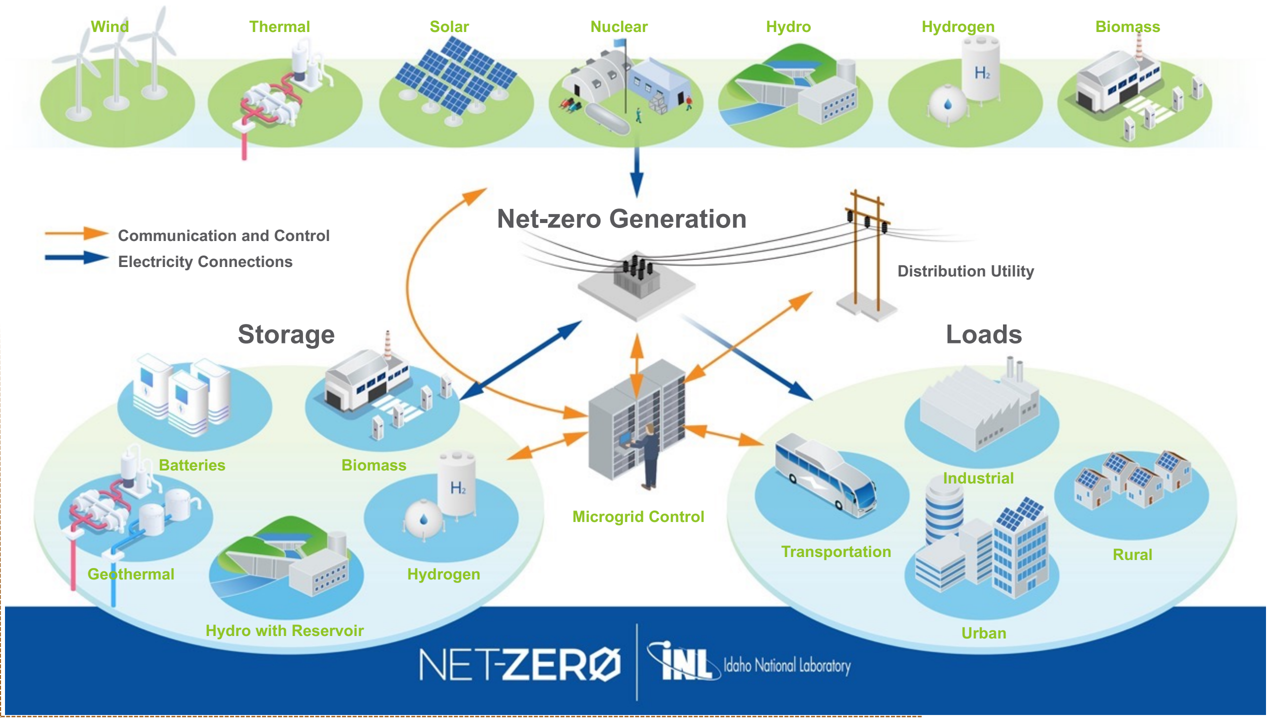
Net-zero Microgrid Program

Objectives & Outcomes

Establish cross-cutting research to accelerate the removal of carbon-emitting generation from microgrids, while enhancing their functionality for resilience, the electrification of infrastructure, and support of distribution systems and the bulk electric grid.
Develop the NZM planning and design planform
Include Nuclear and Hydroelectric as dispatchable resources
"Standardize" microgrid applications specific to diverse communities using a balanced mix of fuels and load profiles



Technical Scope

Develop program (Roadmap, coordination, project definition)
Cooperation with DOE-NE/EERE and DOD to achieve common objectives

Include well defined modules for small nuclear reactors, hydroelectric, and hydrogen in the NZM Platform according to their unique operating characteristics

Produce studies microgrid applications using the full capability of the comprehensive NZM tools, e.g., DC Fast-charging stations, non-powered dams, multi-tier microgrids for disadvantaged community la Cooperative de la Montaña)

Funding Summary ($500K FY22)

FY21 total	FY22, authorized	FY23, requested
$100K (preliminary study)	$400K	TBD

July 26, 2022

Timothy McJunkin

Net-zero Microgrid Program

Office of Electricity Microgrid Program

Microgrid Program Review Meeting

The NZM Program was established to produce the cross-cutting research needed to accelerate removal of carbon-emitting generation from microgrids.

Idaho National Laboratory

Microgrids improve local resilience

…but typically, microgrids depend on fossil fuels for generation

In fact: The portion of carbon-based energy used in microgrids generation is higher than the macro grid (82% compared to 60%)

The Net-Zero Microgrid Program engages in **cross-cutting research** to accelerate the removal of carbon-emitting generation from microgrids, while enhancing their functionality for **resilience**, the electrification of infrastructure, and **support of distribution systems** and the bulk electric grid.

MICROGRID GENERATION – Today

Estimated annual energy microgrid generation (MWh) by fuel type

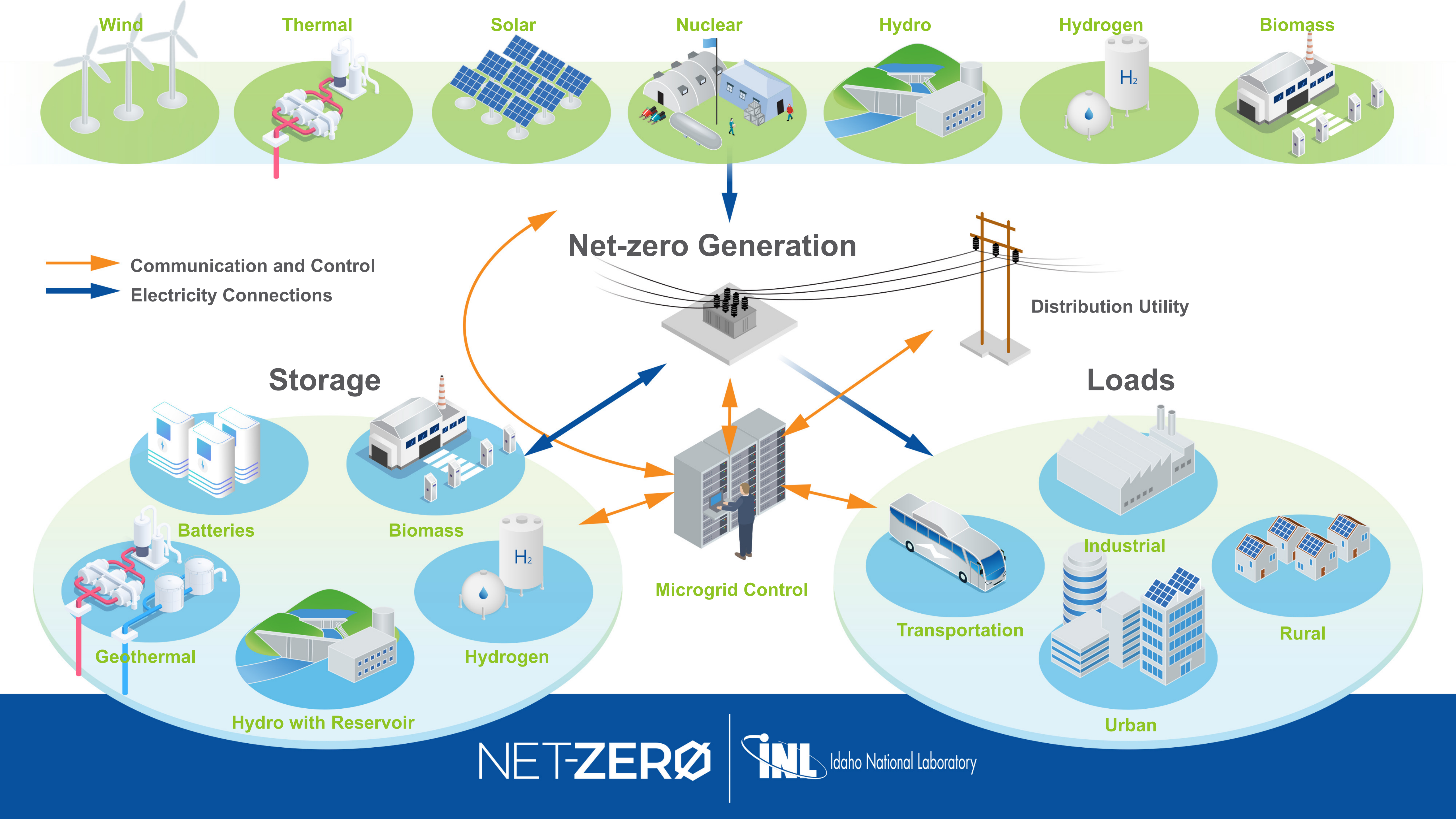
Fuel Type	Generation (MWh)	Ratio	Fossil
Fossil fuels			
Diesel	1,084,107	9.6%	9.6%
Natural gas	454,381	4.0%	4.0%
Natural gas: CHP	6,342,280	55.9%	55.9%
Fuel cell	1,383,540	12.2%	12.2%
Renewables			
Hydro	1,002,736	8.8%	
SPV	831,509	7.3%	
Wind	249,712	2.2%	
Total	11,348,264	100.0%	81.6%

Energy sources for microgrid generation are predominantly diesel and natural gas (82%)

U.S. utility-scale electricity generation by source, amount, and share of total

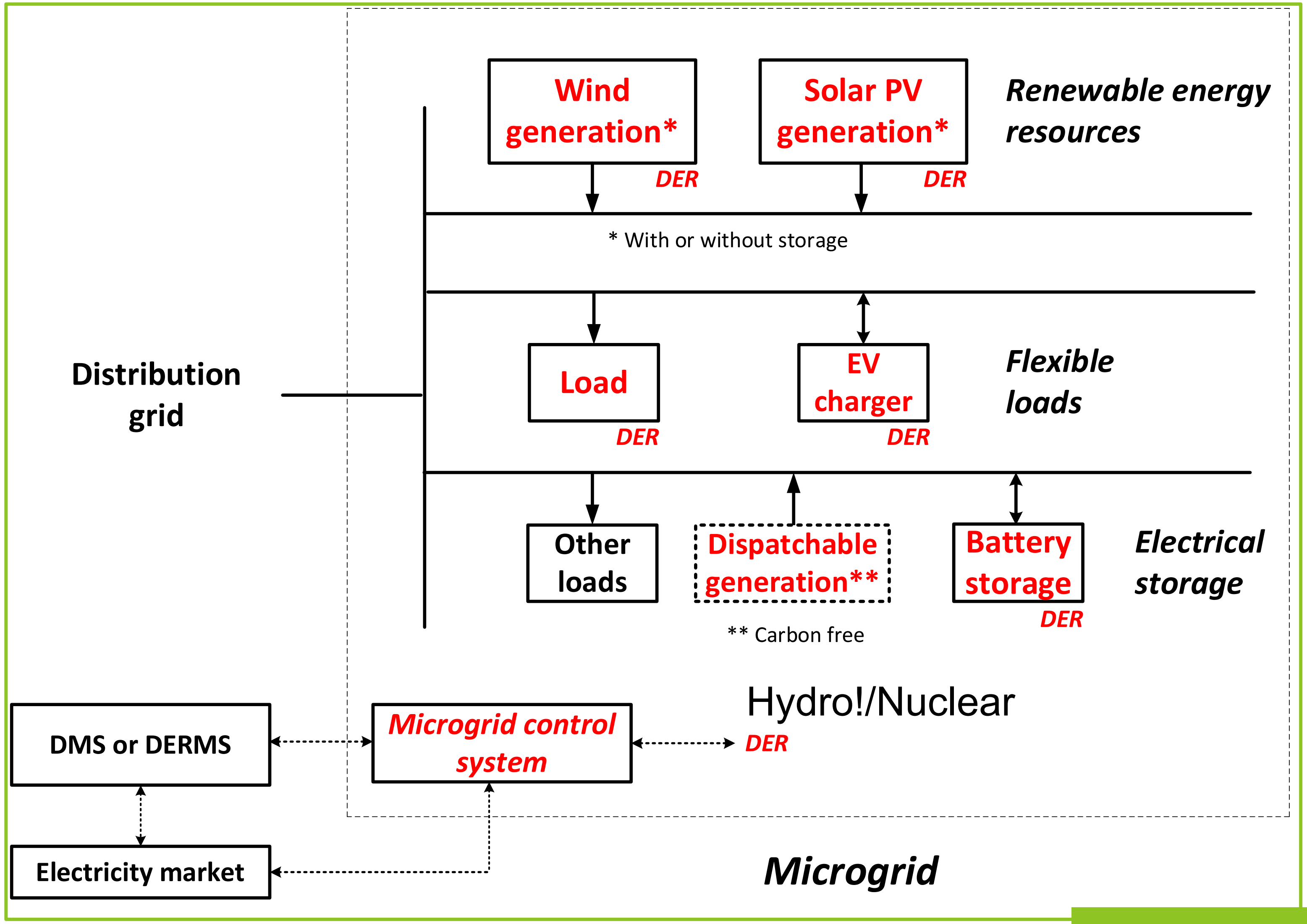
Energy Source	Billion kWh	Share of Total
Fossil fuels	**2,427**	**60.6%**
--Natural gas	1,624	40.5%
--Coal	773	19.3%
--Petroleum	17	0.4%
Renewables	**792**	**19.7%**
--Wind	338	8.4%
--Hydropower	291	7.2%
--Solar	91	2.3%
--Biomass	56	1.4%
--Geothermal	17	0.4%
Nuclear	**790**	**19.7%**
Total, all sources	***4,007***	***100.0%***

Energy mix for all generation: 60% fossil fuels (coal, natural gas, and petroleum), 20% renewable (wind, solar, geothermal), and 20% (carbon free) nuclear

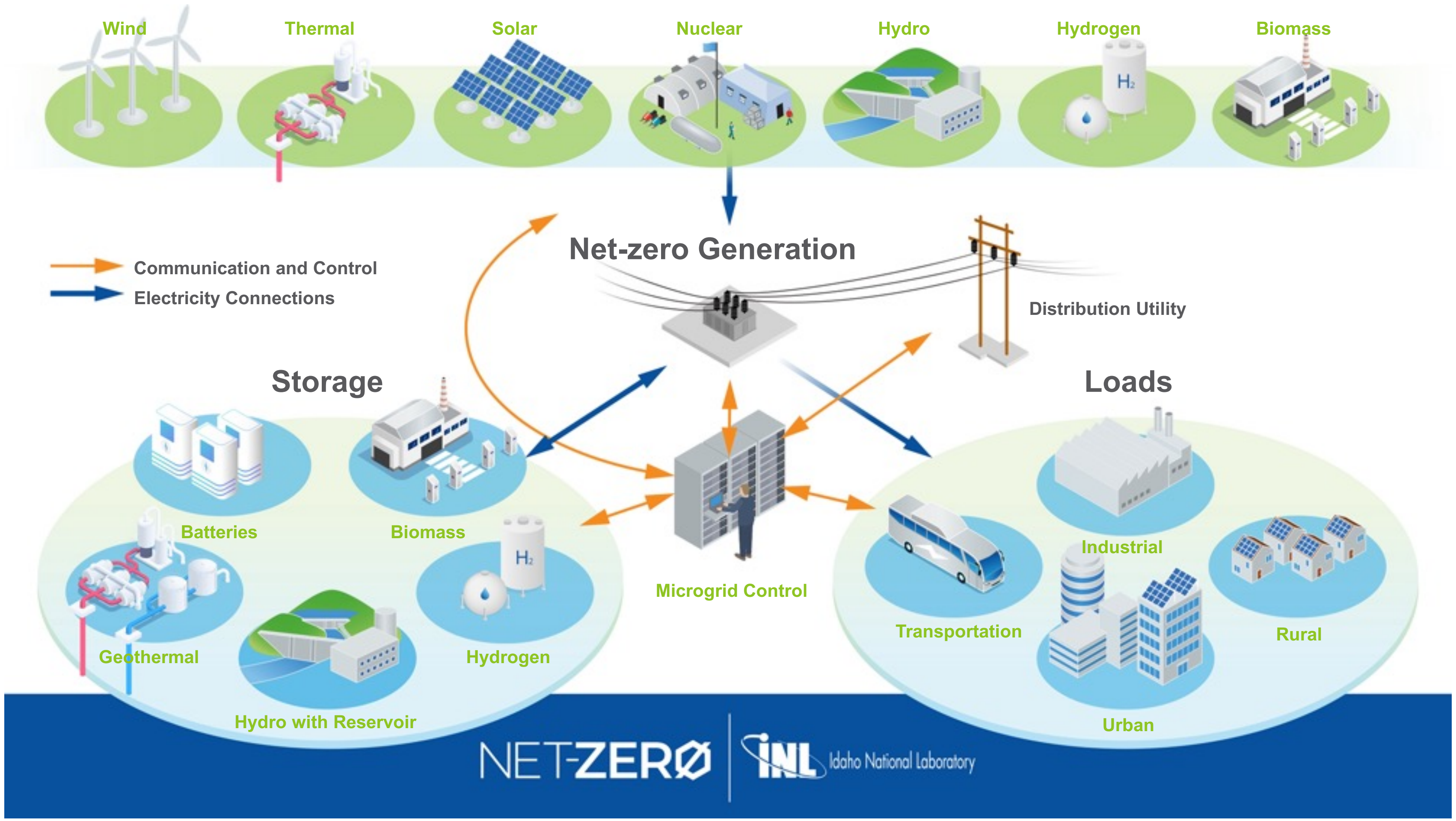


Wind
Thermal
Solar
Nuclear
Hydro
Hydrogen
H_2
Biomass
Net-zero Generation
Communication and Control
Electricity Connections
Distribution Utility
Storage
Loads
Batteries
Biomass
H_2
Industrial
Rural
Geothermal
Hydrogen
Microgrid Control
Transportation
Hydro with Reservoir
Urban
NET-ZERØ
INL Idaho National Laboratory

NZM CONNECTED TO A DISTRIBUTION SYSTEM



Adapted from IEEE 2030.7


Wind
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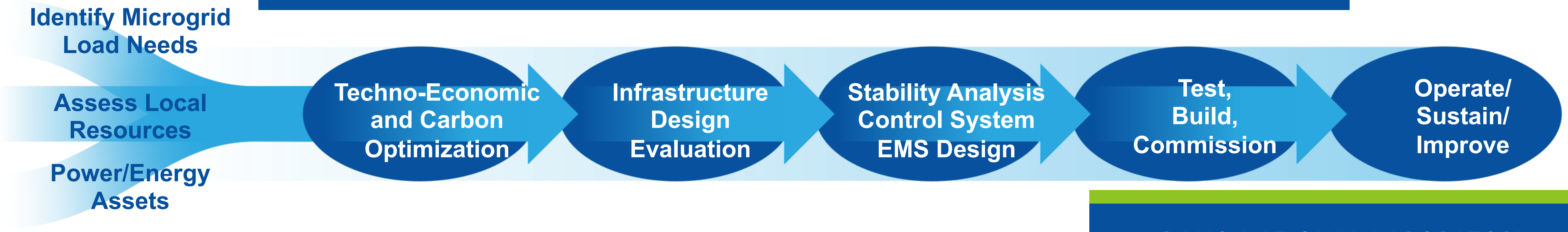

Identify Microgrid Load Needs
Assess Local Resources
Power/Energy Assets
Techno-Economic and Carbon Optimization
Infrastructure Design Evaluation
Stability Analysis Control System EMS Design
Test, Build, Commission
Operate/ Sustain/ Improve

Net-zero Microgrid Program Charter

The program establishes a clear structure for coordination with the DOE-OE federal manager to manage the technical direction, activities, and milestones measuring the effectiveness of the program. The NZM Program includes the following:

- Applying new generation from renewable energy on distribution networks
- Designing zero-carbon microgrids, VPPs, and other aggregations placed optimally to integrate these resources into the grid and markets
- Reducing the prevalence of fossil-fuel generation dominated microgrids, currently more than 86% of total generation
- Innovating with SMRs and microreactors to arrive at the ideal dispatchable resource for a net-zero carbon microgrid
- Working with regulatory and standards stakeholders to support compliance with standards and understanding and resolving regulatory barriers.

NZM Program

The NZM Program engages in cross-cutting research to accelerate the removal of carbon-emitting generation from microgrids, while enhancing their functionality for resilience, the electrification of infrastructure, and support of distribution systems and the bulk electric grid.

The capabilities of the NZM Program are:

- NZM planning and design platform for modeling microgrids renewable energy
- Simulation of microgrid solutions optimizing renewable generation and minimizing GHG

Developed to

- Produce feasibility studies
- Screen of microgrid and Virtual Power Plant projects for RFPs
- Coordinate with Policy and program support for stakeholders—i.e., policy makers, standards bodies and regulators.
- Support for implementation of the Bipartisan Infrastructure Law (BIL) provisions for grid infrastructure and resiliency

Carbon Reduction and Environmental Justice

The NZM Program is committed to achieving decarbonization for resiliency and providing clean energy at the local or distribution level, remote Communities, underserved communities, and large industrial and military facilities. The NZM Planning and Design Platform is a core tool developed as an early deliverable of the NZM Program because only a fully integrated microgrid-design approach will ensure maximum carbon reduction in energy production.

The major product created in FY22 is the NZM platform – a comprehensive microgrid planning and design tool for developing feasibility studies for microgrids that meet the objectives of carbon reduction, resilient power supply, and environmental justice.

NZM Program Cross-cutting Structure

Technical Program Execution

Transition to Practice
- Implementation
- Demonstration
- Deployment

NZ Technology R&D
Modelling
- Integrated Energy Systems
- Applications
- T&D Integration

Regulatory/Standards
- FERC
- NRC
- IEEE

Technology Program Coordination

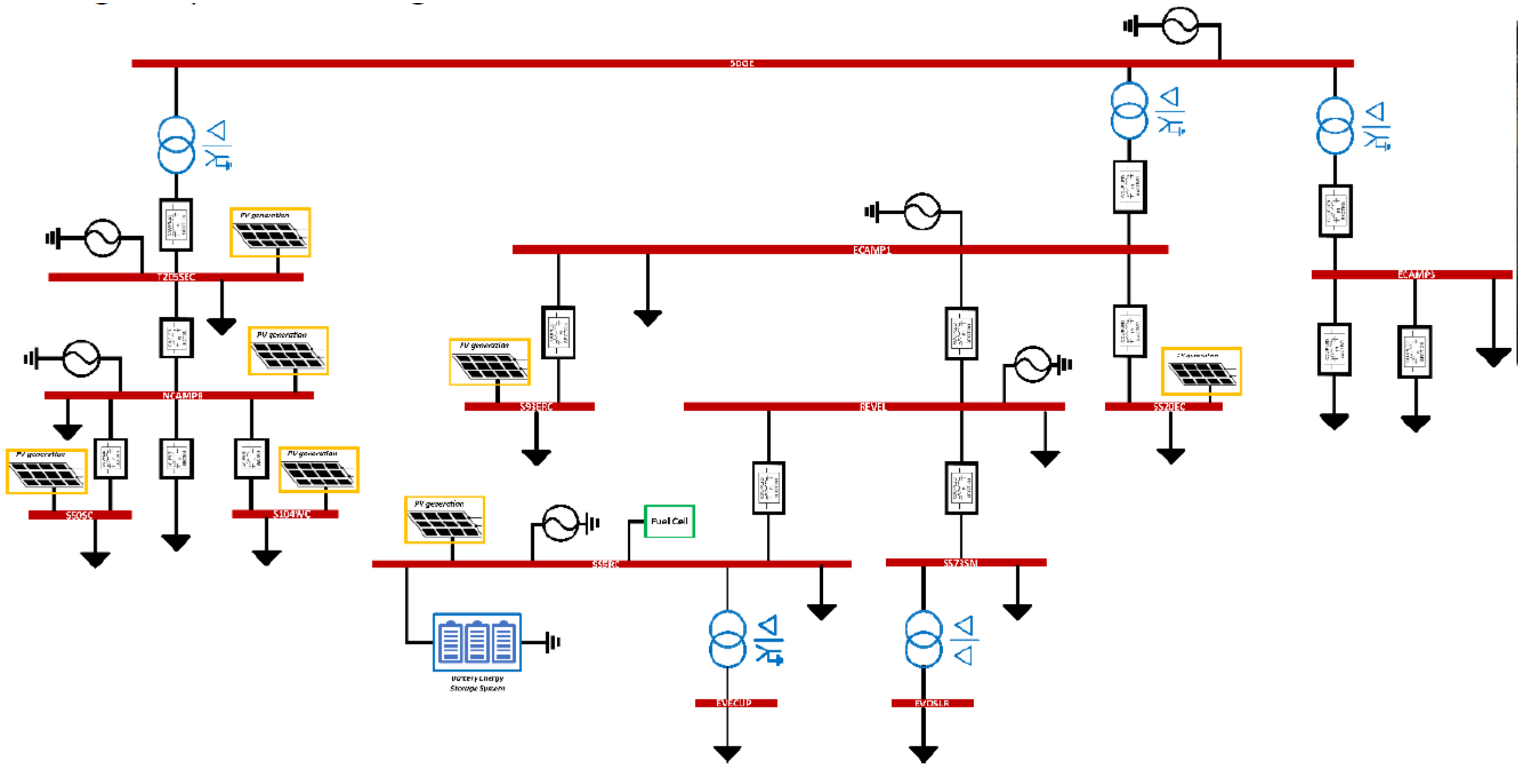
- Advanced Reactor Technologies
- Vehicle Technology / Transportation
- Renewable Energy
  Water/Solar/Wind/Thermal
- Department of Defense
- Storage
  Battery Hydro
- Hydrogen
  Fuel Cells

NZM Program Activities To Date

1. Published of Net-Zero Microgrids Report
2. Initiated coordination with DOE-NE, EERE (WPTO), and DOD microgrid programs for GHG reductions
3. Licensed software for net-zero modeling to support the overall program.
4. Developed the requirements for techno-economic analysis platform of net-zero microgrids
5. Established the systematic approach towards net-zero microgrids for applications for community and military installations
6. Developed program plan for R&D projects, Transition to Practice, and Regulator and Standards engagement
7. Applied Net-zero techno-economic analysis platform to specific applications (e.g., communities) and energy (e.g., small nuclear)

Specific Applications Exemplar Net-zero Microgrids

Microgrid Fast Charging Station Design



Report: *Summary Report Microgrid Fast Charging Station (MFCS) Design Platform*, A. Banerjee, K. Fahy, N. Kang, A. Medam, A. Nasle, Z. Pecenak, M. Stadler, M. U. Usman, Idaho National Lab. (INL), Idaho Falls, ID (United States)
DOI https://doi.org/10.2172/1813548

NZM case study: Non-powered Dam INL/XENDEE

XENDEE

- **Location:**
  - 687 1st St, Calhoun, KY 42327, USA
  - 37.5314 -87.2648
  - U.S. Army Corp of Engineers

- **Hydro Plant Capacity:**
  - 20.2 MW

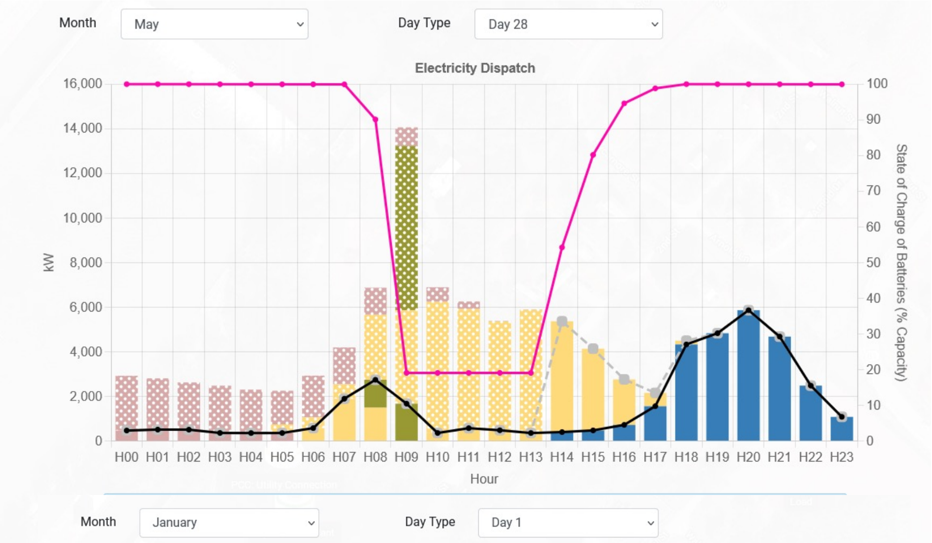
- **Utility rates:**
  - Purchase: 10.56 cents/kWh
  - Sales: 8 cents/kWh

- **Goal:**
  - Optimize hydropower in combination with solar PV, batteries, and utility
  - Supply residential community power
  - Sales to the market when attractive

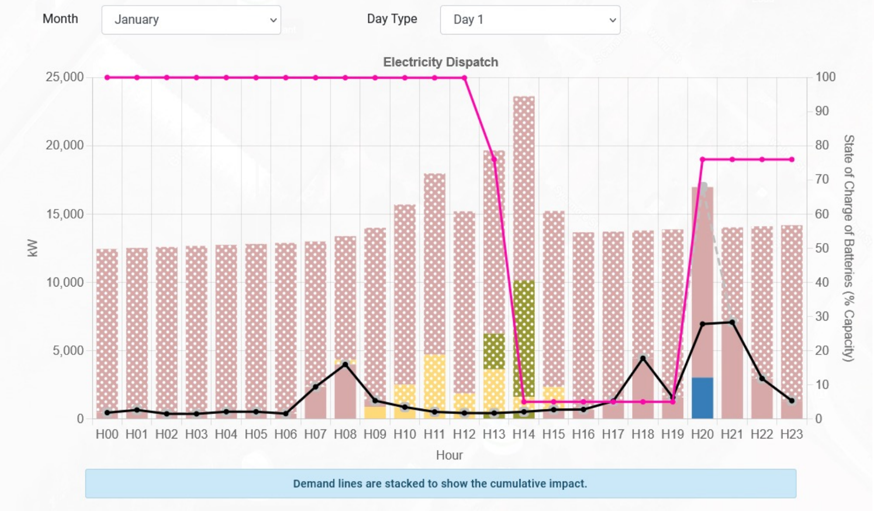
Green River Lock & DAM 2

Non-powered dams potential study of NZM with Solar-storage--Historical Flows

- Achieve a net-zero community microgrid with hydropower generation as backbone.
- Optimal investments: 20 MW hydro, 10 MW PV, 13.4 MWh batteries.
- 20% cost savings by including hydro asset relative to PV and batteries only.
- $55M investment yields:
  - $1M/year rate savings (8 cents/kWH)
  - $3.3M/year electricity sale revenue
  - Resilient zero carbon community



Limited Hydro Season



Plentiful Hydro Season

Use Case on Community Microgrids and Hydropower “Microrred de la Montaña” -- Puerto Rico

Community Microgrid Use Case

- description of the capability (GIS for identifying boundaries)

- social criteria in design and planning model

Hydropower Use Case

-- description of the hydropower component in the NZM model

Case Study – “Microrred de la Montaña”

– application and validation for a microgrid using real world data

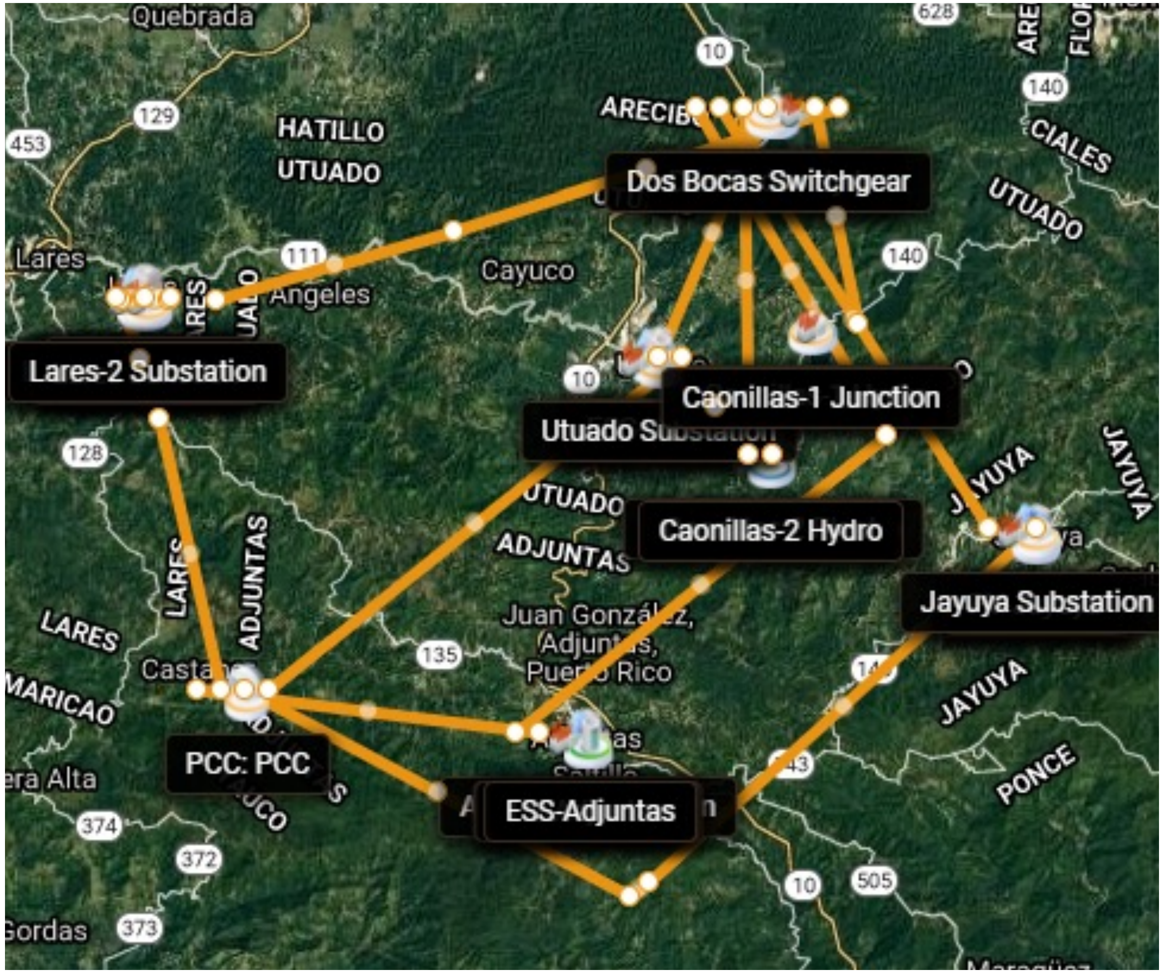
- combines both community and hydropower use cases

- Four communities in one cooperative – “networked” microgrid

- Connection to hydropower plant

- Solar and solar storage in communities

Techno-economic assessment of “Microrred de la Montaña”



System Characteristics

- 2 Hydroelectric pants, Solar and Storage.
- 4 Communities

A great opportunity for the economic development of central Puerto Rico. Joining together as “un pueblo” makes it happen!

XENDEE

Overview of the results

Support up to 3-day outages of the Puerto Rico grid
For four mountain municipalities.

Parameter	Basecase	A	B	C
Annual Energy Costs [k$ | Δ%*]	3,719	2,848.9|23.4%	3,072|17.4%	1,473.5|60.4%
Annual CO_2 Emissions [metric tons | Δ%*]	4,879	101|97.9%	0|100%	13|99.7%
CAPEX [M$]	-	30.5	33.7	47.2
OPEX [Δ%*]	-	95.2%	97%	163.9%
Utility Elec. Purchase [kWh/year]	13,048,998	269,161	0	35,530
Utility Elec. Sale [kWh/year]	-	-	-	9,698,308
Hydro Generation-Renewable [kWh/year]	-	-	0	10,117,685
On-Site Generation-Solar PV [kWh/year]	-	13,485,243	13,967,146	13,467,528
Curtailment-Solar PV [kWh/year]	-	1,041,123	1,627,903	842,073

Three cases for optimization of cost and CO2 emissions
A – Solar and Storage for electricity cost
B – Solar and Storage for CO2 minimization
C – Hydroelectric, Solar, and Storage with cost minimization

DER Technologies		A	B	C
Hydro	Dos Bocas [kW]	-	-	-
	Caonillas-1 [kW]	-	-	-
	Caonillas-2 [kW]	-	-	4,000
Combined	Solar PV [kW]	10,162	10,928	10,002
	Battery ESS [kWh]	20,549	23,666	26,148
Utuado	Solar PV [kW]	9,292	-	-
	Battery ESS [kWh]	9,150	-	4,142
Lares-1	Solar PV [kW]	-	-	923
	Battery ESS [kWh]	5,621	-	3,447
Lares-2	Solar PV [kW]	-	-	5,096
	Battery ESS [kWh]	-	-	3,880
Adjuntas	Solar PV [kW]	-	7,345	3,983
	Battery ESS [kWh]	5,473	11,041	7,349
Jayuya	Solar PV [kW]	870	3,583	-
	Battery ESS [kWh]	305	12,625	7,331

Distributed Energy Resources (DER)

* % ahorro con respecto al caso base

Case studies' results cost

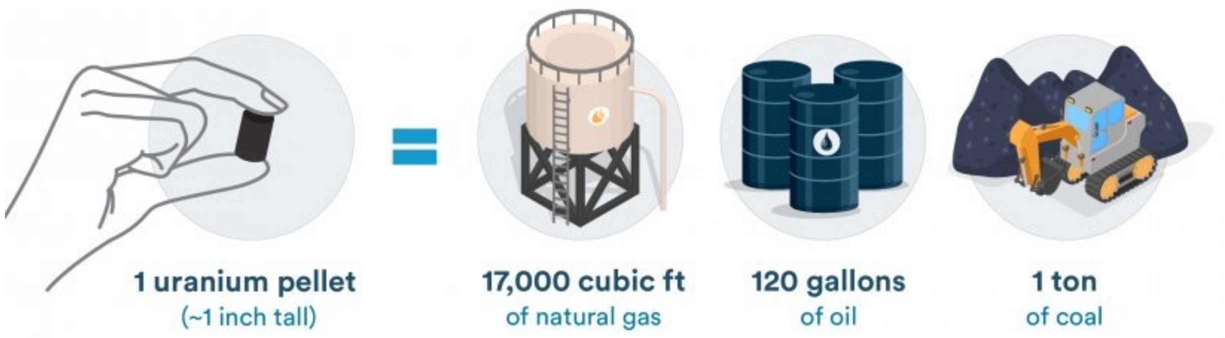
Case	PV	Hydro	Storage	Outage (3 days)	Sale to utility	CAPEX (M$)	OPEX (Δ%)	Cost ($/kWh)
Base	-	-	-	-	-	-	-	0.28
A	x	-	x	x	-	30.5	95	0.20
B	x	-	x	x	-	33.7	97	0.22
C	x	x	x	x	x	47.2	163	0.06

Of note cases A and B could support individual municipalities where C joins the municipalities with improved transmission infrastructure to form four municipalities into a single microgrid ("un pueblo") integrating hydroelectric brings $0.06/kWh and create a huge economic driver for the community.

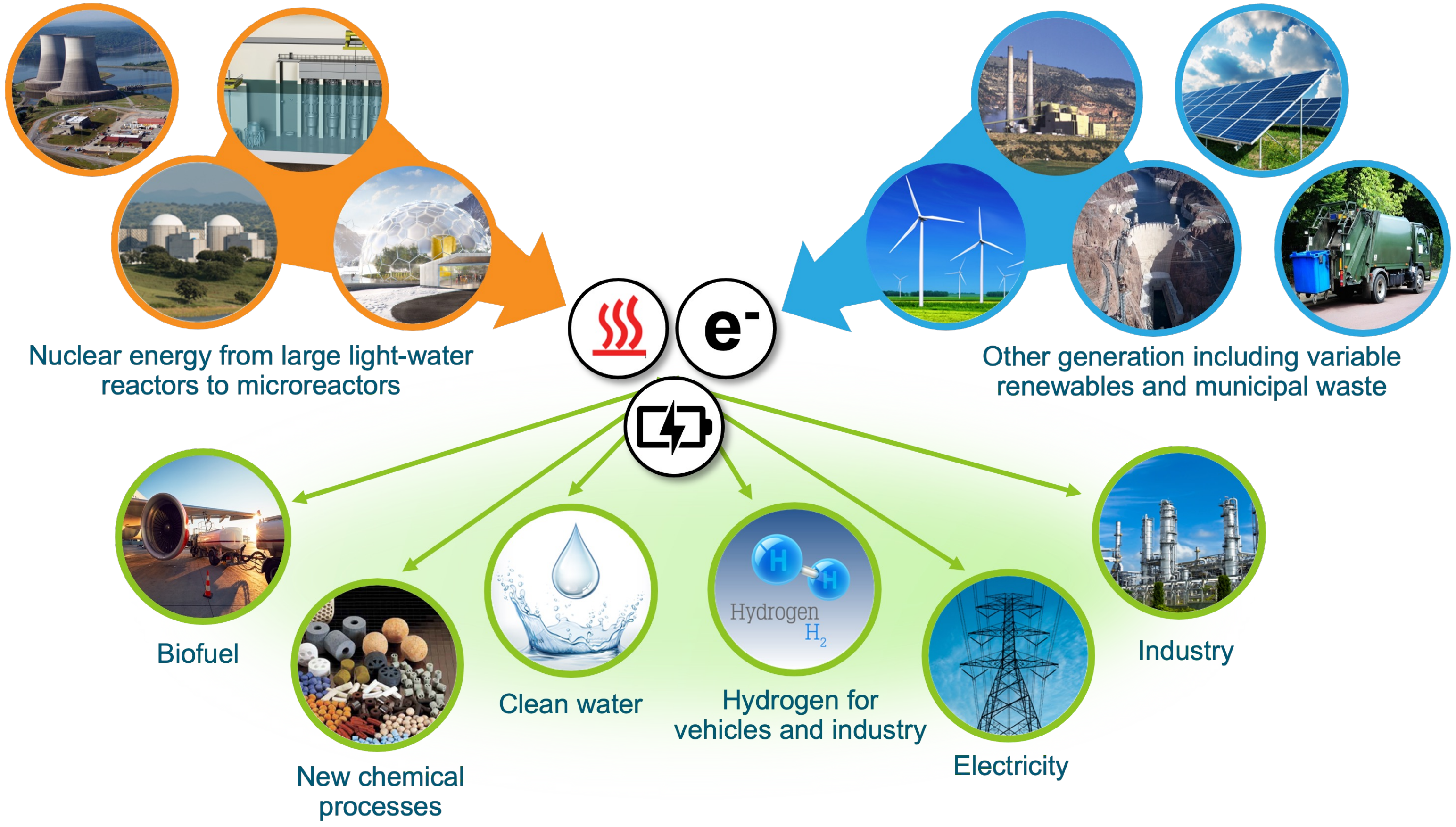
Due diligence to sanity check initial analysis

- Initial load data (publicly available) that produced $0.06 kWH was a gross underestimate (17 times)
- Worked with the community local utility LUMA to obtain substation data
- Hydro + Solar solution would require 100MW of solar… (not feasible)
- Determined reasonable maximum amount of Solar find storage needed for 24/365 resilience
  - Present community with 24/365 power budget as resilience criteria to prioritize loads (approx. 9% of max load)
  - Perform economic analysis based on solar, storage, hydro
  - Consider secondary resilience criteria outage/power trade off
  - Economic benefit remains though not as dramatic.
- No unicorn but solid plan for la Cooperativa de la Montaña to obtain needed resilience posture with a net economic benefit.
  - $0.206kWh vs. (2022)$0.285/kWh – 28% savings
- Feasibility Study writeup in progress FY22 Deliverable.

Nuclear in Net-Zero Microgrids: Technology



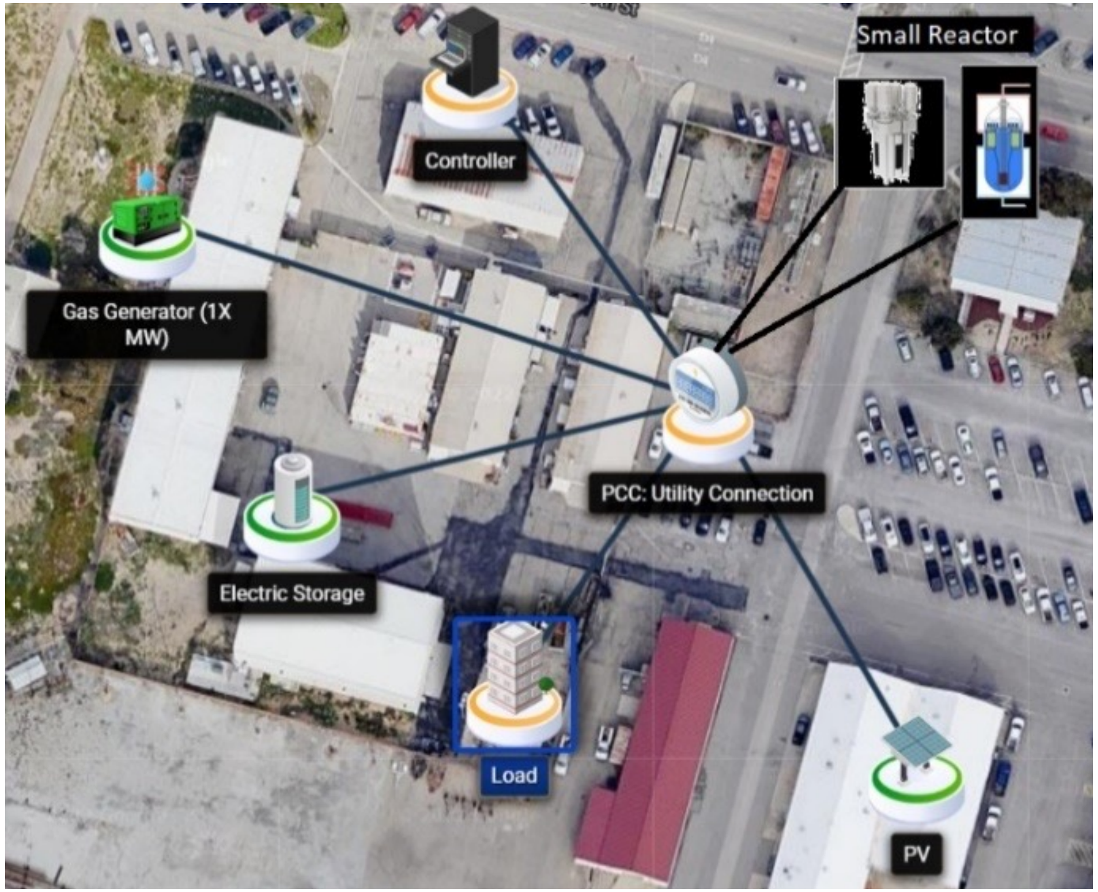
- Clean
- Reliable
- Long-Lasting Fuel
- Small & Scalable
- Modular & Flexible
- High-Grade Heat

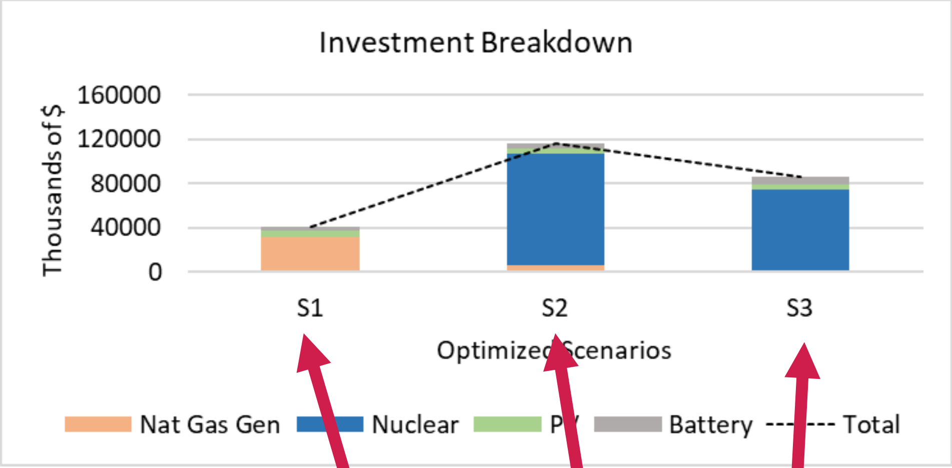


Nuclear in Net-Zero Microgrids: Meeting the Challenges

- Small size, modular construction reduces the uncertainty in time and cost with small nuclear reactors.
- Simpler construction, passive safety features and innovative robust fuels (e.g., TRISO) are some of the efforts to improve safety and safeguards with advanced nuclear.
- Long-standing non-proliferation policy continues to pose regulatory challenges for advanced nuclear reactors requiring highly enriched fuels. Cyber and physical threats and potential terrorism.
- DOE continues looking for novel ideas to resolve nuclear waste issues: storage, reprocessing and disposition.
- Identifying control and operation strategy to meet the right balance between grid and plant needs would be challenging. Human resource development and workforce training is necessary on nuclear side.

The Naval Base: Technoeconomic Study



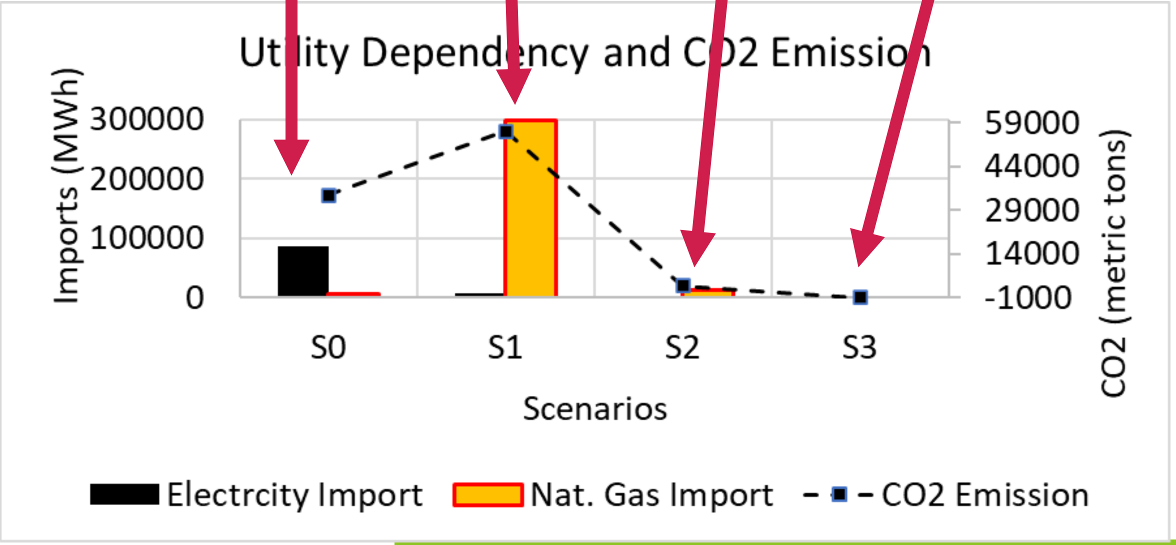


S0: Utility Purchase

S1: Onsite Generation

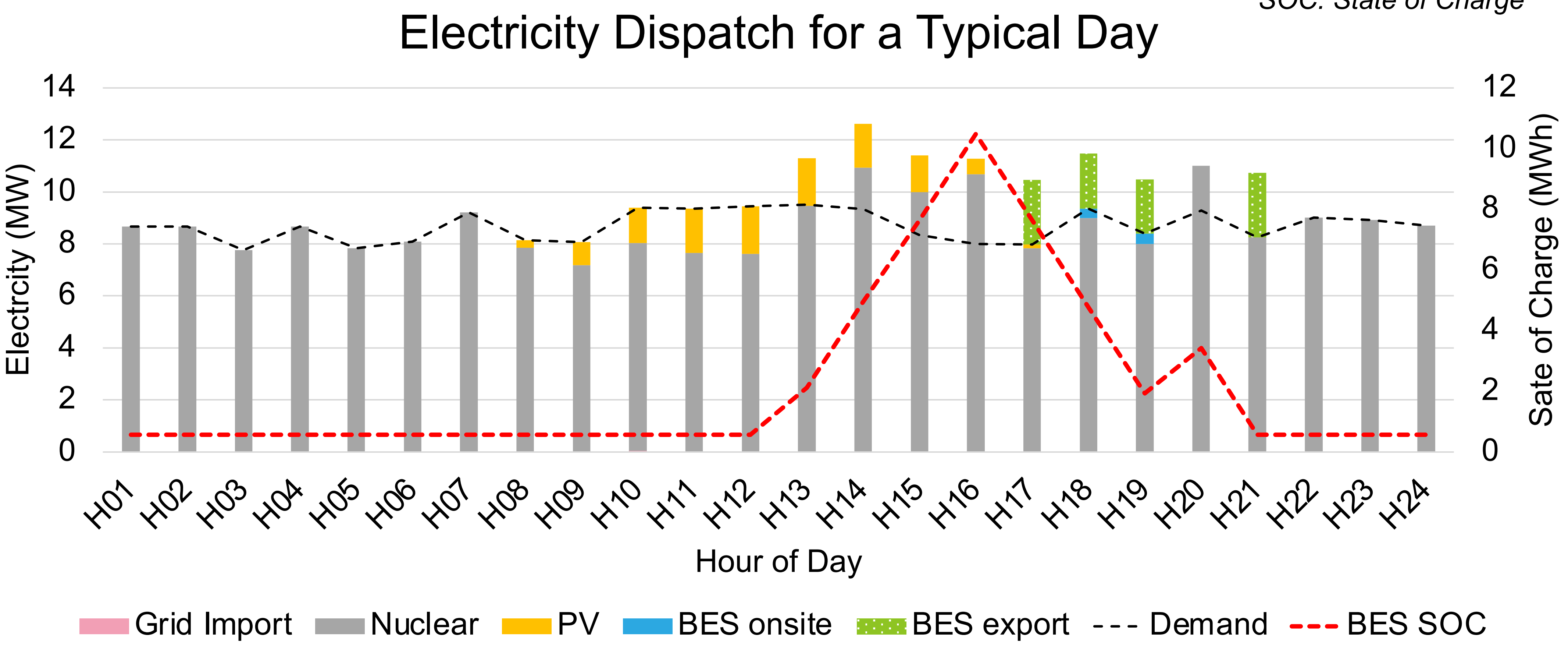
S2: CO2 tax 50 $/ton

S3: Nuclear factory production at scale



Typical Daily Electricity Dispatch in Nuclear-Powered Net-Zero Microgrids

PV: Photovoltaics
BES: Battery Energy Storage
SOC: State of Charge



INL Net-zero Initiate Support

- Use cases for INL site locations – considering microgrid design and techno-economics

INL_MG

Taylor Blvd, Idaho 83221, USA

Objectives

Minimize cost; Outage ride-through from Aug 24 12:00 AM through Aug 26 11:59 PM.

Financing

Interest Rate	6.00 %
Investment Tax Credit	No
MACRS	Yes

Energy Costs

Energy Price	$0.12 / kWh
Avg. Natural Gas Cost	N/A
Avg. Diesel Fuel Cost	N/A
Reference LCOE	$0.14 / kWh

Demand Charges

Peak TOU Rate	N/A
Non-Coincident	N/A

Demand Characteristics

Peak Demand	15 MW
Annual Consumption	86.3 GWh
Schedulable EV	N/A

Preliminary Use Case for INL's. Materials Fuel Complex

Use case analysis

- Consider loads and critical loads
- Available solar and wind resources
- Includes small reactors
- Planning for Q4 – FY22

NET-ZERO STARTS WITH INL

IDAHO NATIONAL LABORATORY

Nuclear-Powered Net-Zero Microgrids with INL

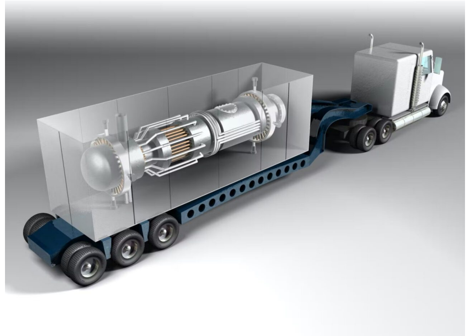
IES Integrated Energy Systems

MRP Microreactor Program

XENDEE

NuScale VOYGR

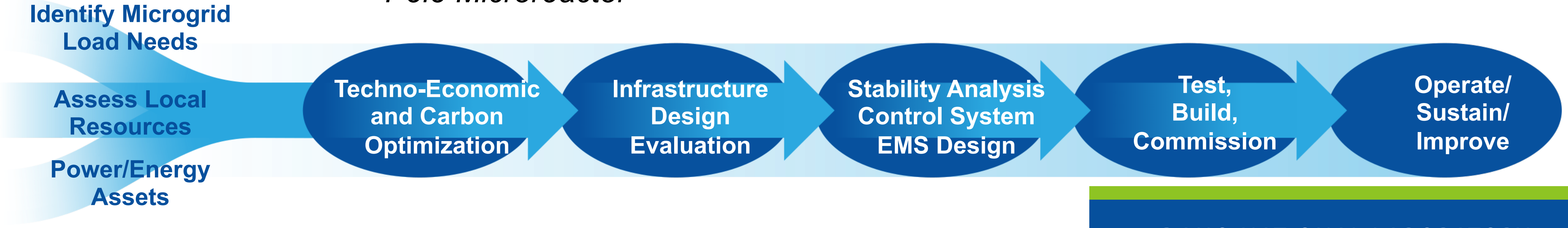
MARVEL Microreactor



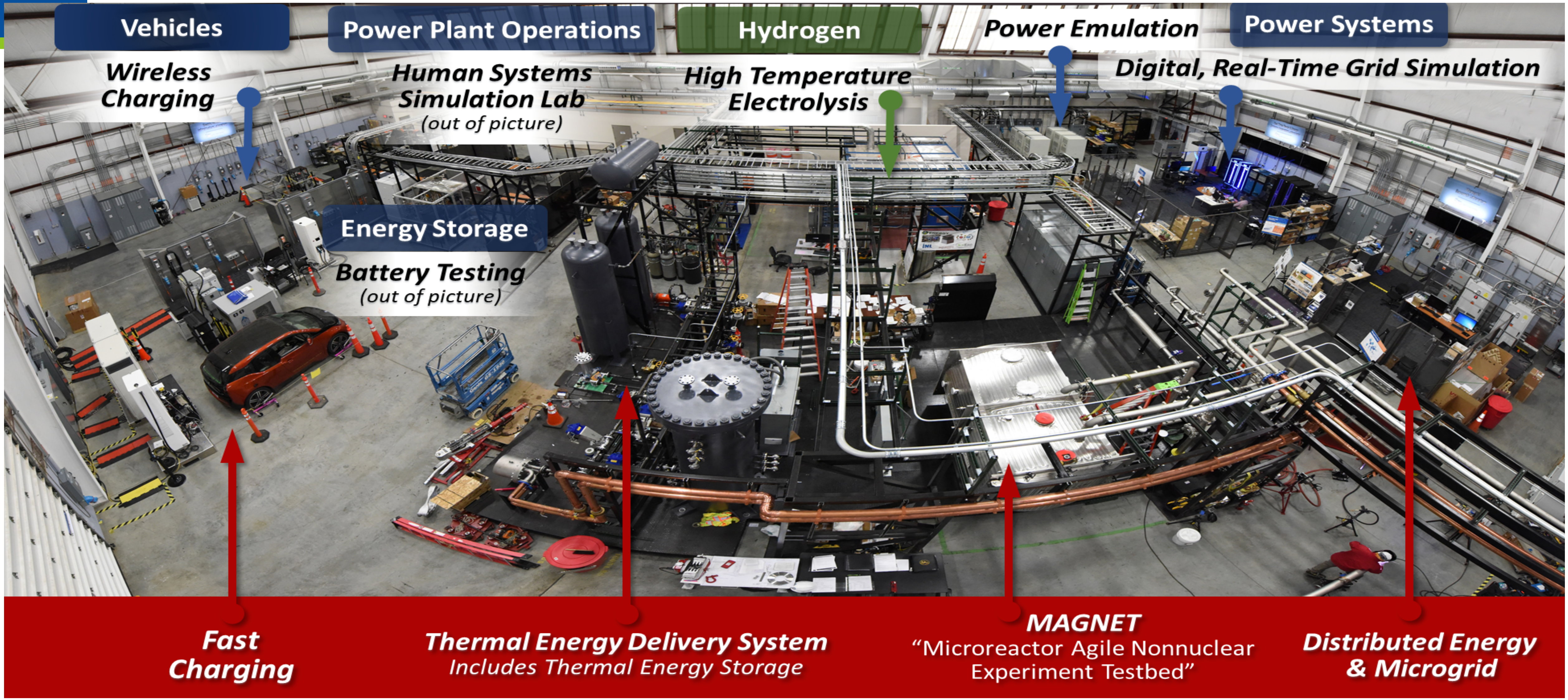
Pele Microreactor

NET-ZERO STARTS WITH US

Net-zero microgrid case for Material and Fuel Complex facility at INL



INL Unique Capabilities – Microgrid Testbed



Anatomy of a Net-zero Microgrid: coordination of energy producing and storage assets to supply critical functions, provide grid services and support resilience. (photo: INL/ESL)

Modeling Platform

Started with 25 capabilities offered by licensing XENDEE software:

- Integrated Platform for Microgrid Design and Implementation
  - Power Flow and Circuit Analysis
- Collaborative process
- Techno-economic analytics
- Financial analysis

A single comprehensive tool for Microgrid design and modeling that efficiently optimizes design and investment, power flow simulations, and organizational goals to meet resiliency requirements and cost efficiency

Greenhouse gas emissions minimized by using various combinations of energy generation technologies, we can harness a variety of solutions to offer sustainability without sacrificing resiliency and energy security.

Modeling Platform (new modules)

- Small Nuclear Reactor financial and operational constraints
- Hydroelectric encapsulating constraints and operational constraints of run of the river, hydro with reservoir, pumped storage
- High grade heat transport from nuclear or fossil-based generation to support
  - Hydrogen: high temperature electrolysis
  - industrial processes

Technical Approach

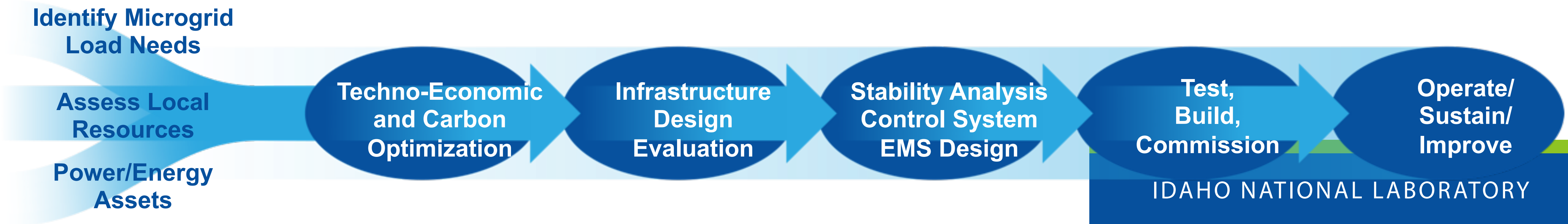
To achieve the stated goals an initial series of research topics are defined. Among the types of research and development that are identified as contributing to the NZM Program goals are

1. Modeling of new types of generators and new fuels and fuel mixes in generators for performance
2. NZM configurations with high content renewable generation, modeling to meet the diverse application needs given the mission and available resources—e.g., critical infrastructure, military bases, communities, EV charging stations
3. Advanced planning tools that can handle more-complex owner structures, grid-topologies, power flows, local energy markets, different tariff systems, dynamic pricing that capture the volatility of renewables
4. New controller techniques for handling/managing microgrids and aggregations of DER with 80% generation from renewable and clean dispatchable energy
5. Net-zero models for microgrid applications: generic for disadvantaged communities following the example of a community microgrid model created for la Cooperativa de la Montaña
6. Microreactor module for NZM modeling, highlighting zero emissions with constraints on operation and realistic cost models
7. NZC microgrid implementation guides by application type and energy resources

Next year and beyond

Each technical approach identifies research needs along the path to ubiquitous NZM commissioning.

1. Incorporate operational characteristics of new fuel mixes and generator types
2. Establish the library of model designs for community mission types
3. Include dynamics as a design function (e.g., renewable volatility, markets)
4. Develop necessary control strategies for new generation types/aggregation
5. Create generic application examples for diverse locations of communities
6. Enhance small reactor module to connect with hydrogen and other processes
7. Work with industry and communities to establish actionable NZM guidance



Outreach

- Nuclear Alternative Project – June 29, 2022 https://www.facebook.com/NuclearAlternativeProject/videos/557734762669097/?vh=e&mibextid=KJeSYY
- Sustainable Idaho – March 8, 2022 https://www.kisu.org/podcast/sustainableidaho/2022-03-08/sustainable-idaho-net-zero-microgrids-with-tim-mcjunkin
- Nuclear Energy Tribal Working Group – June 28-29, 2022
- Indigenous Energy Initiative – June 28, 2022
- Agricultural Districts -- Medford Oregon – Wastewater Net-zero microgrid
- Fall River Cooperative -- February 4, 2022
- Microrred de la Montaña – community engagement (en Español)

Dissemination: Reports

- Net-zero Carbon Microgrids: https://www.osti.gov/biblio/1831061
- Small Nuclear Reactors in Microgrids—Technical Studies Guidance: https://www.osti.gov/biblio/1829672
- *Summary Report Microgrid Fast Charging Station (MFCS) Design Platform:* https://doi.org/10.2172/1813548

Coming soon:

- Small Reactor in Microgrids – Techno-economic Study (August 2022)
- Resilience Week 2022 -- Small Reactors in Microgrids: A Financial, Resilience and Environmental Case, B. Poudel, et.al. (September 2022)
- La Microgrid de la Montaña – Feasibility Study (August 2022)

Discussion and Questions

Contact:
Tim McJunkin
Timohty.mcjunkin@inl.gov
(o) 208 526 7895
(m) 208 520 5771

Thank you!

Additional Slides

Idaho National Laboratory

INTEGRATED PLATFORM FOR MICROGRID DESIGN AND IMPLEMENTATION

Function	Requirements
Project Screening	Archive of technologies, utility data, fuel costs, etc.) to enable fast screening of projects
GIS, integrated	GIS based design level to enable grid topology and on-site detailed power flow analysis, integrated with the platform.
Detailed Economic Engineering	Fast multi-year analyses in minutes that allow investment time-lines depending on changing constraints over time (e.g., tariffs, storage performance degradation); detailed efficiency curves. Consideration of microgrid controller functions Capability to perform power flow across multiple nodes (e.g., buses, loads, generation locations) during the economic design phase (to consider bottlenecks in the distribution system early in the design phase).
Carbon emission reduction as an objective function	CO2 minimization strategies as an objective. Carbon emissions are modeled as being as important as costs and resiliency.
Distributions System Modeling (Power flow)	Full time-series power flow analyses in any time resolution and for as many nodes as the project requires. Identify voltage or line problems in the microgrid or DER project area. This function must be integrated in the platform.
Transient Stability Modeling	Analytics for dynamics in the system for black start capabilities.
Project Management Tools	Time-lines, issue tracking, project summaries, as well as on-the-job online training to efficiently perform the microgrid and DER project implementation.

COLLABORATIVE PROCESS

Share project status and results among users via platform	**Ability for every team member to share projects within his/her team directly on the platform.**
Share custom data catalogs among users via platform	Ability to share technology catalogs, data collected during project development phases.
Single integrated workflow	Allow transfer of same model through all design phases on platform. Connect economic and electrical engineering features. Allow through the entire design and engineering process without the need for data conversions or using a different platform.
One-line diagram interface	One-line diagram of distribution system (detail for power flow analysis between grid and microgrid). Distribution system topologies clearly shown. Graphical interface for designs within the network.
Built-in major catalog categories	Major catalog categories: DER performance characteristics and costs, utility tariffs, circuit element parameters (for transformers and cables, among others), load shapes
Maintenance of online versions of software	Integrated platform that offers all its extended features via cyber-secure web platform that allows for fast and unified updates across all users without burdensome re-installations of software updates.

TECHN0-ECONOMIC ANALYTICS

Derivative-based economic optimization algorithms	Derivative-based optimization algorithms that co-optimize DER technologies/capacities as well as operation of the microgrid.
Multi-year planning for enhanced financial indicators (e.g., IRR, ROI, NPV)	Adaptive multi-year analysis capabilities to solve within minutes compared to hours or days and reassess for each year the optimal investment and operational strategies, given the results from prior years. Identify optimal DER selection and capacity, at time of installation.
Multi-objective economic and emissions optimization	Frontier points that show costs to reduce carbon emissions to a certain level.
Utility grid outage as well as DER technologies redundancy modeling	Outage modeling approach that guarantees energy supply at every time-step and considers DER technology failures (e.g., generators). Optimize system operation through modeled outages to identify the portion of critical and non-critical loads that is optimal to meet or curtail at any given hour, taking into account user-set costs of unserved load.
Power flow and distribution aspects in economic design phase	In the economic design phase consider multiple nodes (e.g., buses, loads, generation locations) on the distribution network.
Automated reporting throughout design process	Bundles all steps of the DER and/or Microgrid design process on an integrated platform; automated reporting for main design steps for project screening, feasibility studies, as well as distribution system modeling.
Auto-sizing of electrical infrastructure	Cable line length calculations (GIS-based); auto sizing of cables for greenfield projects based on optimal DER capacities.
Energy domains modeled	Cooling, refrigeration, heating, domestic hot water, hydrogen, and natural gas loads to allow energy carrier switching (e.g., solar thermal cooling)

FINANCIAL ANALYSIS

DER and Microgrid Technologies modeled	**DER: PV, electric storage, flow batteries, wind turbines, fuel-fired generators, CHP, inverters, boilers, central HVAC, heat pumps, absorption chillers, thermal storage and cold water storage, solar thermal, electric vehicles, hydro, biomass, and hydrogen fuel cells** **Microgrid controller functions (IEEE 2030.7)** **Power System: cables, transformers, and buses.**
Value streams	Behind-the-meter self-generation, load shifting, load shedding, peak shaving, electricity sales, demand response, ancillary services, resilience, load curtailment, tax incentives.
Analytical capabilities for power distribution modeling	Power/load-flow time-series analysis, islanded operation, motor starting, arc flash, fault analysis, harmonics, simple dynamics, short-circuit analysis, distribution automation, volt/VAR optimization, device coordination, feeder reconfiguration, fault detection and restoration, transient stability analysis.
Technical and financial outputs	Optimal solution for DER selection/sizing, DER placement, system operation, incentive programs. Resilience strategy, load management strategy, annual costs and emissions, network voltages and losses; voltage and active/reactive power flow. upfront and annualized investment costs, detailed cash flow, projected year-by-year NPV/IRR/ROI. Timeline for DER investment and system operation.
Modeling multiple financing schemes	**Modeling of multiple financing strategies, e.g., equipment leasing, market participation rights, loans, equity, PPA).**