Co-Simulation as a Technique for Large-Scale and Complex Multi-Energy Modeling

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The Need for Co-Simulation – One Simulator is Not Enough

• Analysis requires the dynamic, two-way interaction between two or more simulation tools and their models
  ▪ Recorded datasets as inputs are not good enough and dynamic interaction is required to meet analysis goals

• Analysis requires development of a system model that transcends traditional simulation tool boundaries
  ▪ Buildings + Power Grid
  ▪ Power Grid + Natural Gas

• Analysis requires a large-scale model not practically captured within a single simulation tool instance.
  ▪ Texas power grid during winter cold snap
Co-simulation is a method for unifying multiple models in a coordinated fashion. Models may or may not:

- Cover similar domains
- Have a similar concept of time
- Be written in the same language
- Be run by simulators on the same computer or operating system, or be in the same network

Co-simulation allows models that have interactions with each other to express those interactions and influence each other’s behavior.
Co-Simulation Platform Key Functions

- Simulator Time Synchronization
- Simulator Data Exchange
  - Timely distribution of appropriate data
  - Data type management
  - Structured data support (e.g. JSONs)
  - Data privacy
Co-Simulation Example

Precipitation, ambient temperature

Humidity, sunlight reflectivity
HELICS co-simulation platform is composed of:

- Libraries and language bindings to use for integrating a simulator
  - C
  - C++
  - Python
  - MATLAB
  - Julia
  - ...

- Executables for running co-simulations and assisting in co-simulation development and testing
  - Data exchange and synchronization services
Co-Simulation Interaction Types

• Physics simulation: value exchanges

![Diagram showing interactions between GridLAB-D and EnergyPlus](image-url)
Co-Simulation Interaction Types

- Communication signals: message exchanges
Co-Simulation with Hardware

- Software-only co-simulation

- Hardware-in-the-loop (HIL) co-simulation
Co-Simulation for Multi-Energy Modeling

• Power System and Natural Gas

Power system physics and operations

Natural gas system physics and operations

Power plant gas pressure

Gas plant electrical power

Interstate pipelines

Intrastate pipelines
Large-Scale Power System Example
Large-Scale and Complex Energy System Example
Popular HELICS Alternatives

- **Functional Mock-up Interface (FMI)**
  - Started out as a means of exchanging dynamic models for automotive components while protecting IP
  - Individual models are called “FMUs”
  - Models must be linked by a master algorithm
  - Most popular implementation is in/with Modelica
  - HELICS has an FMI interface and acts as the master algorithm

- **mosaik**
  - Generic co-simulation framework that started out with a power system focus, just like HELICS.
  - Python based
    - HELICS is C++-based with bindings for a variety of languages including Python
  - Communication over network sockets
    - HELICS also uses network sockets but implements a variety of messaging technologies to fit particular computing environments