Dynamic Energy Transport and Integration Laboratory

DETAIL will answer technical energy integration questions

INL's test lab will consist of heat and electricity producers, thermal and electrical storage, and multiple heat and electricity customers coupled via a thermal and electrical network.

Future energy systems will need to be highly flexible and responsive. Integrated energy systems will couple nuclear, renewable and fossil energy sources to produce electrical and nonelectrical energy products such as heat to make hydrogen or ammonia. The benefits of such systems include a more secure, resilient and sustainable energy infrastructure, resource efficiency, national economic stability, and international competitiveness.

An integrated energy system coordinates renewable energy sources — mostly variable, low-cost wind and solar — with nuclear or fossil fuel plants that dynamically balance net generation demand. Such a system can flexibly divert thermal energy to an industrial process that uses heat or steam. The integrated system concept expands the market for nuclear energy in a manner that optimizes capital investments and increases the efficiency of energy use.

NATIONAL LABORATORY ROLE

The U.S. Department of Energy's Idaho National Laboratory is uniting distinctive capabilities to overcome the technical and economic barriers that limit wider use of nuclear and renewable energy in integrated energy systems.

Specifically, INL's Dynamic Energy Transport and Integration Laboratory (DETAIL) will consist of 1) multiple heat and electricity producers, 2) thermal and electrical storage, and 3) multiple heat and electricity customers coupled via a thermal and electrical network. Each component will be semiautonomous and able to operate independently or in a response mode to thermal and/or electrical grid needs.

The research and demonstration objective for the DETAIL facility is to demonstrate simultaneous, coordinated, controlled and efficient multidirectional distribution of electricity and heat for power generation, storage and industrial end uses.

DETAIL will provide capabilities accessible to industry, other national laboratories and universities to elevate the Technology Readiness Level (TRL)

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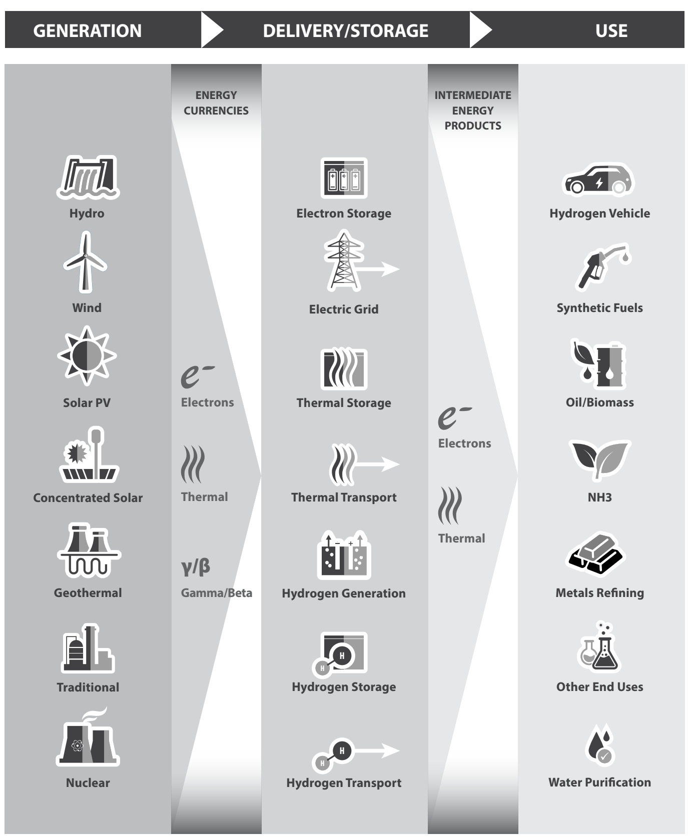
of system components, subsystems and overall integrated systems configurations to scales ranging from experiment/ bench scale to lab scale, and eventually to pilot scale (TRL 3-6). By providing this capability, technologies and their associated modeling and simulation results can be validated prior to field demonstration and implementation.

Workshop participation by public and private stakeholders ensure the research aligns with clean energy targets, strategic plans and technology development needs. The needs of energy producers, electrical utilities and industry vary by region, electricity market structure and grid regulation needs.

THERMAL COMPONENT

The integrated energy system concept involves two energy distribution networks: electric and thermal. Although electric networks (grids) are well-understood, thermal networks need to dramatically improve transport, storage and conversion to enable cost-effective, scalable systems.

Because of the transportation lags associated with a thermal network, control solutions are complex. They often rely on predictive controllers anticipating multiple variables in an attempt to reduce lags. Effective control is further complicated by heat losses and variation of supply temperatures and pressures, caused by shifting heat from power generation to other industrial processes as needed to meet demand.



Integrated energy systems could make it possible for power plants to contribute excess energy to users beyond the electric grid.

The integrated system's thermal energy component will support development of heat delivery for both power generation and a tenant heat user. INL will design and install a versatile, non-nuclear, electrically heated thermal energy delivery loop. The Thermal Energy Distribution System (TEDS) will transport heat to lab-scale thermal energy customers or a thermocline thermal energy storage system. It will use a controllable heater (200 kW) and the heat transfer fluid Therminol 66, which can accommodate operating temperatures up to 340 C. TEDS can later be expanded to represent advanced nuclear reactors and concentrating solar systems that deliver higher temperature heat.

The Microreactor Agile Nonnuclear Experiment Testbed (MAGNET) will also be installed for eventual integration with DETAIL. MAGNET will use electrical heating elements to emulate the heat from nuclear fuel, and it will provide a facility for researchers and technology developers to test new microreactor concepts in a relevant environment to advance technical maturity.

This portion of the test bed is funded by DOE's Office of Nuclear Energy.

ELECTRIC NETWORK

Thermal and electrical grid needs will be anticipated via a digital real-time simulator (DRTS)and thermal supervisory control system. These components serve as electrical and thermal grid "operators," respectively.

One operational mode would give the DRTS master control of all supply and demand allocations. Decisions would be driven by defined optimization criteria to determine generator and customer responses. Example optimization criteria may include maintaining maximum grid stability (both internal grid as well as external grid events), minimizing electricity cost, or studying intentional disruptions such as a cyberattack.

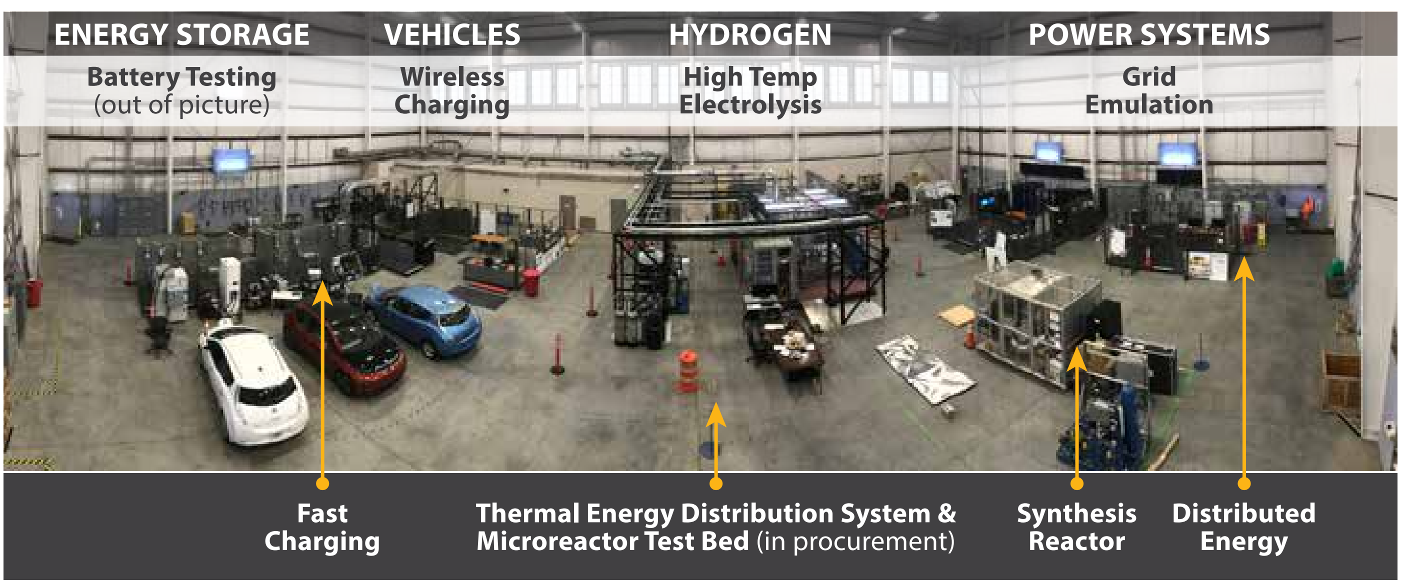
The more advanced and perhaps most relevant operating mode would have the DRTS monitor electrical grid conditions and requirements, then issue requests to other components within DETAIL. Each component will have its own criteria (e.g., profit maximization, wear and tear minimization, maintenance scheduling) and will function independently based upon the instantaneous value of thermal and electrical energy.

Thermal and electrical grid needs will be anticipated via a digital real-time simulator (DRTS).

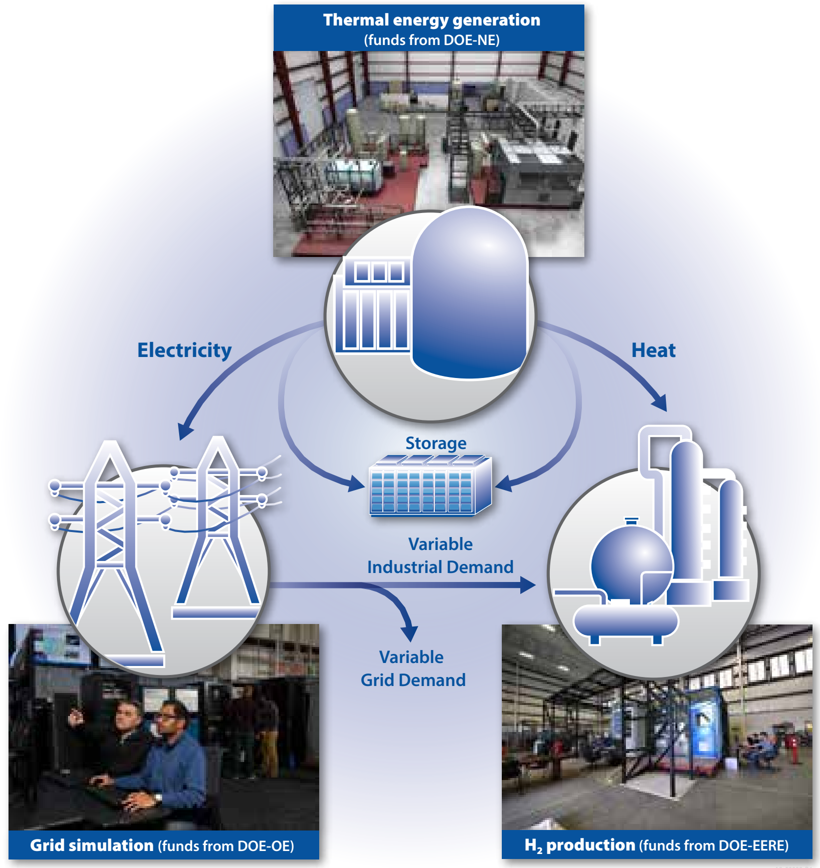
In this latter case, the central administration is minimized, and each component can enter and exit the energy grids voluntarily. The DRTS will essentially forecast demand, compare to current conditions and generate incentives (e.g., forecast market price) to participants. The balance of supply and demand would be achieved through various optimization strategies, rules and economic incentives.

Participants can then "bid" to participate, and the DRTS will determine which participants "win." Today, this process is split in a day-ahead market based upon predictions, and an "imbalance" market based upon real-time deviations.

This portion of the test bed is funded partly by offices of Electricity (OE) and Energy Efficiency & Renewable Energy (EERE).



The INL Energy Systems Laboratory connects physical demonstration capabilities and also virtually connects to other critical validation capabilities across INL and with partners.



The Dynamic Energy Transport and Integration Laboratory (DETAIL) is being constructed at INL's Energy Systems Laboratory.

INDUSTRIAL USER ELEMENT

An industrial customer for electricity and thermal energy will initially be represented by a high-temperature electrolysis (HTE) test station producing hydrogen. This can be adapted to innovative thermo-electrocatalytic processes that could revolutionize many of the largest industry manufacturing processes.

Hydrogen is an essential input to many large domestic industries including oil refining, ammonia production and the growing market for fuel cell electric vehicles. In addition, electrolyzers have been demonstrated to be capable of dynamic operation with subsecond responses to fluctuations in power.

The test station in DETAIL will reduce technical risks and allow users to validate that an HTE can be operated intermittently. It will provide the ability to test issues related to thermal fatigue, component development and controls interfaces. And it will help validate hydrogen generation technologies that have industry support while also lowering the cost of unit operation.

This portion of the test bed is funded by DOE's Fuel Cell Technologies Office (within EERE).

A PROMISING FUTURE

Investments from multiple DOE offices are supporting design and construction of DETAIL. Each office has an interest in demonstrating coordinated use of baseload and renewable energy systems to help overcome diverse technical barriers.

DETAIL will make it possible to understand and solve technical challenges surrounding cogeneration of electricity and heat from multiple sources so it can be distributed and sold to multiple consumers. Successful integrated energy systems will more closely couple the electrical grid with the manufacturing industry.

In this manner, nuclear and renewable energy may have far-reaching impact on reducing emissions across all aspects of the energy sector while using fossil resources as feedstock for various industrial applications. Effective coordination of clean energy generators could enhance U.S. competitiveness in manufacturing, with investments based on long-term reliable and affordable energy.

FOR MORE INFORMATION

Technical contact

Richard Boardman

208-526-6083

richard.boardman@inl.gov

Shannon Bragg-Sitton

208-526-2376

shannon.bragg-sitton@inl.gov

General contact

Abby Todd

Communications Liaison

208-526-6166

abby.toddbloxham@inl.gov

www.inl.gov

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