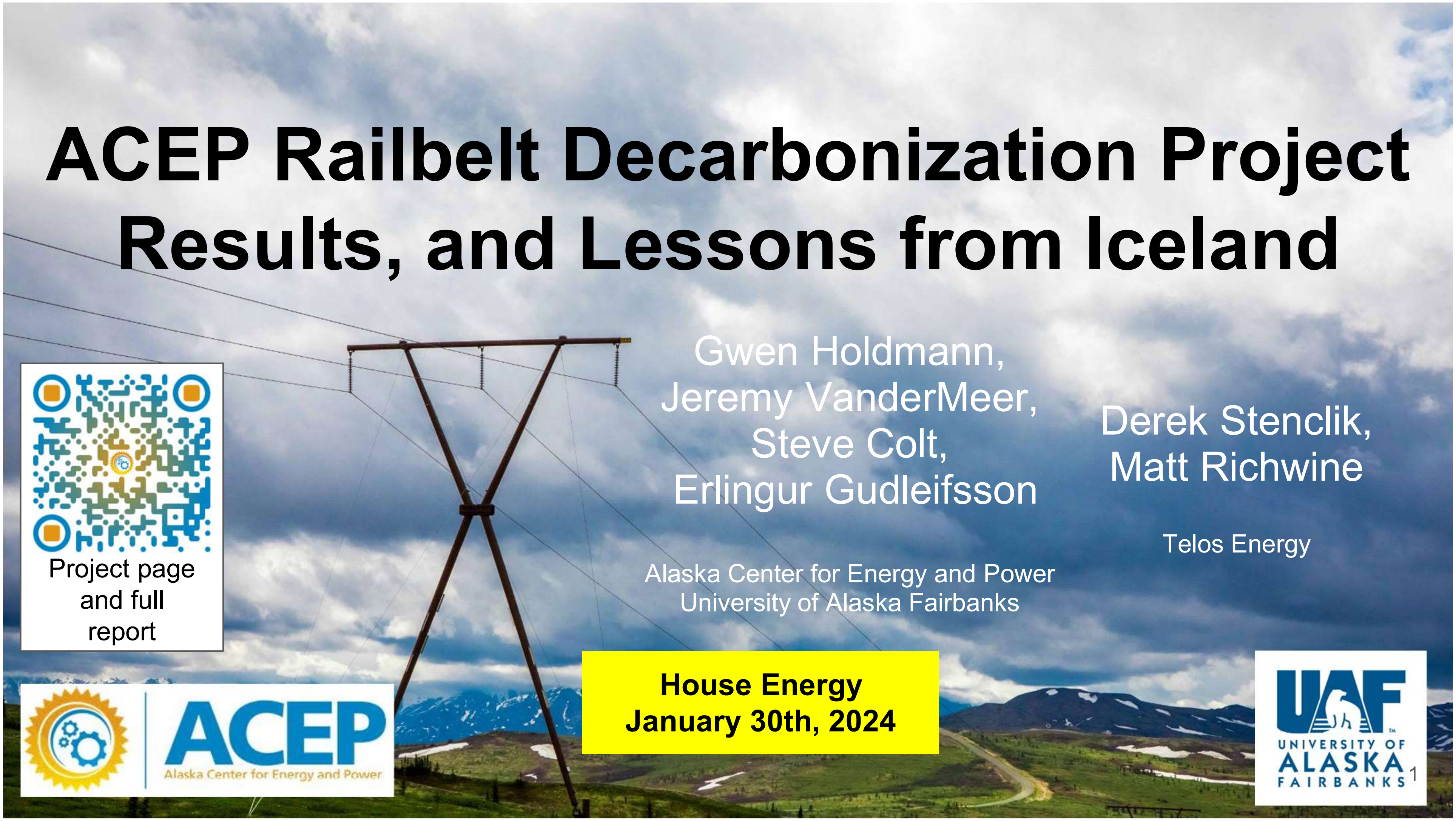


ACEP Railbelt Decarbonization Project Results, and Lessons from Iceland

Gwen Holdmann,
Jeremy VanderMeer,
Steve Colt,
Erlingur Gudleifsson

Alaska Center for Energy and Power
University of Alaska Fairbanks

Derek Stenclik,
Matt Richwine

Telos Energy

Project page and full report

House Energy
January 30th, 2024

ACEP Alaska Center for Energy and Power

UAF UNIVERSITY OF ALASKA FAIRBANKS

ACEP

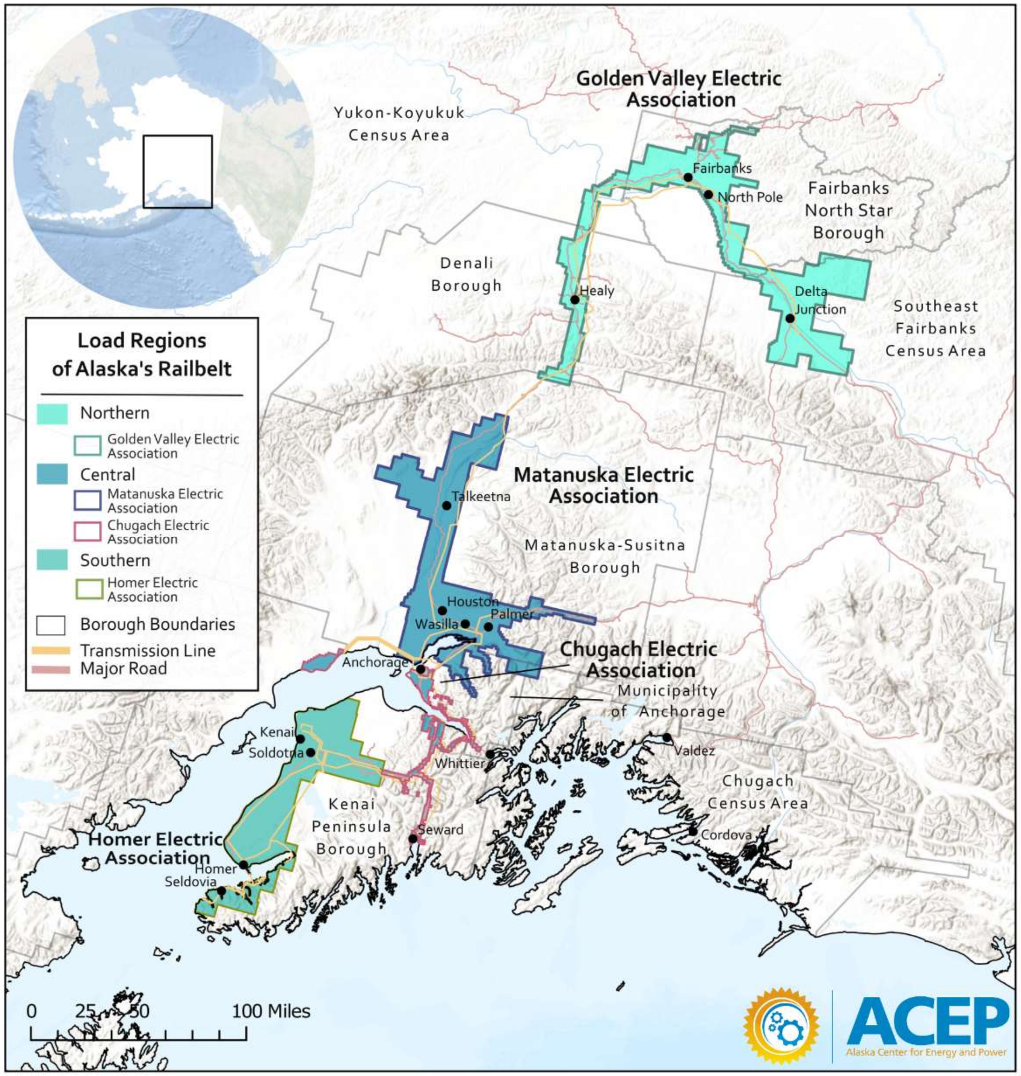
Alaska Center for Energy and Power

Our Mission

Develop and disseminate practical, cost-effective and innovative energy solutions for Alaska and beyond.

Our Research

As an applied energy research group, we provide leadership in sustainable energy systems for islanded, non-integrated electric grids, and heat and transportation systems.



Goal

Exploring and quantifying scenarios that aim for *100% Railbelt Electric Grid Decarbonization in 2050.*

Outcomes

- Quantify the ***economic and reliability implications of decarbonization scenarios***
- ***Create information*** for Railbelt planning discussions and studies
- ***Build capacity***

The Team

ACEP
Alaska Center for Energy and Power

Phylicia Cicilio, Steve Colt, Jeremy VanderMeer, Alexis Francisco, Emilia Hernandez, Cameron Morelli, Chris Pike, Michelle Wilber, Leif Bredeson (former intern), Mariko Shirazi, Dominique Pride, Noelle Helder, Gus Lewis, Dallas Fisher, and advice and review from many others

ALASKA MICROGRID GROUP

Brian Rogers, Peter Asmus

information insights

Jamie Hansen,
Frana Burtness-Adams

TELOS ENERGY

Derek Stenclik,
Matthew Richwine,
Isabela Anselmo,
Christopher Cox

TELOS ENERGY

ANALYTICS & ENGINEERING FOR A CLEAN, RELIABLE, & EFFICIENT POWER GRID.

Transmission Planning

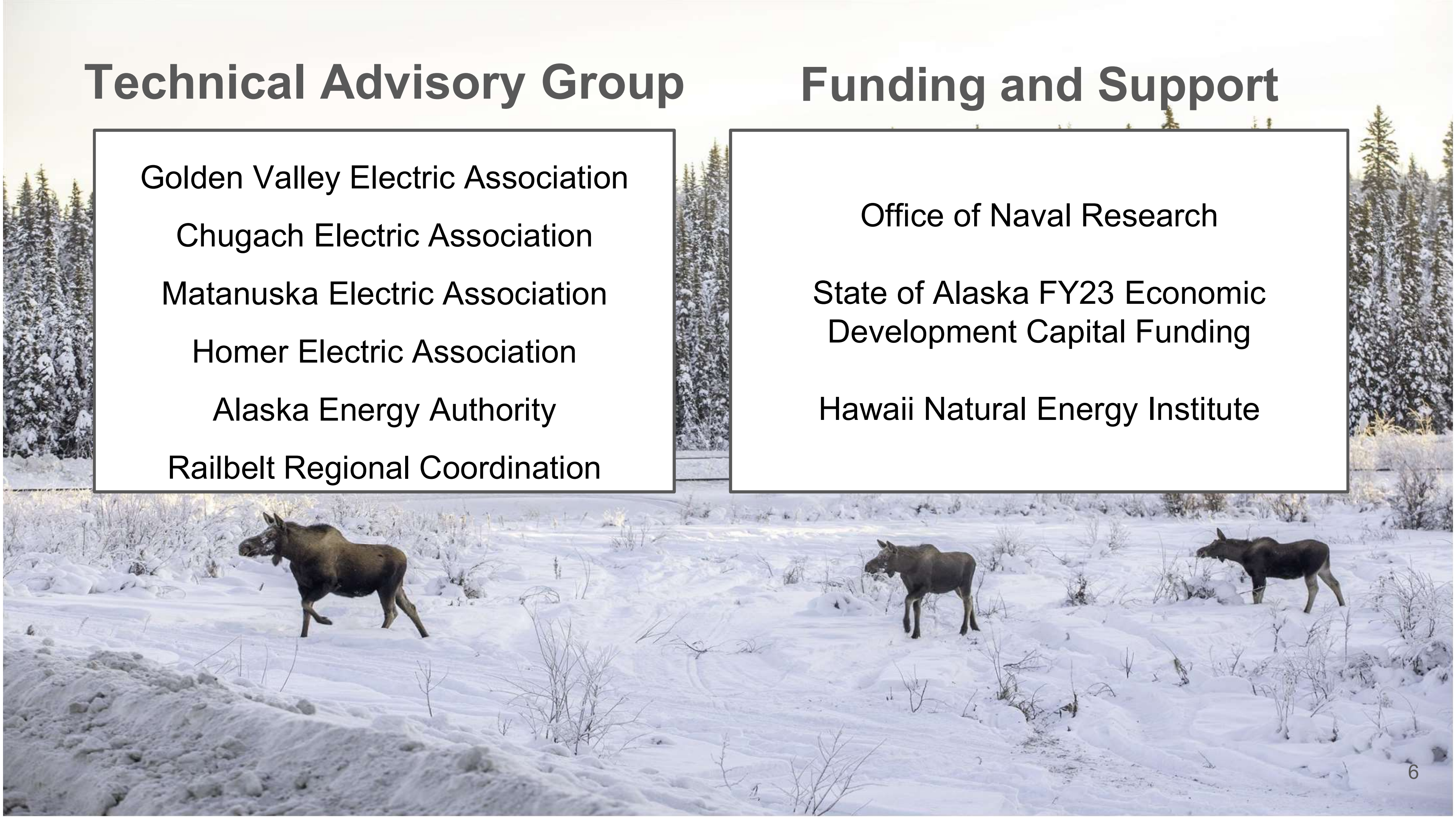
Wind and Solar Integration

Inverter Controls & Grid Monitoring

DER Planning and Storage Specification

Public Policy & Market Design

At Telos Energy, we're here to solve the industry's toughest challenges related to renewable integration.



Technical Advisory Group

Golden Valley Electric Association

Chugach Electric Association

Matanuska Electric Association

Homer Electric Association

Alaska Energy Authority

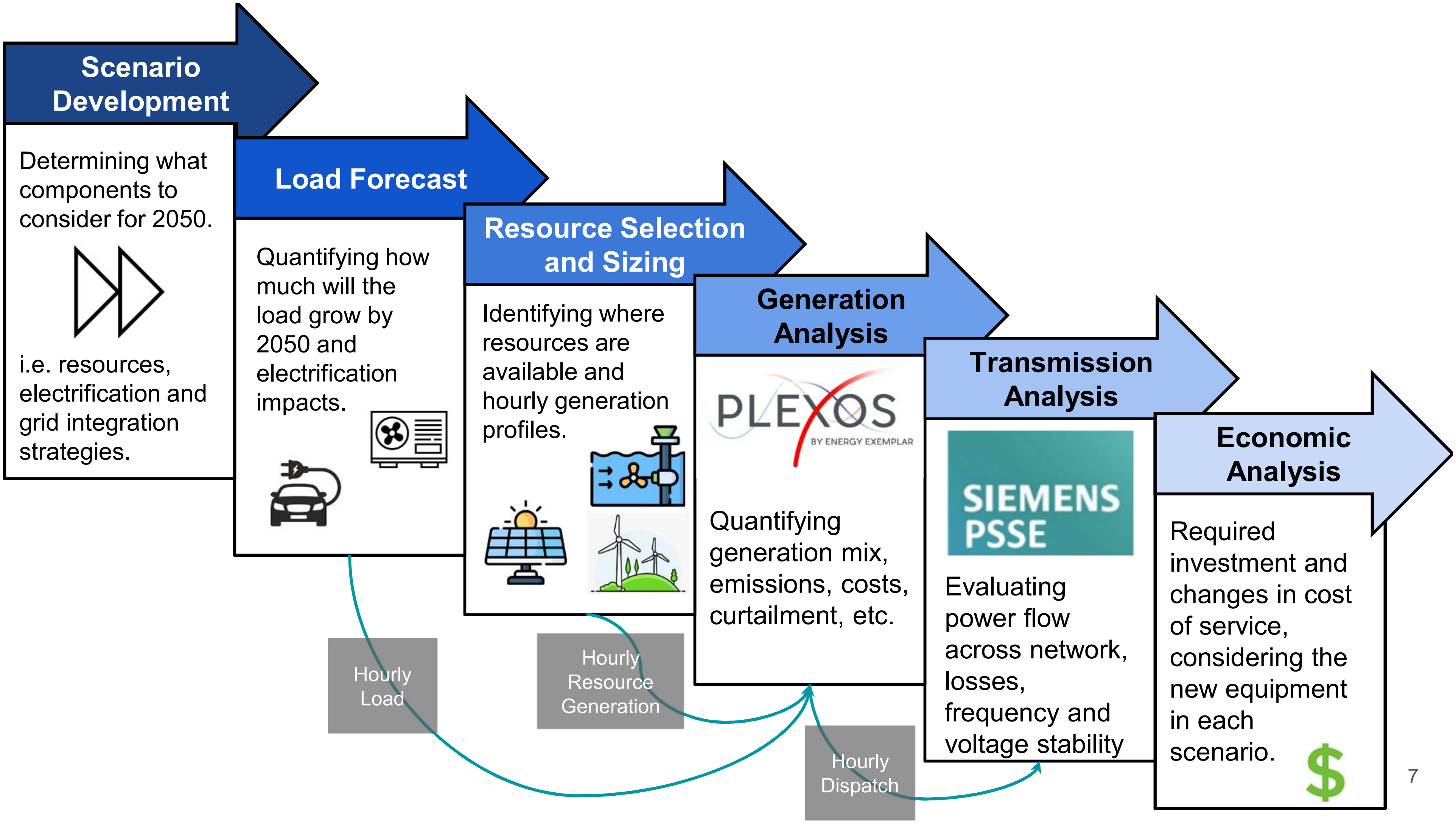
Railbelt Regional Coordination

Funding and Support

Office of Naval Research

State of Alaska FY23 Economic Development Capital Funding

Hawaii Natural Energy Institute



Scenario Development

Determining what components to consider for 2050.

i.e. resources, electrification and grid integration strategies.

Load Forecast

Quantifying how much will the load grow by 2050 and electrification impacts.

Resource Selection and Sizing

Identifying where resources are available and hourly generation profiles.

Generation Analysis

Quantifying generation mix, emissions, costs, curtailment, etc.

Transmission Analysis

Evaluating power flow across network, losses, frequency and voltage stability

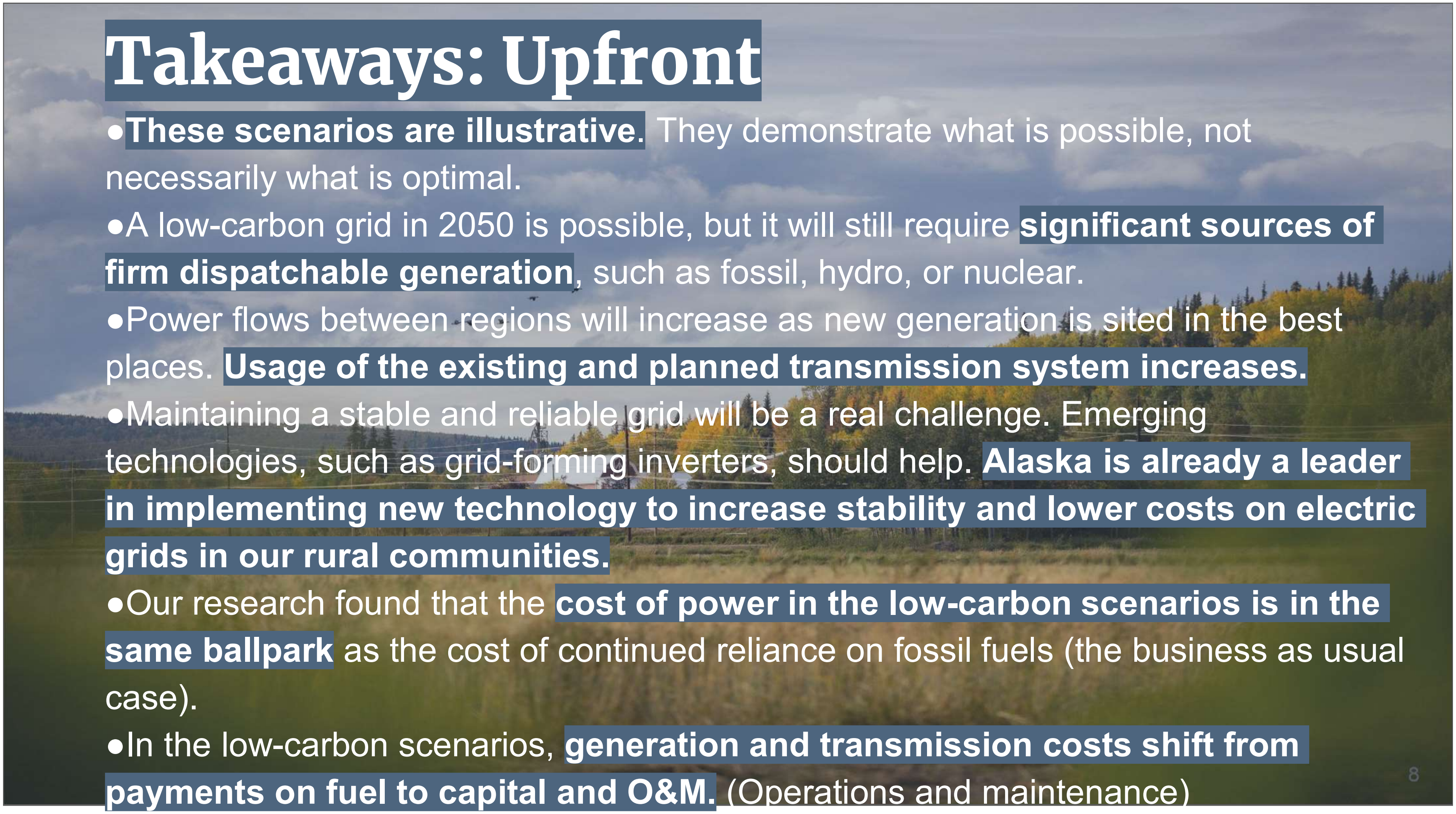
Economic Analysis

Required investment and changes in cost of service, considering the new equipment in each scenario.

Hourly Load

Hourly Resource Generation

Hourly Dispatch



Takeaways: Upfront

- **These scenarios are illustrative.** They demonstrate what is possible, not necessarily what is optimal.
- A low-carbon grid in 2050 is possible, but it will still require **significant sources of firm dispatchable generation**, such as fossil, hydro, or nuclear.
- Power flows between regions will increase as new generation is sited in the best places. **Usage of the existing and planned transmission system increases.**
- Maintaining a stable and reliable grid will be a real challenge. Emerging technologies, such as grid-forming inverters, should help. **Alaska is already a leader in implementing new technology to increase stability and lower costs on electric grids in our rural communities.**
- Our research found that the **cost of power in the low-carbon scenarios is in the same ballpark** as the cost of continued reliance on fossil fuels (the business as usual case).
- In the low-carbon scenarios, **generation and transmission costs shift from payments on fuel to capital and O&M.** (Operations and maintenance)

- Scenario Development
  - Load Forecast
  - Resource Selection and Sizing
  - Generation Analysis
  - Transmission Analysis
  - Economic Analysis
  - Lessons from Iceland

Scenarios

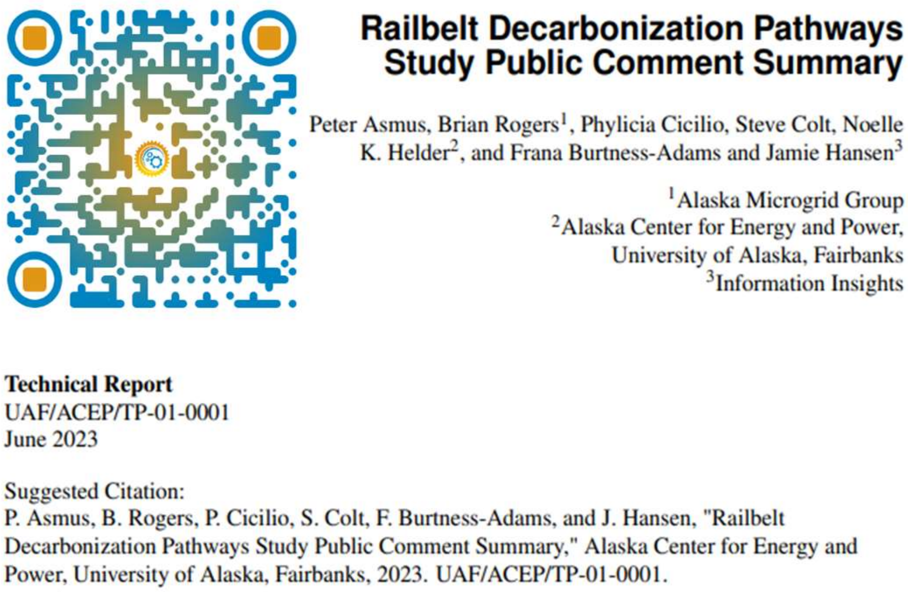
1	Business as Usual	Represents a future system with projected load growth, including from electric vehicles and heat pumps, projected residential solar installations, and announced generator additions and retirements. This scenario serves as a reference point for subsequent scenarios.
2	Wind/Solar/Hydro	This scenario considers significant additions of wind and solar resources, and a large investment in new hydro resources, namely the Susitna Watana Hydro Project. The load growth and residential solar installations are the same as the BAU.
3	Wind/Solar/Tidal	This scenario considers significant additions of wind and solar resources, a large investment in tidal resources in the Cook Inlet. The load growth and residential solar installations are the same as the BAU.
4	Wind/Solar/Nuclear	This scenario considers significant additions of wind and solar, and a large investment in nuclear energy resources in two locations, one in the central region in Beluga, AK and the other in the northern region in Healy, AK. The load growth and residential solar installations are the same as the BAU.

These scenarios are illustrative. We explored what is possible. We know that there are many ways that our scenarios are not optimal. We make no recommendations.

The focus of our research is on the implications to stability and system cost of energy sources in a clean energy standard.

We are not analyzing or proposing a renewable portfolio standard.

Scenario development was driven by public interest.



Railbelt Decarbonization Pathways Study Public Comment Summary

Peter Asmus, Brian Rogers[1], Phylicia Cicilio, Steve Colt, Noelle K. Helder[2], and Frana Burtness-Adams and Jamie Hansen[3]

[1]Alaska Microgrid Group
[2]Alaska Center for Energy and Power, University of Alaska, Fairbanks
[3]Information Insights

Technical Report
UAF/ACEP/TP-01-0001
June 2023

Suggested Citation:
P. Asmus, B. Rogers, P. Cicilio, S. Colt, F. Burtness-Adams, and J. Hansen, "Railbelt Decarbonization Pathways Study Public Comment Summary," Alaska Center for Energy and Power, University of Alaska, Fairbanks, 2023. UAF/ACEP/TP-01-0001.

“The ACEP team, in collaboration with Information Insights, sought input from ratepayers, residents, organizations, and individuals on the study scenarios that could lead to decarbonization of the Alaska Railbelt electric grid. Answers were used to help improve ACEP’s [Railbelt] study.

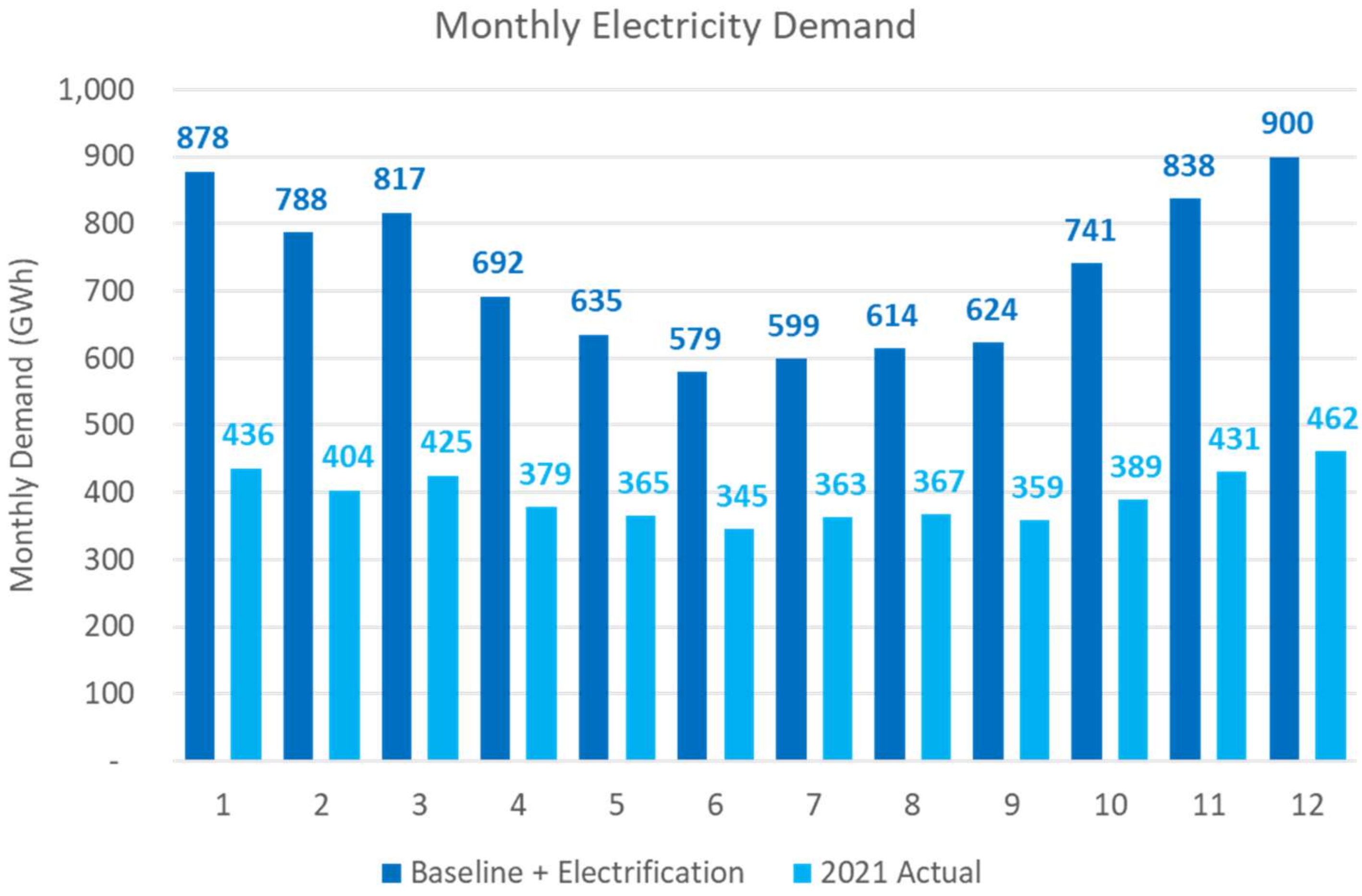
…

The survey was distributed to an outreach list of environmental and conservation nonprofits and organizations, railbelt utilities and their ratepayers, state railbelt energy entities, commercial and independent power producers, ACEP staff and newsletter, telecommunications organizations, solar and other renewable energy service firms, oil, gas, and mining industry entities, tribal and Alaska Native associations, governments, corporations, economic development entities, unions, municipal governments, energy group members, and individuals who expressed interest in being kept in the loop about the study.

…

Contacts totaled approximately 275 and multiple rounds of emails and phone calls were made from October 27 to November 13, 2022. A total of 64 public comment surveys were completed.”

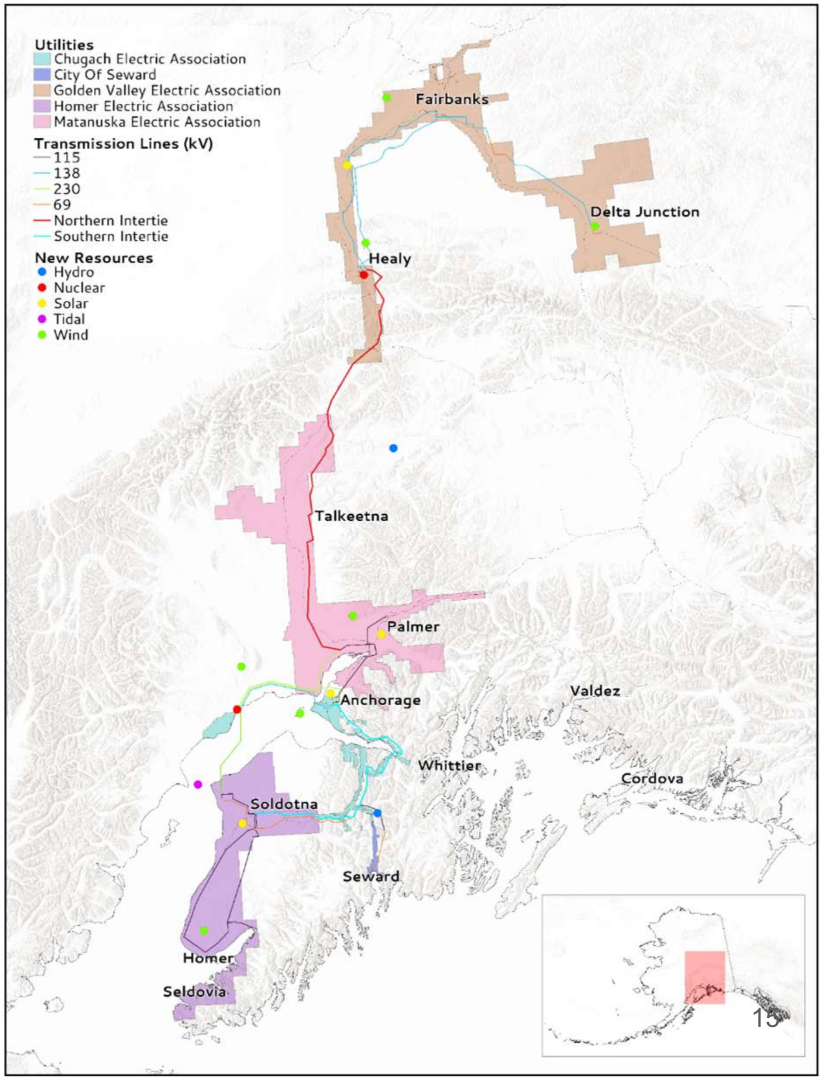
- Scenario Development
- Load Forecast
- Resource Selection and Sizing
- Generation Analysis
- Transmission Analysis
- Economic Analysis
- Lessons from Iceland


Monthly Electricity Demand
Monthly Demand (GWh)
1,000
900
800
700
600
500
400
300
200
100
-
878
788
817
692
635
579
599
614
624
741
838
900
436
404
425
379
365
345
363
367
359
389
431
462
1
2
3
4
5
6
7
8
9
10
11
12
Baseline + Electrification
2021 Actual

- Scenario Development
- Load Forecast
- **Resource Selection and Sizing**
- Generation Analysis
- Transmission Analysis
- Economic Analysis
- Lessons from Iceland

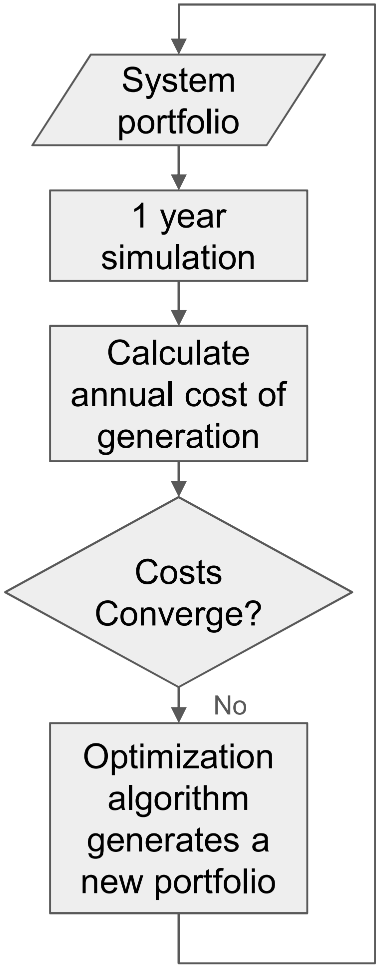
Resource selection

Resource Type	Project
Hydro	Susitna-Watana, Grant Lake, Bradley Lake, Eklutna Lake, Cooper Lake
Wind	Delta Wind, Eva Creek, Fire Island, Homer, Houston, Little Mount Susitna, Shovel Creek
Solar	Fairbanks, Houston, Nenana, Point Mackenzie, Sterling, Willow
Residential Solar	Northern, Central, Southern
Tidal	Cook Inlet
Nuclear	Healy, Beluga



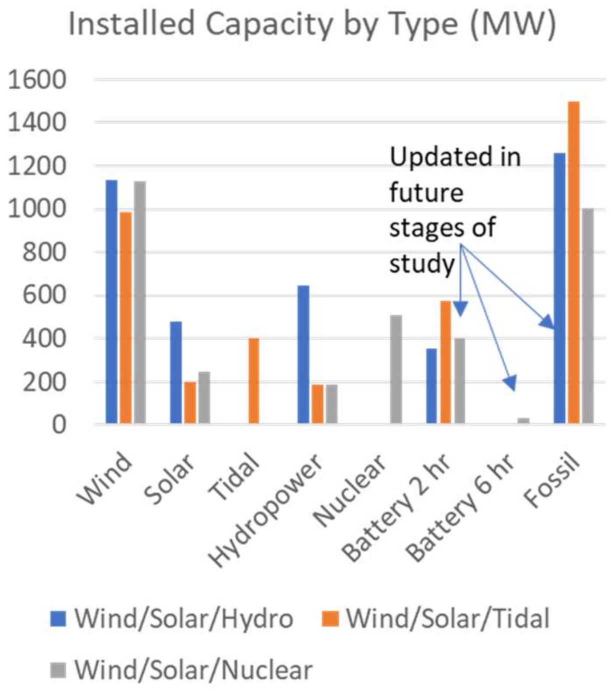
Resource sizing method

- What size to build each project?
- Predetermined project sizes for each scenario
    - Hydro, tidal, and transmission
- Size remaining projects based on cost
    - Wind, solar, battery, nuclear, and fossil fuel
    - Iterate until converge on lowest cost portfolio
- Only partial optimizations
    - Not all projects were sized based on cost
    - Stability costs were calculated at a later stage



Resource sizing results

- Generation from wind and solar was cheapest
  - Curtailment costs limited their installed capacity
  - Additional stability costs were identified in the Transmission Analysis
- Firm sources of power were needed
  - Hydro, nuclear, fossil fuel, and batteries
- Nuclear was not competitive with LNG
  - W/S/Nuclear scenario assumed no LNG imports
  - Hydro and tidal competitiveness was not investigated
- Cost projections are uncertain
  - Especially for nuclear and tidal
  - Sensitivity analyses were run



- Scenario Development
- Load Forecast
- Resource Selection and Sizing
- **Generation Analysis**
- Transmission Analysis
- Economic Analysis
- Lessons from Iceland

Generation Analysis

Simulate **grid operations** across the Railbelt across **all hours of the year,** considering changing load, wind and solar availability, reliability needs, and operating constraints.

- How are resources scheduled (dispatched) to meet load in a least cost manner?
- How can grid operators manage variability and uncertainty of wind and solar generation?
- How should batteries be scheduled to charge, discharge, and provide reliability reserves?
- How do transmission flows change across different weather conditions and load levels?
- Which generators are displaced by new renewables and what are are the fuel cost savings?

Power system operations methods

Inputs → Modeling & Simulation → Outputs & Results

Inputs

Detailed plant and system details

- Load profiles
- Wind and solar profiles
- Hydro water budgets
- Gas, coal, and oil plant characteristics (efficiency, cycling constraints, etc.)
- Operating reserve requirements
- Transmission constraints

Modeling & Simulation

PLEXOS
BY ENERGY EXEMPLAR

Production cost simulation

Least cost, security-constrained, unit commitment, dispatch, and resource scheduling across all 8760 hours of the year

Utilizes third-party, industry recognized optimization software

Outputs & Results

Operations and Economics

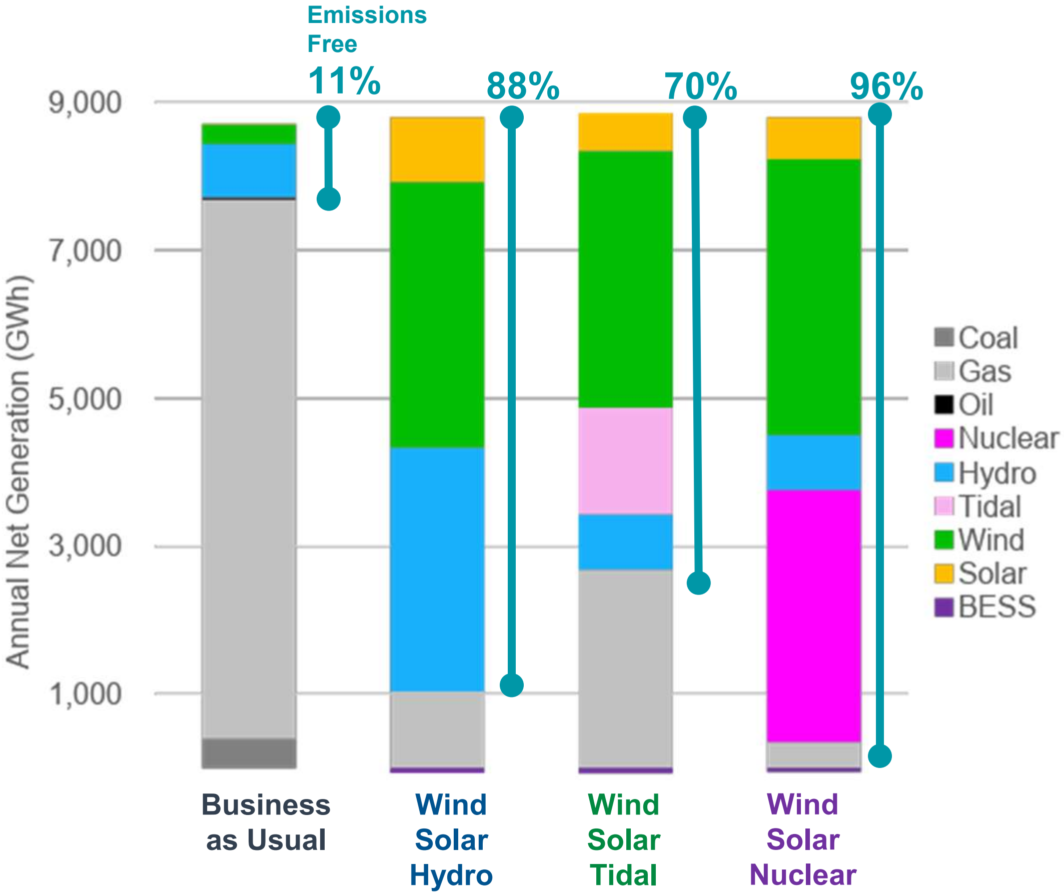
- Plant operations and starts
  → Stability analysis
- Fuel consumption and cost
  → Economic analysis step
- Emissions

Resource Portfolios and Annual Generation

Installed Capacity by Portfolio (MW)

	BAU	Wind Solar Hydro	Wind Solar Tidal	Wind Solar Nuclear
Fossil	2,090	1,330	1,740	1,330
Nuclear				540
Solar	180	710	430	470
Tidal			400	
Wind	80	1,100	1,000	1,130
Battery	220	650	580	540
Total	**2,570**	**3,790**	**4,150**	**4,010**

*rounded to the nearest 10 MW



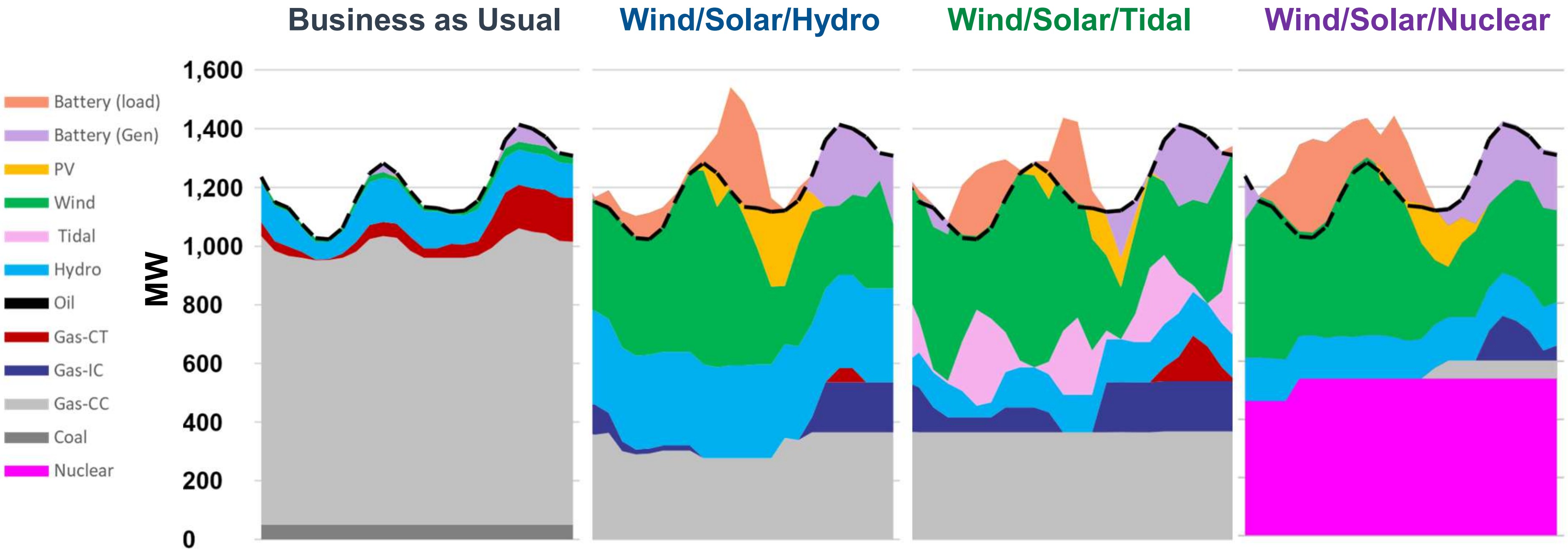
Curtailment stays below 10% across all portfolios

Representative Daily Generation & Operations

"Typical" Winter Day

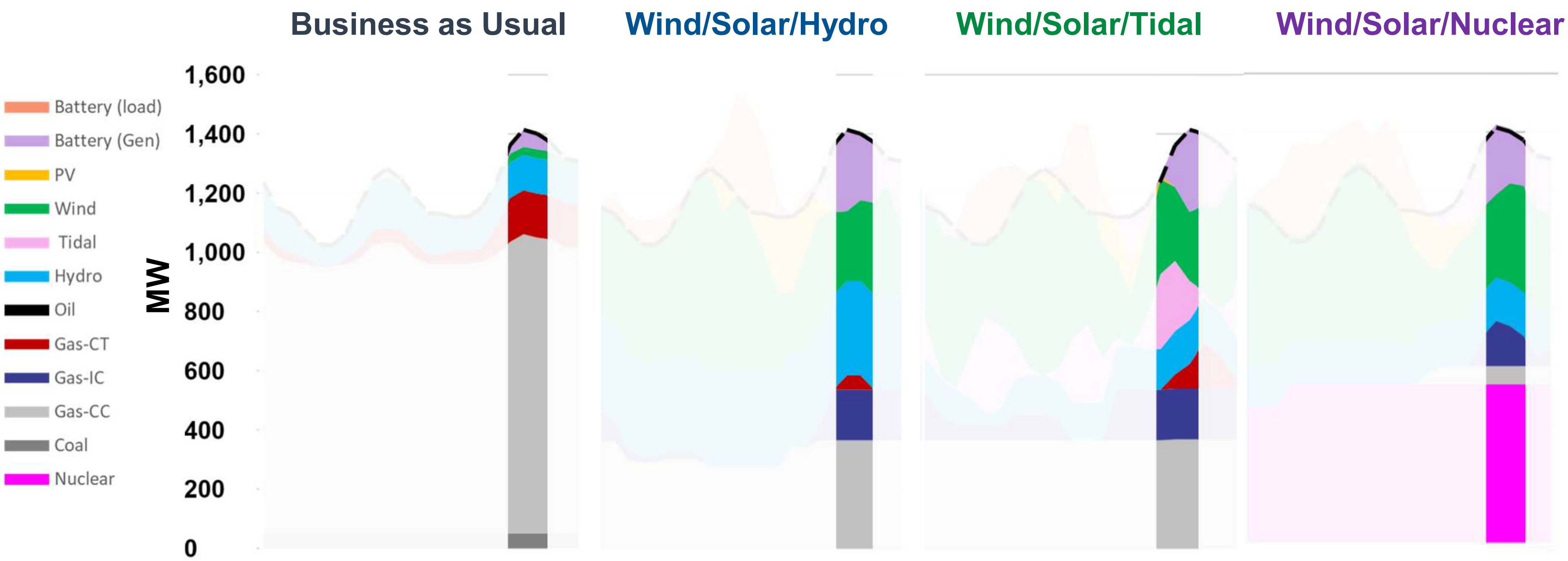
System operations will change considerably in high wind, solar, decarbonized portfolios

… but variability can be managed and reliability can be maintained



Challenging Conditions are evaluated further for stability

We screened through thousands of hours of operations across the year to evaluate transmission reliability and stability in more detail (more on that soon)



Business as Usual

Wind/Solar/Hydro

Wind/Solar/Tidal

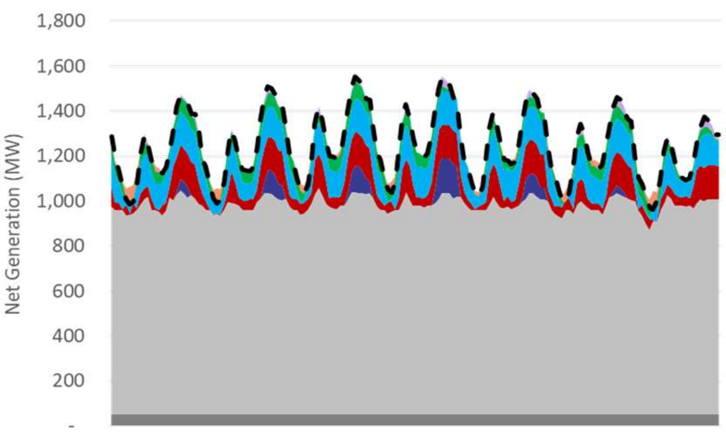
Wind/Solar/Nuclear

These "dispatch conditions" evaluated further in transmission analysis

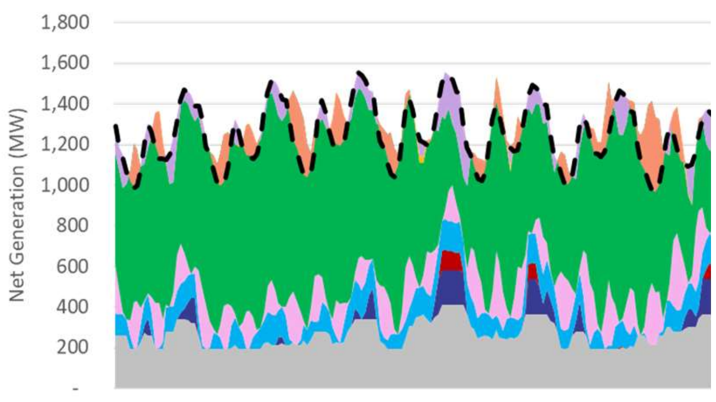
This process was repeated across the entire year

Highest Renewable Week, December

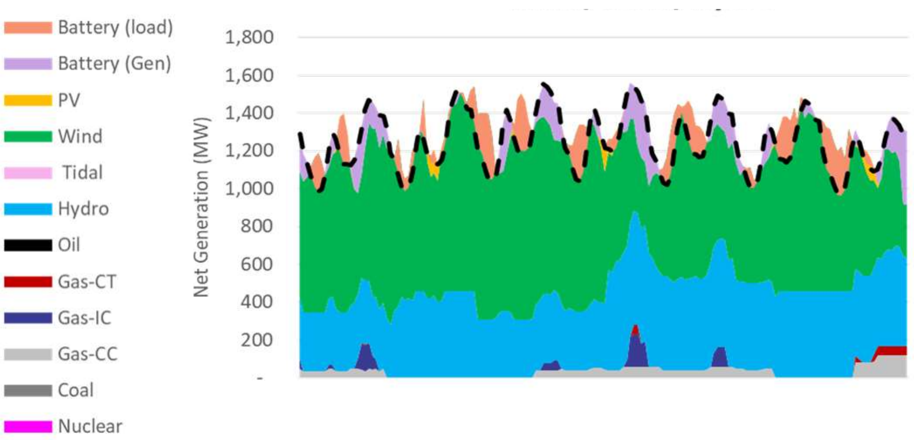
Business as Usual



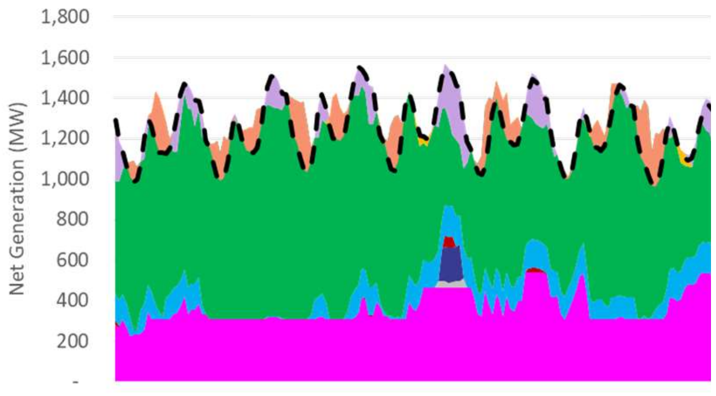
Wind/Solar/Tidal



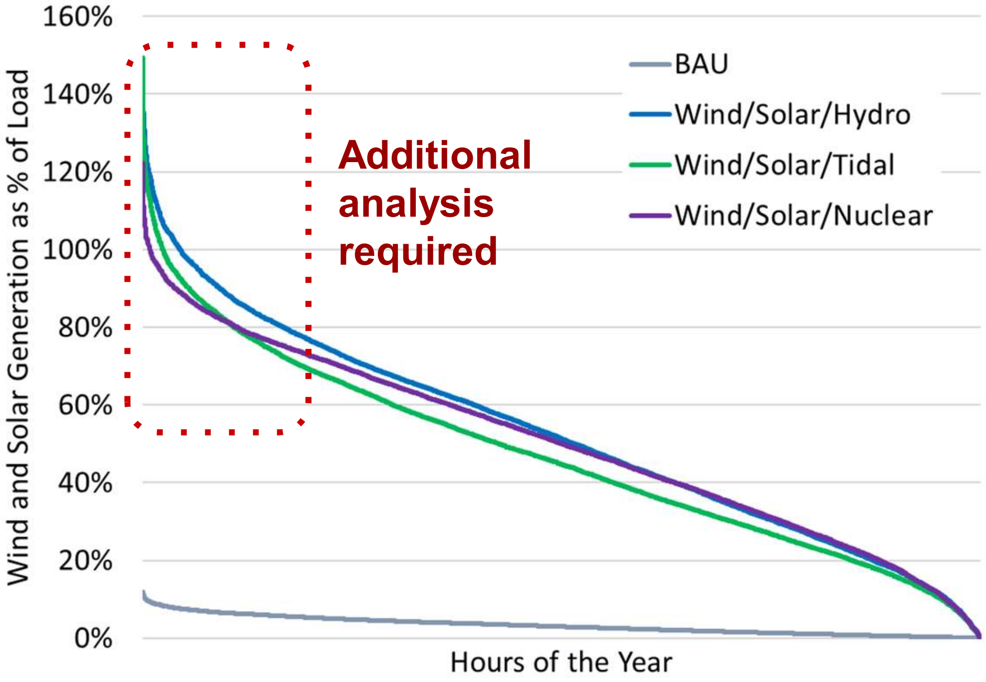
Wind/Solar/Hydro



Wind/Solar/Nuclear



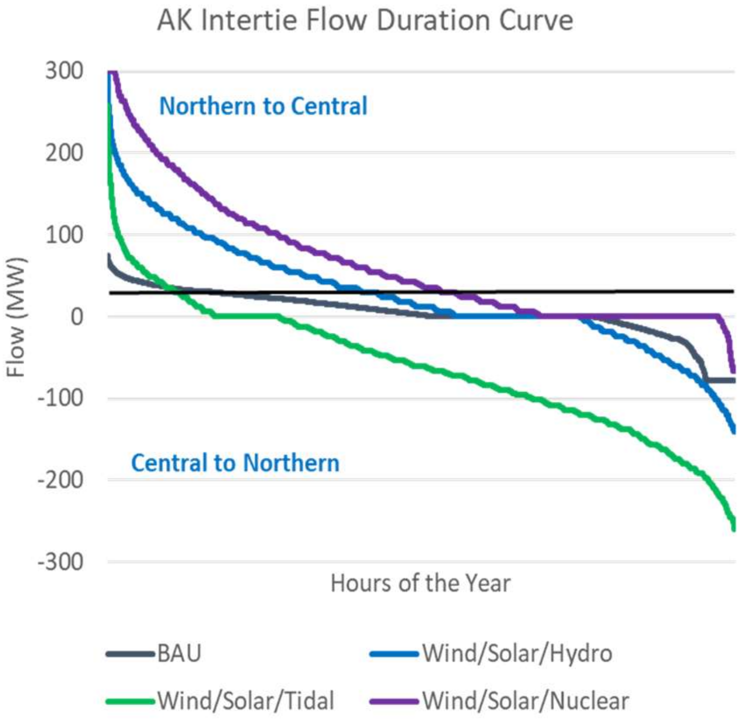
Timing of wind and solar generation will vary significantly across the year

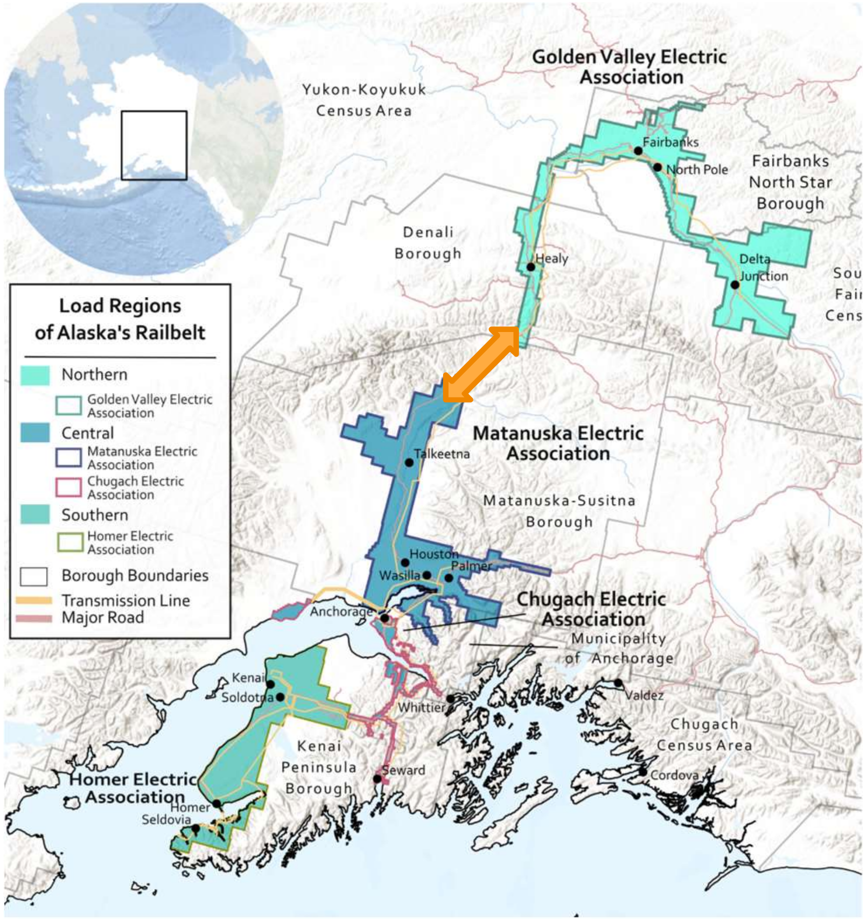


- A portfolio with 50% wind and solar will see periods exceeding 100% of total load (due to battery charging)
- Inverter-based resources (IBRs) like wind, solar, and batteries have different controls and interactions with the grid
- Periods of high penetration (see chart) must be evaluated in further detail for transmission reliability.

The *location* of generation will also change

and transmission network utilization increases across all scenarios





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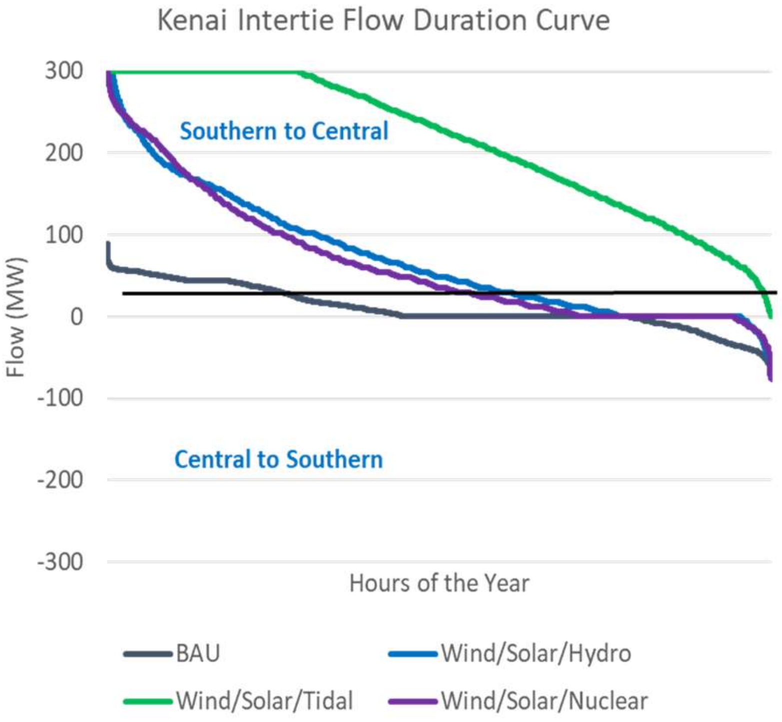

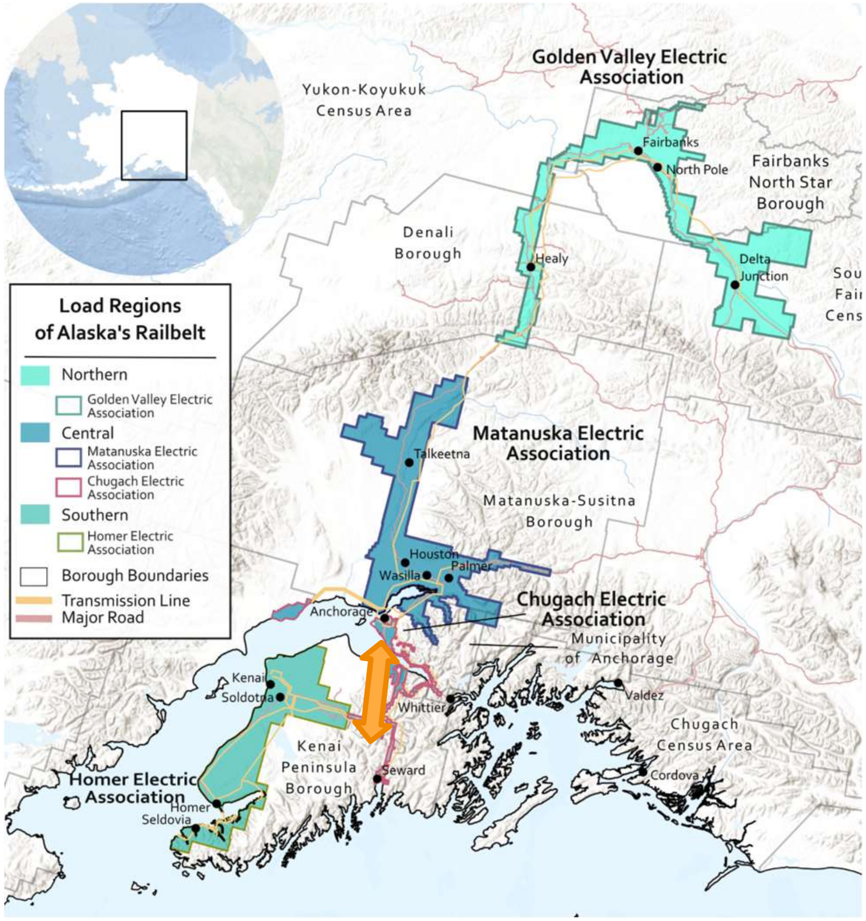

- Scenario Development
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Matt's Notes on Slide Applicability
Chugach Meeting (~20 mins + Q&A):
- I'd skip (or go super quick) until case selection
- Skip the slide on PSSE
- Include the last slides on models, weak grids, risk metrics

Public Library Meeting (15 mins + Q&A):
- Bulk of the deck (exclude the extra for Chugach)

State Legislature Meeting (5-10 mins)
- Bulk of the deck
  - skip/go fast for: case selection (5), Steady-State Analysis (6), Dynamics Initial Results (7);
  - exclude the extra for Chugach

Transmission Analysis

Alaska Railbelt Presentations, Jan 18 & 19, 2024

What is Analyzed?

Steady State Analysis

Can the grid sustain operations in all credible grid conditions?

- Thermal → look for overloading of lines
- Voltage → ensure enough voltage support

Dynamic Analysis

Can the grid recover from the "shock" of a sudden disturbance?

- Frequency Stability
- Voltage Stability

Analyses consider a defined set of grid disturbances and acceptance criteria, per Grid Planning Documents AKTPL-001, AKTPL-002

Appendix K:

Alaska Standard AKTPL-002-0

System Performance Following Loss of
a Single BES Element and Likely
Subsequent Contingencies

Transmission analysis is performed on "snapshots" in time – Stability must be satisfied at every moment

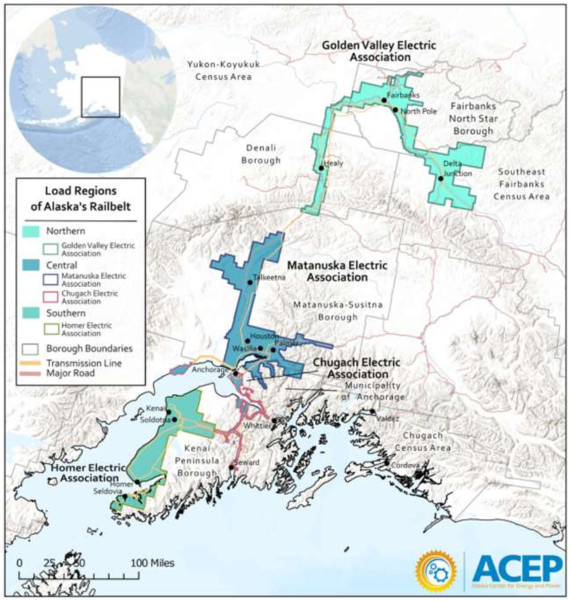
What are the Challenges?

Steady-State

- New resources + retirements = different flow patterns
- Different flow patterns → different needs/locations for voltage support

Dynamics

- Sudden loss of a power plant → loss of power and voltage support must be quickly recovered
- Sudden loss of a tie line → power and voltage support must be quickly reallocated
- Successful recovery is a matter of **sufficiency** & **timeliness** of response from the remaining resource



This is true for all grids, but the Railbelt is especially challenged because of the small size, isolated nature, and grid separation that occurs

Resource Technologies

Synchronous Machines (SM) (i.e., Fossil, Nuclear, Hydro)

- Frequency Response: Inertia (fast/immediate) + Governor Droop (slower, seconds)
- Voltage Support: Grid strength (fast/immediate) + Voltage Regulation (slower, seconds)

→ Behavior dominated by physical geometries

Inverter-Based Resources (IBR) (i.e., Wind, Solar, Battery, Tidal)

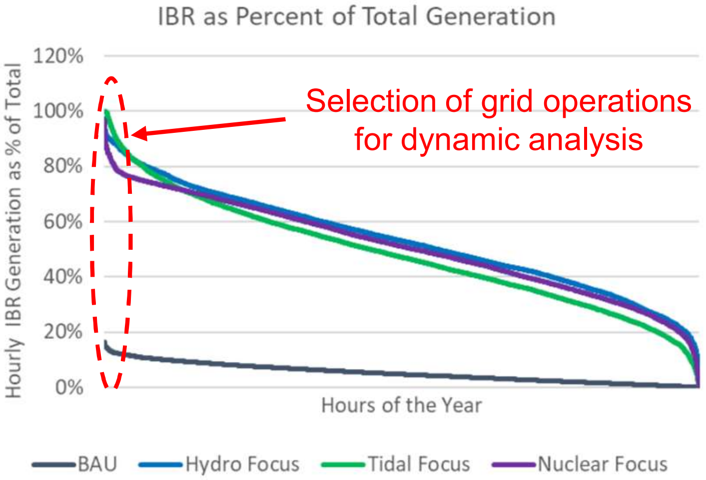
- Frequency Response: Droop (slower, seconds)
- Voltage Support: Voltage Regulation (slower, half a second – seconds)

→ Behavior dominated by firmware code

Case Selection

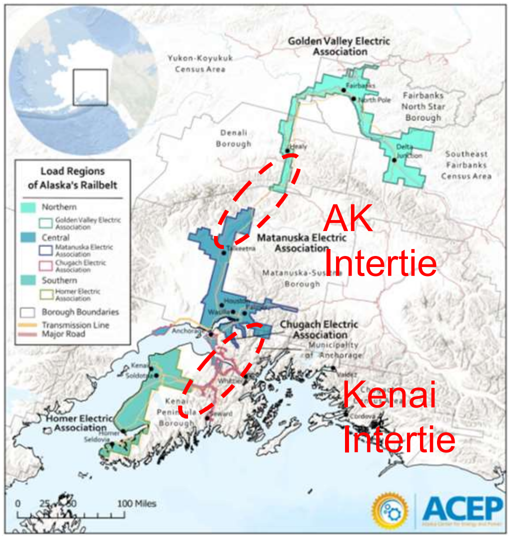
The study analyzed periods where both:

1. Generation is dominated by IBR



Fewest synchronous machines online (historical providers of stability services)

2. Highest Tie-Line Loading Event



High tie-line loading makes the sudden loss of the line a more severe disturbance

Steady-State Analysis

Violations Identified	Mitigations Applied
Thermal Power transfer limits of existing infrastructure exceeded Why? Increased power flow due to electrification and new resource interconnections	Increased rating by upgrading lines (voltages or replacing conductors) and adding new lines (AC and DC)
Voltage Low voltage violations (<95% nominal voltage) found at many buses (substations) across the system Why? Increased power flows results in more demand for voltage support	Several, made in sequence: • Updated voltage schedule of resources • Adjusted the new HVDC line power flow • Added shunt capacitors • Added BESS projects for voltage support and line loading relief

Dynamics: Initial Results

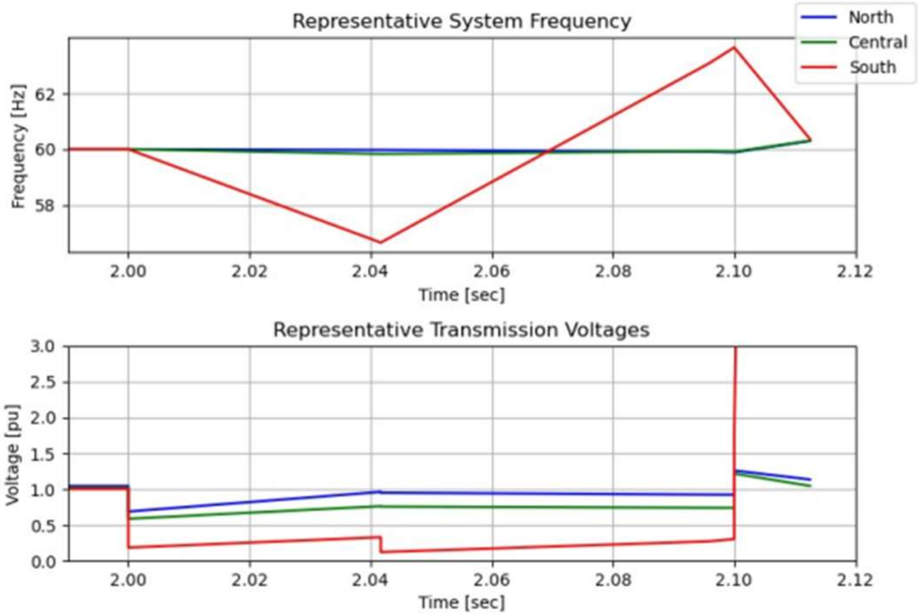
Simulation Setup

- Hydro scenario, loss of the Kenai Intertie
- Typical IBR plant configuration was used (typical of IBR installations today)

Initial Results

- Grid frequency and voltage become out of control at the onset of the disturbance
- There are insufficient reliability services being provided collectively from the remaining resources on the grid
- Critical reliability services: frequency response and voltage support

Mitigations are needed…



Potential Mitigation Approaches

Operational Mitigations

- Force more SM to remain online; not recommended for long-term action; not pursued here

Capital Investment Mitigations

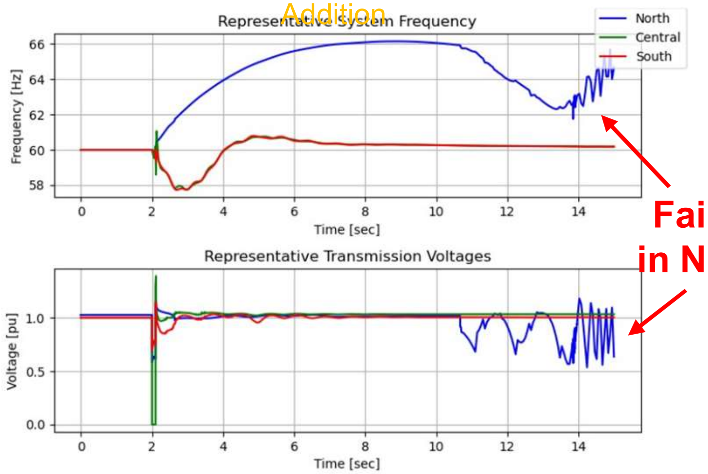
- Synchronous Condensers - a connected synchronous machine that does not produce power or consume fuel
- Inverter Tuning for Performance – adjusting the configuration of IBR for more aggressive responses
- Grid-Forming Inverters (GFM) – an emerging, commercially available inverter technology that can stabilize the grid much as synchronous machines do

These mitigations were applied in this study

Impact of Mitigations

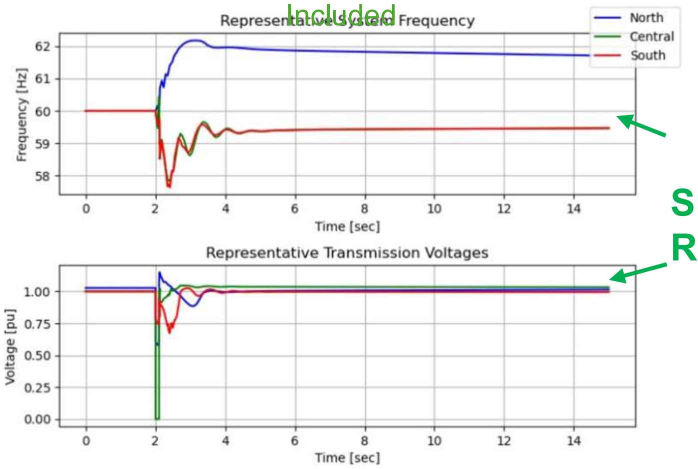
Summary	GFL only	SC addition	GFL tuned	GFM
Stability	System collapsed	Stable except for Hour #7763	Stable	Stable
Synchronous MVA needed	System collapsed	564 - 624 MVA	290 - 494 MVA	No need for synchronous condensers
Worst case underfrequency load sheding	System collapsed	398.7 MW	282.2 MW	255.9 MW

Loss of the AK Intertie for Hour 7763, GFL with SC Addition



Failure in North!

Loss of the AK Intertie for Hour 7763, GFM Included



Stable, Sustained Recovery!

GFM inverter technology is effective in replacing the reliability services from retiring synchronous plants

Emerging Technology: Grid-Forming Inverters

What is it?

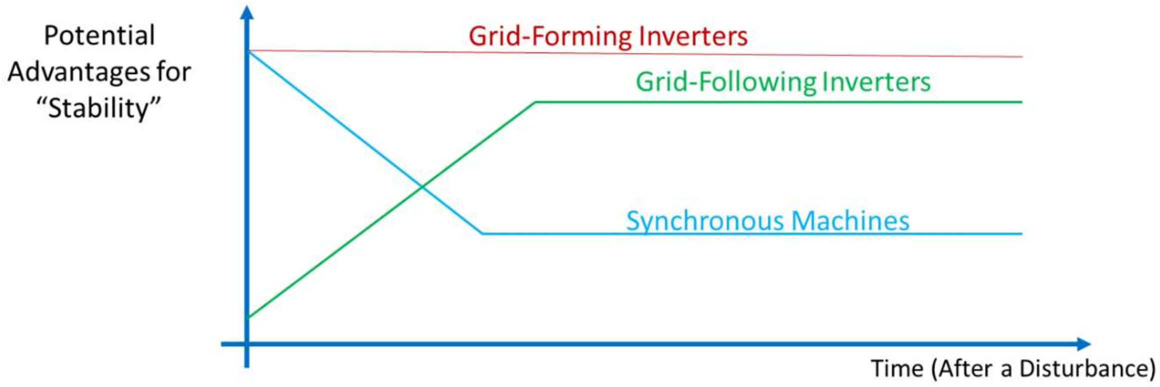
Grid-forming (GFM) technology is largely a controls technology

- BESS: no changes to hardware are needed
- Wind: likely to be controls-only

What does it do?

Attempts to capture the “best of both worlds” from SM and IBR

- Immediate responses of SM (inertia, grid strength) + resilience of synchronization from IBR



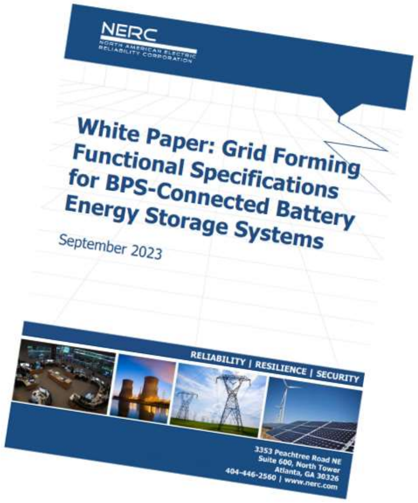
GFM – Industry Experience

Recent Industry GFM Installations (Utility-Scale)

- 2017 St. Eustatius BESS (SMA)
- 2018 Dalrymple BESS, Australia (ABB/Hitachi)
- 2018 Kauai BESS projects (Telsa)
- 2019 Dersalloch Wind, Scottland – (Siemens)
- 2019-2020 IID BESS for Blackstart, California (GE)
- 2022 Wallgrove BESS, Australia (Telsa)
- 2022 Hornsdale BESS, Australia (Tesla)
- Others I've likely missed…

More on the Horizon: HECO Stage 2&3, Australia 8 BESS GFM Projects, NationalGridESO, etc.

North American Electric Reliability Corporation (NERC) Released a White Paper in 2023 recommending GFM for all BESS projects going forward



NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

White Paper: Grid Forming Functional Specifications for BPS-Connected Battery Energy Storage Systems

September 2023

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

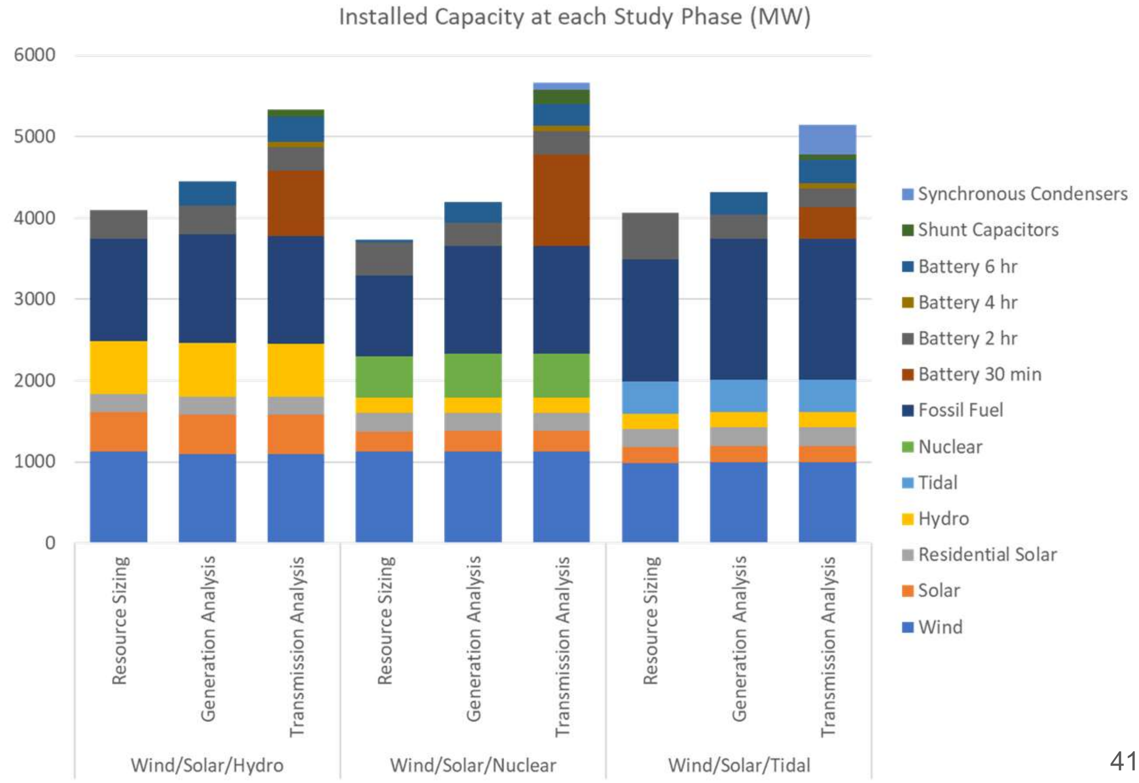
A Note on Analysis Methods & Tools

SIEMENS
PSSE

- Commercially available software (Siemens PSSE)
- Same tools used by Railbelt utilities and numerous others throughout the world
- Many thousands of inputs to the model
  - Grid – Lines, transformers, shunts
  - Resources – generators, DER, loads
- Engineering judgment and special care is needed with inputs, runs, and interpretation of outputs
- It is critical to know and understand the limits of the tools, and a what point different tools are needed

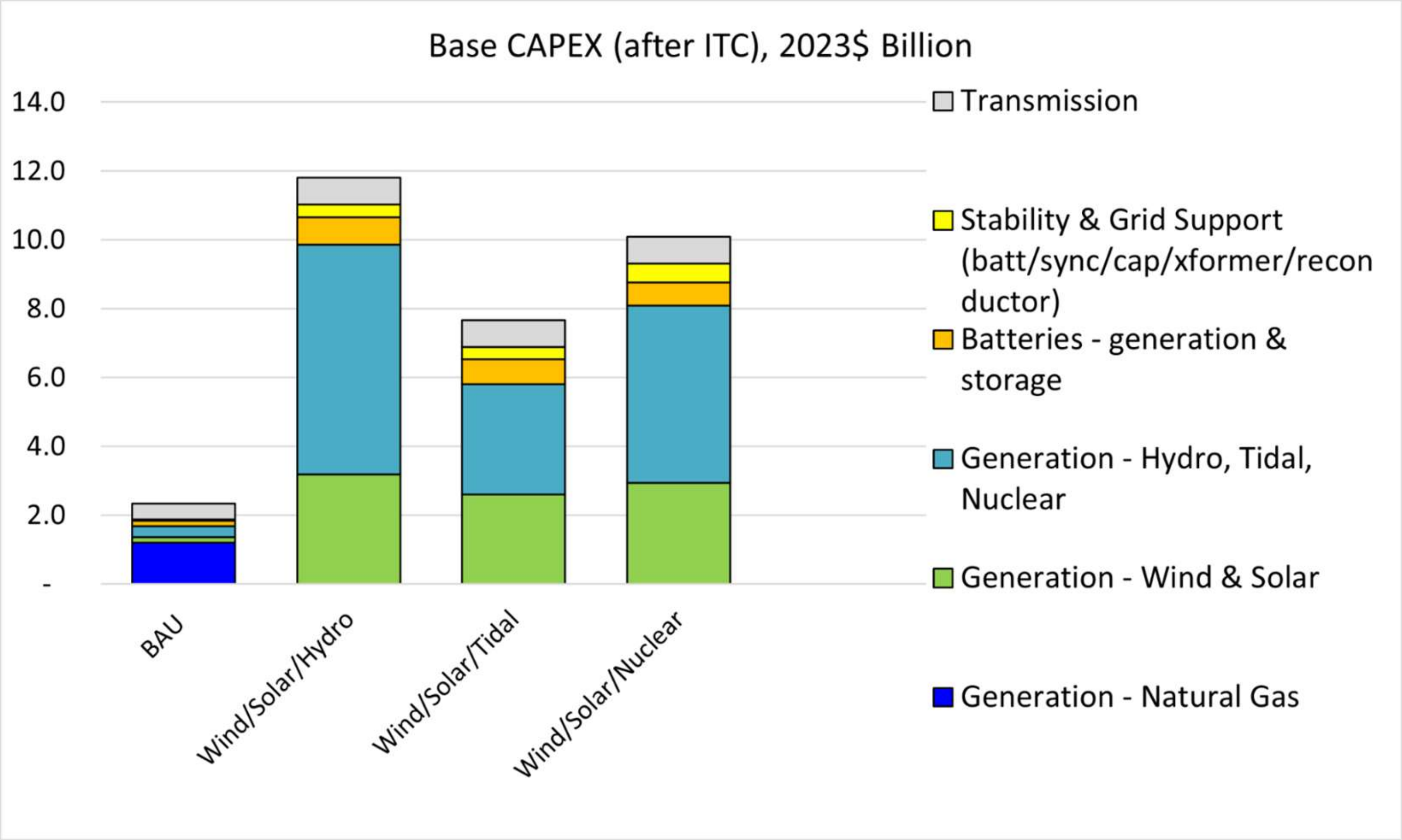
Compare installed capacity at each study phase

- Resource Sizing
  - Initial estimates
- Generation Analysis
  - Fossil fuel and battery capacity increased for capacity reserve margin
- Transmission Analysis
  - Battery, shunt capacitor, and synchronous condensers added for stability
- Significant increase above initial estimates



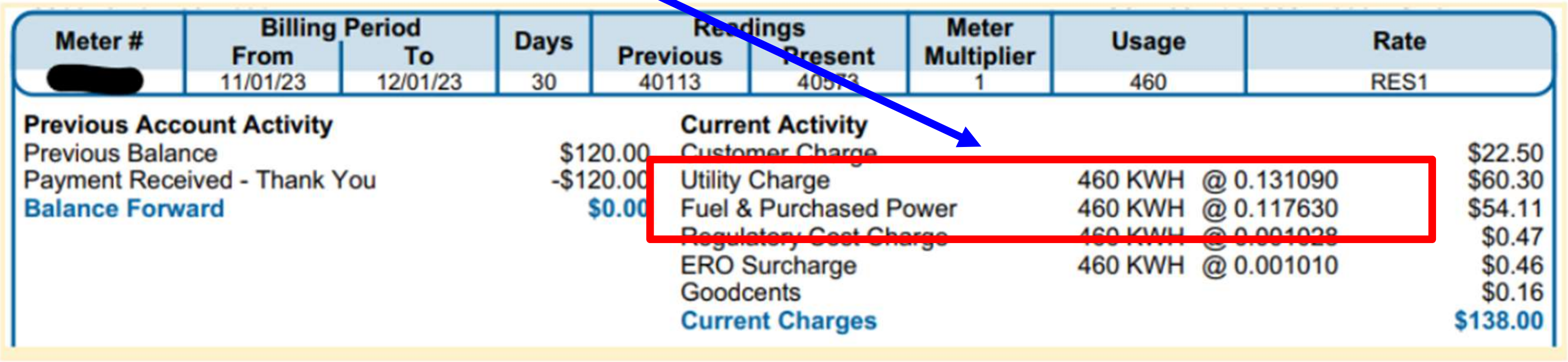
- Scenario Development
- Load Forecast
- Resource Selection and Sizing
- Generation Analysis
- Transmission Analysis
- **Economic Analysis**
- Lessons from Iceland

Required Capital Investment



Generation & Transmission Cost of Service:

- G&T Cost of Service equals:
  Fuel
  + Variable O&M
  + Fixed O&M
  + Annualized Capital Cost of new generation & transmission
  + Margin (a financial cushion)
- On your bill, = ”Fuel & Purchased Power” + *SOME* of “Utility Charge”



Meter #	Billing Period From	Billing Period To	Days	Readings Previous	Readings Present	Meter Multiplier	Usage	Rate
[redacted]	11/01/23	12/01/23	30	40113	40573	1	460	RES1

Previous Account Activity

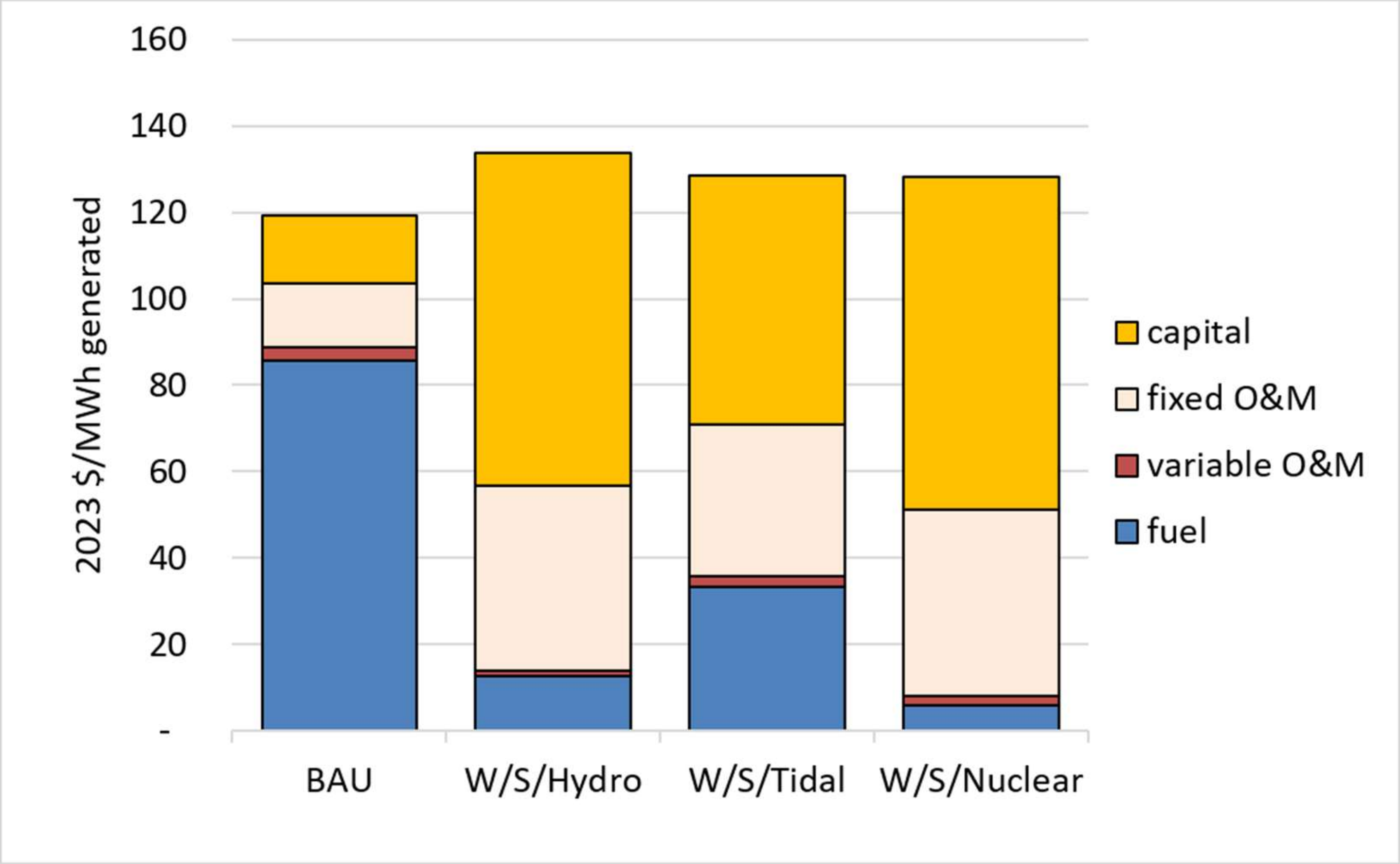
Previous Balance	$120.00
Payment Received - Thank You	-$120.00
Balance Forward	**$0.00**

Current Activity

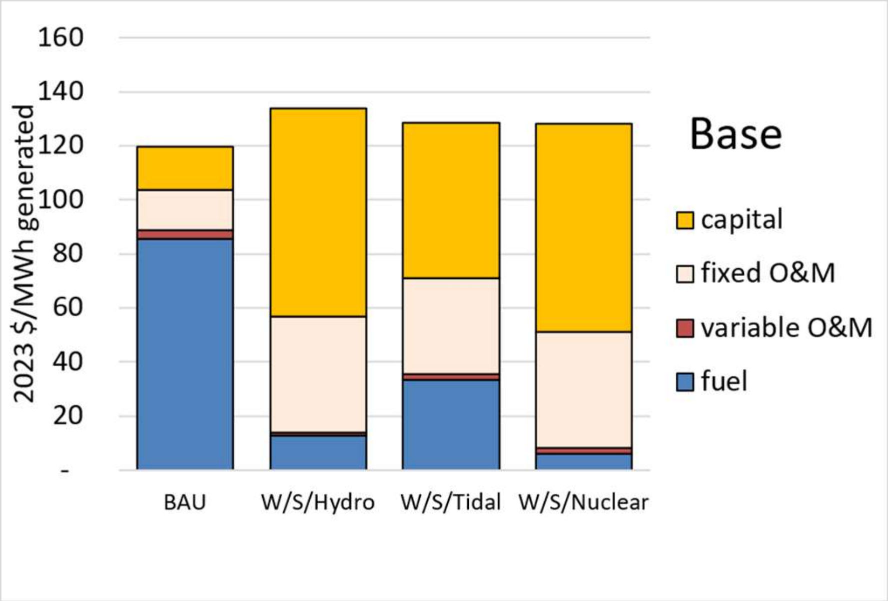
Customer Charge			$22.50
Utility Charge	460 KWH	@ 0.131090	$60.30
Fuel & Purchased Power	460 KWH	@ 0.117630	$54.11
Regulatory Cost Charge	460 KWH	@ 0.001028	$0.47
ERO Surcharge	460 KWH	@ 0.001010	$0.46
Goodcents			$0.16
Current Charges			**$138.00**

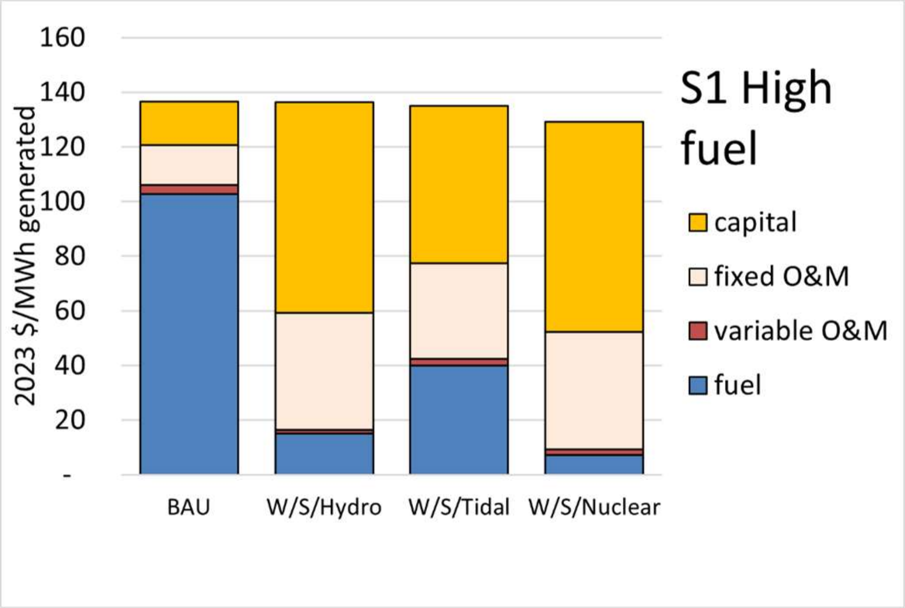
If G&T cost of service goes up by $10/MWh, rates go up by 1 cent per kWh.

Base Case Generation & Transmission Cost of Service



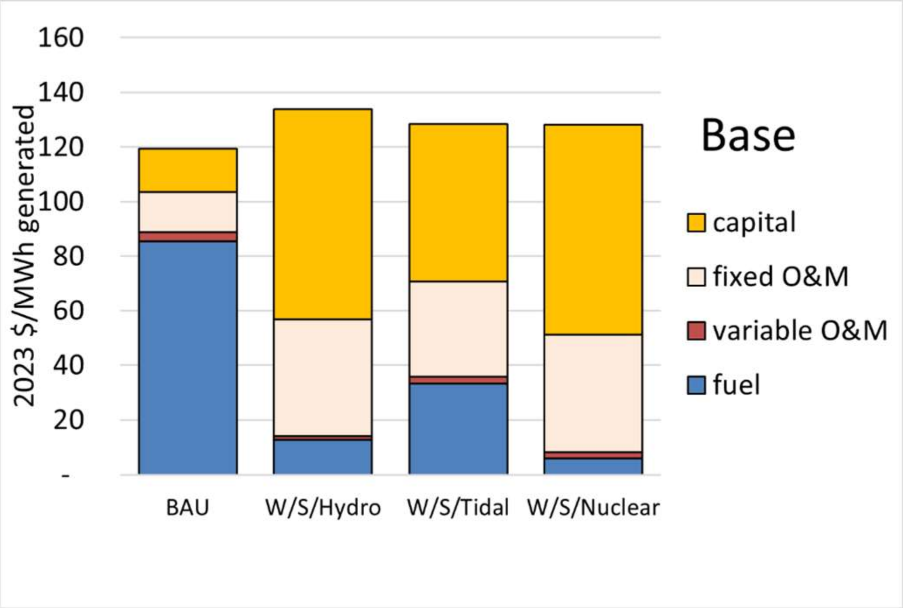
Base vs. S1: High fuel costs

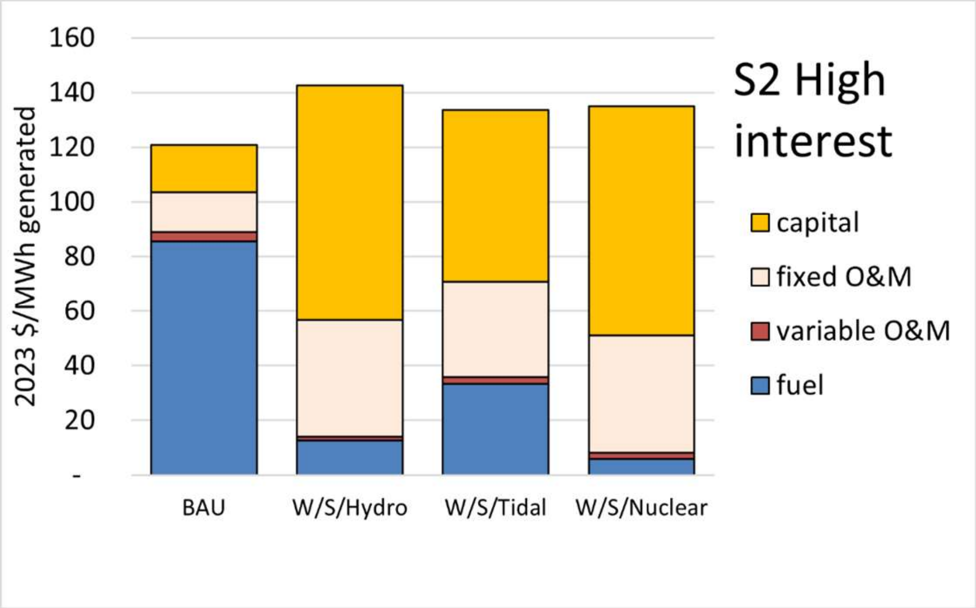




S1: Fuel costs are 20% higher than Base.
Natural gas is increased from $14 to $16.80 per million btu; Oil from $20 to $24; Coal from $4 to $4.80

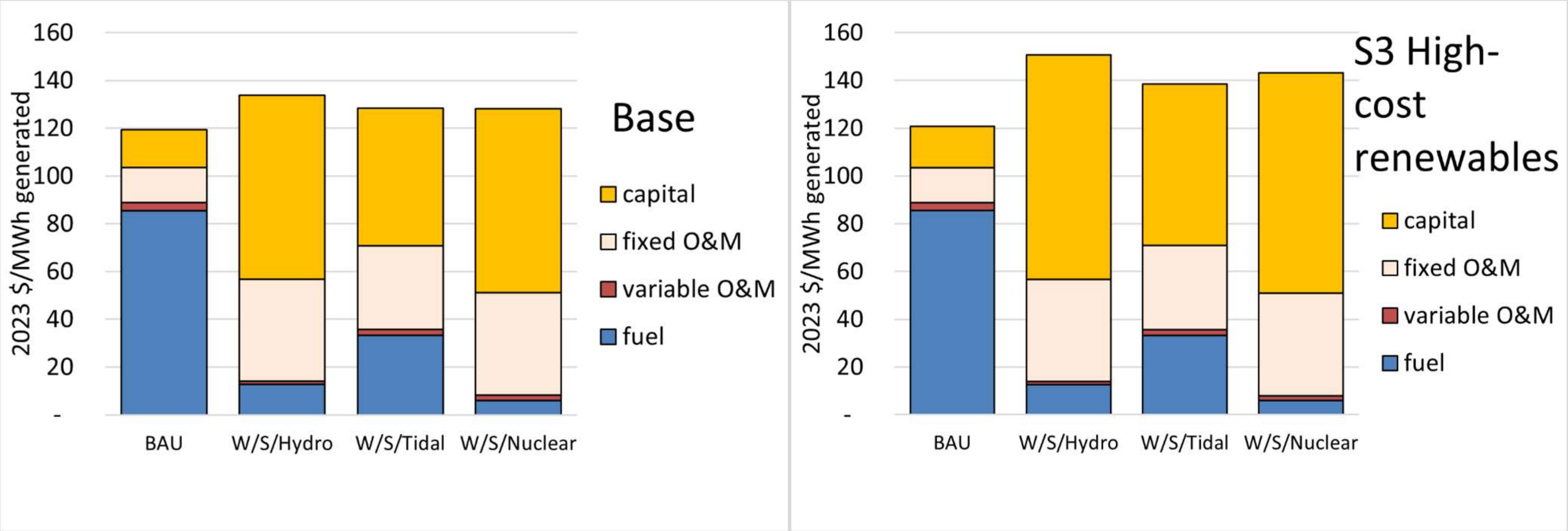
Base vs. S2: High Interest





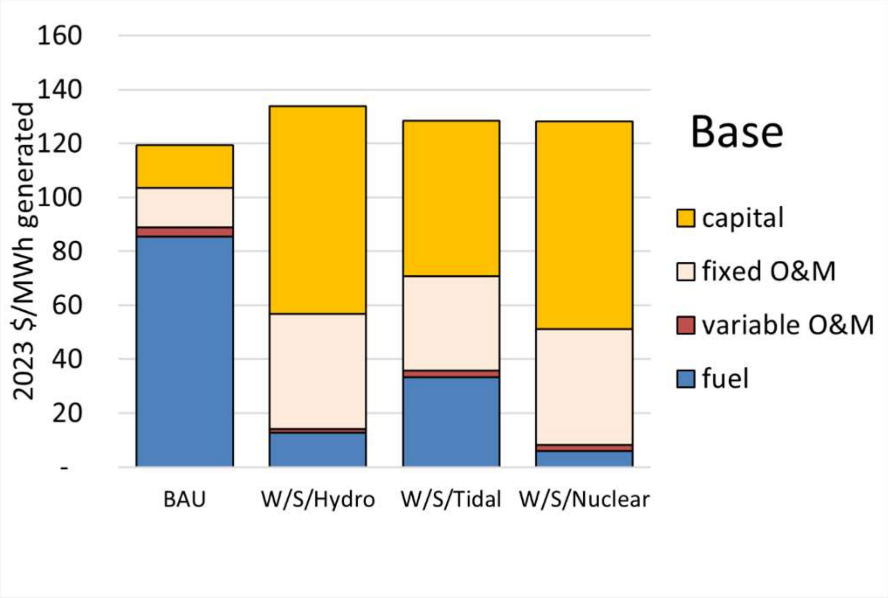
S2: Interest rate is 20% higher than Base; increased from 5% to 6%.

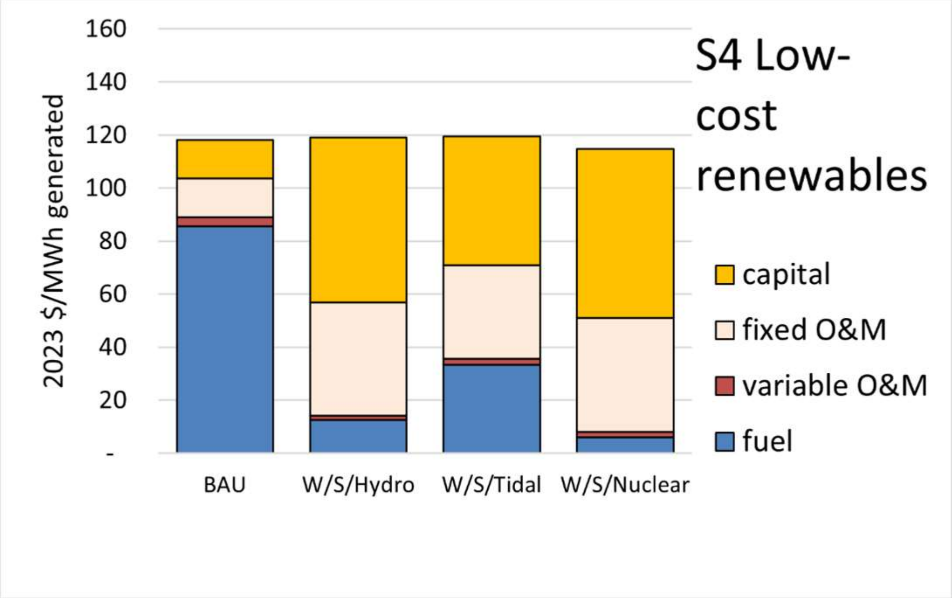
Base vs. S3: High-cost renewables



S3: Capital costs (CAPEX) of Susitna-Watana, Tidal, & Nuclear are 20% higher than Base. Interest rate is 6% vs. 5% in Base.

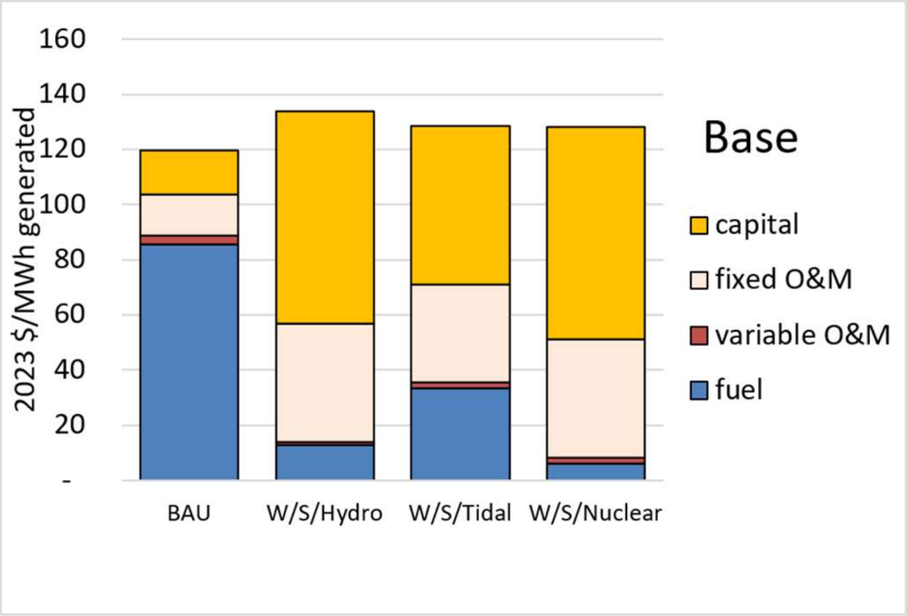
Base vs. S4: Low-cost renewables

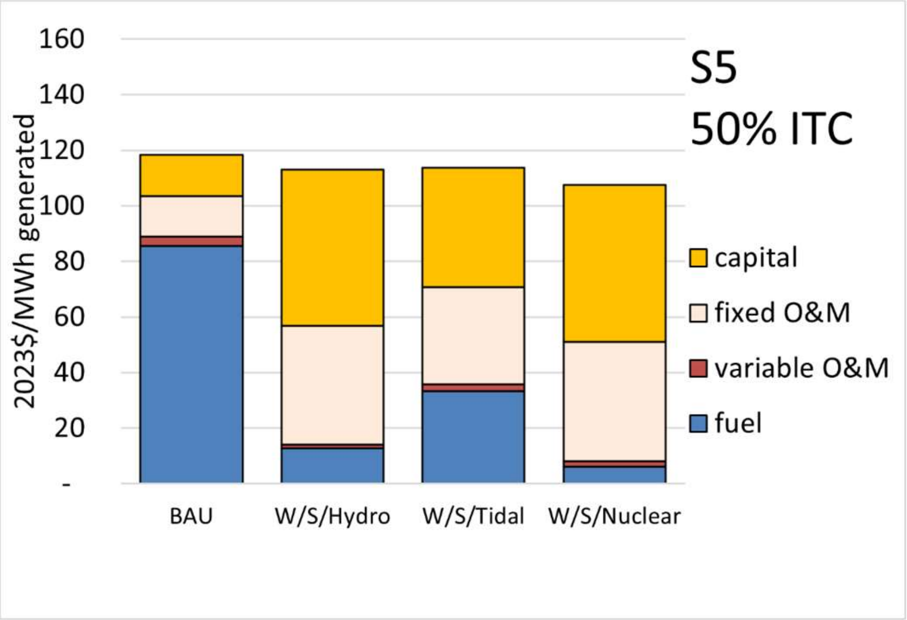




S4: Capital costs (CAPEX) of Susitna-Watana, Tidal, & Nuclear are 20% lower than Base. Interest rate is 4% vs. 5% in Base.

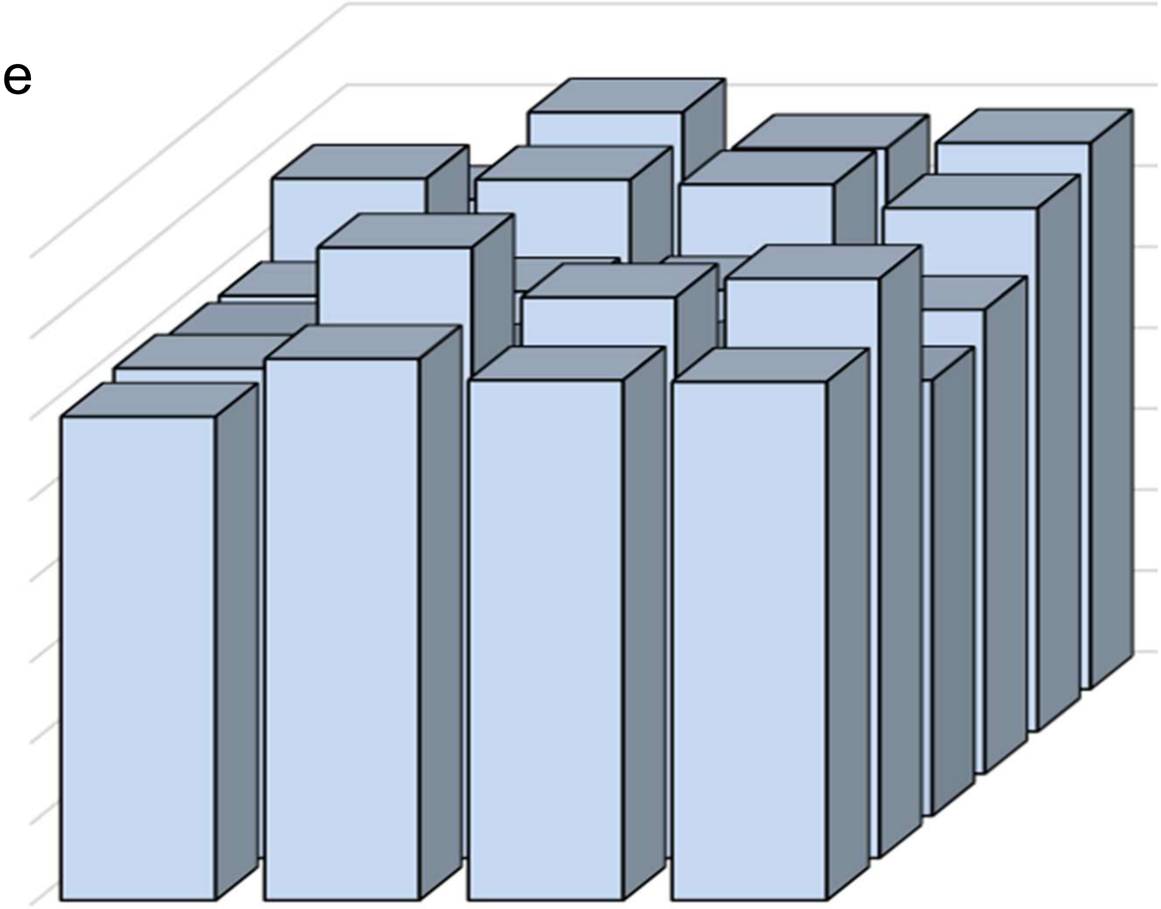
Base vs. S5: 50% ITC

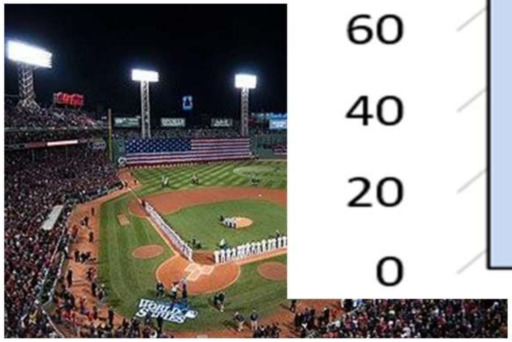




S5: The investment tax credit (ITC) percentage is 50%, vs. 30% in Base.

Costs are all in the
same ballpark





Recap of Sensitivity Cases

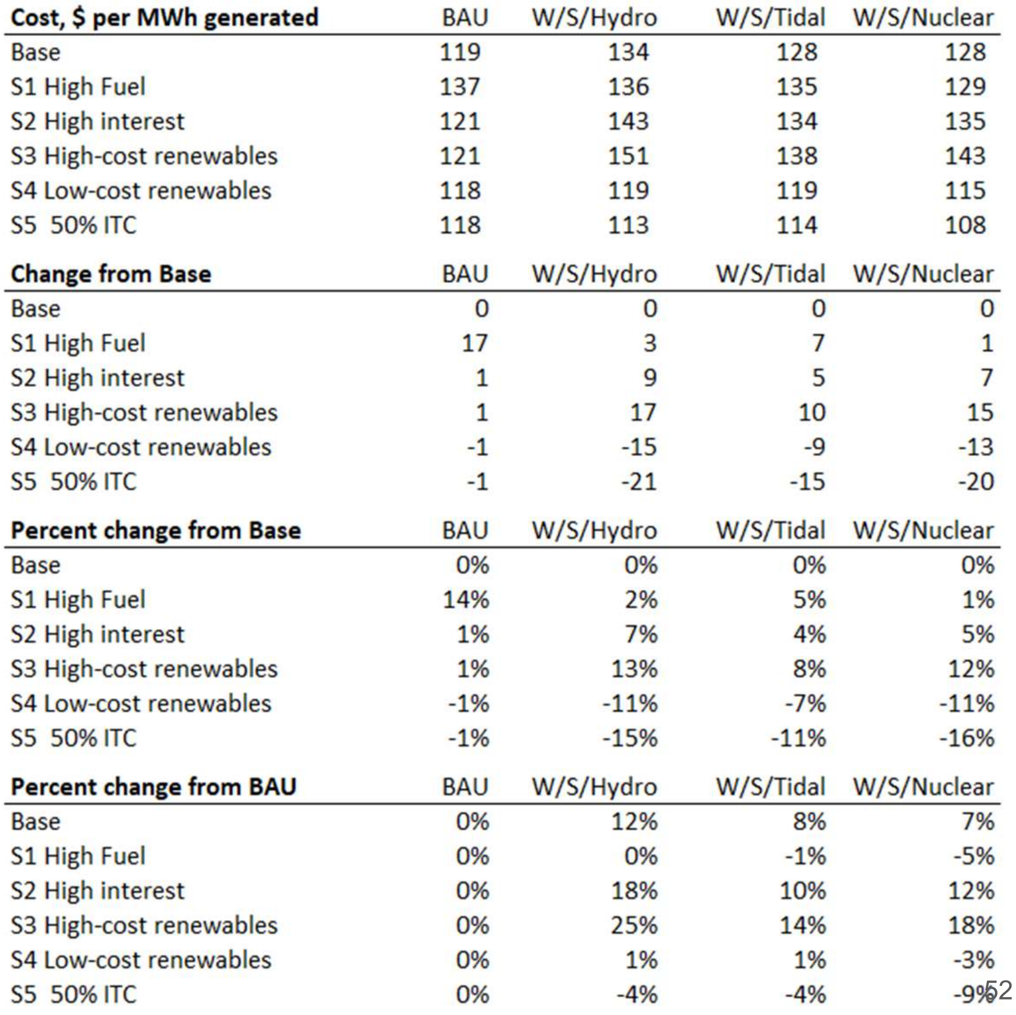
S1 High Fuel:
Fuel costs are 20% higher

S2 High interest:
Debt interest rate is 6% (vs 5%)

S3: High-cost renewables:
Major projects CAPEX is 20% higher, interest rate = 6%

S4: Low-cost renewables:
Major projects CAPEX is 20% lower, interest rate = 4%

S5: 50% ITC:
50% credit vs. 30% in Base



Cost, $ per MWh generated	BAU	W/S/Hydro	W/S/Tidal	W/S/Nuclear
Base	119	134	128	128
S1 High Fuel	137	136	135	129
S2 High interest	121	143	134	135
S3 High-cost renewables	121	151	138	143
S4 Low-cost renewables	118	119	119	115
S5 50% ITC	118	113	114	108

Change from Base	BAU	W/S/Hydro	W/S/Tidal	W/S/Nuclear
Base	0	0	0	0
S1 High Fuel	17	3	7	1
S2 High interest	1	9	5	7
S3 High-cost renewables	1	17	10	15
S4 Low-cost renewables	-1	-15	-9	-13
S5 50% ITC	-1	-21	-15	-20

Percent change from Base	BAU	W/S/Hydro	W/S/Tidal	W/S/Nuclear
Base	0%	0%	0%	0%
S1 High Fuel	14%	2%	5%	1%
S2 High interest	1%	7%	4%	5%
S3 High-cost renewables	1%	13%	8%	12%
S4 Low-cost renewables	-1%	-11%	-7%	-11%
S5 50% ITC	-1%	-15%	-11%	-16%

Percent change from BAU	BAU	W/S/Hydro	W/S/Tidal	W/S/Nuclear
Base	0%	12%	8%	7%
S1 High Fuel	0%	0%	-1%	-5%
S2 High interest	0%	18%	10%	12%
S3 High-cost renewables	0%	25%	14%	18%
S4 Low-cost renewables	0%	1%	1%	-3%
S5 50% ITC	0%	-4%	-4%	-9%

- Scenario Development
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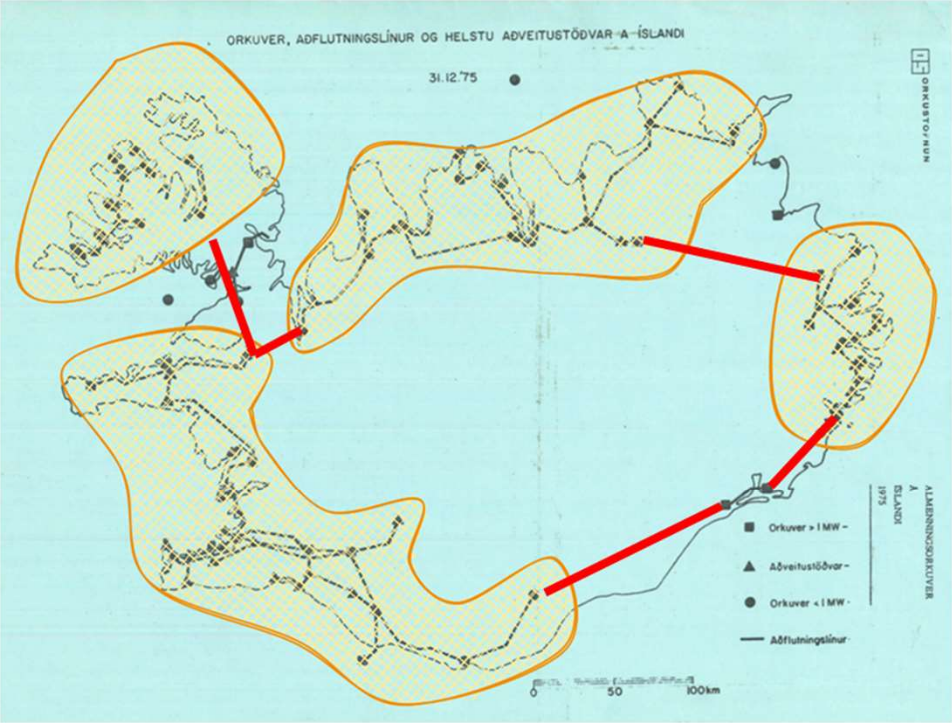
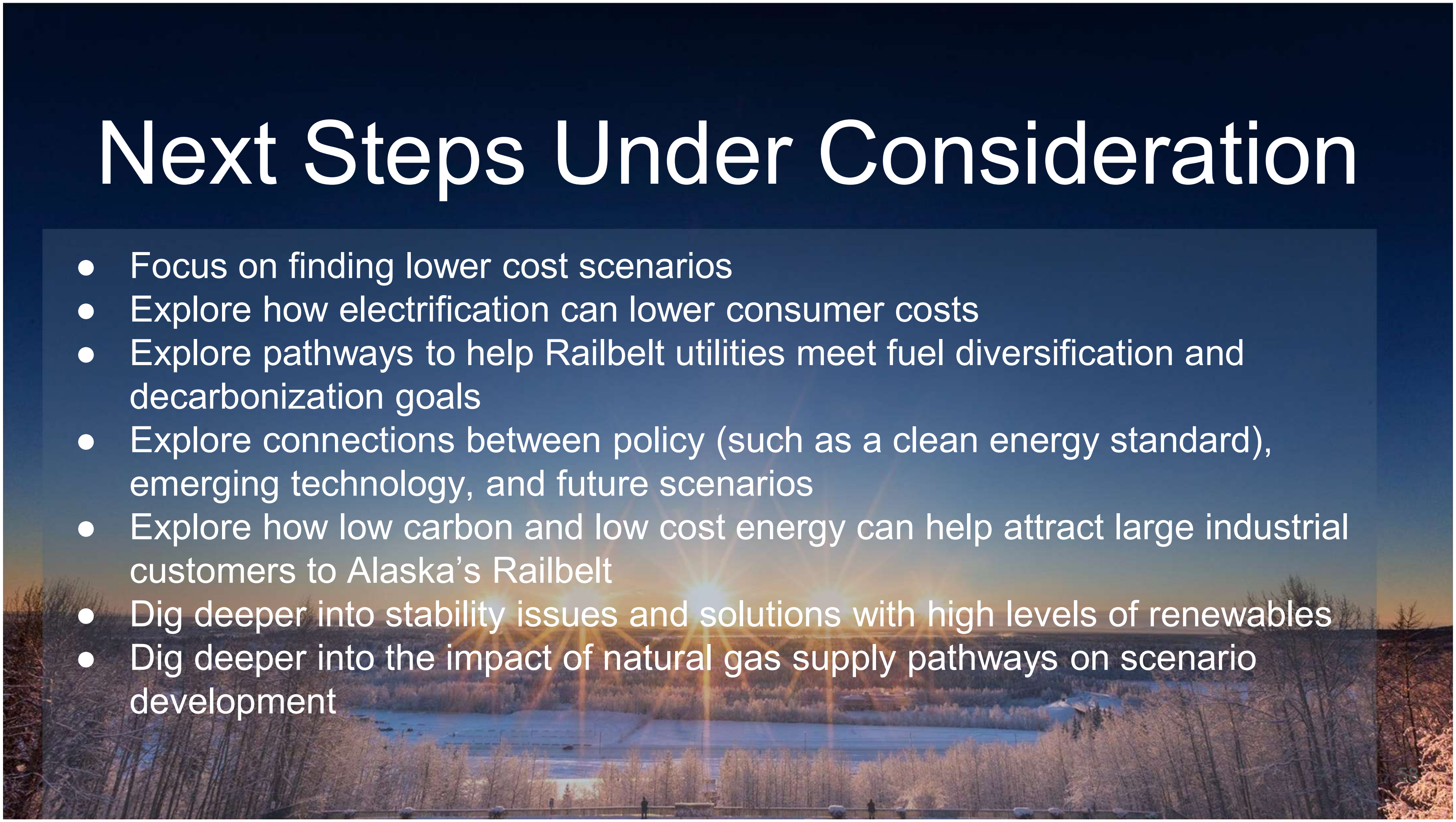
Iceland Loads = 5x Railbelt

	Population	Installed capacity	Annual sales	Length	Per capita sales
	total	[MW]	[GWh]	miles	[MWh/capita]
Railbelt Grid	521,000	2,000	4,400	~1300	~9 MWh/capita
Ring Grid	370,000	2,900	19,100	~2000	~54 MWh/capita

Iceland’s Ring Grid

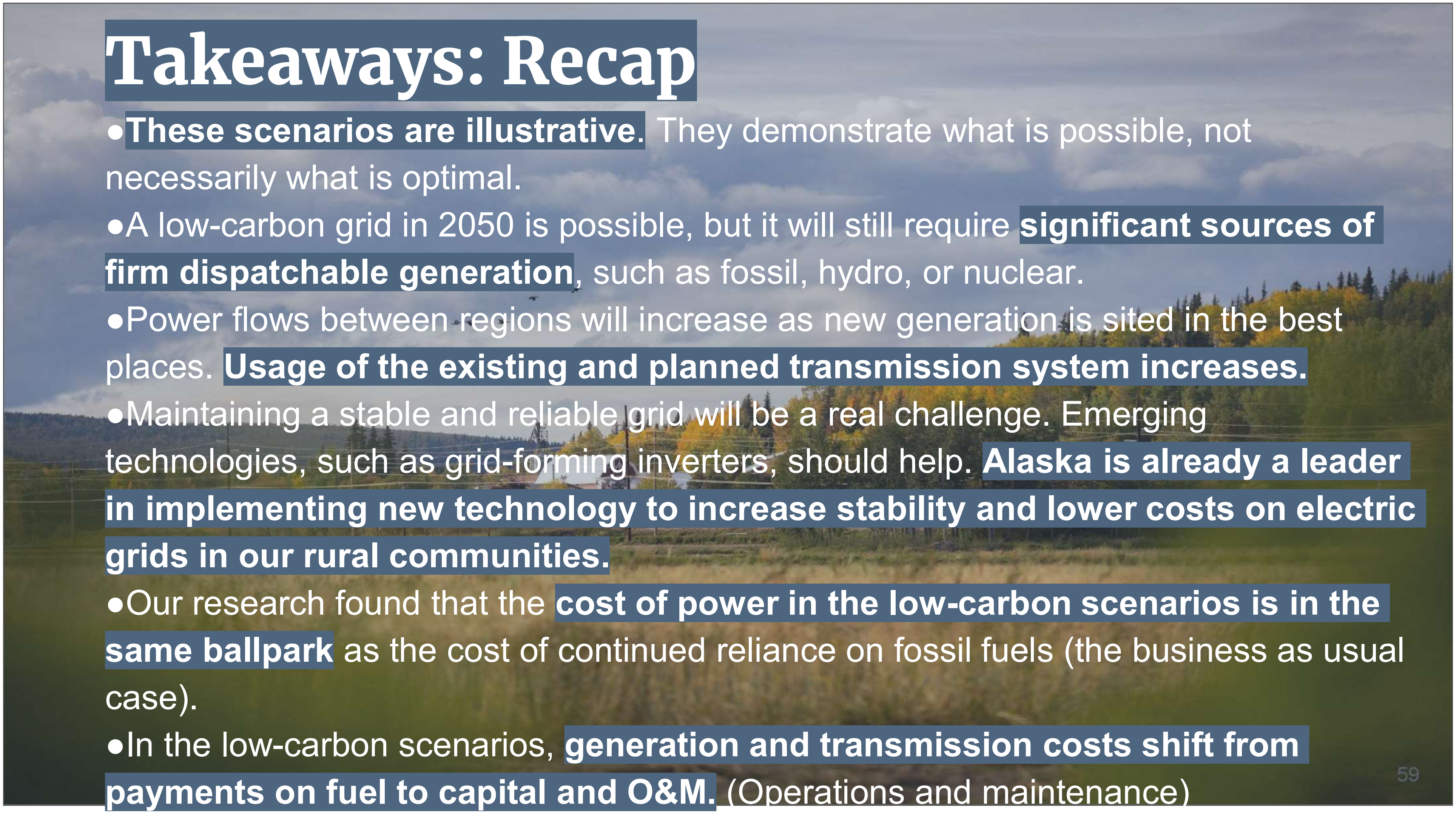


What does this mean?



Next Steps Under Consideration

- Focus on finding lower cost scenarios
- Explore how electrification can lower consumer costs
- Explore pathways to help Railbelt utilities meet fuel diversification and decarbonization goals
- Explore connections between policy (such as a clean energy standard), emerging technology, and future scenarios
- Explore how low carbon and low cost energy can help attract large industrial customers to Alaska’s Railbelt
- Dig deeper into stability issues and solutions with high levels of renewables
- Dig deeper into the impact of natural gas supply pathways on scenario development



Takeaways: Recap

- **These scenarios are illustrative.** They demonstrate what is possible, not necessarily what is optimal.
- A low-carbon grid in 2050 is possible, but it will still require **significant sources of firm dispatchable generation**, such as fossil, hydro, or nuclear.
- Power flows between regions will increase as new generation is sited in the best places. **Usage of the existing and planned transmission system increases.**
- Maintaining a stable and reliable grid will be a real challenge. Emerging technologies, such as grid-forming inverters, should help. **Alaska is already a leader in implementing new technology to increase stability and lower costs on electric grids in our rural communities.**
- Our research found that the **cost of power in the low-carbon scenarios is in the same ballpark** as the cost of continued reliance on fossil fuels (the business as usual case).
- In the low-carbon scenarios, **generation and transmission costs shift from payments on fuel to capital and O&M.** (Operations and maintenance)

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Thank you!

For more information