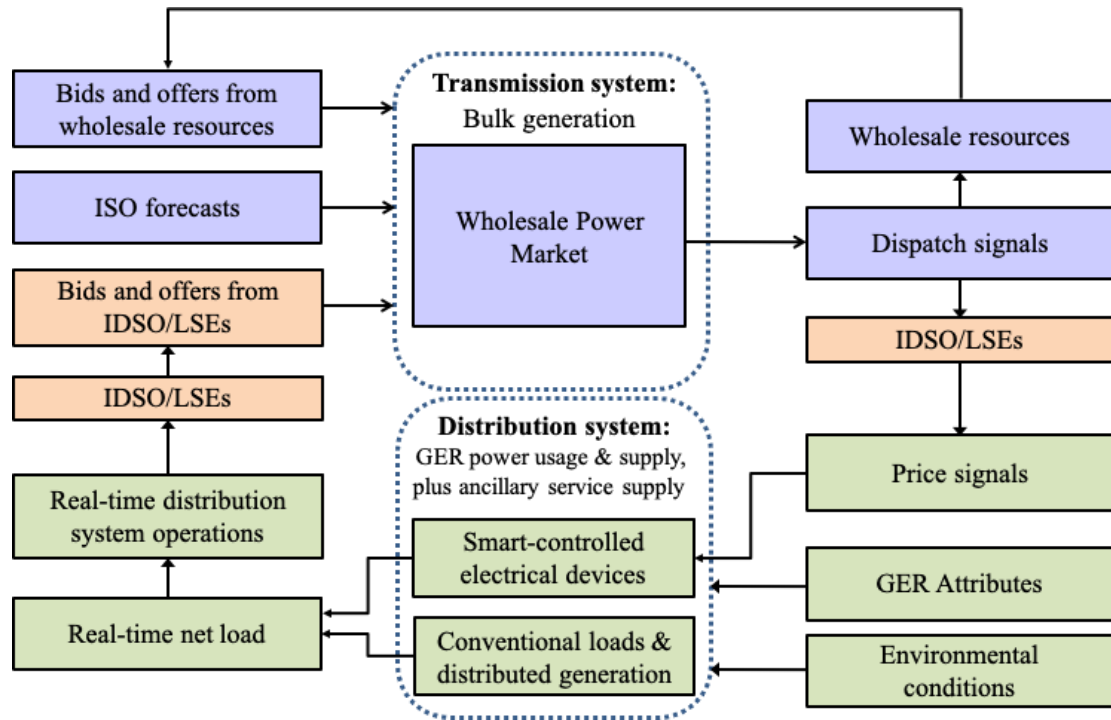


Eight-bus ERCOT test grid



Eight-bus ERCOT test grid  
superimposed on ERCOT region

## ITD TES Platform (Java/Python/GLD): GitHub Repository [6]



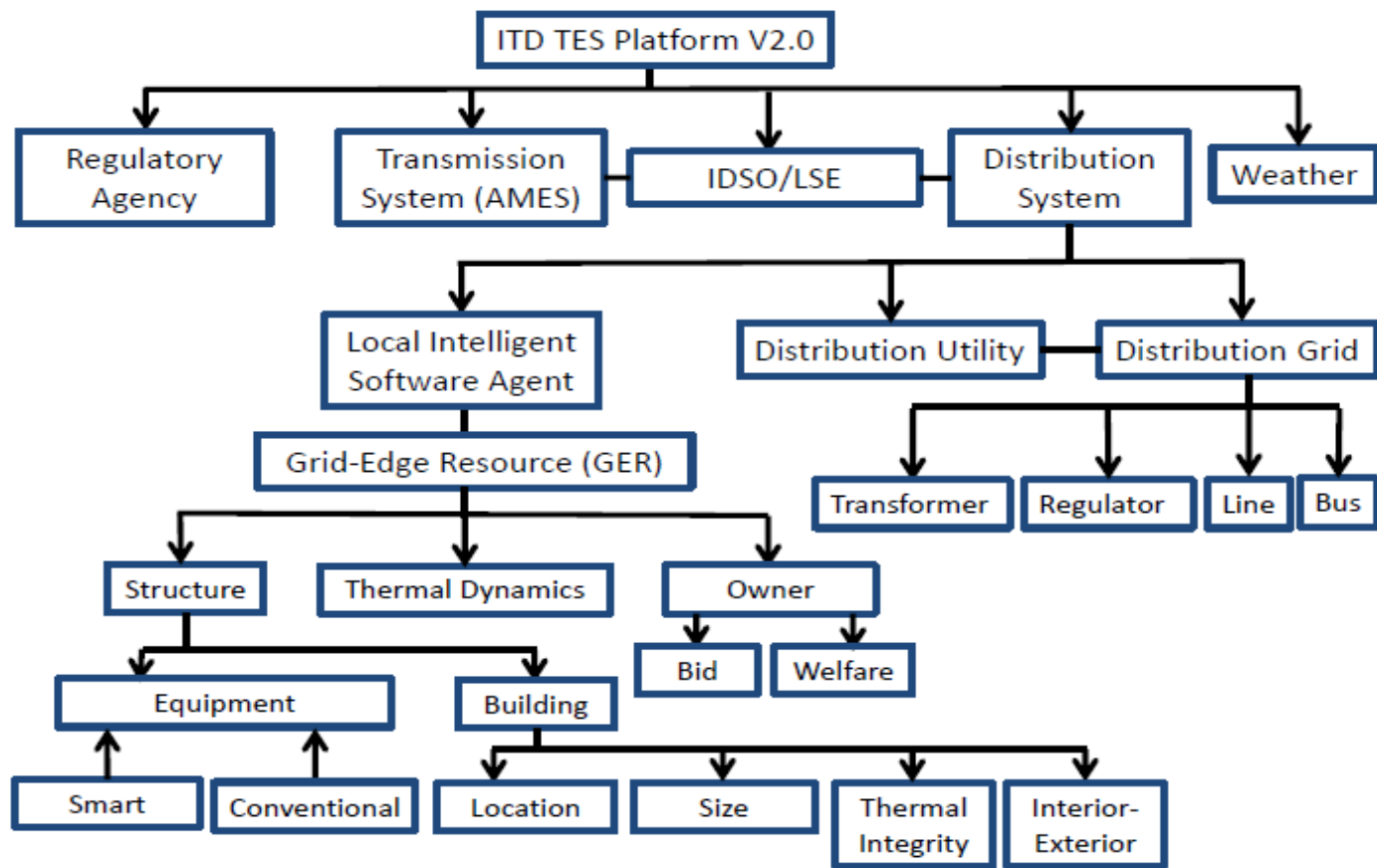
The ITD TES Platform implements an **Integrated Transmission and Distribution (ITD)** system.

**Independent Distribution System Operators (IDSOs)** and **Load-Serving Entities (LSEs)** function as linkage agents at T-D interfaces.

**GER = Grid-Edge Resource**  
= Power resource with a direct connection to a distribution grid

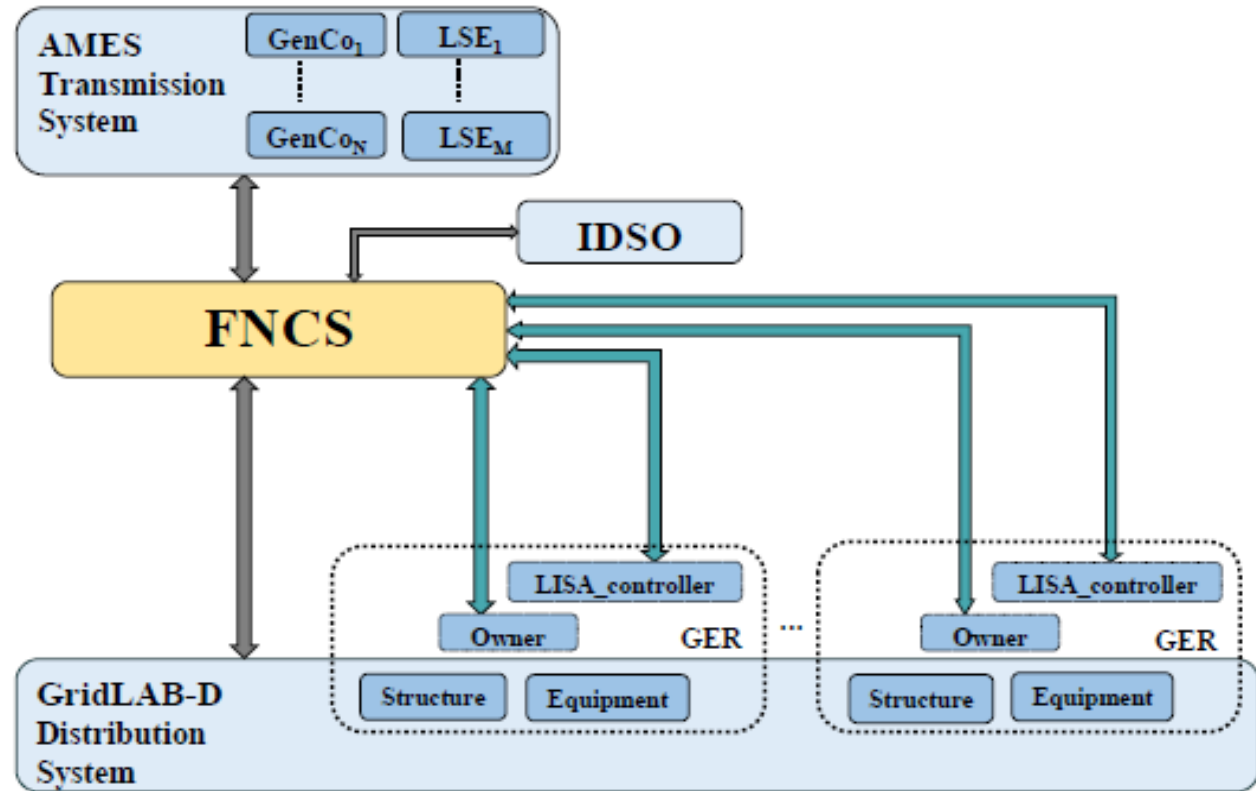


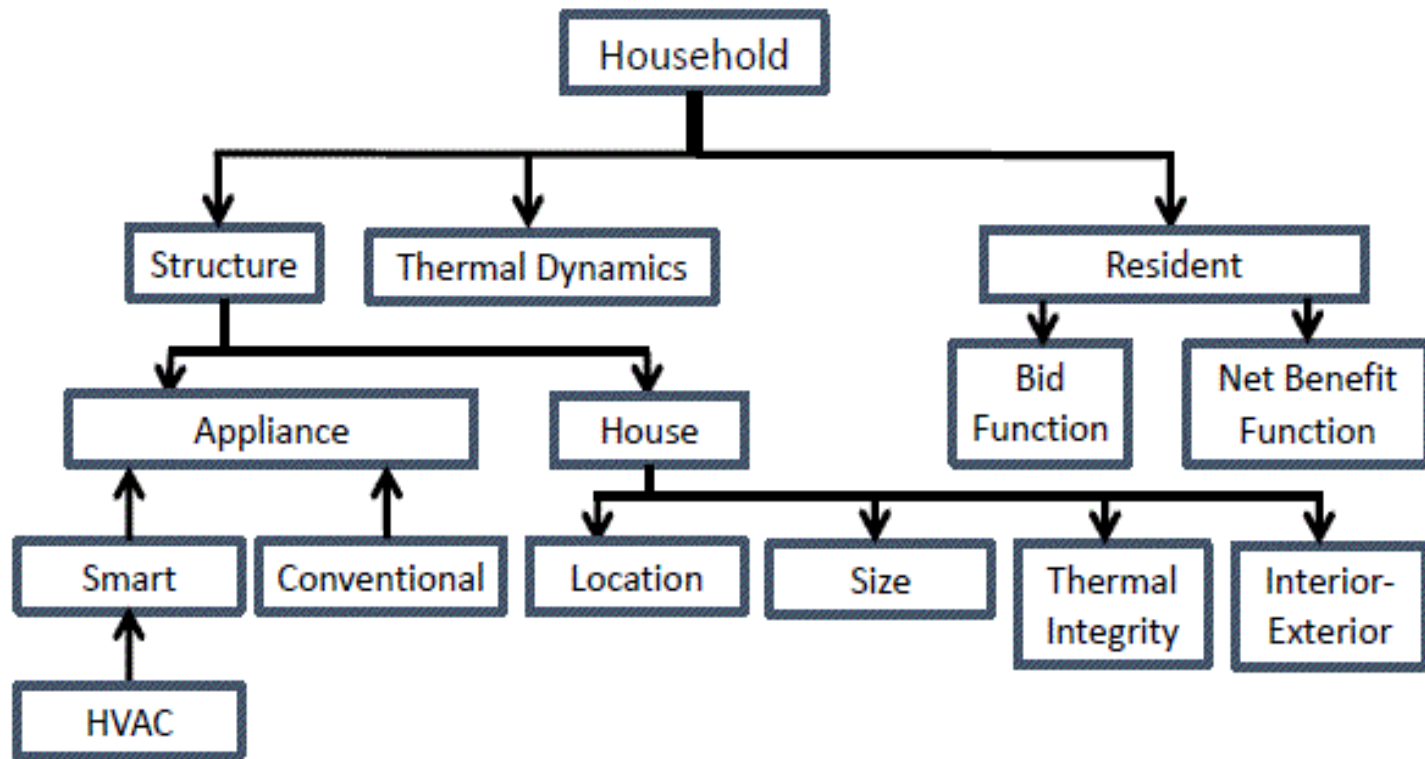
# ITD TES Platform: Hierarchy of Agents [6]





**FNCS** = Framework for  
Network Co-Simulation  
(developed at PNNL)





- Design implementation should be based on strong empirical evidence.
- Ensuring a design is ready for implementation typically requires multiple modeling efforts at different scales, and with different degrees of empirical validation.
- Moving too soon to design implementation entails major risk of unintended consequences.

# Standardized Design Readiness Levels (DRLs) [8]

**DRL-1:** Conceptual design idea

**DRL-2:** Analytic formulation

**DRL-3:** Low-fidelity model

**DRL-4:** Moderate-fidelity small-scale model

**DRL-5:** High-fidelity small-scale model

**DRL-6:** Prototype small-scale model

**DRL-7:** Prototype large-scale model

**DRL-8:** Field study

**DRL-9:** Real-world implementation

Basic research  
carried out at  
universities...

**“Valley of Death”**

Industry,  
government,  
regulatory  
agencies

- Infrequency of design studies in the “Valley of Death” (DRLs 4-6) hinders design development

***Concept*** ➡ ***Implementation***

- ABM is well suited for bridging this valley.
  - ABM computational platforms permit design development and performance testing at DRLs 4-6.

- ABM ability to bridge the “Valley of Death” facilitates the use of **Iterative Participatory Modeling (IPM)**
- **IPM for Complex Design Problems:** Modelers and stakeholders repeatedly cycle through the nine design readiness levels (DRLs 1-9) in an open-ended learning process.
- **Goal of IPM for Complex Design Problems:** Ongoing learning rather than attempted delivery of a “definitive” solution

## Conclusion: Why ABM Platforms for Electric Power Systems? [8]

- **Permit modeling of economic & physical operations** with empirical fidelity ranging from low to high, depending on purpose.
- Permit operations to be **simulated over successive days with run-time visualization** for more comprehensive performance evaluation under normal conditions and in response to **High-Impact Low-Frequency (HILF)** events.
- Permit proposed novel design features to be studied **at increasing scales with increasing degrees of empirical fidelity**, thus helping to bridge the “Valley of Death” between conceptual design development and practical design application
- Permit **inclusion of human/social behaviors (e.g., learning)** in two ways: computational agents that express human/social behaviors; and actual humans and social groupings directing the run-time behavior of certain types of computational agents.
- Permit **inclusion of data-driven agents (e.g., weather, physical devices, ...)** whose actions are guided or driven by external data streams.



- [1] L. Tesfatsion (2021), Agent-Based Computational Economics: Homepage  
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- [2] L. Tesfatsion (2021), Agent-based Modeling of Electricity Systems (**AMES**) Homepage  
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- [3] S. Battula, L. Tesfatsion (2020), AMES V5.0 (OSS, Java/Python), *GitHub Repository*  
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- [4] S. Battula, L. Tesfatsion, T.E. McDermott (2020), ERCOT Test System (OSS, Java/Python), *GitHub Repository*  
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- [5] L. Tesfatsion (2021), Integrated Transmission and Distribution (**ITD**) Project Homepage,  
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- [6] S. Battula, L. Tesfatsion (2021), ITD TES Platform (OSS, Java/Python/GLD), *GitHub Repository*  
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- [7] S. Battula, L. Tesfatsion (2020), Household Module (OSS, Python/GLD), *GitHub Repository*  
<https://github.com/ITDProject/HouseholdFormulationRepository>
- [8] L. Tesfatsion (2018), “Electric Power Markets in Transition: Agent-Based Modeling Tools for Transactive Energy Support,”  
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