State of Hawai‘i Decarbonization Strategy Pathways to Net Negative

November 14, 2023 @ 9-11am

Zoom

HAWAI‘I STATE ENERGY OFFICE

Housekeeping & Community Agreements

- A reminder that we will be recording this meeting. The recording will be posted on the HSEO Decarbonization Webpage.
- Please stay muted and raise your hand using the Zoom feature to share comments.
- Time is limited – please hold comments until the end of the presentation. If you have a clarifying question, please use the chat.
- Feel free to come on camera when speaking, otherwise to save bandwidth please keep your camera off.
- **Aloha Spirit Law (HRS §5-7.5)**

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Agenda

- Welcome and Act 238 Overview
- Presentation by National Renewable Energy Lab (NREL)
  - Electric Sector Modeling and Feedback Loop w/ E3 Pathways Model
- Presentation by Energy and Environmental Economics Inc. (E3)
  - Strategies to Decarbonize – Pathways Model Outputs
    - Emissions, Costs, and Next Steps
- Questions and Feedback

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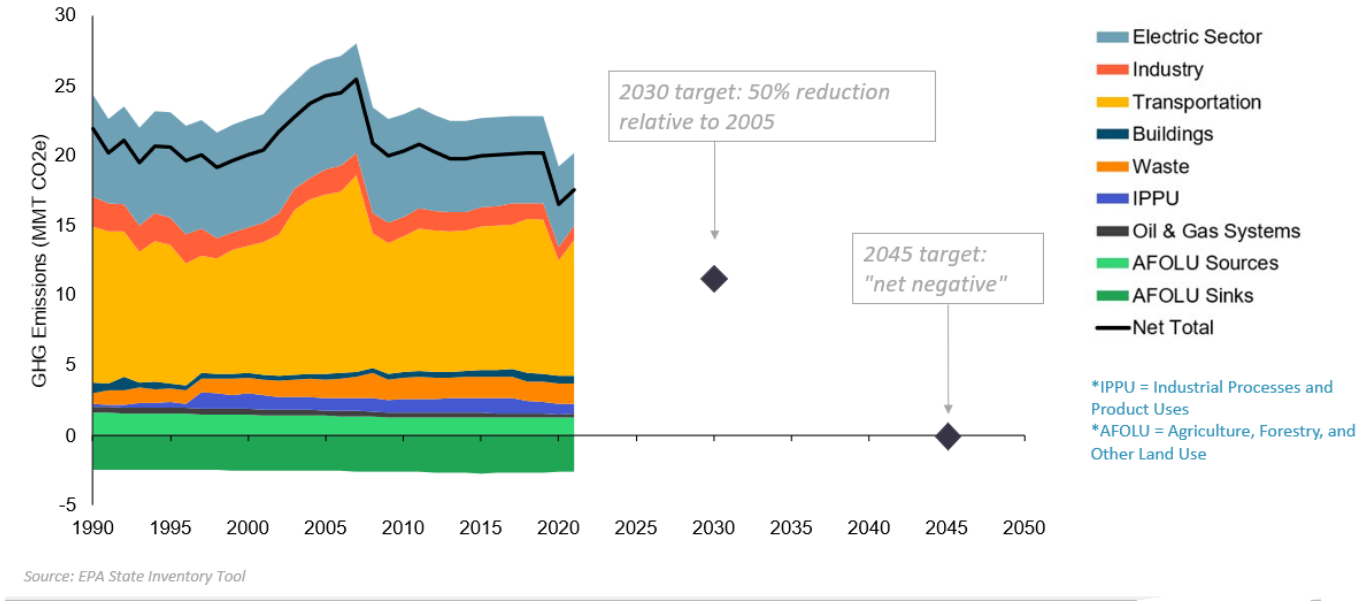
HRS §225P-5: Zero Emissions Clean Economy Target (2018, 2022*)

Mandated Target: **Net negative** as quickly as practicable but **no later than 2045** and **50% reduction by 2030**

- HSEO tasked with **analyzing pathways and developing recommendations** for achieving the state's economywide decarbonization targets
- Contracted with **E3 and NREL** to analyze different pathways accounting for energy use, equipment lifetimes, emissions, and policy measures in all sectors of Hawai‘i’s economy



*Act 238 (2022) added an interim 2030 greenhouse gas emissions target using a new **baseline of 2005** instead of 1990.

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Electric Sector Analysis

Cameron Weiner & Tom Harris

National Renewable Energy Laboratory (NREL)

Cameron.Weiner@nrel.gov

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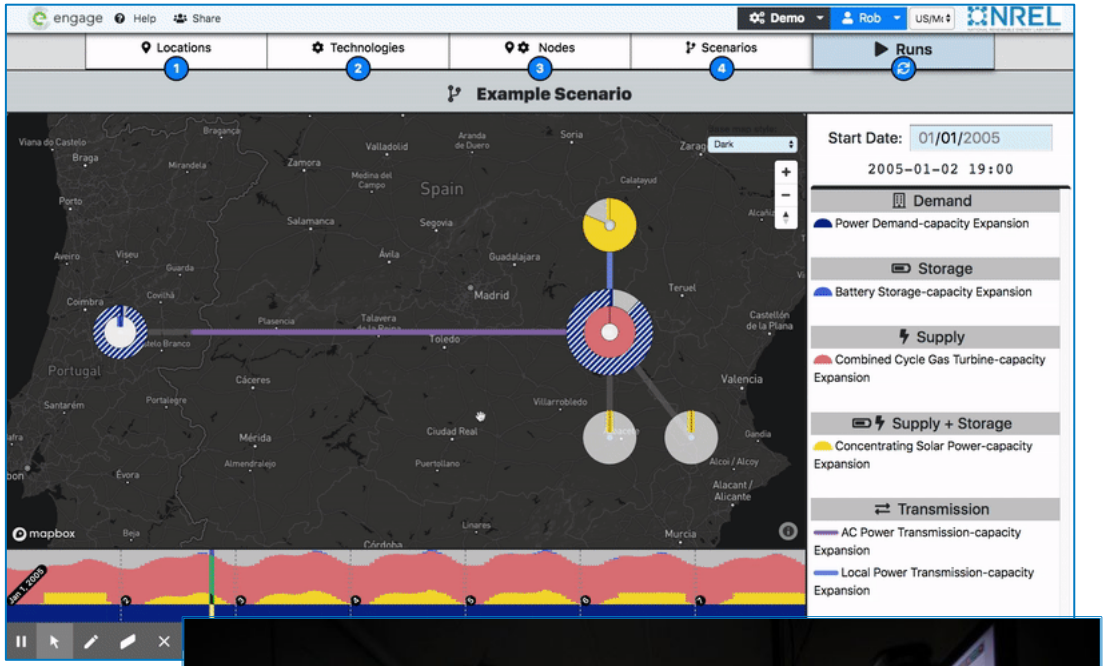
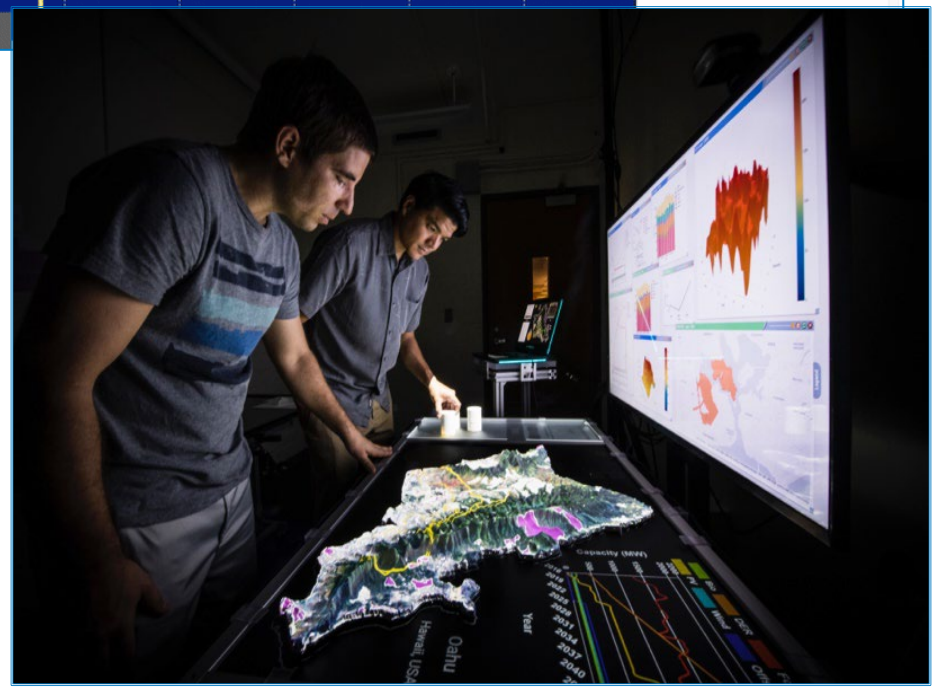
engage

accessibility
collaboration
communication

Engage™ is a capacity expansion model co-designed between the Hawai‘i State Energy Office and NREL in 2017. Engage was developed to support the Energy Office in examining the trade-offs between different future energy system scenarios.





Capacity Expansion Modeling

Determines the least-cost technology mix needed to meet demands, respecting all identified constraints. Engage is built around Calliope, a tested and well-documented open-source capacity expansion model.

Target users

- ✓ Developers, engineers, or planners
- ✓ State or local policymakers
- ✓ Researchers

Relevance

Usable for all locations. Data and users needed to make use of tool.

Service tiers

- ✓ Hosted and free to use
- ✓ Open source
- ✓ Supported

Training available

Recorded trainings / training decks available.

Link

https://engage.nrel.gov

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Methodology

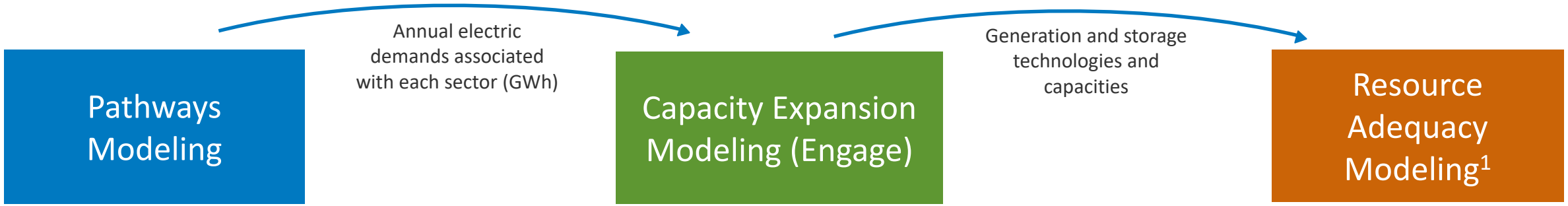
For each scenario & island…

Calculates costs, emissions, and demands for future decarb. pathways across the transportation, residential, commercial, and industrial sectors.

Calculates the most cost-effective mix of technologies and capacities (MW/MWh) that meet the demand in each scenario.

Calculates the costs and emissions associated the electric sector in each scenario.

Evaluate the probability that the system can meet demand considering random forced outages as well as solar and wind resource availability across multiple weather years.



[1]Using an NREL tool called the Probabilistic Resource Adequacy Suite (PRAS) – learn more here: https://www.nrel.gov/analysis/pras.html

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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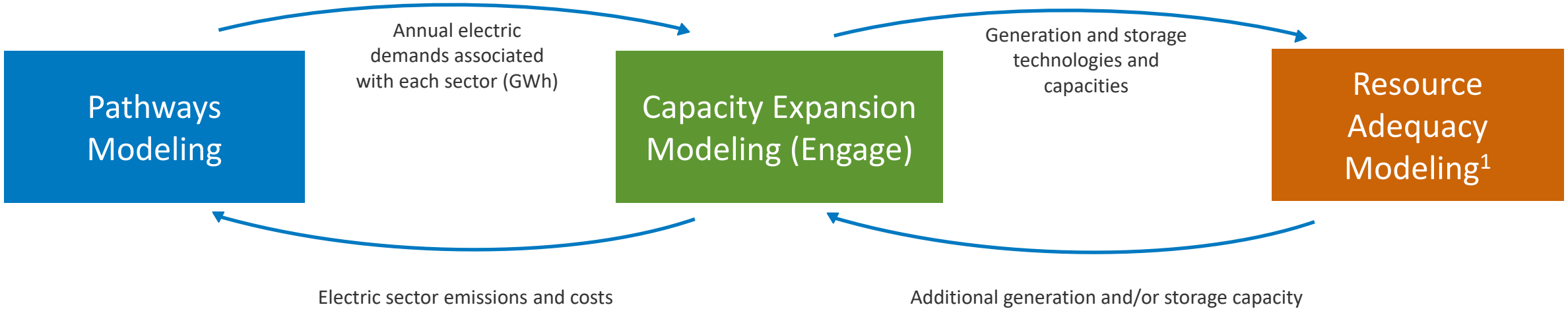

[1]Using an NREL tool called the Probabilistic Resource Adequacy Suite (PRAS) – learn more here: https://www.nrel.gov/analysis/pras.html

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Inputs and Assumptions

For each island…

Existing System Representation
The baseline system (system as it exists today and as planned in the near term)

Future System Technology Options
Technologies the model can build to meet projected demand

Technologies

Generators: Fossil Generators, Utility-Scale PV, Wind, Biofuel Generators, distributed PV

Storage: Utility-scale and distributed battery energy storage

Technology Attributes

Land constraints, costs, emissions, generator heat rates, capacity factors etc.

Capacity Expansion Modeling Tool

Inputs and Assumptions

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Land constraints, costs, emissions, generator heat rates, capacity factors etc.

Additional Constraints

- Scenario definitions from this decarb study
- RPS constraints on the Electric sector

engage

Capacity Expansion Modeling Tool

Electricity Demands

Annual GWh demands for each sector are sourced from the Pathways model.

Hourly load profile shapes are sourced from HECO, KIUC, and NREL.

Least-cost system that meets the electricity demands respecting all constraints

For each island & scenario

Optimized assets

Capacity (MW) of existing and new-build generation and storage technologies

Resulting costs

Annual snapshot costs which include:

- Fuel costs
- Existing system operation and maintenance costs
- Existing and new PPA prices

Other

- Emissions
- Hourly electricity production by technology type
- Fuel consumption

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Strategies to Decarbonize Hawai‘i

Draft Results

11/14/23

Amber Mahone, Managing Partner
Ari Gold-Parker, Associate Director
Jessie Knapstein, Associate Director
Jen Cardona, Senior Consultant
Hannah Platter, Consultant

Energy+Environmental Economics

Study Timeline

Current Status

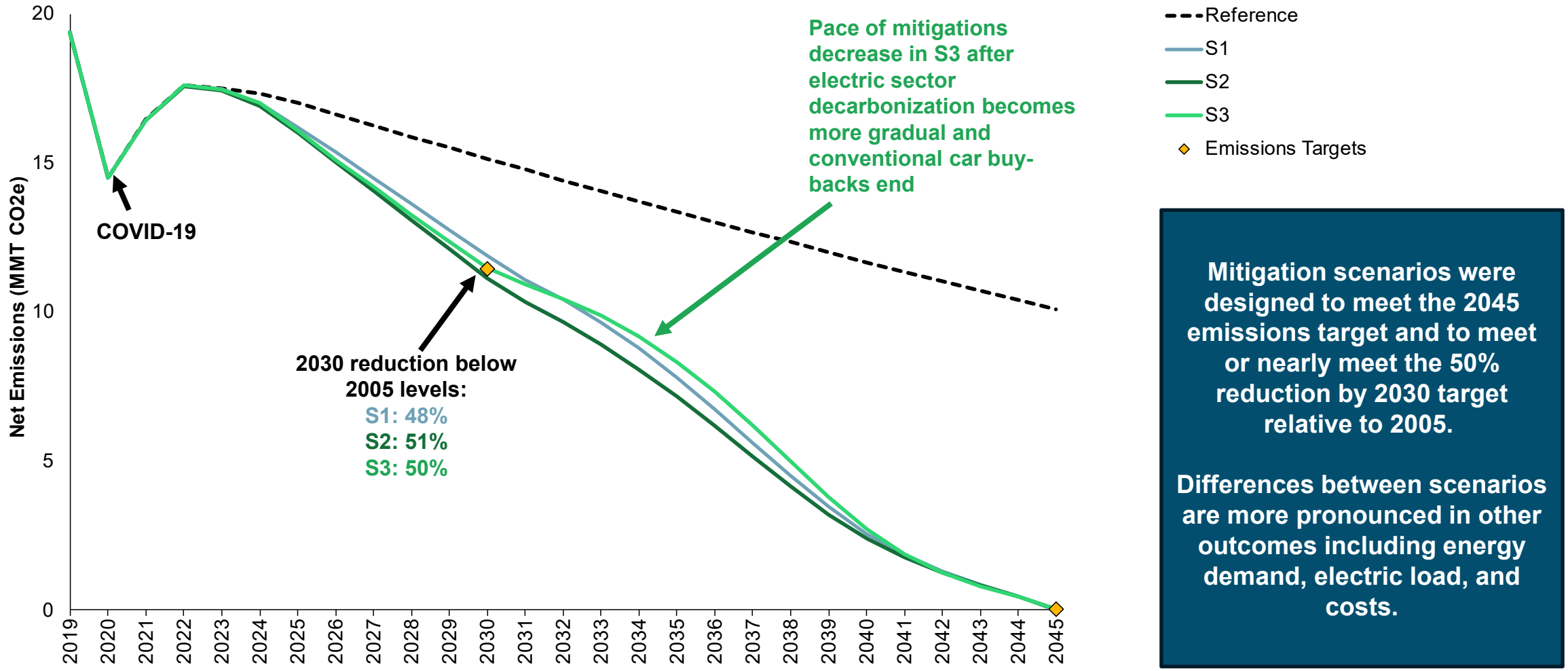
Activity	Jul	Aug	Sep	Oct	Nov	Dec
Internal and External Stakeholder Coordination						
Development of Electric Sector Loads (by island)						
NREL Electric Sector Modeling						
GHG Emissions by Sector and Scenario						
Key Outcomes: Bill Impacts, Workforce Transition Recommendations, Impacts to Low-income and Environmental Justice Communities						
Reporting						

Data collection and calibration
Draft and final analysis
Meeting
Draft and final report

Act 238 mandates final report delivery no later than 20 days before the start of the 2024 legislative session

Economy-Wide Net Greenhouse Gas Emissions

Draft Results



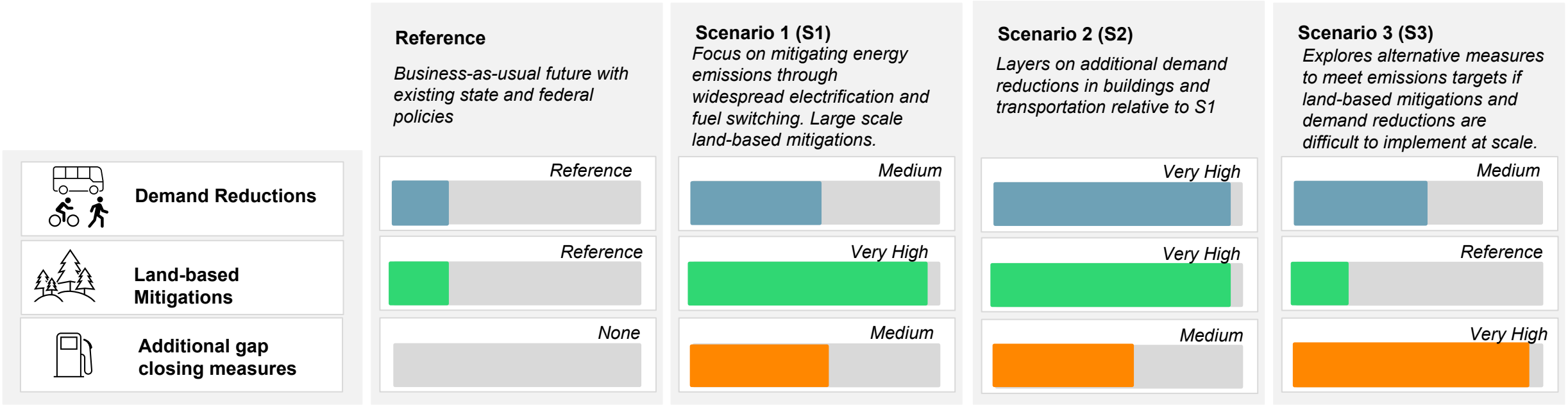
Mitigation scenarios were designed to meet the 2045 emissions target and to meet or nearly meet the 50% reduction by 2030 target relative to 2005.

Differences between scenarios are more pronounced in other outcomes including energy demand, electric load, and costs.

Key Scenario Differences

Mitigation scenarios explore tradeoffs between different decarbonization measures. Key differences among the scenarios are in:

- **Demand reductions** in transportation and buildings (reductions in vehicle miles traveled, flight mile reductions, building EE)
- **Land-based mitigations** that impact the size of the natural carbon sink
- **Additional "gap closing measures"**
  - **Scenarios 1 and 2:** decarbonized fuel blending
  - **Scenario 3:** Accelerated electricity sector decarbonization, conventional car buy-backs, additional decarbonized fuel blending, and negative emissions technologies



Key Scenario Results Metrics

Draft Results

Evaluation Criteria	Reference	Scenario 1 (S1)	Scenario 2 (S2)	Scenario 3 (S3)
Emissions Targets Achievement (% net emissions reduction in 2030 and 2045 relative to 2005)	2030: 34% 2045: 56%	2030: 48% 2045: 100%	2030: 51% 2045: 100%	2030: 50% 2045: 100%
Land impacts from electricity infrastructure (2030 electricity demand, TWh)*	9.4 TWh	10.2 TWh	8.9 TWh	10.6 TWh
Reliance on decarbonized fuels (2030 low carbon fuel demand, excluding electric sector, Tbtu)	4 Tbtu	12.3 Tbtu	11.2 Tbtu	11.6 Tbtu
Scale of land-based net carbon sink (2030 size of net land sink, MMT CO2)	1 MMT	2 MMT	2 MMT	1 MMT
Scale of demand reductions required (% reduction in total energy demand relative to reference in 2030)	N/A	2% reduction	10% reduction	6% reduction
Reliance on negative emissions technologies (2045 MMT CO2 sequestered)	0 MMT	0 MMT	0 MMT	0.5 MMT
Cost of energy transition (Billion 2021$, 2019-2045 NPV relative to Reference, excluding GHG benefits)	N/A	$4.3B	-$3.8B	$6.9B

Color Key:
Orange = higher level of challenge compared to other GHG mitigation scenarios
Green = lower level of challenge compare other GHG mitigation scenarios

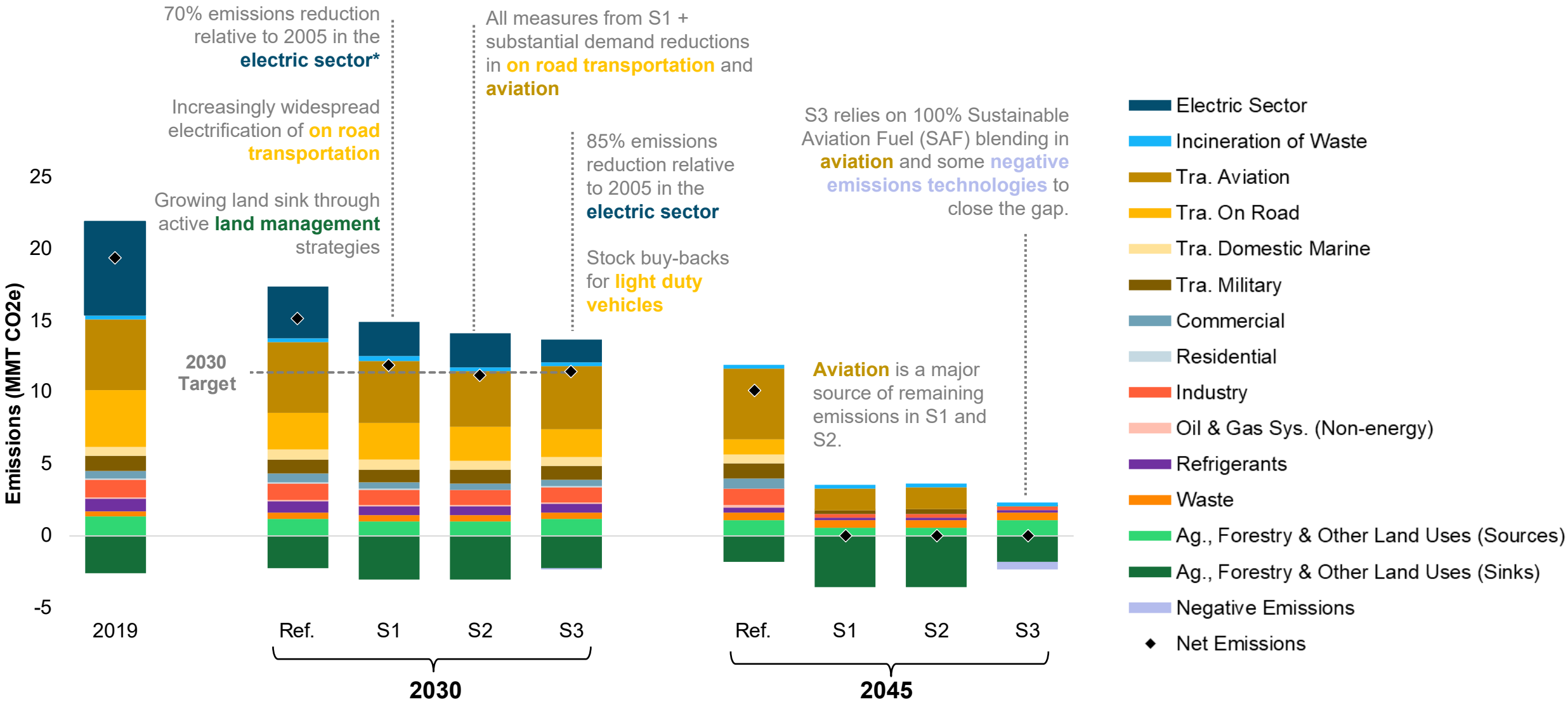
*Electric sector modeling is on-going. Land impact metric to be updated to reflect square footage of resource builds

Emissions

Energy+Environmental Economics

Emissions Snapshots

Draft Results

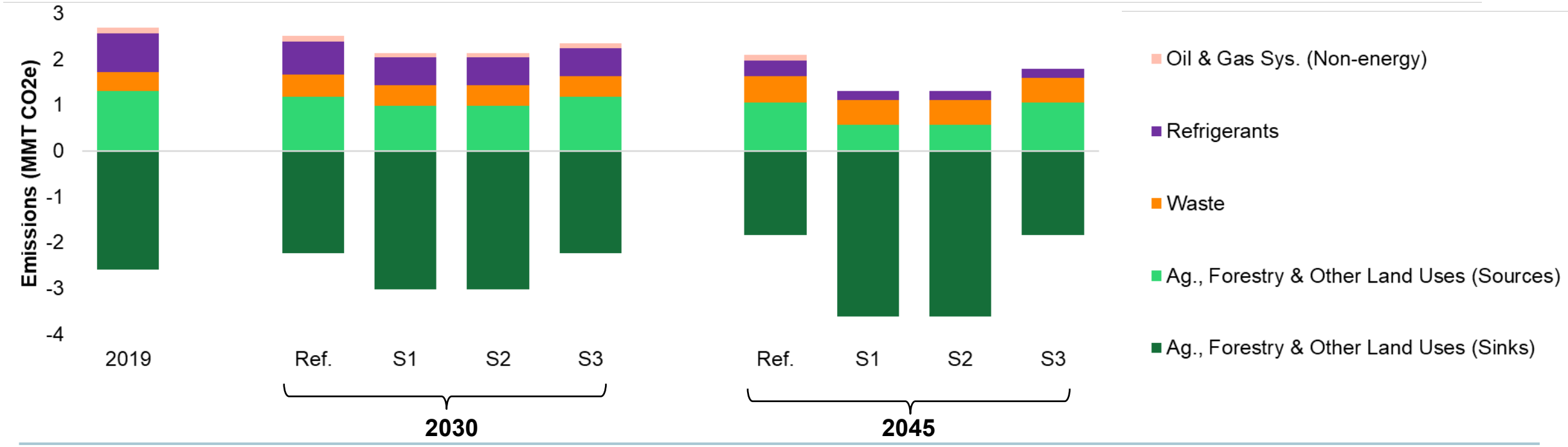


*Electric sector emissions are draft for the Reference Scenario

Non-energy Emissions

Draft Results

+ **All mitigation scenarios include:**
  - Far-reaching refrigerant management programs to mitigate emissions from **refrigerants**
  - The maximum abatement for **waste** emissions under a $200/tCO2e threshold
  - Non-combustion emissions from **oil & gas systems** decline to zero as the refinery converts to producing renewable fuels
+ **S1 and S2 include land management and agricultural practices that contribute to major reductions in agriculture, forestry, and other land uses**
  - These measures lead to a net sink of **3 MMT** CO2 in 2045, compared to **0.8 MMT** CO2 in the Reference and S3 scenarios



Energy Demands and Stock Transitions

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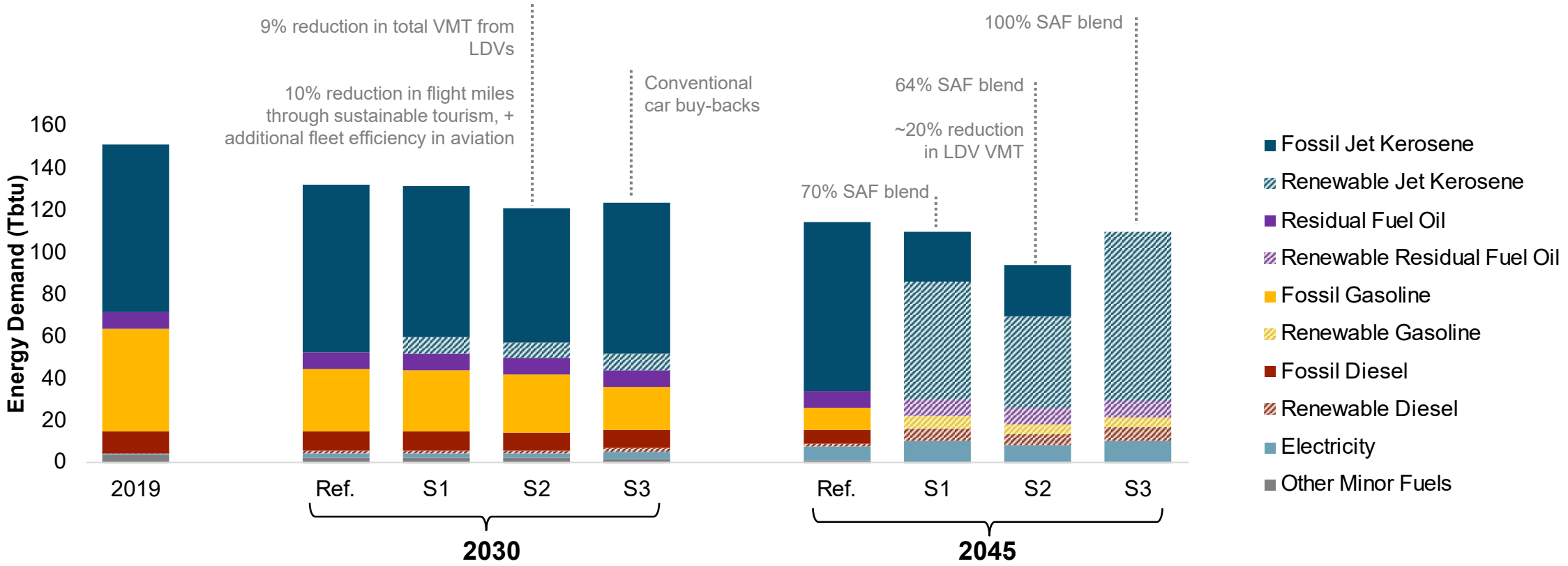
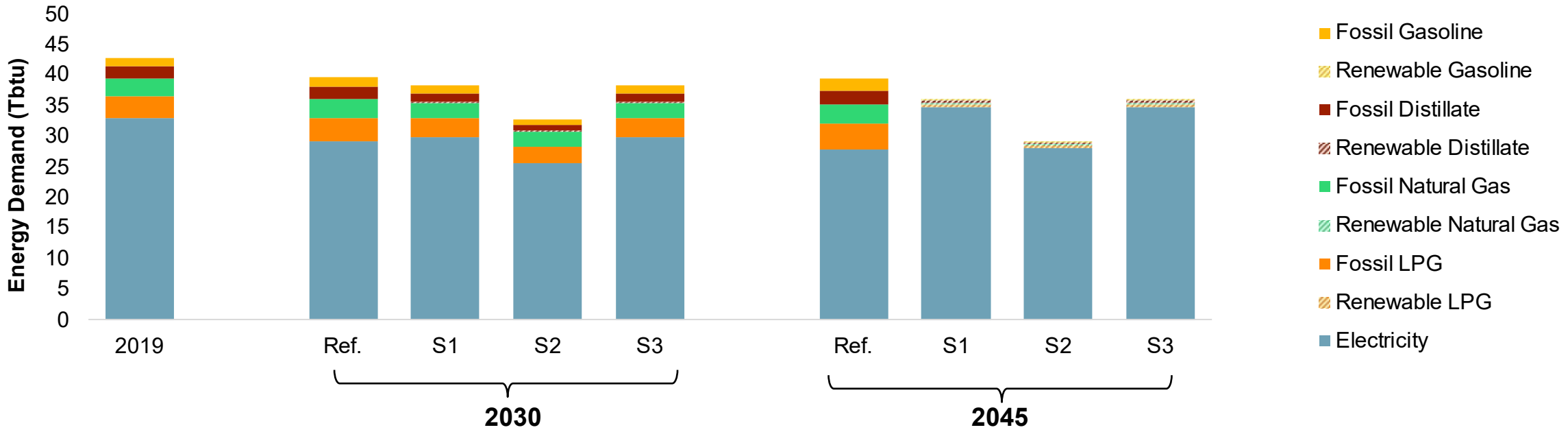
Transportation Energy Demand

+ **All mitigation scenarios include:**
  - 100% zero-emissions vehicle sales by 2035 for light duty and 2045 for medium and heavy duty
  - 100% decarbonized diesel, gasoline, and residual fuel oil by 2045
  - 10% sustainable aviation fuel (SAF) blend by 2030 and 64-100% by 2045
+ **Demand for decarbonized liquid transportation fuels ranges from 62-99 Tbtu in 2045 (42-68% of 2019 fossil fuel demands)**



Residential & Commercial Energy Demand

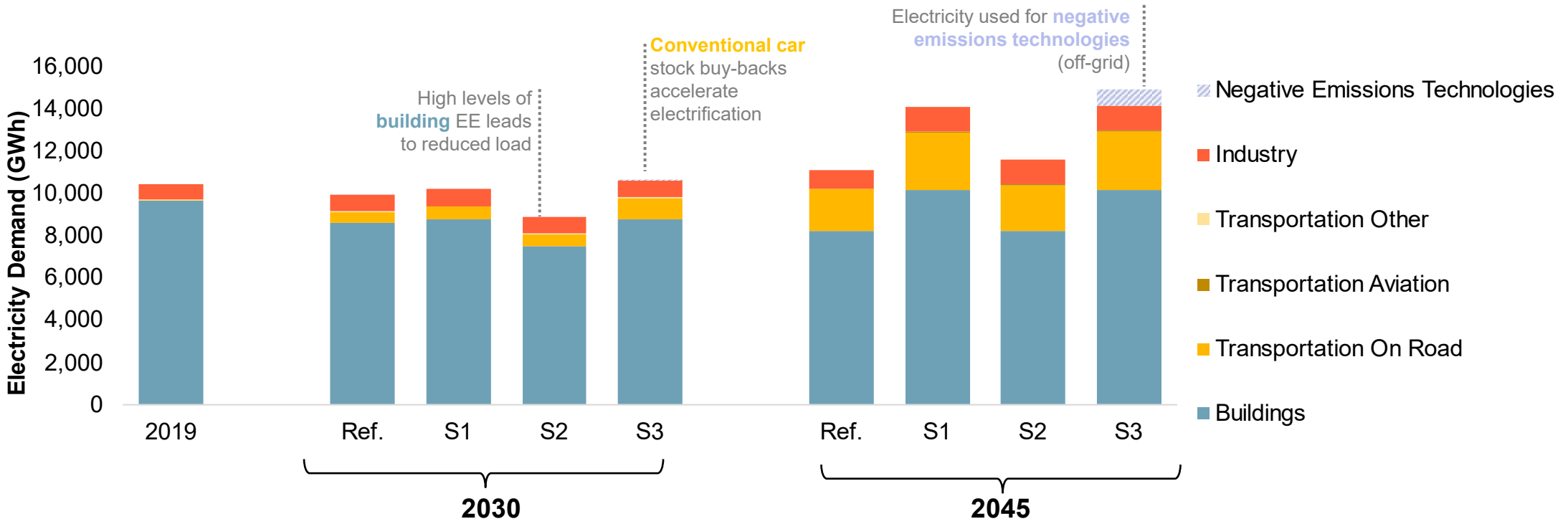
- **All mitigation scenarios include:**
  - 100% sales of electric devices for all end uses by 2035 in residential buildings and 2040 in commercial buildings
  - 100% renewable fuel blending by 2045 for fuels used in the residential and commercial sectors
- **S1 and S3 assume a high level of energy efficiency aligned with the "BAU High" scenario from the 2020 AEG Market Potential Study**
- **S2 assumes additional energy efficiency aligned with the "Economic Potential" scenario from the 2020 AEG Market Potential Study**



Electricity Demands

+ All mitigation scenarios:

- Rely on significant energy efficiency (EE) in **buildings** to curb load growth (most pronounced in S2, which has the highest level of building EE)
- Show load growth relative to the reference from increased transportation electrification dominated by **on-road vehicles** with minor loads from some electrification of short inter-island **flights**
- Show load growth in **industry** from electrification of equipment in construction and agriculture



On-Road Transportation Adoption Transition

Draft Results

- All mitigation scenarios require 100% Light Duty Vehicle (LDV) Zero-Emission Vehicle (ZEV*) sales by 2035, leading to ~80-90% stock shares of ZEVs by 2045
- S3 shows accelerated adoption of LDV ZEVs due to internal combustion vehicle buy-back program spanning 2025-2030
- All mitigation scenarios require 100% Medium- and Heavy-Duty Vehicle (MHDV) ZEV sales by 2045

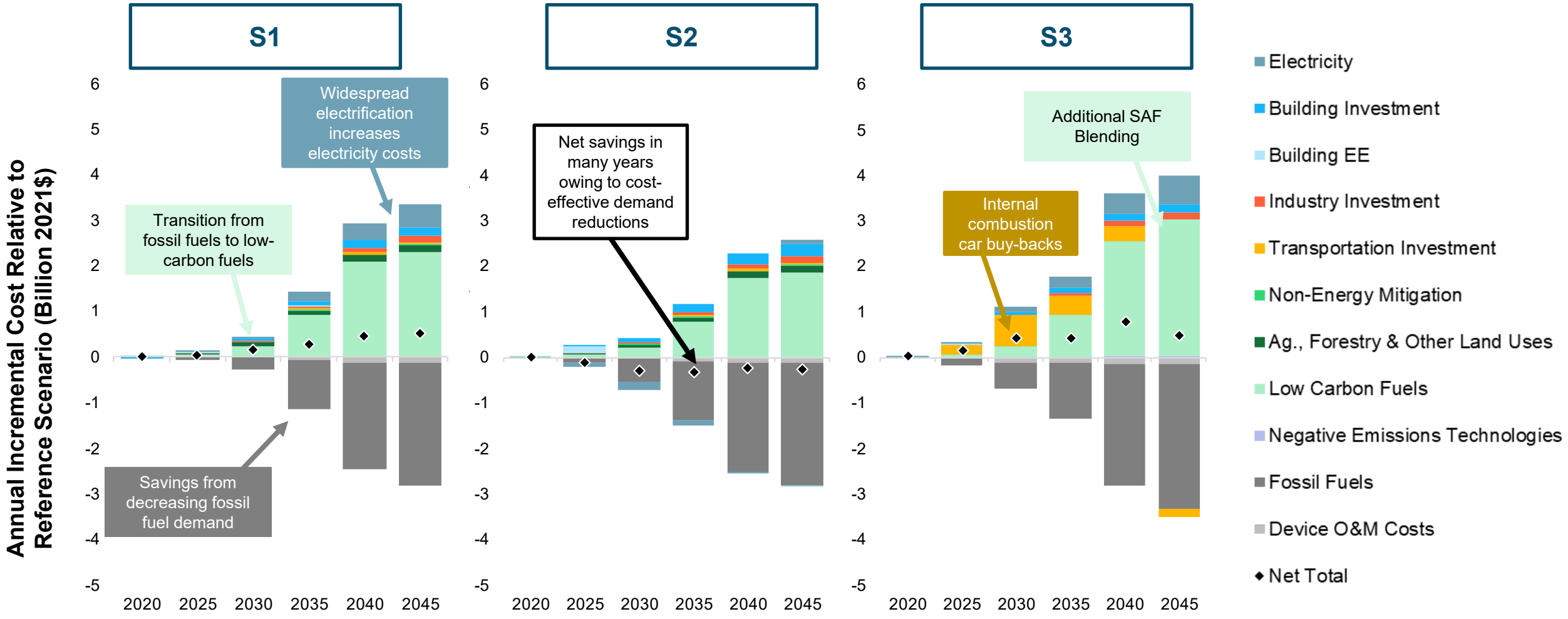
*ZEVs = Battery Electric Vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEVs), and Hydrogen Fuel Cell vehicles (H2)

Costs

Energy+Environmental Economics

Annual Incremental Costs Relative to Reference

Draft Results



Measures with no costs modeled: VMT reductions, flight mile reductions

Note: electricity costs are currently placeholders assuming a total incremental cost for load growth of $170/MWh

Net Direct Costs of Decarbonization Relative to Forecasted State GDP

+ **The 2045 net direct cost of the mitigation scenarios relative to the Reference ranges from -0.2% (savings) to 0.3% (cost) of state GDP (2045 projection from DBEDT)**

2045 Net Direct Cost as % of state GDP

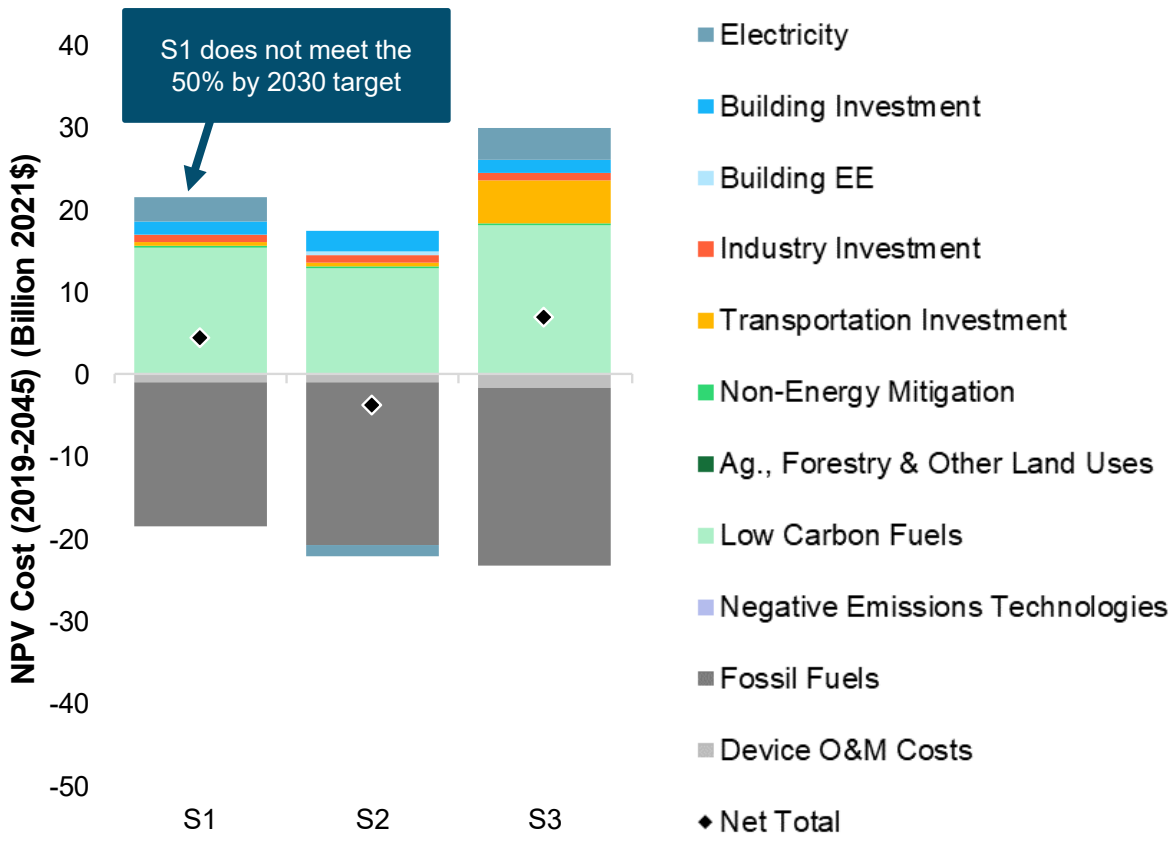
S1	S2	S3
0.3%	-0.2%	0.3%

+ **The net direct costs in the net-zero target year are significantly lower as a % of state GDP than what has been reported in other net-zero studies across the US. Examples include:**
  - Illinois Decarbonization Study: 1.4%-1.7% of state GDP (E3, 2022)[1]
  - Princeton Net-Zero America: ~1-2% of U.S. national GDP (Larson et al., 2020)[2]
  - New York Scoping Plan: 1.3% of state GDP (E3, 2022)[3]
+ **The lower net costs of decarbonization in Hawai‘i relative to other jurisdictions in the US are due to key differences in Hawai‘i including higher fossil fuel prices, less industrial energy demand, very little gas use in buildings, and less heavy-duty trucking**

1 https://www.ethree.com/wp-content/uploads/2022/12/E3-Commonwealth-Edison-Decarbonization-Strategy-Report.-December-2022-1.pdf
2 https://netzeroamerica.princeton.edu/img/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf
3 https://climate.ny.gov/resources/scoping-plan/-/media/project/climate/files/Appendix-G.pdf

Net Present Value Incremental Cost (2019-2045)

Draft Results



- **S3 is more expensive relative to S1 and S2 because of additional gap-closing measures including**
  - Internal combustion car buy-backs
  - Additional sustainable aviation fuel
- **Net savings in S2 from demand reductions in buildings and transportation**

2019-2045 NPV Cost* (Billion 2021$)

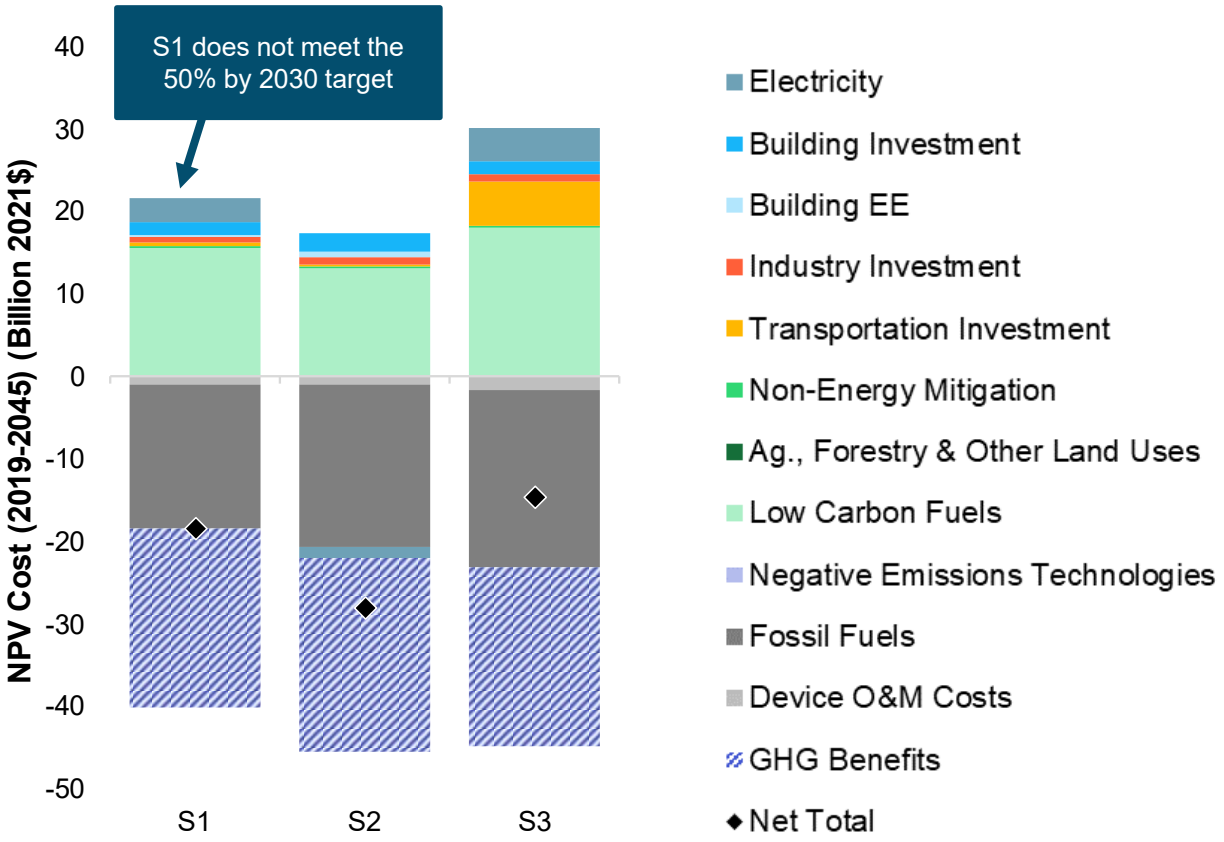
	S1	S2	S3
Net Total	$4B	(-$4B)	$7B

*NPV calculations assume a 2% discount rate

Net Present Value Incremental Cost (2019-2045)

Draft Results

Including Societal Benefits from Avoided GHGs



- **All scenarios show large net benefits when societal benefits from avoided climate damages are accounted for**
- **Social cost of GHGs use a 2% discounting rate from the EPA Draft "Report on the Social Cost of Greenhouse Gases"**
  - 2045: Carbon dioxide valued at $287/ton with 2% discounting

2019-2045 NPV Cost* (Billion 2021$)

	S1	S2	S3
GHG Benefits	(-$22B)	(-$24B)	(-$22B)
Net Total	**(-$17B)**	**(-$27B)**	**(-$15B)**

**NPV calculations assume a 2% discount rate*

Next Steps

Energy+Environmental Economics

Next Steps

- **Incorporate results from the electric sector analysis that is being conducted concurrently by NREL**
  - Results from this analysis will inform scenario costs as well as land impacts from energy infrastructure
- **Further analysis on the key scenario outcomes including:**
  - Assessment of land impacts from energy infrastructure
  - Qualitative assessment of energy equity
  - Qualitative assessment of workforce transition
- **Finalize modeling results**
- **Final report and recommendations**

Comments & Questions

- Do you have any questions on the analysis presented?
- Based on these results, what types of carbon mitigation policies would you recommend the state prioritize?
- Given the presentation today and draft results - what are the recommendations you think should be prioritized for the report to the state legislature?

https://forms.office.com/g/j1ujfaAgcd?origin=lprLink

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Appendix 1

Energy+Environmental Economics

Scenario Measures: Electricity, gas, and refinery

Measure	Reference	S1	S2	S3
2030 Electric Sector Emissions Reductions	40% RPS-eligible generation	70% emissions reduction relative to 2005	70% emissions reduction relative to 2005	**85% emissions reduction relative to 2005**
2045 Electric Sector Emissions Reductions	100% RPS-eligible generation	100% emissions reduction	100% emissions reduction	100% emissions reduction
Gas Pipeline and Propane Blend	N/A	100% decarbonized gas by 2045	100% decarbonized gas by 2045	100% decarbonized gas by 2045
Refinery Renewable Fuels Production Transition	5% of operations convert to produce renewable fuels in 2025.	5% of operations convert to produce renewable fuels in 2025. 100% of operations convert to produce renewable fuels by 2045.	5% of operations convert to produce renewable fuels in 2025. 100% of operations convert to produce renewable fuels by 2045.	5% of operations convert to produce renewable fuels in 2025. 100% of operations convert to produce renewable fuels by 2045.

Note: Key measures that differentiate scenarios are in orange

Scenario Measures: Aviation

Measure	Reference	S1	S2	S3
Fuel Efficiency	50% of fuel efficiency improvement from AEO projections	50% of fuel efficiency improvement from AEO projections	**100% of fuel efficiency improvement from AEO projections**	50% of fuel efficiency improvement from AEO projections
Fuel Blending	N/A	**10% SAF blend by 2030 and 70% SAF blend by 2045**	**10% SAF blend by 2030 and 64% SAF blend by 2045**	**10% SAF blend by 2030 and 100% by 2045**
Visitor Arrivals	Visitor arrival forecast from DBEDT	Visitor arrival forecast from DBEDT	Visitor arrival forecast from DBEDT + **10% reduction in flight miles by 2030**	Visitor arrival forecast from DBEDT
Electrification	N/A	Small amount of electric inter-island aviation by 2045 (~0.2% of demand)	Small amount of electric inter-island aviation by 2045 (~0.2% of demand)	Small amount of electric inter-island aviation by 2045 (~0.2% of demand)

Scenario Measures: Transportation

Measure	Reference	S1	S2	S3
Light Duty Zero-Emissions Vehicle Sales	ICCT projection	100% by 2035	100% by 2035	100% by 2035 **+ stock buy backs (2025-2030)**
Medium and Heavy Duty Zero-Emissions Vehicle Sales	ICCT projection	100% by 2045	100% by 2045	100% by 2045
Fuel Transition	N/A	100% decarbonized diesel, gasoline, and residual fuel oil by 2045	100% decarbonized diesel, gasoline, and residual fuel oil by 2045	100% decarbonized diesel, gasoline, and residual fuel oil by 2045
Reductions in Vehicle Miles Traveled	5% reduction for light duty vehicles on O‘ahu	5% reduction for light duty vehicles on O‘ahu	**~20% state-wide reduction**	5% reduction for light duty vehicles on O‘ahu

Note: Key measures that differentiate scenarios are in orange

Scenario Measures: Buildings

Measure	Reference	S1	S2	S3
Energy Efficiency	AEG Market Potential Study "BAU – Reference"	AEG Market Potential Study "BAU – High"	AEG Market Potential Study **"Economic Potential"**	AEG Market Potential Study "BAU – High"
Residential Electrification	Solar water heating for all new residential buildings	100% sales of electric devices by 2035	100% sales of electric devices by 2035	100% sales of electric devices by 2035
Commercial Electrification	N/A	100% sales of electric devices by 2040	100% sales of electric devices by 2040	100% sales of electric devices by 2040

Note: Key measures that differentiate scenarios are in orange

Scenario Measures: Non-Energy, Non-Combustion

Measure	Reference	S1	S2	S3
Waste	Reference from EPA Non-CO2 report	Max abatement available below $200/tCO2e	Max abatement available below $200/tCO2e	Max abatement available below $200/tCO2e
Agriculture	Baseline from EPA non-CO2 report	**Max abatement under $200/tCO2e from EPA non-CO2 report**	**Max abatement under $200/tCO2e from EPA non-CO2 report**	Baseline from EPA non-CO2 report
Land Use, Land Use Change, Forestry	Baseline from USGS report on carbon fluxes in Hawai‘i	**Increase in net land sink based on the “High Sequestration” projection from White House 2021 Biennial Report**	**Increase in net land sink based on the “High Sequestration” projection from White House 2021 Biennial Report**	Baseline from USGS report on carbon fluxes in Hawai‘i
Refrigerants	Kigali Amendment	SNAP program for refrigerant management	SNAP program for refrigerant management	SNAP program for refrigerant management

Note: Key measures that differentiate scenarios are in orange