Work supported by the U.S. Department of Energy's Office of Energy Efficiency & Renewable Energy, Water Power Technologies Office (WPTO)

THE PROSPECTS FOR PUMPED STORAGE HYDROPOWER IN ALASKA

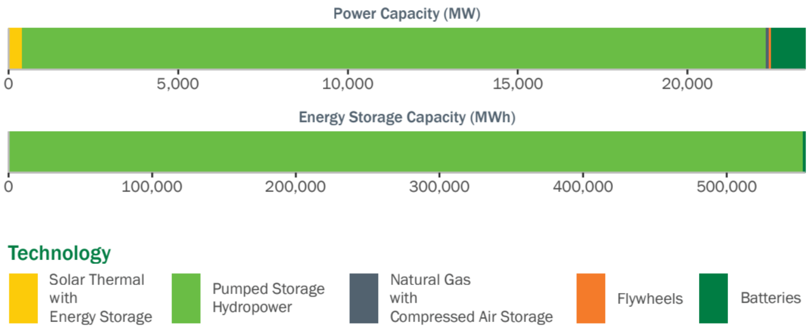
JONGHWAN KWON, PATRICK BALDUCCI, VLADIMIR KORITAROV

Energy Systems Engineer

Center for Energy, Environmental & Economic Systems Analysis (CEEESA)
Energy Systems and Infrastructure Analysis Division
Argonne National Laboratory

PUMPED STORAGE HYDROPOWER (PSH)

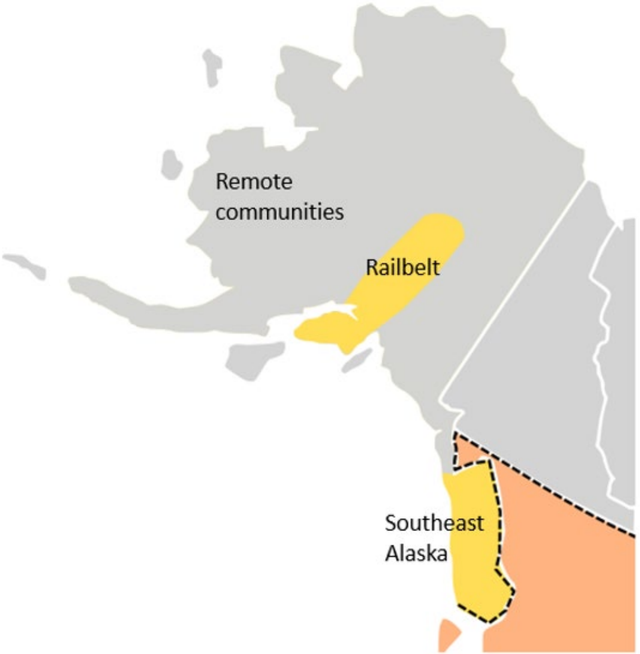
- PSH is a commercially mature energy storage technology and represents the bulk of the United States' current energy storage capacity.
  - There are 43 PSH plants in the U.S. with a total of 22 GW of installed capacity.
  - High efficiency and long plant lifetimes
  - Attractive solution for longer-duration storage needs, particularly as the use of renewable energy grows in the U.S.



U.S. Utility-scale energy storage capacity by technology type (source: 2021 edition of the Hydropower Market Report)

PROSPECTS AND OPPORTUNITIES FOR PUMPED STORAGE HYDROPOWER IN ALASKA

- PSH offers various grid services that are particularly advantageous in Alaska
  - Unique electric power systems: two larger independent transmission grids (Railbelt and Southeast Alaska) and over 150 small stand-alone power systems that are serving remote communities
  - Seasonal variability of wind and solar resource potential (i.e., little to no daylight during winter months)
  - Cold climate affects battery performance.



PROJECT OVERVIEW

- **Goal**: Investigate the prospects and needs for PSH in Alaska, both in the integrated Railbelt system and in the isolated remote communities
- **Key research areas**:
  - PSH resource potential (NREL)
    - Geospatial analysis of PSH resource potential in Alaska
  - Analysis for the Railbelt system (ANL)
    - Investigate the potential timing and locations of PSH capacity in the integrated Railbelt system
  - Analysis for the remote communities (NREL)
    - Analyze the viability of small PSH projects in rural communities

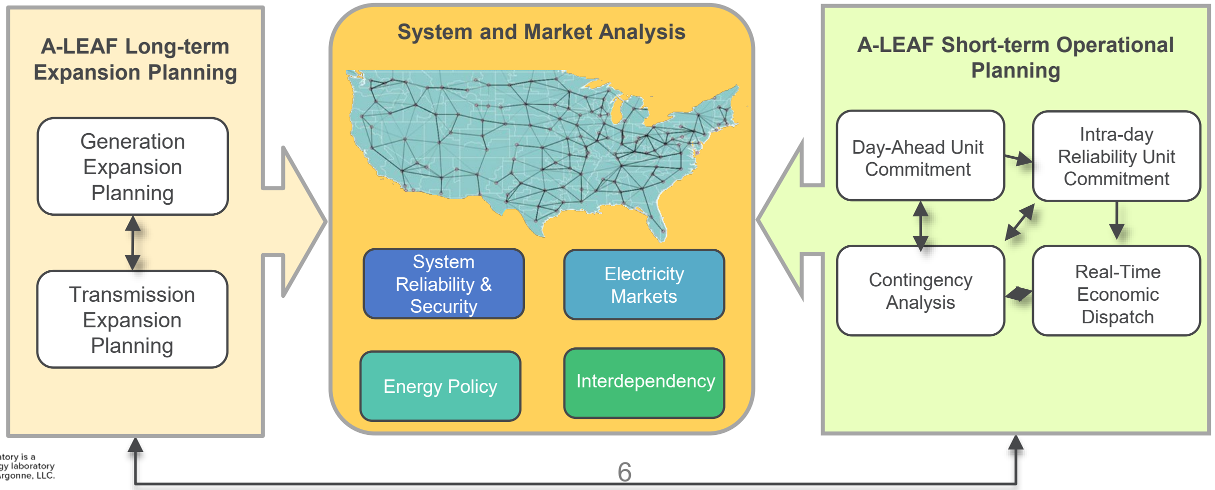
TECHNICAL APPROACH

- Perform a simplified long-term generation expansion planning (GEP) study
  - Using a least-cost generation expansion planning model
  - Assess the possible size, location, and timing of new PSH investments
- This study does NOT include:
  - A detailed integrated resource planning for the Railbelt system or local utilities
  - A complicated reliability assessment
  - A comprehensive market analysis
- Instead, our focus is to see prospects and needs for PSH in Alaska in the integrated Railbelt system under multiple scenarios

ARGONNE LOW-CARBON ELECTRICITY ANALYSIS FRAMEWORK (A-LEAF)

Core Modeling Framework

- Integrated ***national-scale*** power system simulation framework developed at ANL that has been applied to analyze different issues related to power system evolution.
- Suite of least-cost generation & transmission expansion, unit commitment, and economic dispatch models
- Determine system optimal generation portfolio and hourly or sub-hourly unit dispatch under a range of user-defined input assumptions for technology characteristics and system/market requirements.

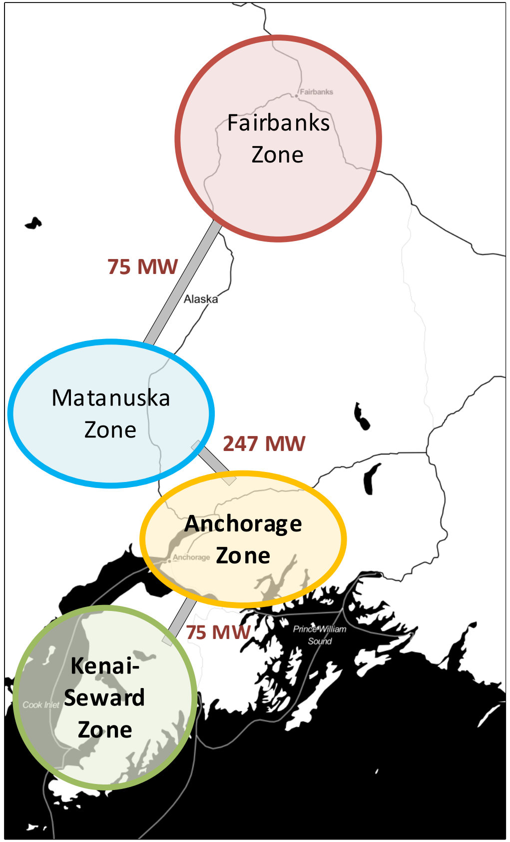


RAILBELT SYSTEM MODELING

- Railbelt system modeling in A-LEAF
  - Zonal network topology

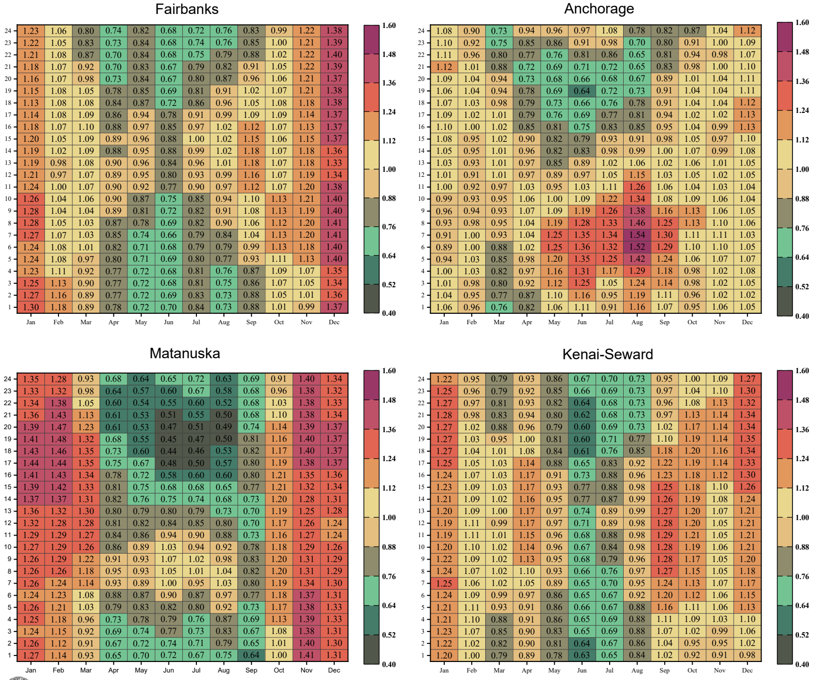
Zone	Local Utilities	Winter Peak Demand (MW)
Fairbanks	Golden Valley Electric Association	194
Matanuska	Matanuska Electric Association	131
Anchorage	Chugach Electric Association	352
Kenai-Seward	Homer Electric Association, Citi of Seward	78

  - Existing fleet (source: EIA)
    - Total installed capacity (winter capacity): 1,768.4 MW

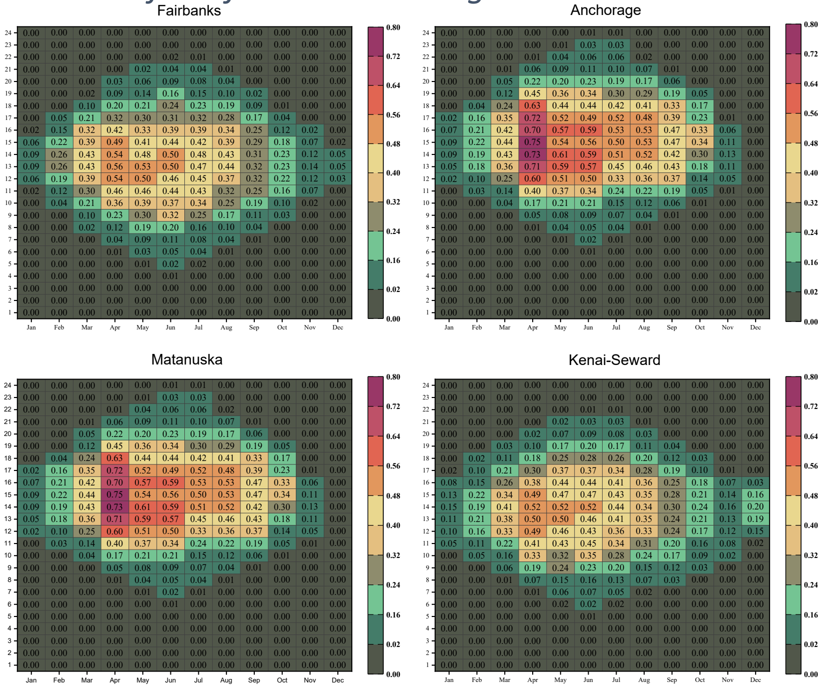


WIND AND PV RESOURCES IN THE RAILBELT SYSTEM

Average hourly wind speeds in each month of the four modeled regions (m/s)



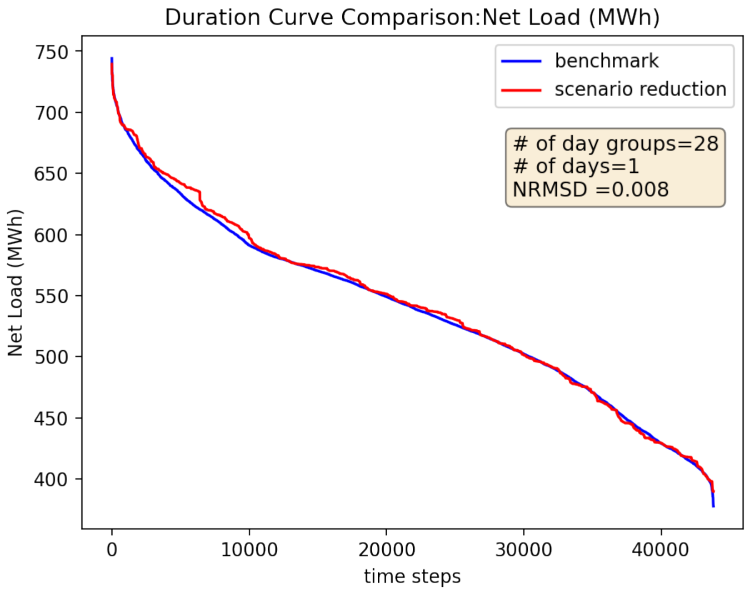
Average hourly PV capacity factor in each month of the four modeled regions



PLANNING DESIGN

- Planning Horizon
  - 2025 - 2046
  - Making investment decisions every three years
  - 0.6% annual load growth
    (winter peak, based on population growth estimates)
  - Planning reserve margin: 30%*

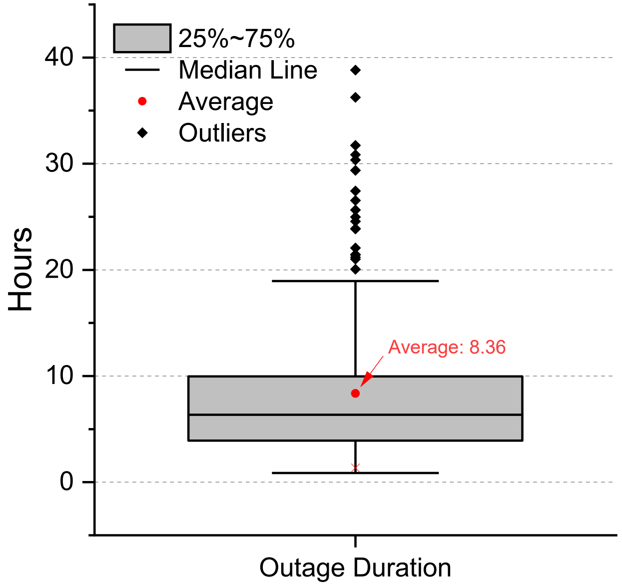
- Representative days
  - Selected 28 *days*
  - Using a backward scenario reduction algorithm
    - Attributes: Load shape, Wind shape, Solar shape



(* BLACK&VEATCH, Alaska Railbelt Regional Integrated Resource Plan (RIRP) Study, 2010)

RELIABILITY CRITERIA

- Ancillary services requirements
  - Regulating reserve: 2% of demand
  - Contingency reserve: *N-N-2*
    - *Mandates securing an N-1 status after the simultaneous loss of any two elements*
- Continuous contingency reserve provision requirement
  - 8 hours
  - Considering the radial network of the Railbelt system
  - The 8-hour requirement is estimated based on the average outage duration of the transmission lines below 345kV in the lower 48 states



Historical Outage Duration of Overhead Transmission Lines

INVESTMENT OPTIONS

- Generation Technology (investment options)
  - NGCC, NGCC-CCS, NGCT, PV, Wind, Battery, and PSH
  - Model parameters in 2040

Technology	NGCC	NGCC-CCS	NGCT	PV	Wind	Battery	PSH
Capacity (MW)	250	250	60	50	50	10	100
Storage Duration (Hour)	-	-	-	-	-	4	10
CAPEX ($/kW)	948.3	2,160.1	865.5	762.1	1,163.2	885.0	1,969.0
CAPEX ($/kWh)	-	-	-	-	-	221.2	196.9
Annualized CAPEX ($/kW)	56.1	127.8	51.2	38.4	62.5	92.3	122.0
Annualized CAPEX ($/kWh)	-	-	-	-	-	23.1	12.2
Fixed O&M Cost ($/kW-Year)	12.8	26.9	11.4	8.9	36.0	3.1	30.4
Variable O&M Cost ($/kWh)	2.2	5.7	4.5	0.0	0.0	0.5	0.5
Lifespan (years)	40	40	30	30	20	15	100

Source: 2022 NREL Annual Technology Baseline, Energy Storage Technology and Cost Characterization Report (Mongird et al. 2020)

COST AND PERFORMANCE SCALING FACTORS

- Battery Performance during cold weather
  - The round-trip efficiency is reduced by 10% when the average temperature in a region falls below 32F to compensate the needed thermal management
- Alaska cost scaling factors

Regions	Coal-CCS	NGCC-CCS	PV	Onshore Wind	Battery	PSH
Fairbanks	1.22	1.35	1.43	1.56	1.49	1.38
Matanuska, Anchorage	1.21	1.3	1.22	1.3	1.39	1.24
Kenai-Seward	1.21	1.3	1.22	1.3	1.39	1.24

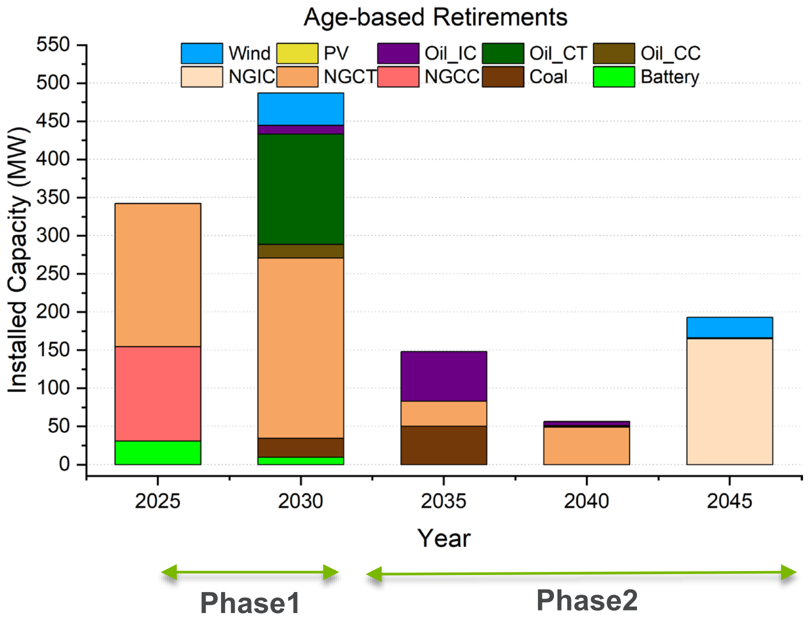
Source: 2016 EIA Capital Cost Estimates for Utility Scale Electricity Generating Plants Report

  - The battery cost adjustment factor is based on recent utility-scale battery investment report
  - The PSH cost adjustment factor is determined by taking the average scaling factors of other technologies.

AGE-BASED RETIREMENTS

- Two-phase Approach
  - Given the lack of retirement schedules in the Railbelt system, we use a two phase-based approach for age-based retirements
  - **Phase 1 (through 2030)**
    - Allow extended operations of older generators until 2030
    - The optimization model determines the optimal timing of retirements of generators subject to age-based retirements in the phase 1
  - **Phase 2 (after 2030)**
    - Fixed retirements based on plant age

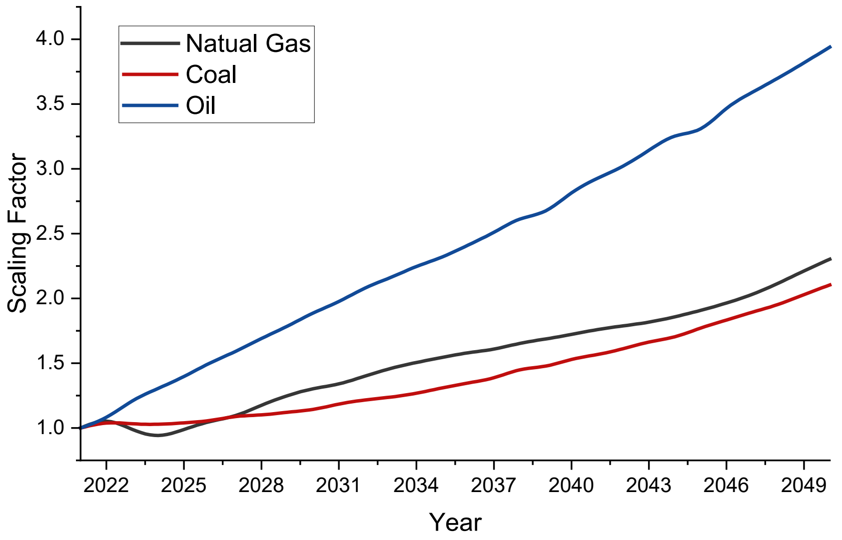
<example>



FUEL PRICES

- Base fuel price in 2022
  - Provided by local utilities

Type	Region	Price ($/MMBtu)
Coal	Fairbanks	4.8
Coal	Matanuska-Susitna Valley	4.8
Coal	Anchorage	4.8
Coal	Kenai-Seward	4.8
NG	Fairbanks	9.1
NG	Matanuska-Susitna Valley	8.2
NG	Anchorage	7.6
NG	Kenai-Seward	8.0
Oil	Fairbanks	17.2
Oil	Matanuska-Susitna Valley	17.2
Oil	Anchorage	17.2
Oil	Kenai-Seward	17.2



- Scaling factor for future years
  - based on the EIA Annual Energy Outlook 2022

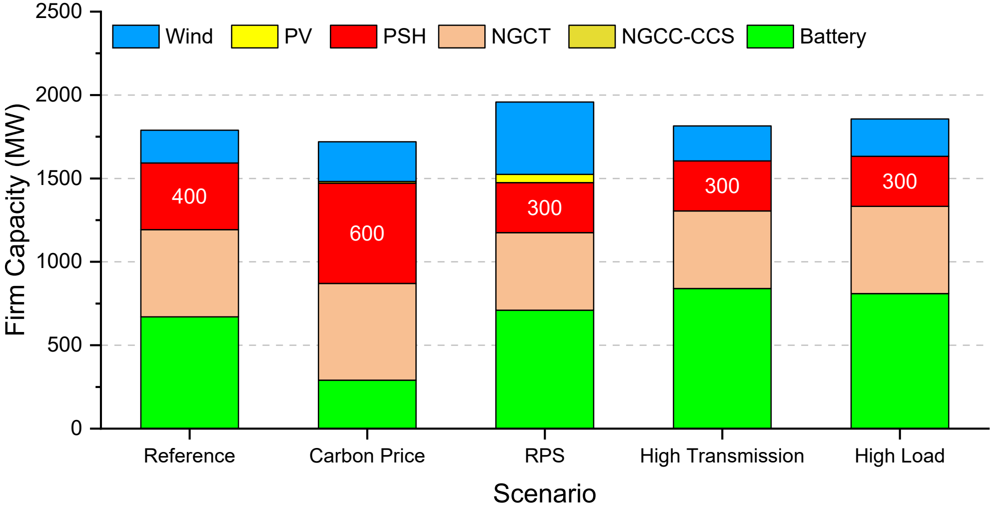
SCENARIOS

Scenario	Load	Topology	Environmental Policy
Reference	**19.9% increase by 2050**	**Southern intertie: 75 → 100 MW in 2030**	**ITC (40%), PTC (1.65 cents/kWh)**
Carbon Price	Same as Reference	Same as Reference	**Carbon Price ($40/ton)**
RPS	Same as Reference	Same as Reference	**80% target in 2040, ITC (40%), PTC (1.65 cents/kWh)**
High Transmission	Same as Reference	**AK intertie: 75 → 250 MW in 2040**	Same as Reference

- Additional assumptions
  - The Fairbanks region will not have access to natural gas before 2035
  - The earliest in-service year for PSH is assumed to be 2030, taking into account the long construction time

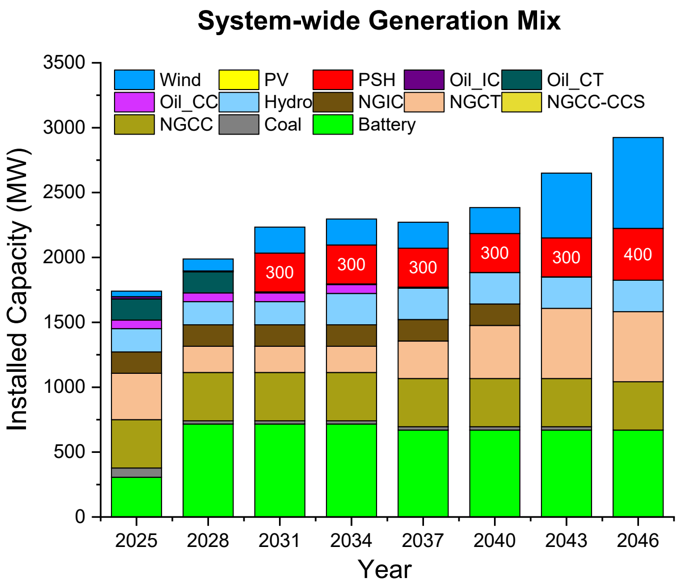
SUMMARY OF MODELING RESULTS

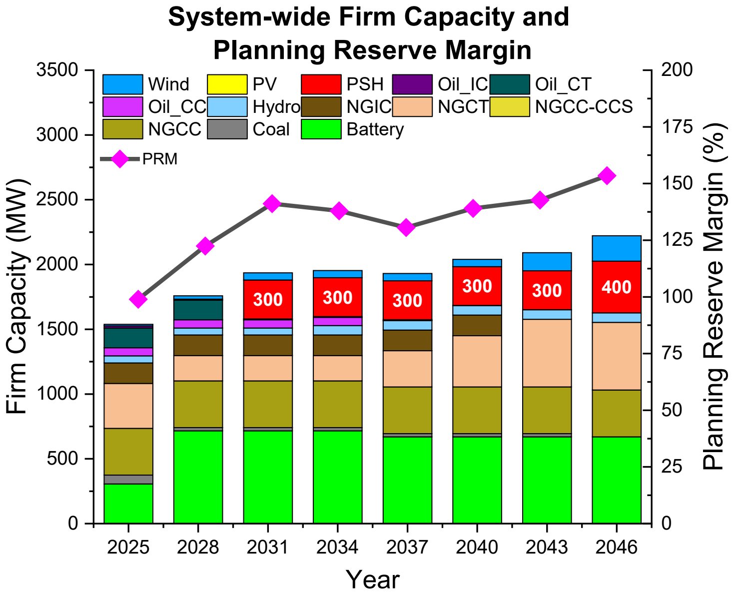
- In summary, the Railbelt system analysis shows the need for both short- and long-duration energy storage (i.e., PSH) in all scenarios. The optimal future generation portfolios under all scenarios include new PSH capacity between 300 MW and 600 MW.



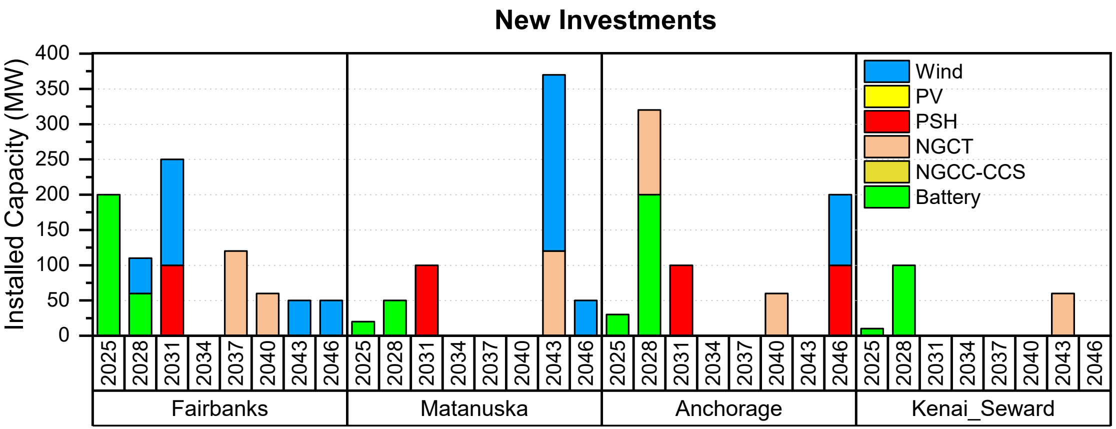
REFERENCE CASE

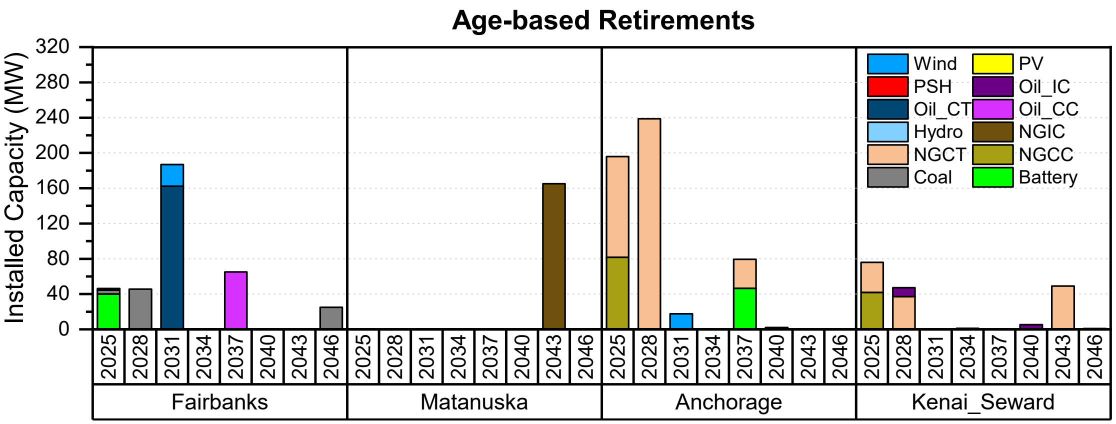
- The reference case shows the optimal generation expansion solution, which is determined by economic factors and modeled reliability constraints





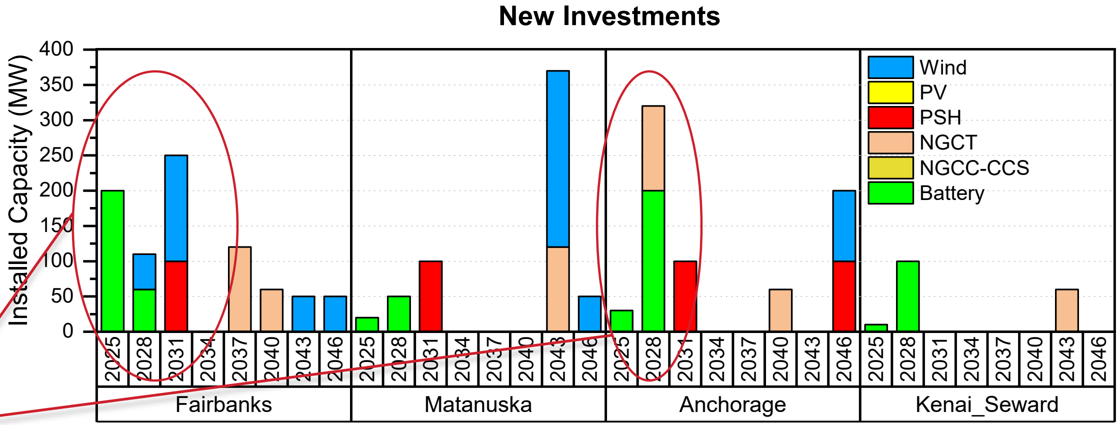
REFERENCE CASE

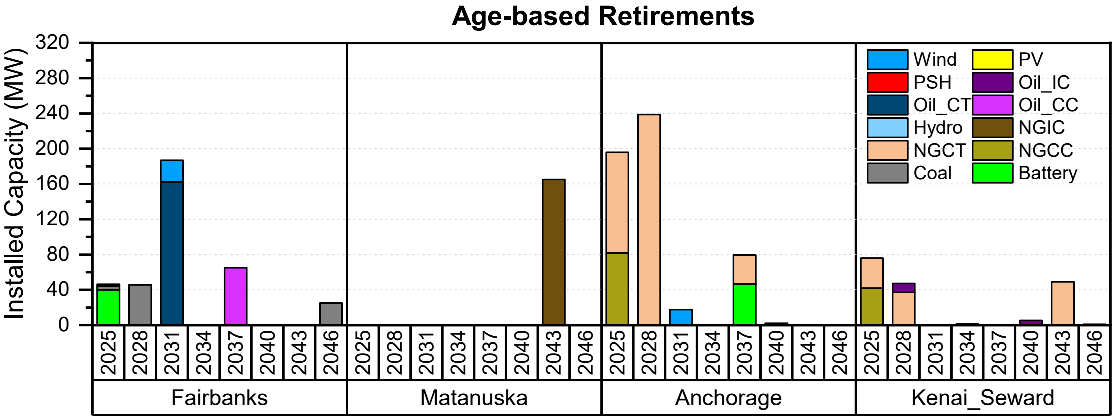




REFERENCE CASE

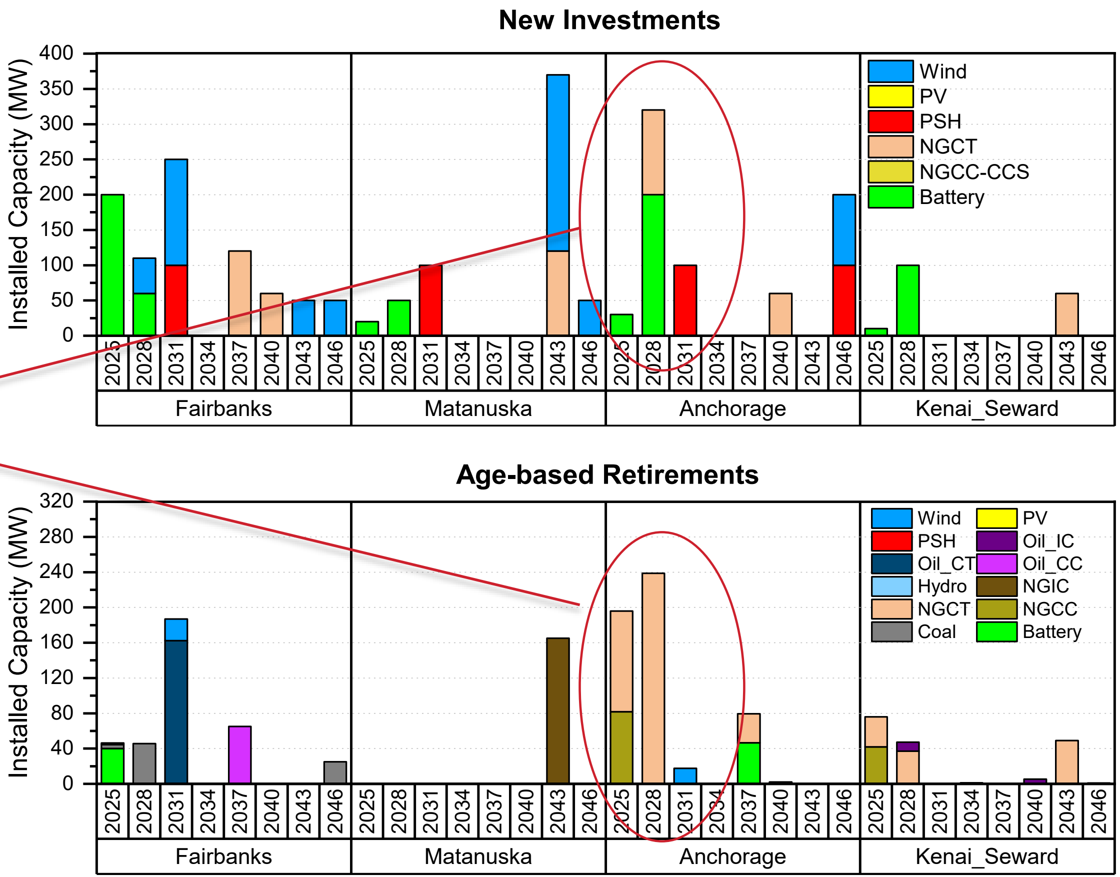
The short construction period of battery resources (compared to PSH) results in higher battery investments in the early years





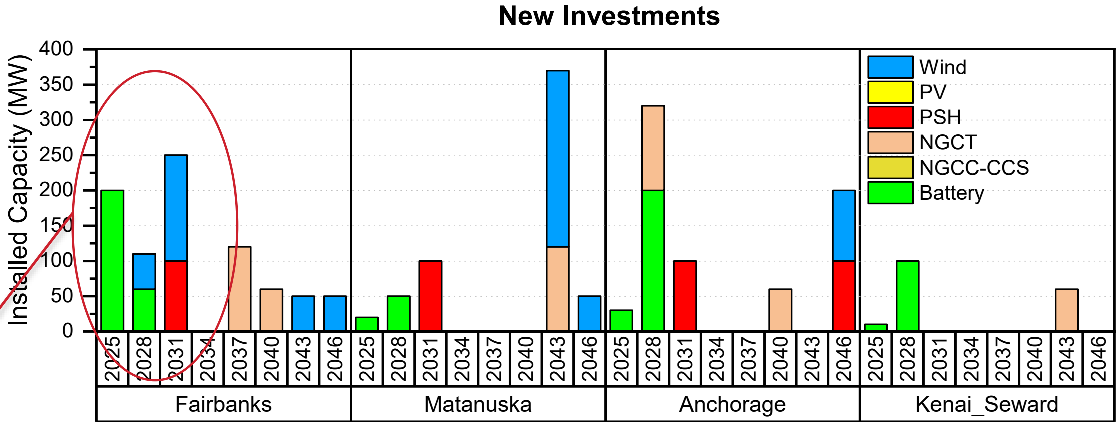
REFERENCE CASE

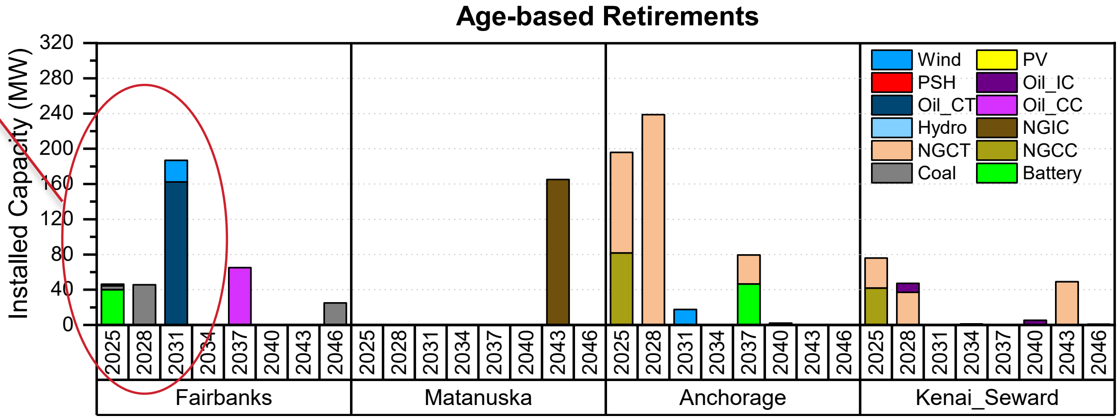
The retirement of thermal resources in the Anchorage region is offset by new investments in NGCT, battery, and PSH capacity in the early years



REFERENCE CASE

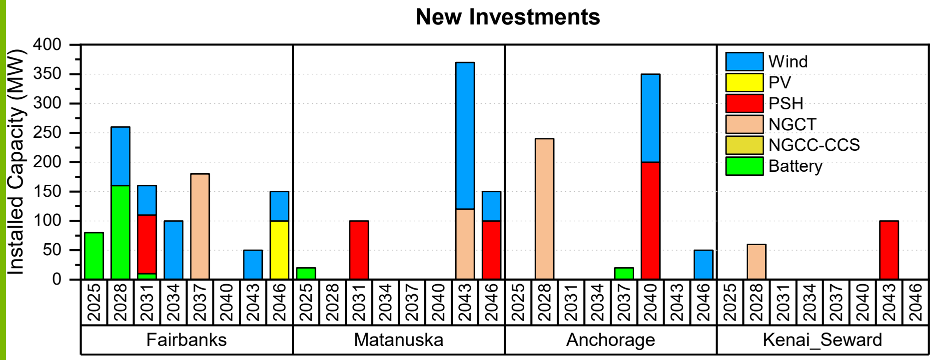
The Fairbanks region compensates for thermal retirements with a combination of new battery, wind, and PSH investments, as it is assumed that the Fairbanks region will not have access to natural gas before 2035

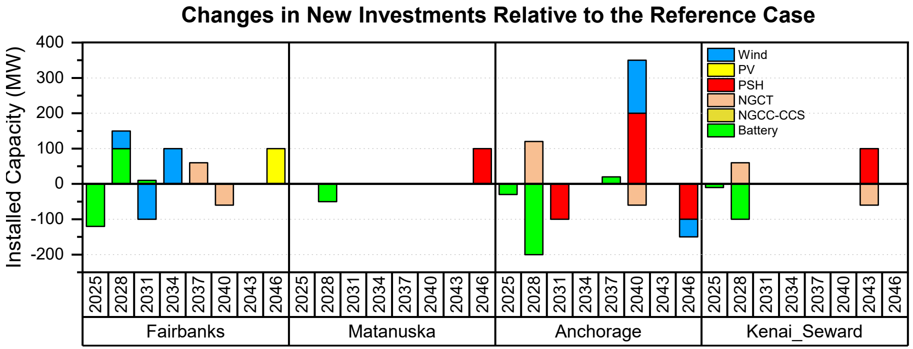




CARBON PRICE SCENARIO

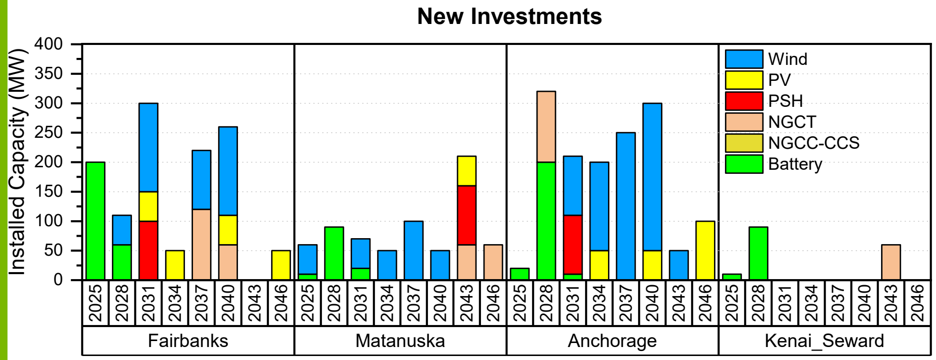
- The added carbon price increases the operating costs of thermal generators in the system; therefore, the results show increased wind, PV and PSH investments compared to the reference case.
- The Carbon Price scenario also highlights the effect of tax credits on battery investments, with a substantial decrease in battery investments due to the absence of ITC in the Carbon Price scenario.

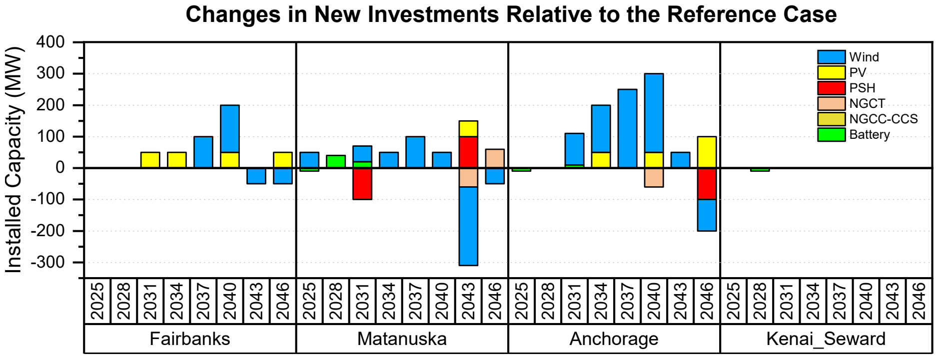




RPS SCENARIO

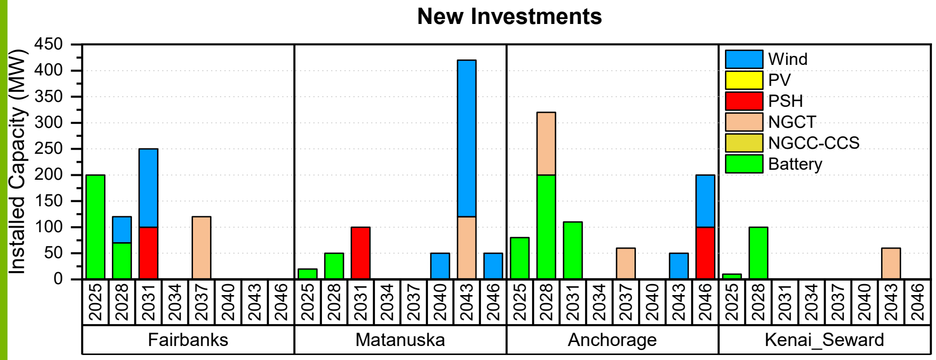
- The RPS scenario mandates the system to have enough VRE capacity that can supply 80% of the total annual demand by 2040.
- The RPS scenario shows rapid increase in PV and wind investments. The high penetration of VRE resources promotes increased investment in energy storage. However, as the earliest PSH service year is assumed to be 2030, battery investments are elevated in the early years and PSH investments are deferred.

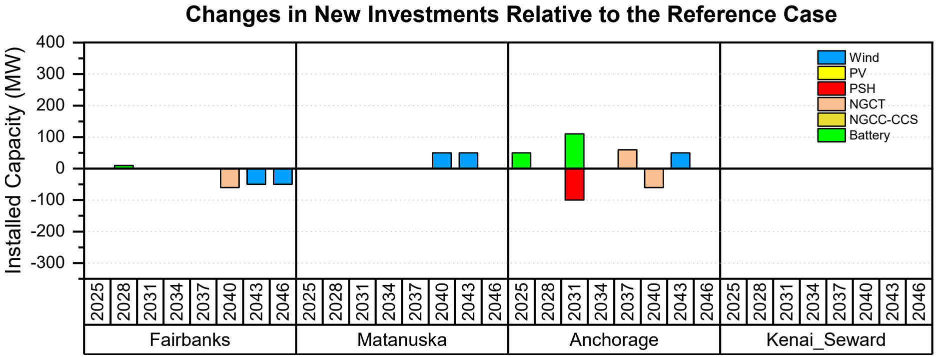




HIGH TRANSMISSION SCENARIO

- In the High Transmission scenario, the Alaska intertie capacity increases from 75 MW to 250 MW in 2040.
- The High Transmission scenario shows increased wind investments in the Matanuska region after the expansion of the Alaska intertie in 2040. Also, the increased intertie capacity eliminates the needs for wind and NGCT investments in the Fairbanks region in later years.





CONCLUSIONS

- The Railbelt system analysis shows the need for both short- and long-duration energy storage in all scenarios.
- The optimal future generation portfolios under all scenarios include new PSH capacity between 300 MW and 600 MW. The location and timing of new PSH investments vary under different scenarios.
- The Railbelt system analysis considers the age-based retirement of existing fleet. The results show that the retirement capacity of thermal generating resources is replaced by new NGCT, wind, battery, and PSH resources.
- This analysis also shows the impact of the ITC and PTC. The Carbon Price scenario, which does not consider ITC and PTC, shows a substantial decrease in battery investments compared to other scenarios.

THANK YOU

kwonj@anl.gov