Microgrid Analysis Tools Summary

1.3.21 Alaska Microgrid Partnership

Developing affordable, clean, reliable, and scalable islanded-power systems for rural Alaska

Shivani Mathur, Scott Haase, Tony Jimenez
National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories
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Background: Overview of Alaska Microgrid Partnership

- The over-arching goal of the Alaska Microgrid Partnership is to reduce the use of total imported fuel into communities to secure all energy services by at least 50% in Alaska's remote microgrids without increasing system life cycle costs while also improving overall system reliability, security, and resilience. One goal of the Alaska Microgrid Partnership is to investigate whether a combination of energy efficiency and high-contribution (from renewable energy) power systems can reduce total imported energy usage by 50% while reducing life cycle costs and improving reliability and resiliency.
- This presentation provides an overview of the following four renewable energy optimization tools. Information is from respective tool websites, tool developers, and author experience.
  - Distributed Energy Resources Customer Adoption Model (DER-CAM)
  - Microgrid Design Toolkit (MDT)
  - Renewable Energy Optimization (REopt) Tool
  - Hybrid Optimization Model for Electric Renewables (HOMER).

DER-CAM

- Decision support tool for decentralized energy systems
  - Finds simultaneously the optimal portfolio, sizing, placement, and dispatch of distributed energy resources in buildings and microgrids
  - Allows objectives to be defined in the optimization (or perform multi-objective analysis)
  - Can account for multiple revenue streams in the optimization (self-generation, load shifting, peak shaving, electricity sales, ancillary services)
  - Supports grid-connected and islanded operation (including load prioritization and curtailment)
  - Supports multi-energy systems (electric, cooling, and heating loads)
  - Considers power flow and heat flow in multi-node systems
  - Supports N-1 security-constrained design.

MDT

- Decision support software tool for microgrid designers
  - First capability: Microgrid Sizing Capability, used to determine the size and composition of a new microgrid in the early stages of the design process
  - Second capability: Relies on two models, Technology Management Optimization Model and Performance Reliability Model
    - Technology Management Optimization uses a genetic algorithm to create and refine a collection of microgrid designs using Performance Reliability Model, a simulation-based reliability model, to assess the performance of these designs.
    - The primary output of Technology Management Optimization is a set of efficient trade-off microgrid designs, also referred to as a Pareto frontier.

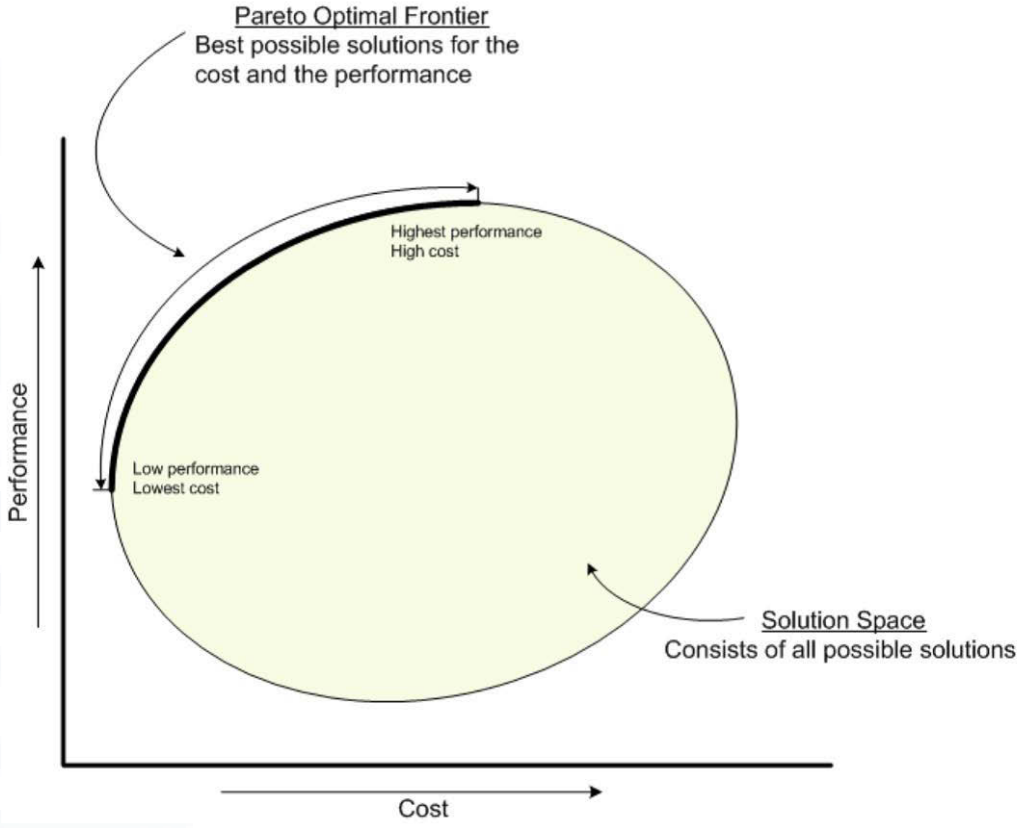
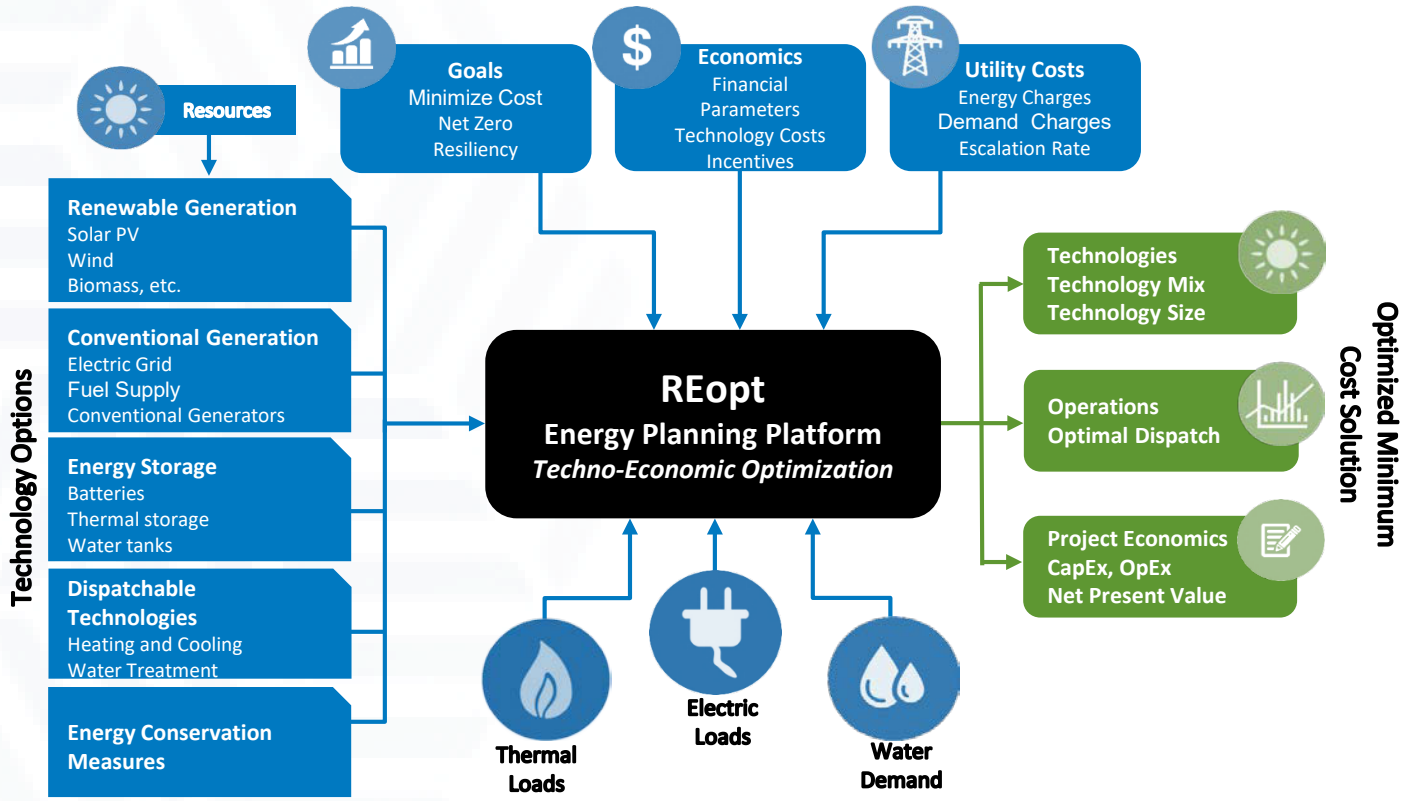


Illustration of a Pareto Optimal Frontier (MDT Technical Documentation and Component Summaries, 2015)

REopt Tool

- Techno-economic decision support model used to optimize energy systems for buildings, campuses, communities, and microgrids
  - Evaluates how renewable energy and storage can be incorporated alongside conventional generation in grid-connected or off-grid microgrids to meet critical electric, thermal, and water loads at the lowest life cycle cost
  - Optimizes system sizes and operating strategies to provide economic savings while grid-connected and extend site survivability during outages.



HOMER

- Micropower simulation and optimization model to help design off-grid and grid-connected systems
  - Simulates the operation of a hybrid microgrid for an entire year, in time steps from 1 minute to 1 hour
  - Finds the least-cost combination of components that meets electrical and thermal loads
  - Users can select from one of two methods of optimization:
    - User lists possible sizes for each component; HOMER examines all possible combinations of listed component sizes
    - Proprietary solver
  - Capable of sensitivity analyses on most inputs.

Tools: Basic Information

Parameter	DER-CAM	MDT	REopt	HOMER
Tool name	Distributed Energy Resources Customer Adoption Model	Microgrid Design Tool	Renewable Energy Optimization Tool	Hybrid Optimization Model for Electric Renewables
Publisher	Lawrence Berkeley National Laboratory (LBNL)	Sandia National Laboratories (SNL)	National Renewable Energy Laboratory (NREL)	HOMER Energy (Originally developed at NREL)
Contact	Gonçalo Cardoso, gfcardoso@lbl.gov	John Eddy, jpeddy@sandia.gov	Kate Anderson, kate.anderson@nrel.gov	http://homerenergy.com/contact.html
Website	https://building-microgrid.lbl.gov/projects/der-cam	http://energy.sandia.gov/download-sandias-microgrid-design-toolkit-mdt/	https://reopt.nrel.gov/	https://www.homerenergy.com/
Available to public?	Available at https://building-microgrid.lbl.gov/projects/how-access-der-cam	Available at https://www.energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-syst-0	Full version of REopt is not available to the public. REopt-Lite, a simplified version that optimizes PV and battery storage, is available at https://reopt.nrel.gov/tool	HOMER Pro is available for purchase. A simplified version, HOMER Quickstart, is available for free at https://www.homerenergy.com/homer-quickstart.html

Tools: Basic Information

Parameter	DER-CAM	MDT	REopt	HOMER
Optimization method	Mixed integer linear programming	Mixed integer linear programming and genetic algorithms	Mixed integer linear programming	Exhaustive search, proprietary optimization algorithms
Simulation time step	Hourly or sub-hourly	Not a time-stepping simulation. Discrete event (change in load, fuel outage, something breaks)	Hourly or sub-hourly	Hourly or sub-hourly
User customization	High. Source code can be altered to add additional capability	Limited	High. Source code can be altered to add additional capability	Some. With the appropriate module, users can create custom dispatch strategies

Tools: Mode Capabilities and Load Modeling

	DER-CAM	MDT	REopt	HOMER
Grid-connected capability	Yes	Yes (Microgrid Sizing Capability mode)	Yes	Yes
Islanded mode or stand - alone capability	Yes	Yes (Islanded mode)	Yes	Yes
Load management strategies available	• Demand response • Directly controllable loads • Load shifting • Resiliency-outage costs • Utility outages • Load prioritization • Curtailments	Loads can be defined in load tiers as Critical, Uninterruptible; Critical, Interruptible; Priority; and Non-Priority	• Dispatchable loads • Load shifting • Demand response • Critical loads • Utility outages • Resiliency-outage costs	• Deferrable electric loads • Optional electric loads

Tools: Mode Capabilities and Load Modeling

	DER-CAM	MDT	REopt	HOMER
Thermal load modeling	Yes	Limited	Yes	Yes
Thermal load modeling details	Considers the concurrent operation of heating, ventilation, air conditioning, and refrigeration systems; combined heat and power (CHP) units; heat pumps; solar thermal panels; or absorption chillers to meet thermal loads. Multi-node systems consider heat-flow	Capability limited to modeling waste heat from fossil generators	Models primary and deferrable thermal loads. Considers the concurrent operation of heating, ventilation, and air conditioning; CHP units; heat pumps; solar thermal panels; and thermal storage to meet thermal loads	Modeling limited to a primary thermal load that can be served by a boiler, generator recovered heat, and/or surplus electricity

Tools: Load Modeling and Resource Data Input

Parameter	DER-CAM	MDT	REopt	HOMER
Types of loads	Electricity, cooling, refrigeration, space heating, water heating, natural gas loads	Electrical load	Electrical load, thermal load, dispatchable load, water load	Primary electric, deferrable electric, primary thermal
Load data input	User can enter load profiles or import a time series file	User can enter load profiles or import a time series file	User can enter load profiles or import a time series file	User can enter load profiles or import a time series file

Tools: Load Modeling and Resource Data Input

Parameter	DER-CAM	MDT	REopt	HOMER
Load profile development	Three types of daily profiles (Week, Weekend, and Peak) with hourly loads for different types of loads based on location can be used to generate load profiles	Load profiles can be generated with user input	Users may enter a time series load data file Users may enter building type and climate zone data to create electric and thermal load time series files	Users may enter a time series load file User can create a time series file by specifying typical daily load profiles
Solar and wind resource data input or availability	Solar or wind data can be input by user Solar resource database can be used to generate time series file	Users may enter solar and wind profile data Users may import a time series file or users can use solar and wind data generator to create a time series file Note: Data are in fraction of rated output	Solar and wind resource database can be used to create a time series file Solar or wind data can be input by user	Solar and wind resource database can be used to create a time series file

Tools: Technology and Storage Capabilities

Parameter	DER-CAM	MDT	REopt	HOMER
Distributed generation technology capabilities	PV, solar thermal, wind turbines, fossil fuel generators, fuel cells, CHP	PV, wind turbines, fossil fuel generators	PV, solar hot water, solar ventilation-air pre-heating, wind turbines, fossil fuel generators, biomass, waste-to-energy, landfill gas, fuel cells, CHP, ground source heat pumps	PV, wind turbines, run-of-river hydro power, fossil fuel generator, biomass, biogas, boiler, fuel cell, CHP
Energy storage capabilities	Batteries, electric vehicles, heat storage, cooling storage, hydrogen storage	Batteries	Batteries, electric vehicles, thermal energy storage	Batteries, supercapacitors, flywheels, hydrogen

Tools: Financial Data Input

Parameter	DER-CAM	MDT	REopt	HOMER
Economic data	Discount rate	Discount rate	Discount rates, depreciation schedules, inflation rate	Discount rate, inflation rate
Cost input data	Capital, fixed, and variable O&M costs; value of lost load; utility tariff	Capital, fixed, variable, utility tariff	Capital, O&M costs, fuel, feedstock, utility tariff, value of lost load	Capital, replacement, O&M, fuel, value of lost load, utility tariff
Tariff input or database availability	Tariff database available	Not available; user input required	Tariff database available or user may enter custom tariff	Not available; user input required

Tools: Outputs

Parameter	DER-CAM	MDT	REopt	HOMER
Outputs	• Optimal system configuration • Optimal placement of DER in multi-node microgrids • Optimized strategic dispatch of all DER, taking into account energy management procedures. • Fuel consumption • Energy flows • Net present cost • Levelized cost of energy • Capital costs • O&M costs	• Pareto frontier of efficient microgrid designs • Reliability metrics, impacts of reliability on energy service • Capital costs • O&M costs	• Optimal system configuration • Optimal operating strategy in each time-step • Prioritization across a portfolio of sites • Fuel consumption • Net present value • Levelized cost of energy • Capital costs • O&M costs	• Optimal system configurations • Fuel consumption • Energy flows • Net present cost • Levelized cost of energy • Capital costs • O&M costs

Thank You

Tony Jimenez

National Renewable Energy Laboratory

antonio.jimenez@nrel.gov