MA 2050 Roadmap ACEC/MA Briefing

Michael Jay Walsh, Ph.D.

michael.jay.walsh@outlook.com

4/1/2021

Agenda

- Introductions & Acknowledgements
- Study Overview
- The Commonwealth in 2050
- Renewable Electricity and the Need for Reliable Resources
- Building Decarbonization & the Limits of Fuels
- Costs, Economic and Health Impacts

Introductions

- **Michael Jay Walsh**
  - Project Director for *Massachusetts Decarbonization Roadmap Study* with the Cadmus Group
  - Technical Lead for *Carbon Free Boston* with the Boston University Institute for Sustainable Energy
  - Integrated Energy & Climate Systems Modeling & Policy Expert
  - Ph.D. Environmental Engineering, Cornell University

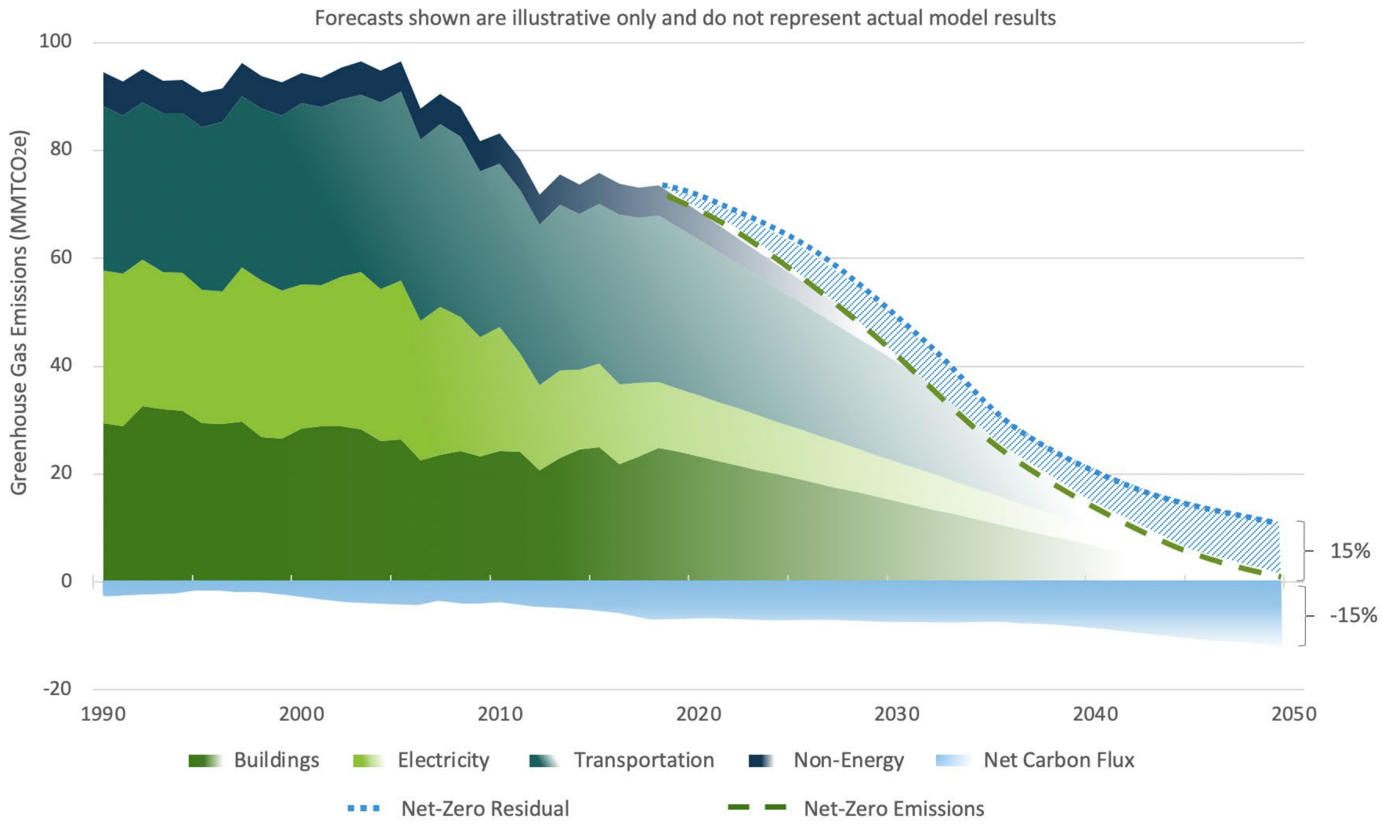
Acknowledgements

- Executive Office of Environmental Affairs
- State Agency Team
  - DOER
  - MassCEC
  - MassDOT
  - DPU
  - DCR
- Technical Steering Committee

- Cadmus Group
- Evolved Energy Research
- Harvard Forest
- VEIC
- Arup
- Jonathan Krones
- Wendy Cohen
- Leah Jacobs

Study Overview

Net Zero target for the Commonwealth

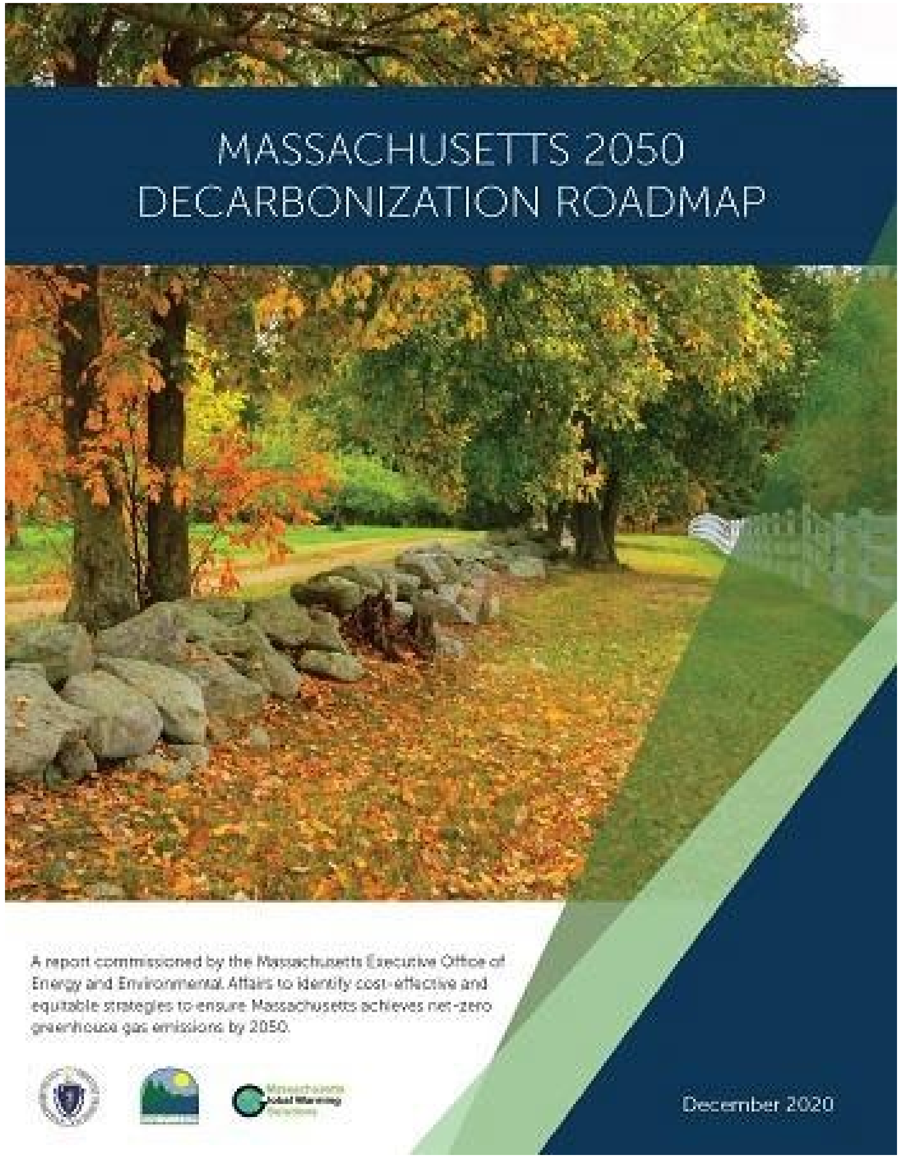


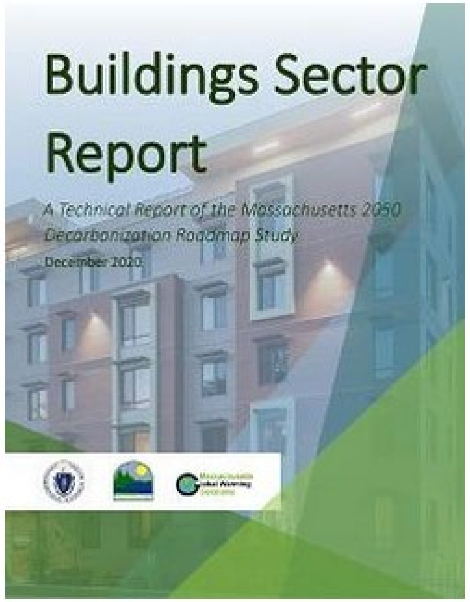
At least an 85% reduction in *gross* emissions from 1990 levels.

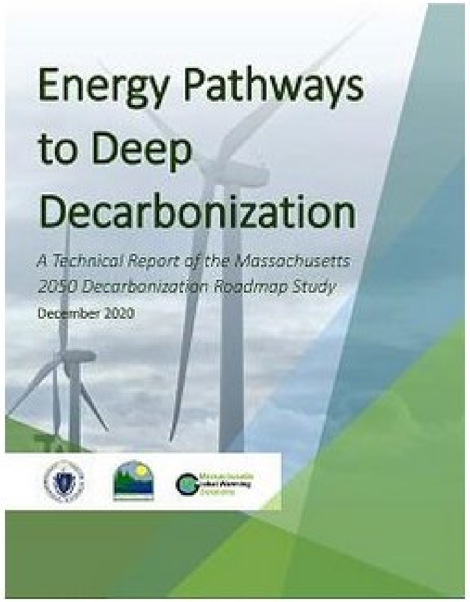
Balanced by carbon dioxide removals – predominantly Massachusetts natural and working lands.

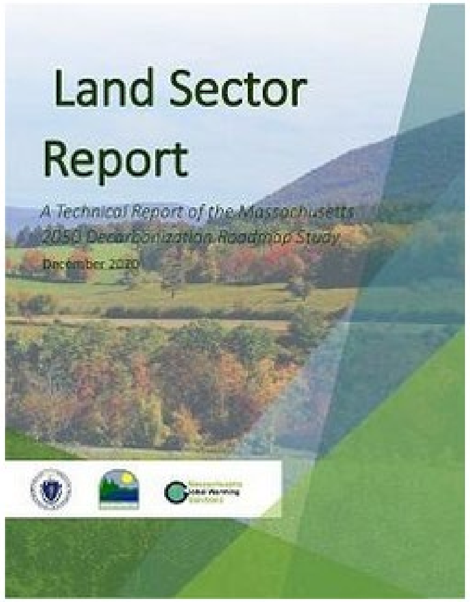
Includes interim targets

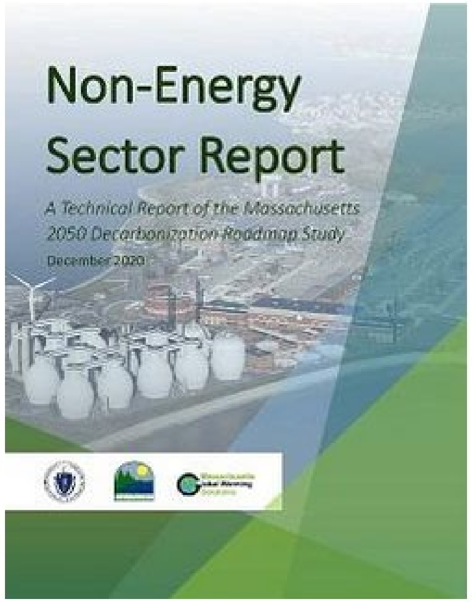
100% Renewables

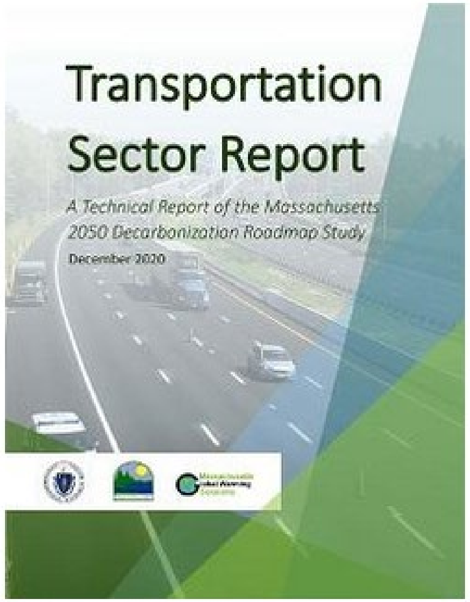




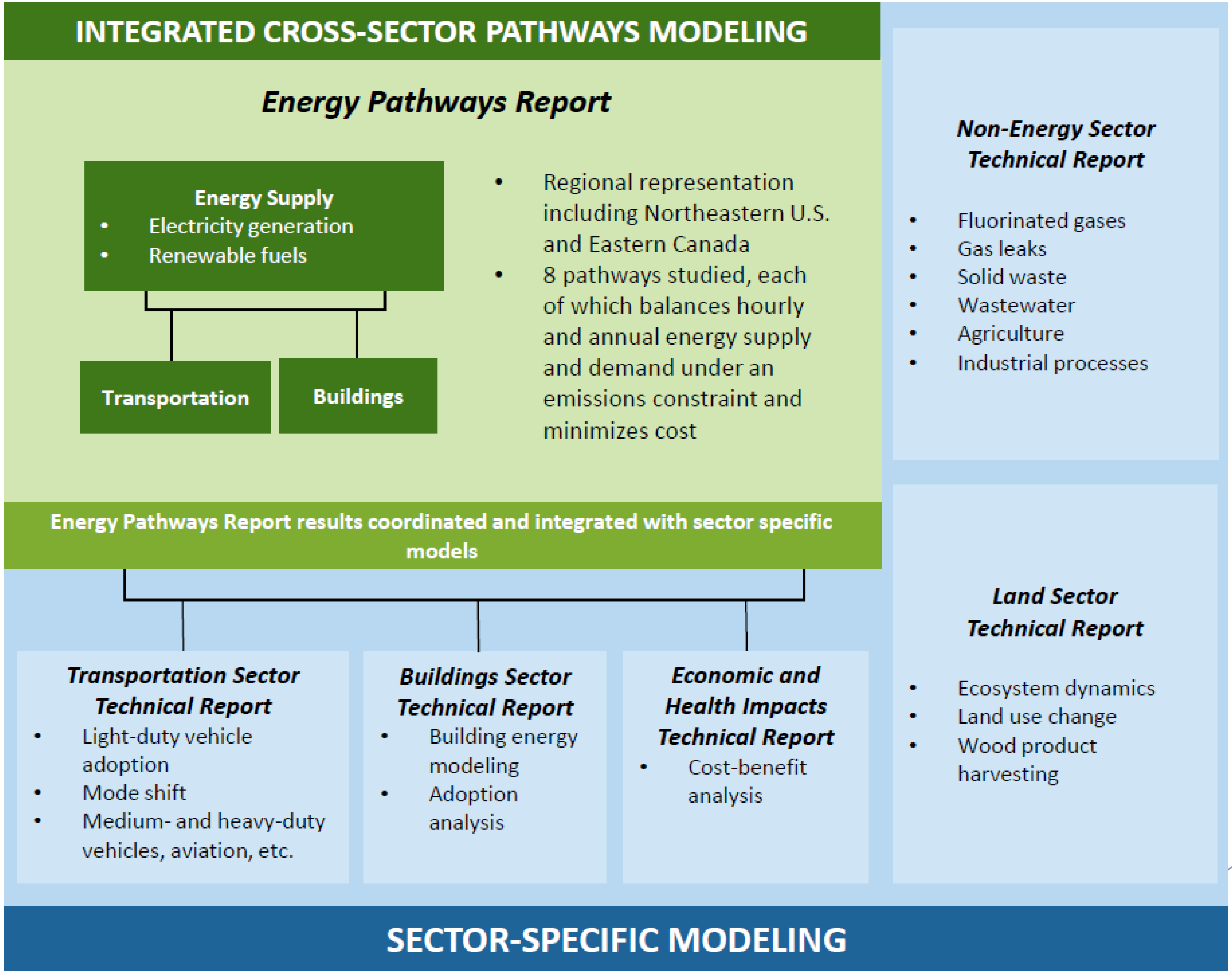








Mass.gov/2050Roadmap


INTEGRATED CROSS-SECTOR PATHWAYS MODELING
Energy Pathways Report
Energy Supply
• Electricity generation
• Renewable fuels
Transportation
Buildings
• Regional representation including Northeastern U.S. and Eastern Canada
• 8 pathways studied, each of which balances hourly and annual energy supply and demand under an emissions constraint and minimizes cost
Non-Energy Sector Technical Report
• Fluorinated gases
• Gas leaks
• Solid waste
• Wastewater
• Agriculture
• Industrial processes
Energy Pathways Report results coordinated and integrated with sector specific models
Transportation Sector Technical Report
• Light-duty vehicle adoption
• Mode shift
• Medium- and heavy-duty vehicles, aviation, etc.
Buildings Sector Technical Report
• Building energy modeling
• Adoption analysis
Economic and Health Impacts Technical Report
• Cost-benefit analysis
Land Sector Technical Report
• Ecosystem dynamics
• Land use change
• Wood product harvesting
SECTOR-SPECIFIC MODELING

Roadmap and Clean Energy and Climate Plan (CECP) Process

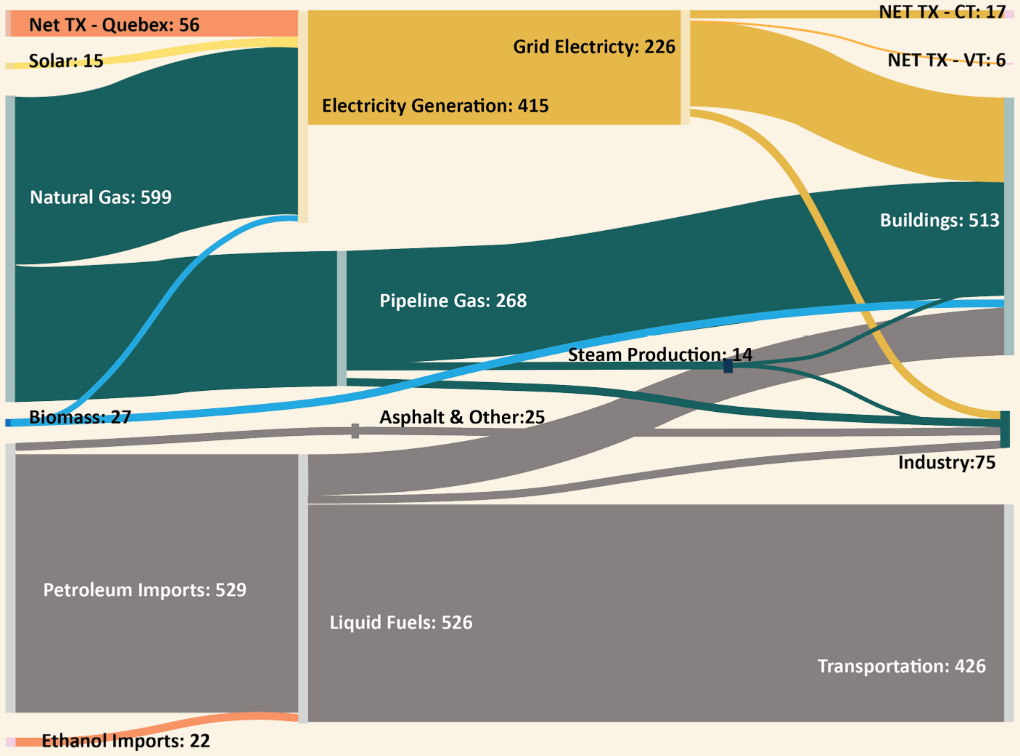
- **December 30, 2020**: Roadmap and Interim 2030 CECP posted
  - **Jan. 4, 2021** Legislature passes S.2995: *An Act creating a next-generation roadmap for Massachusetts climate policy*
- **January 7, 2021**: Comment period opens for the Interim 2030 CECP
  - **Jan. 14, 2021** Governor Baker vetoes S.2995
  - **Jan. 28, 2021** Legislature passes S.9
  - **Feb. 8, 2021** Governor returns with amendments
  - **Mar. 18, 2021** Legislature accepts some amendments and returns to the Governor
- **March 22, 2021:** Public comments due on Interim 2030 CECP
  - **Mar. 26, 2021** Governor signs bill into law
- **~April/May 2021:** Final 2030 CECP posted

The Commonwealth in 2050

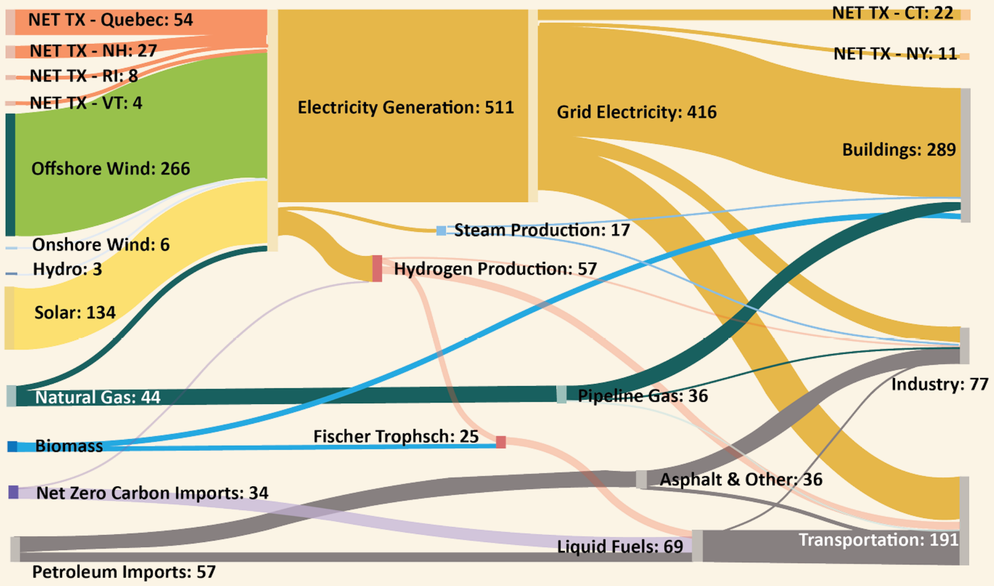
Energy Flows

The two figures below illustrate key changes in energy supply and end use from 2020 to 2050. On the left of each figure are energy sources. The height of a bar indicates the relative quantity of energy used. The right of each figure indicates the energy use sectors like transportation and buildings. The middle of each figure shows energy transformations.

2020 Commonwealth Energy Use (TBtu)



2050 Commonwealth Energy Use (TBtu)



1. The Commonwealth shifts from being primarily powered by fossil fuels in 2020 to renewable resources in 2050. The main sources of energy in 2050 are offshore wind, solar, and electricity transmission imports.

2. The electrification of many end uses in the buildings and transportation sectors results in efficiency improvements and a reduction in overall energy demand. This is exhibited by the lower amount of primary energy sources in the figure with 2050 energy use.

3. Gas use declines significantly from 2020 to 2050 but is still used in 2050 for some electricity generation, building heating, and transportation uses.

4. Sectoral coupling with flexible industrial loads (like steam and hydrogen production) help to balance the electricity generated by high levels of renewable energy.

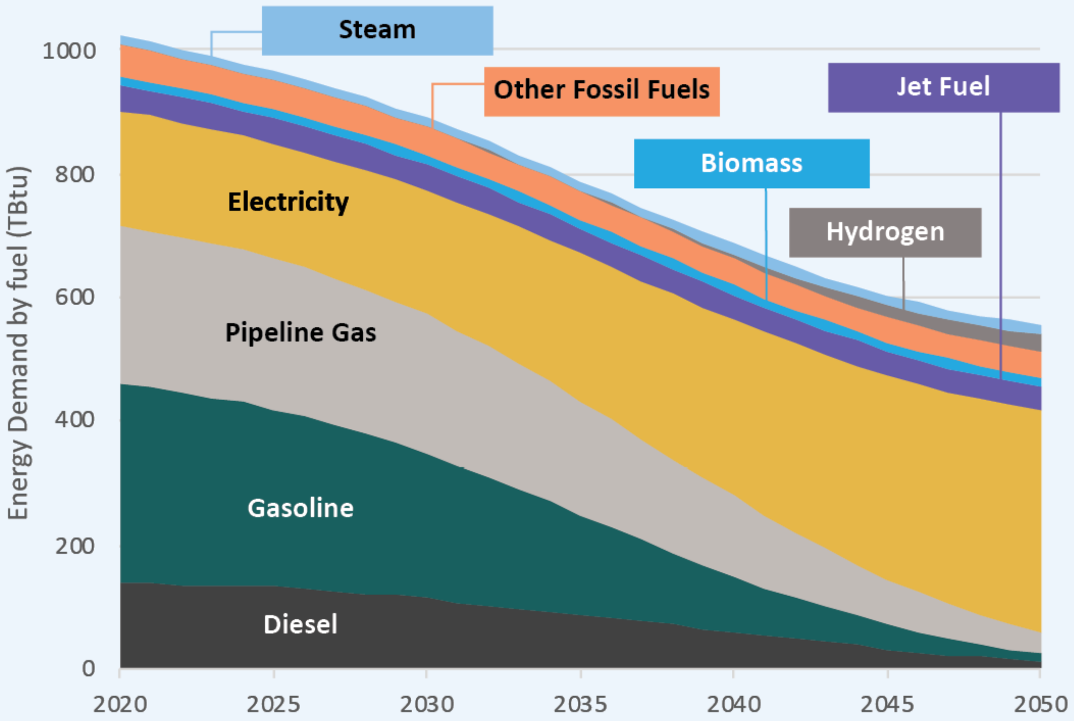
Energy Demand and Supply

Rapid transformation of the energy system has impacts on energy services and supply.

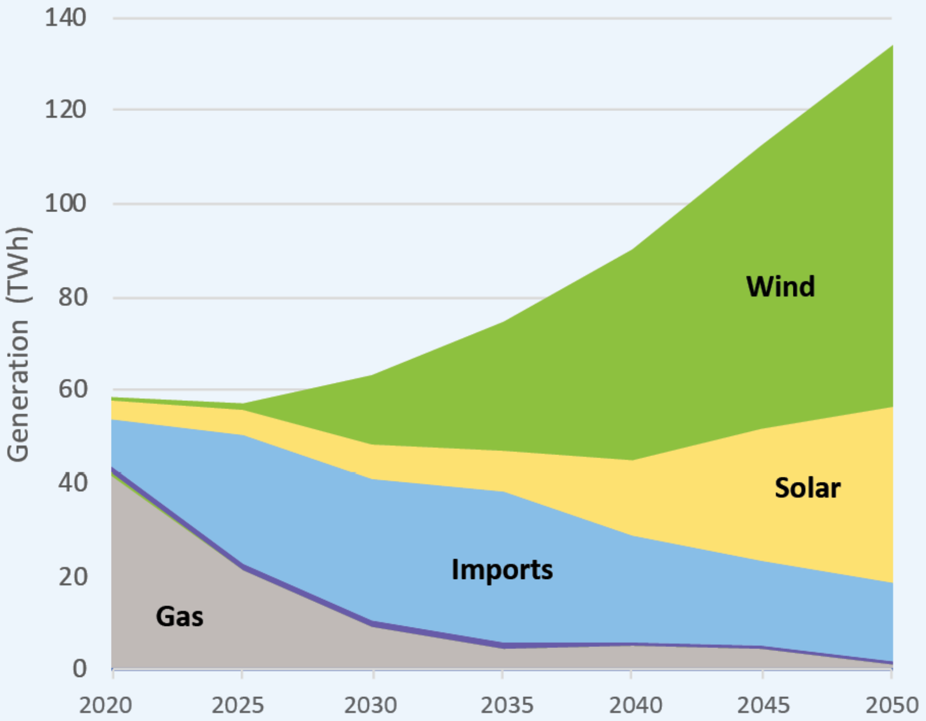
5. Over time, end uses in the buildings and transportation sectors are electrified resulting in efficiency savings and a reduction in overall energy demand.

6. Electrification results in growing demand for electricity. Solar and wind generation increase dramatically from 2025 through 2050.

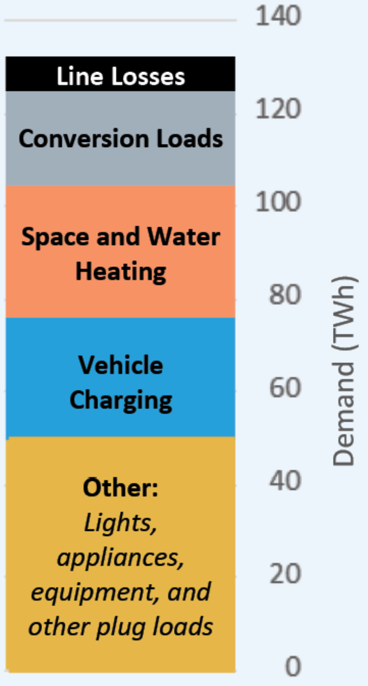
Energy Demand by Fuel



Electricity Generation by Source



2050 Electricity Demand



Characteristics of low-cost, low-impact decarbonization

End Use Energy

Transitioning buildings, vehicles, and other end uses away from consuming fossil fuels

Energy Efficiency and Flexibility

Aggressively pursuing energy efficiency and flexibility to enable cost-effective decarbonization

Decarbonizing Energy Supply

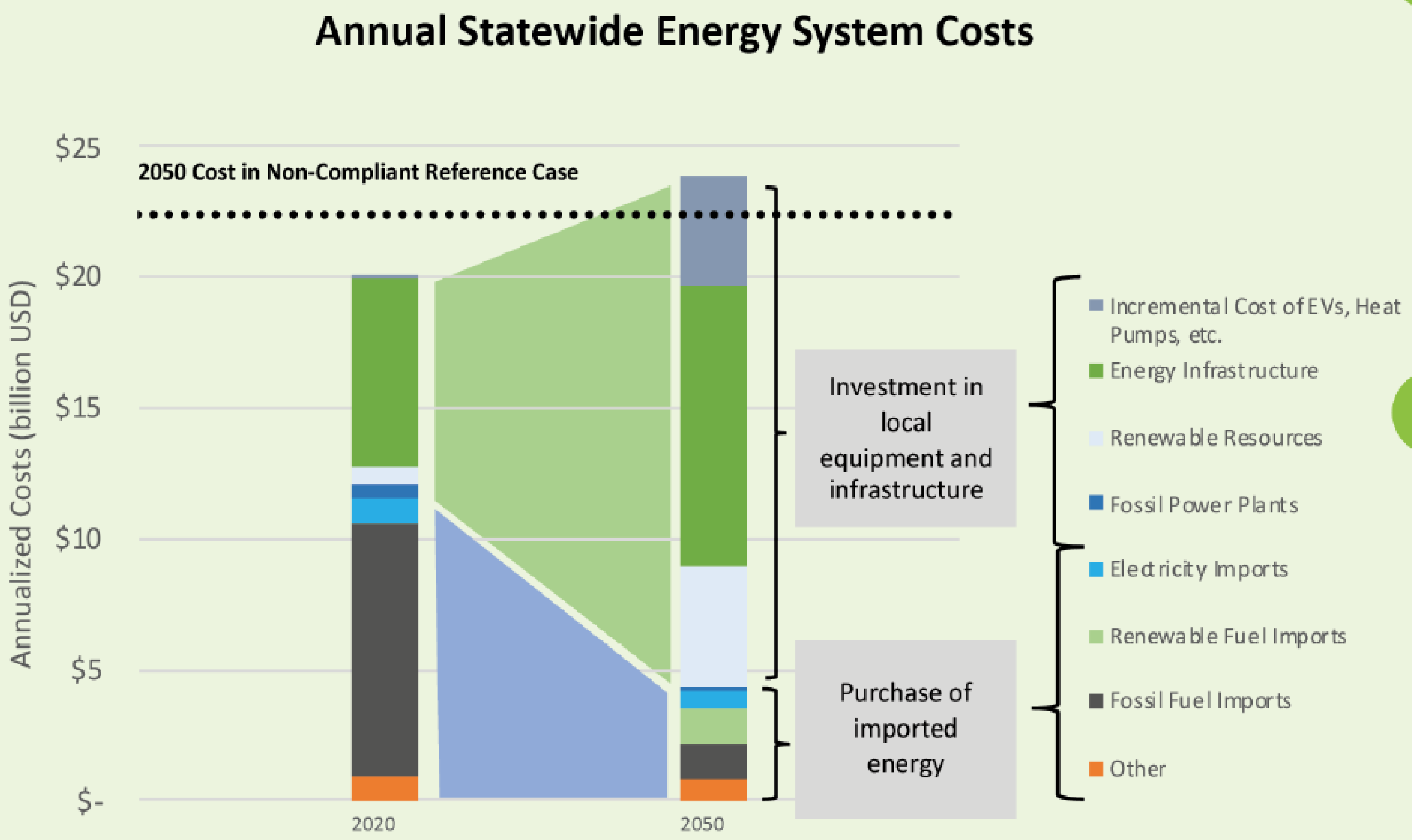
Producing zero and low-carbon energy supplies to power our energy system

Carbon Sequestration

Balancing remaining emissions by facilitating carbon dioxide removal from the atmosphere

Energy Costs

Decarbonized energy system costs are not significantly higher than the costs associated with a 2050 fossil-based system.



7. Investment in local equipment and infrastructure increases from 2020 to 2050, allowing decreased operating costs.

8. The purchase of imported energy decreases from 2020 to 2050 due to the replacement of imported fossil fuels with a diverse, largely regional, energy mix.

Distinct Tradeoffs in How We Get There

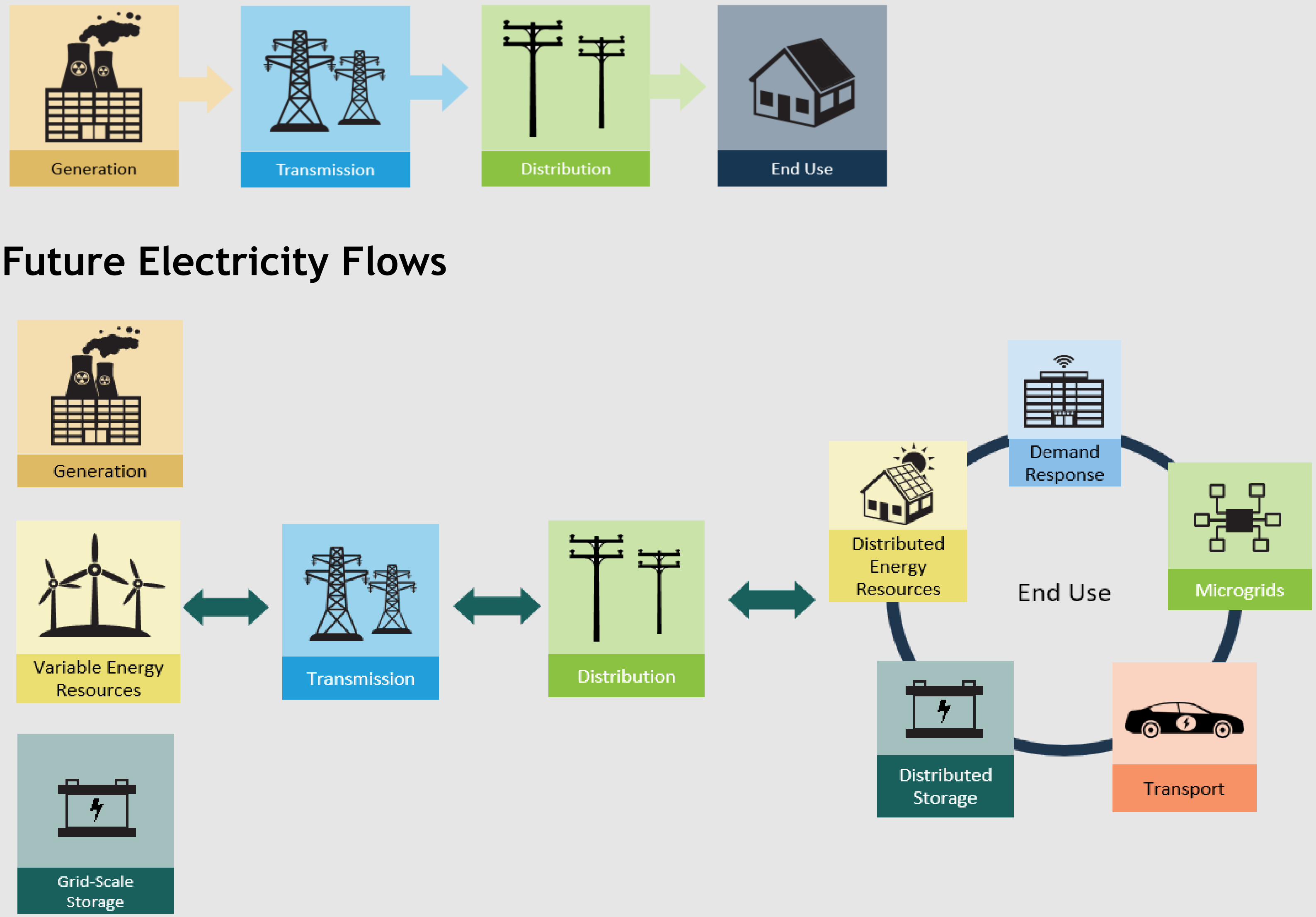
Pathway	Assumption	2050 Emissions	Costs	Solar Land Needs (% MA land)*	Non-Fossil Carbon Needs	Risks
Limited Offshore Wind	Offshore wind capped in region	5 Mt CO_2e	+$	1%	Low	Reliant on T&D and out of state resources, and additional solar, & hydro
No Thermal	All "firm" capacity retired by 2050	5 Mt CO_2e	+$$$ Solar+ storage	3%	Low	Reliant on additional solar and low-cost storage
100% Renewable Primary Energy	No fossil fuels allowed, zero carbon fuels used in thermal plants	0 Mt CO_2e	+$$$ Fuel imports	1%	High	Reliant on large bio-based or syntenic fuels industries to emerge
Pipeline Gas	Limited electrification of buildings currently using natural gas	5 Mt CO_2e	+$$ Fuel imports	1%	High	Reliant on large bio-based or syntenic fuels industries to emerge
Limited Efficiency	~10% reduction in energy demand (vs. 30%)	5 Mt CO_2e	+$$ Additional resources	1%	Moderate	Needs a faster development of T&D and wind

*Impact subject to policy influencing rooftop vs. ground shares

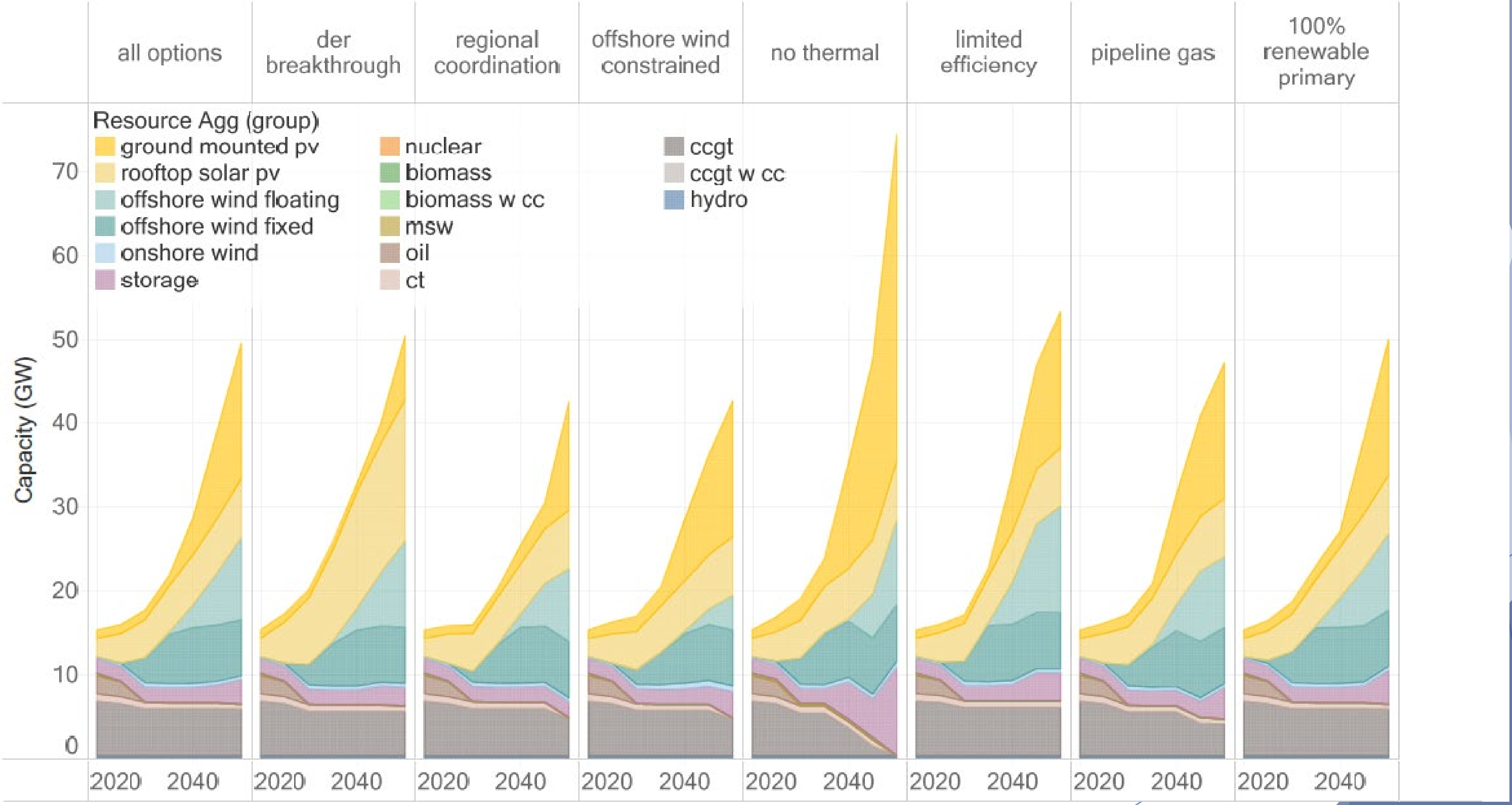
Renewable Electricity and the Need for Reliable Resources

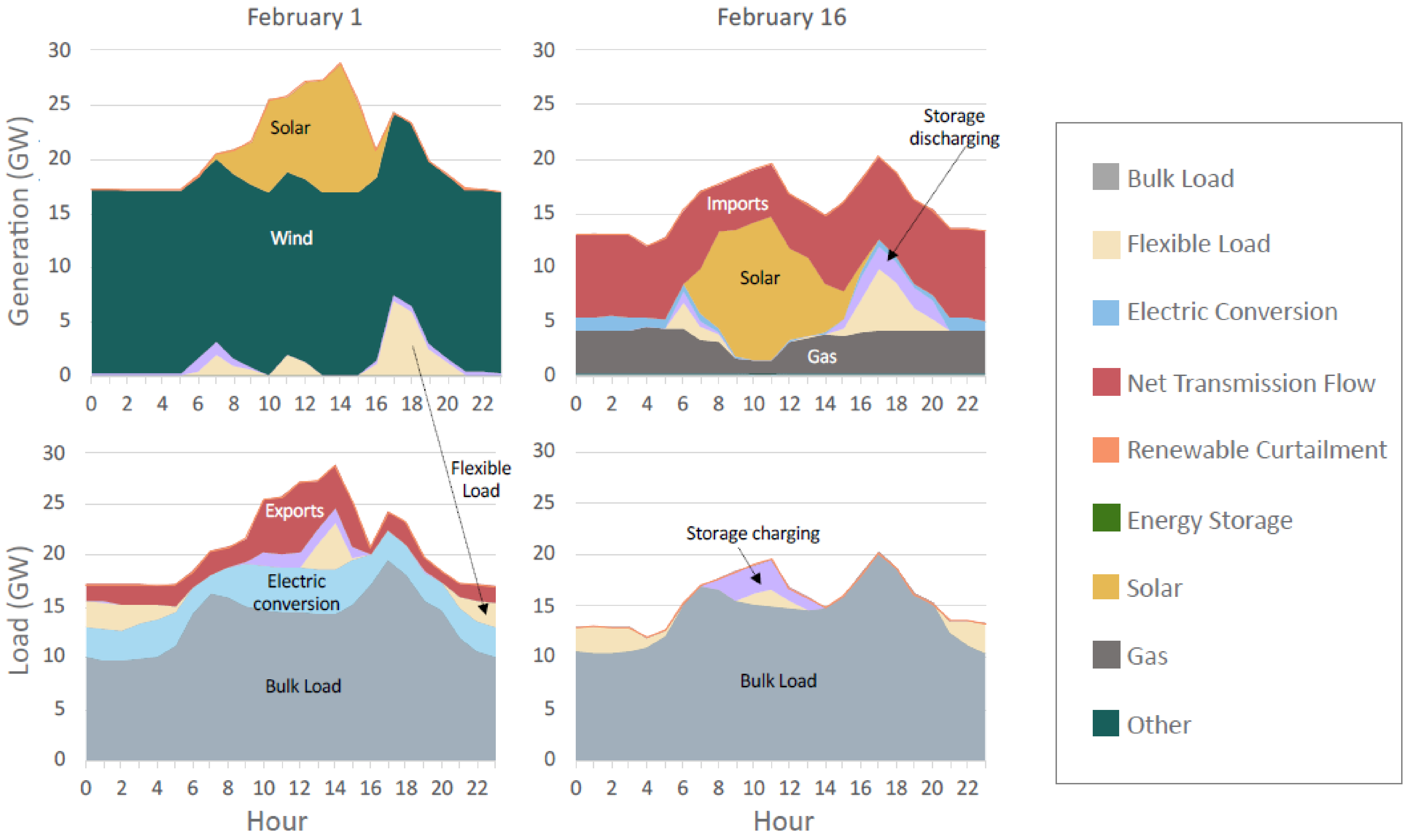
Traditional Flow of Electricity

Future Electricity Flows

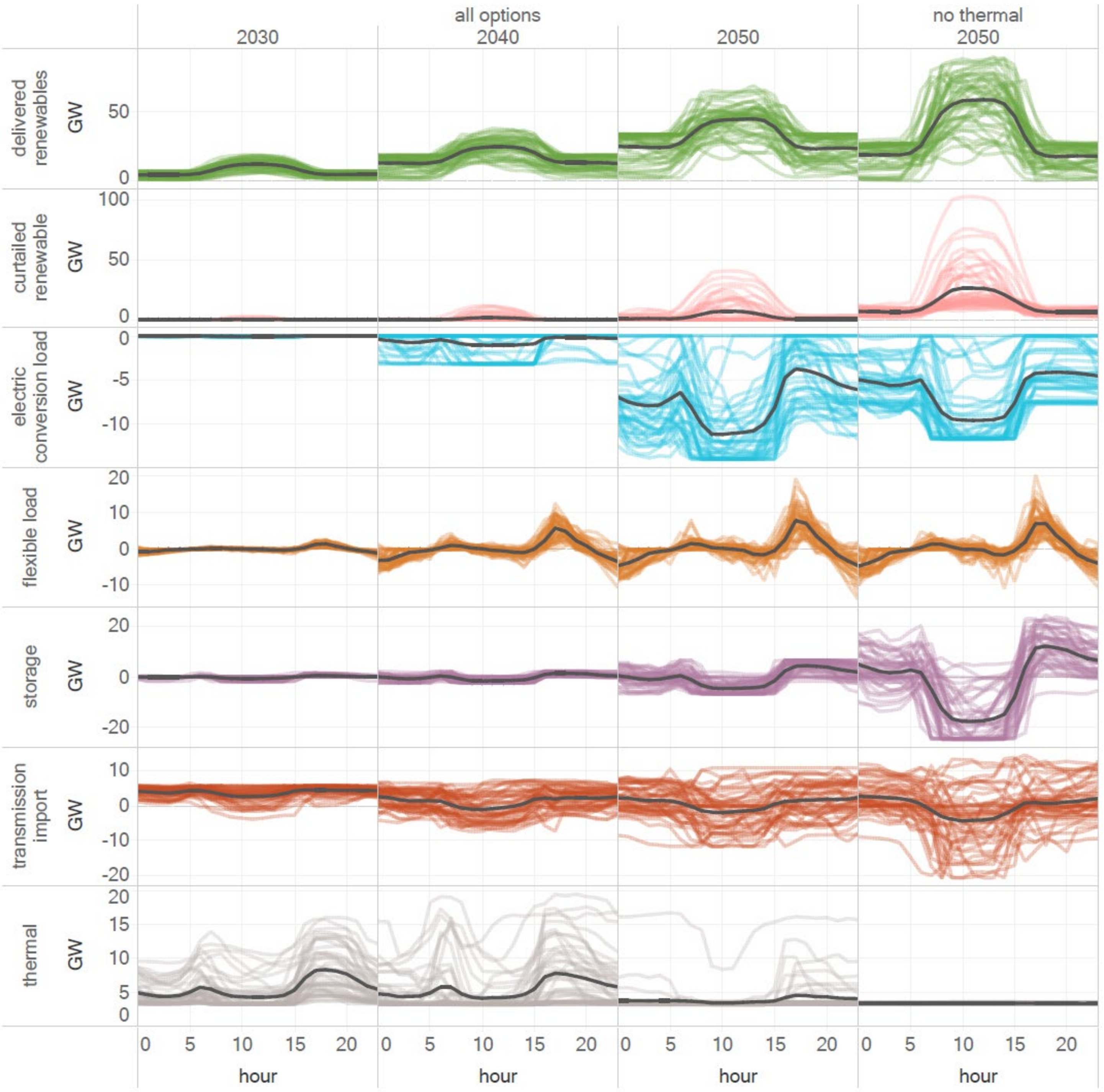


Mass Electricity Capacity by Year and Pathway



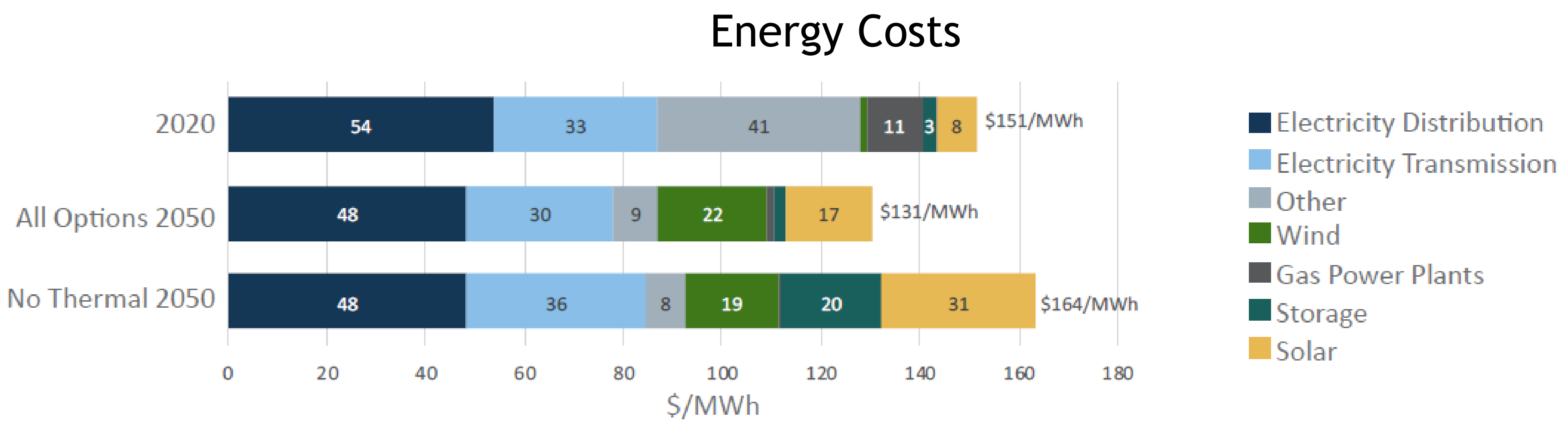


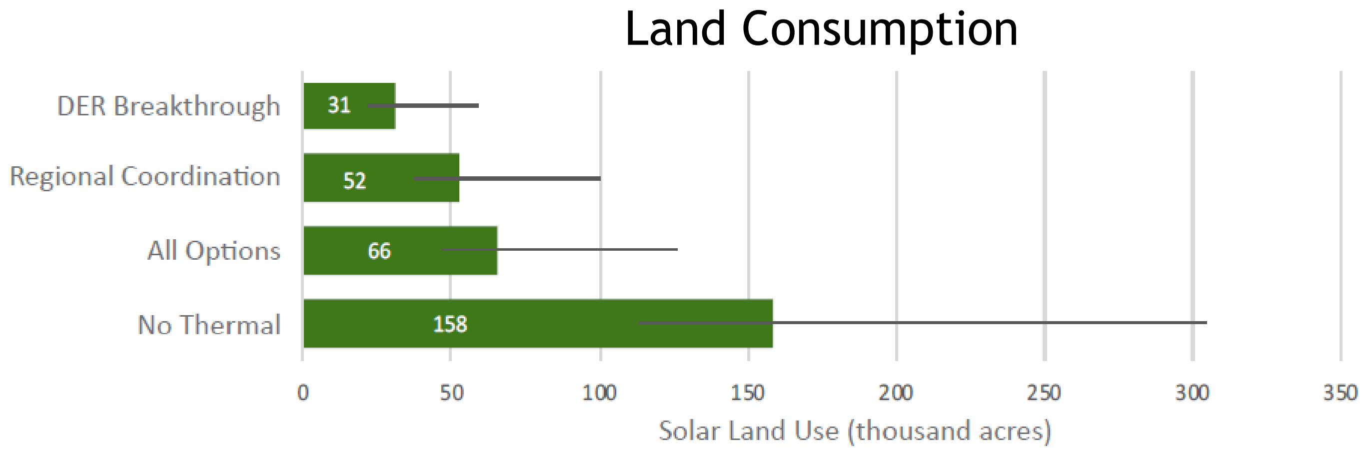
February 1
February 16
Generation (GW)
Load (GW)
Solar
Wind
Imports
Gas
Storage discharging
Exports
Electric conversion
Bulk Load
Flexible Load
Storage charging
Hour
Hour
Bulk Load
Flexible Load
Electric Conversion
Net Transmission Flow
Renewable Curtailment
Energy Storage
Solar
Gas
Other



all options
no thermal
2030
2040
2050
2050
delivered renewables
curtailed renewable
electric conversion load
flexible load
storage
transmission import
thermal
GW
hour

Pathway Choice Impacts Costs and Resource Demand



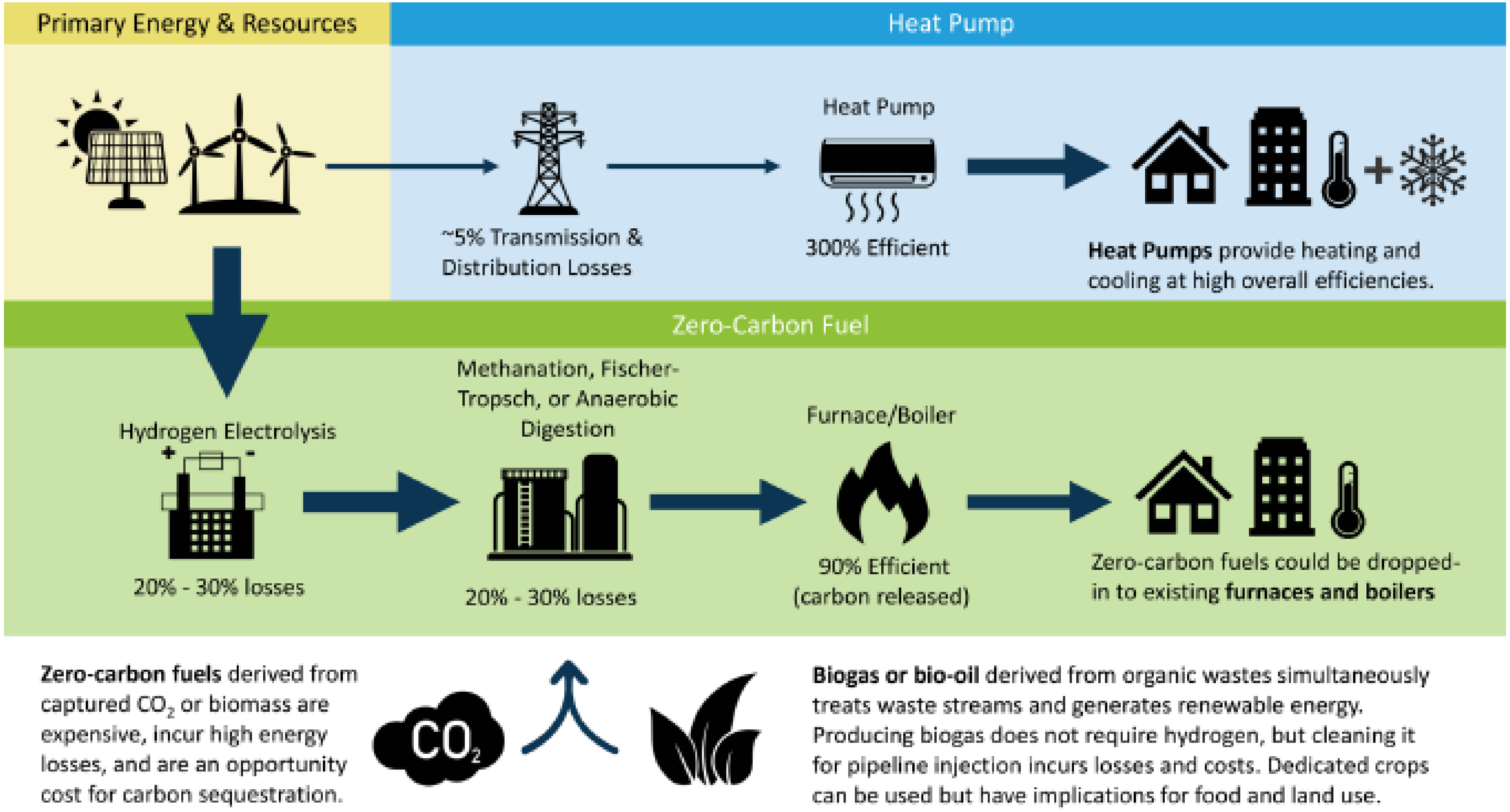


Renewable Energy Goals for MA

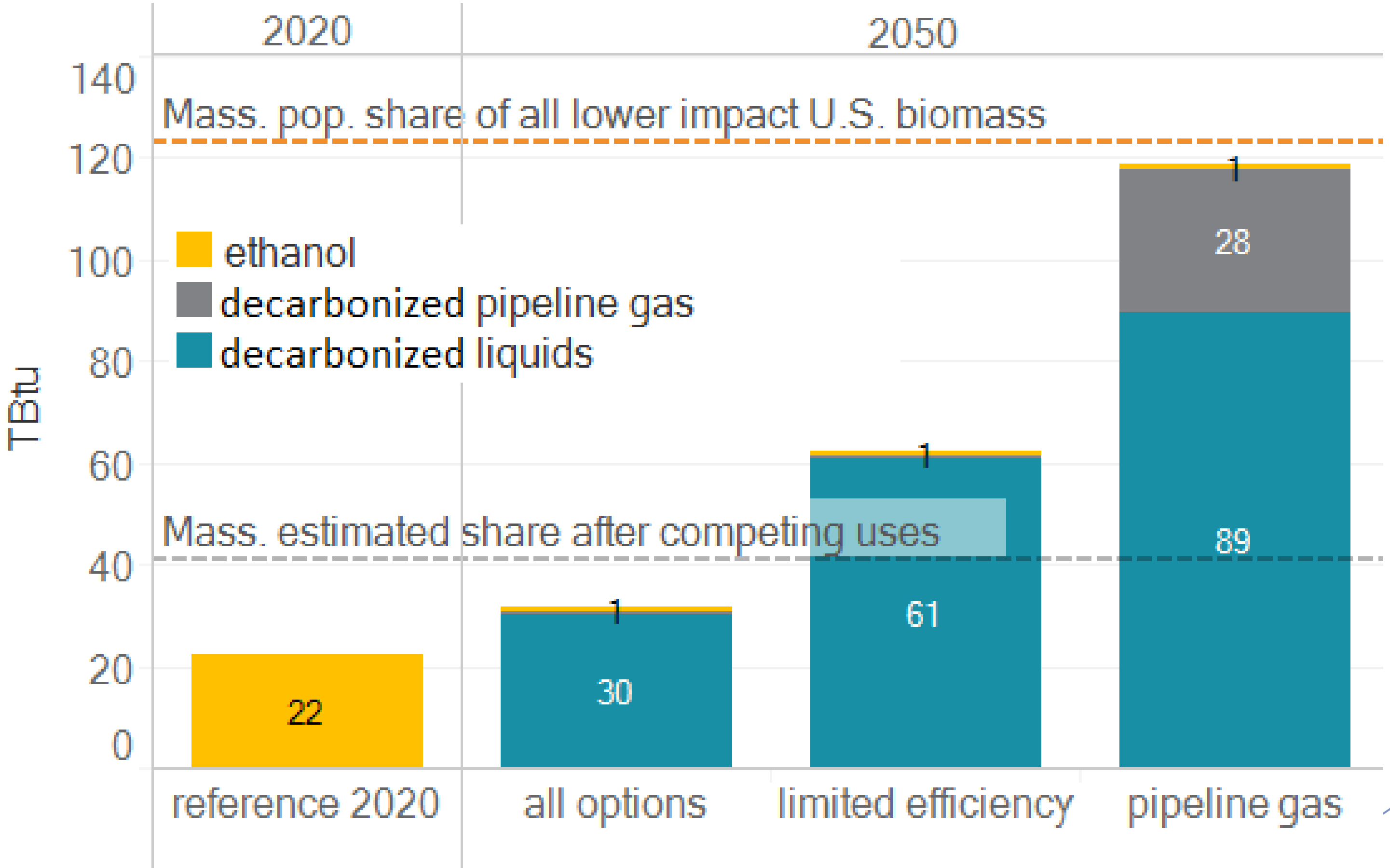
- **Offshore wind and solar** are the lowest cost low-carbon energy resources and will comprise the bulk of the Commonwealth's (15-20 GW each) and the region's electricity generation in 2050.
- Complementary resources and technologies, including imported **hydropower** and additional interstate **transmission**, is required to reliably operate a cost-effective, ultra-low emissions electricity grid based on variable renewable resources.
- Specific reliability resources (infrequently used **thermal capacity** without carbon capture, and/or new **bulk storage**) will be needed.
- *Key take-a-way:* we can get to 95-98% renewable energy cost effectively, but 100% will require large amount of storage and higher levels of land-consuming solar.

Building Decarbonization & the Limits of Fuels

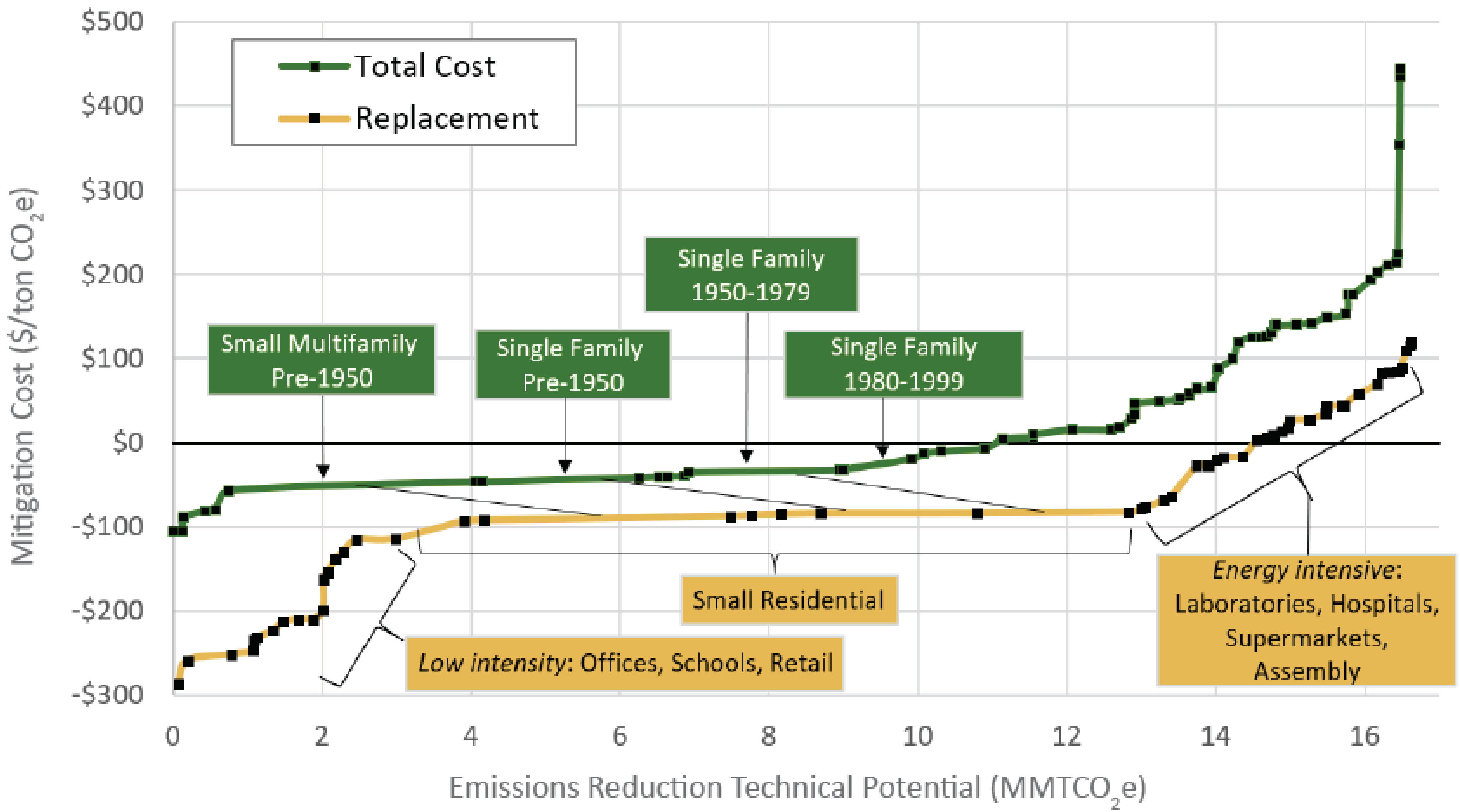
Use of Decarbonized Fuels in Buildings



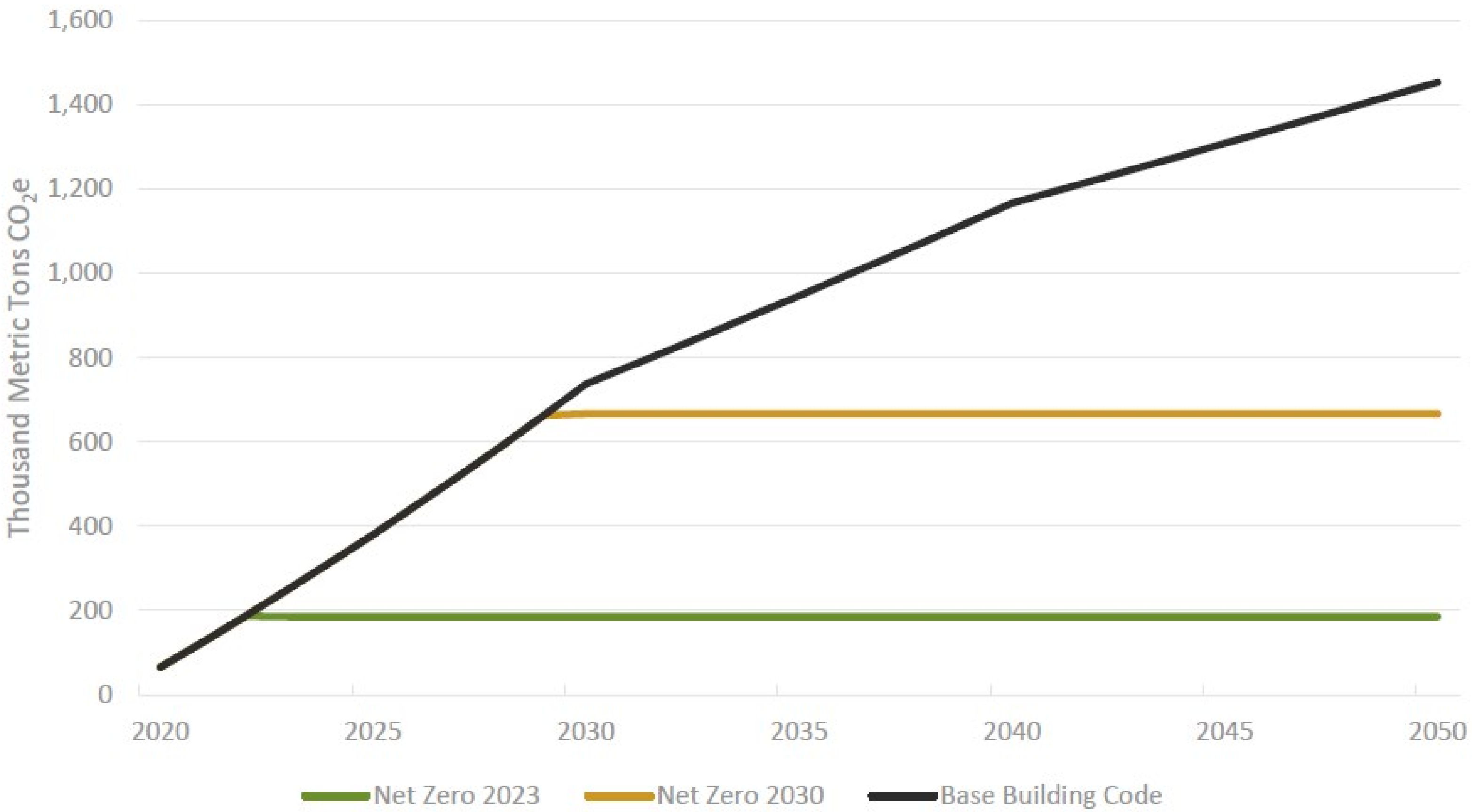
Reliance on bio-renewable fuels will likely strain bioenergy systems



Electrification Costs & Opportunity



Implementing a Net Zero code soon will avoid locking in fossil fuel infrastructure



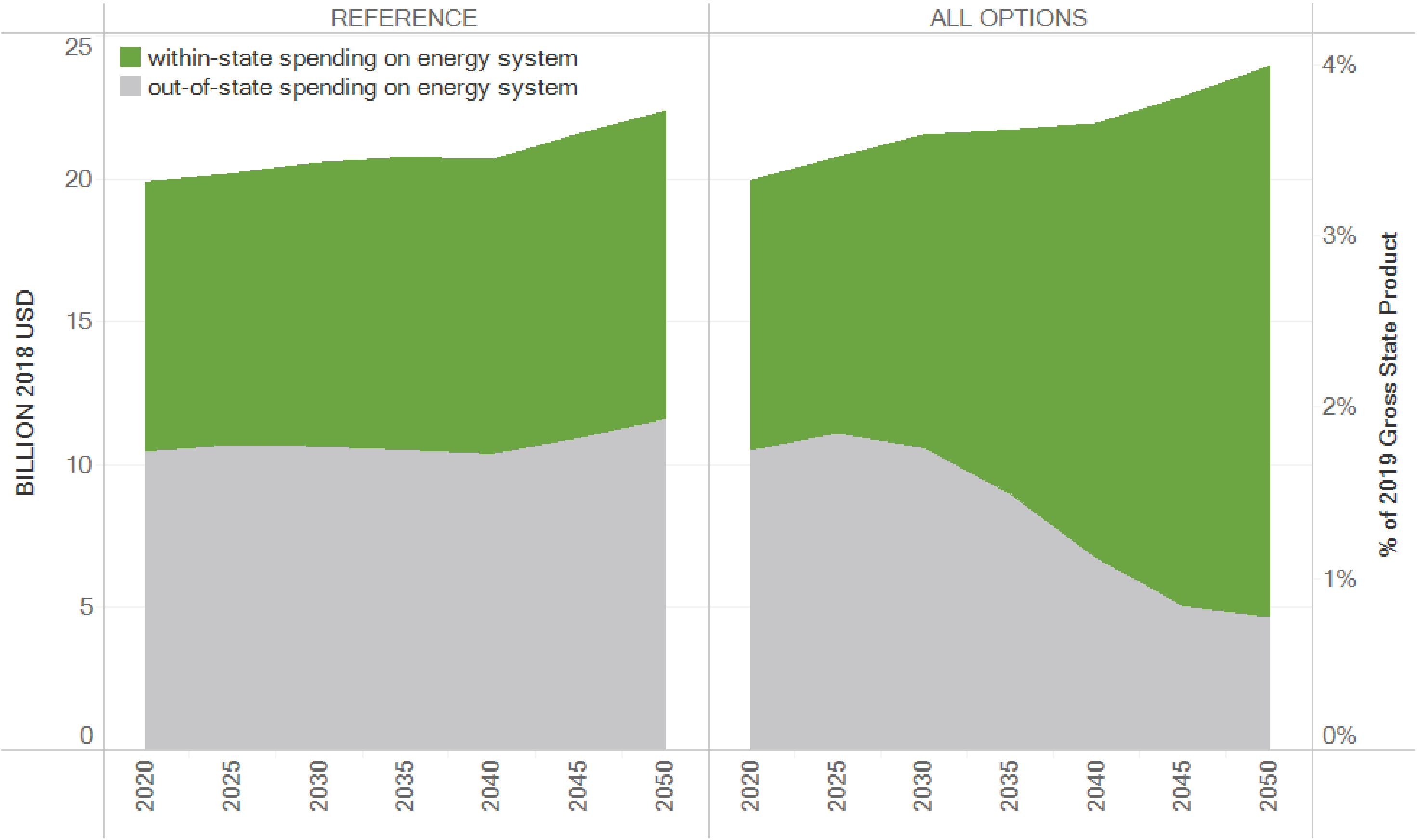
Building Sector Goals for MA

- **Electrification** of space and water heating is a low-risk, cost-effective strategy for decarbonizing the majority of the Commonwealth's building stock.
- Investing in **envelope efficiency** drives down costs to consumers and the entire energy system.
- A limited amount of **decarbonized fuels** may be available and be an appropriate strategy for some buildings, but in order to achieve Net Zero, the use of gas for building heat must start to decline in the near term.

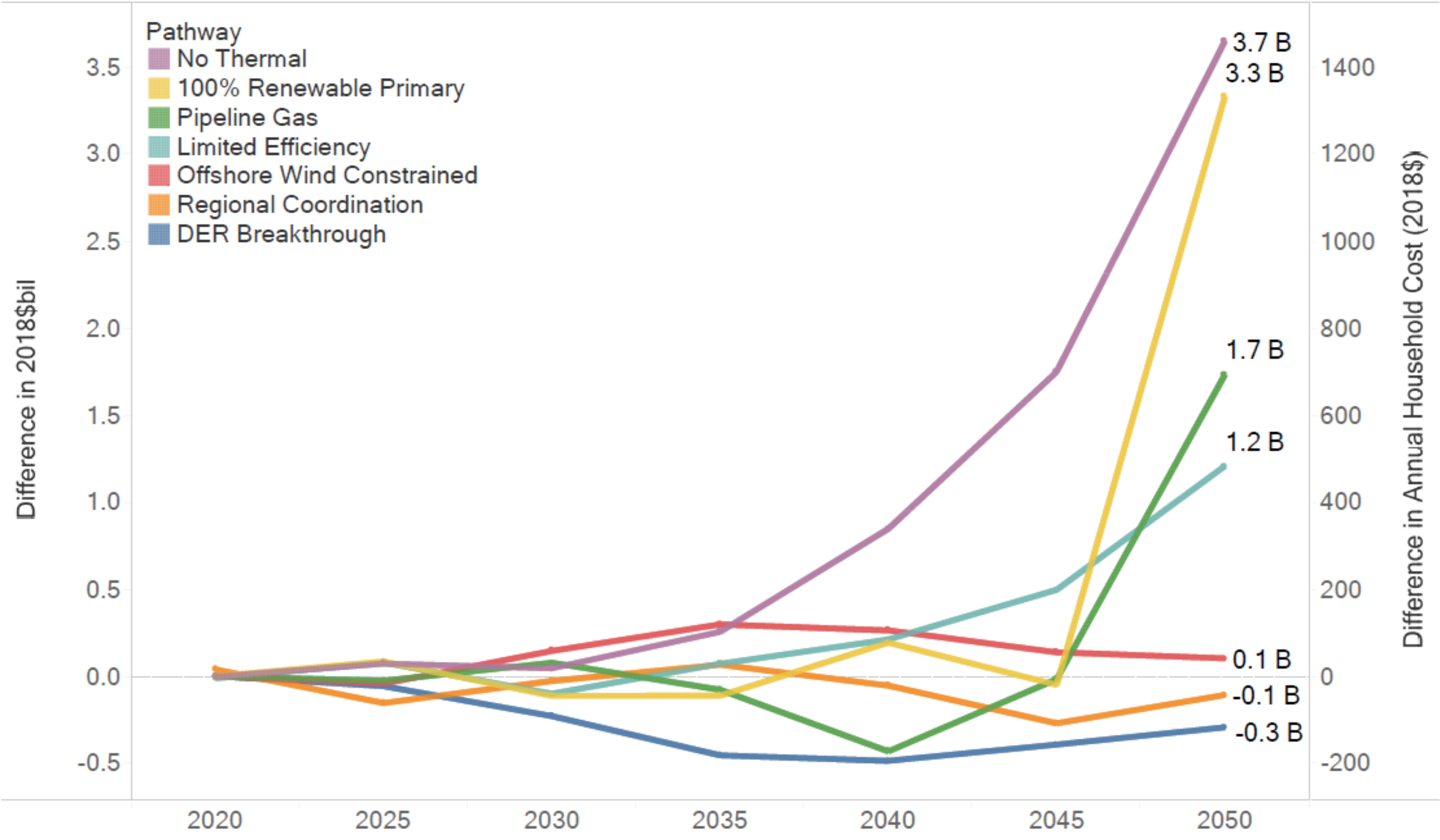
- *Key take-a-way*: electrification coupled with energy efficiency and flexibility is the most cost effective strategy for decarbonizing the buildings sector.

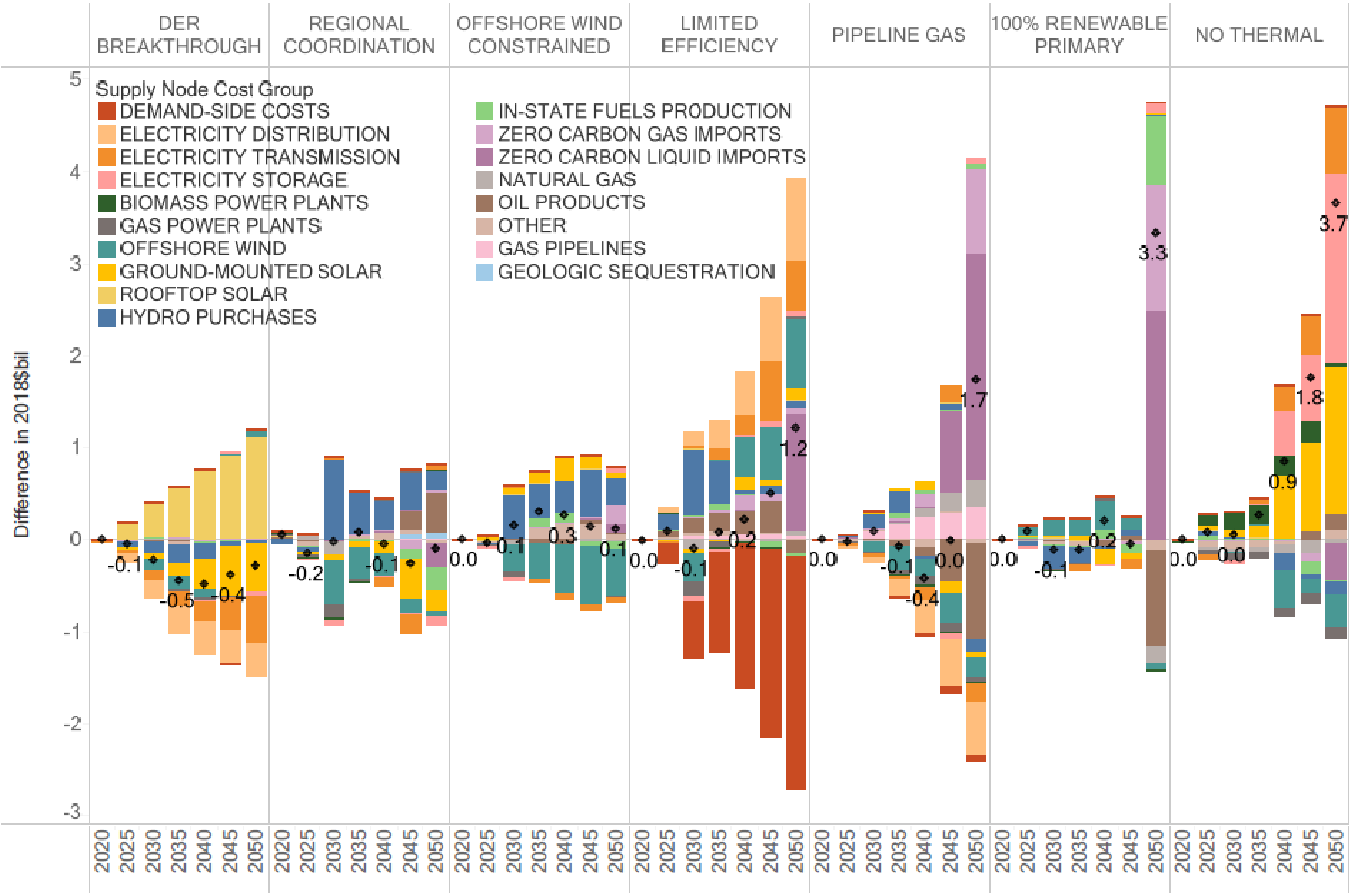
Cost, Economic, & Health Impacts

Decarbonization shifts spending from out-of-state energy purchases to capital equipment deployment in the state



Choice of how you decarbonize has long-term cost impacts

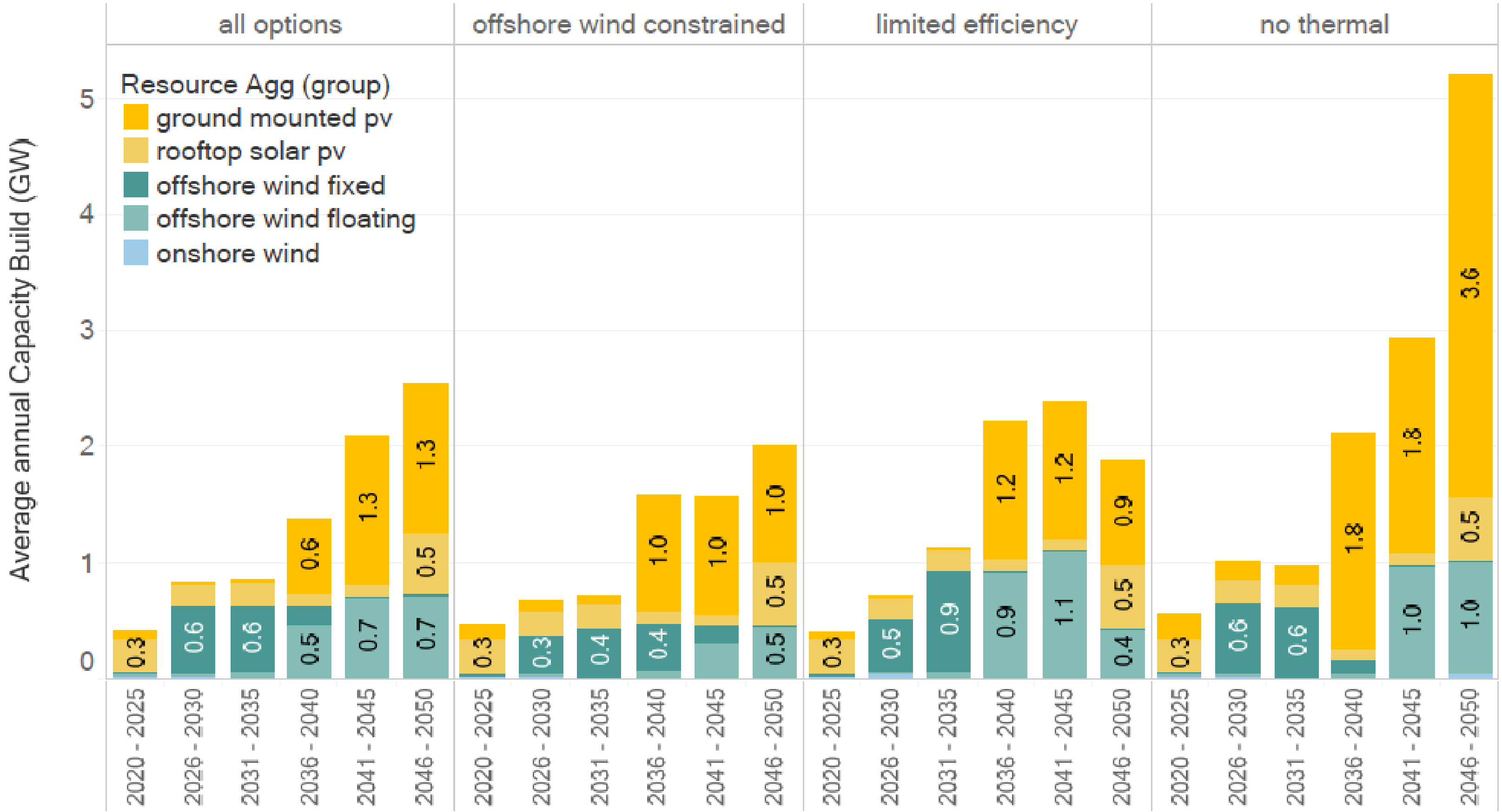



DER BREAKTHROUGH
REGIONAL COORDINATION
OFFSHORE WIND CONSTRAINED
LIMITED EFFICIENCY
PIPELINE GAS
100% RENEWABLE PRIMARY
NO THERMAL
Supply Node Cost Group
DEMAND-SIDE COSTS
ELECTRICITY DISTRIBUTION
ELECTRICITY TRANSMISSION
ELECTRICITY STORAGE
BIOMASS POWER PLANTS
GAS POWER PLANTS
OFFSHORE WIND
GROUND-MOUNTED SOLAR
ROOFTOP SOLAR
HYDRO PURCHASES
IN-STATE FUELS PRODUCTION
ZERO CARBON GAS IMPORTS
ZERO CARBON LIQUID IMPORTS
NATURAL GAS
OIL PRODUCTS
OTHER
GAS PIPELINES
GEOLOGIC SEQUESTRATION
Difference in 2018$bil
5
4
3
2
1
0
-1
-2
-3
-0.1
-0.5
-0.4
-0.2
-0.1
0.0
0.1
0.3
0.1
0.0
-0.1
0.2
1.2
0.0
-0.1
-0.4
0.0
1.7
0.0
-0.1
0.2
3.3
0.0
0.0
0.9
1.8
3.7
2020
2025
2030
2035
2040
2045
2050

How you decarbonize impacts economic benefits

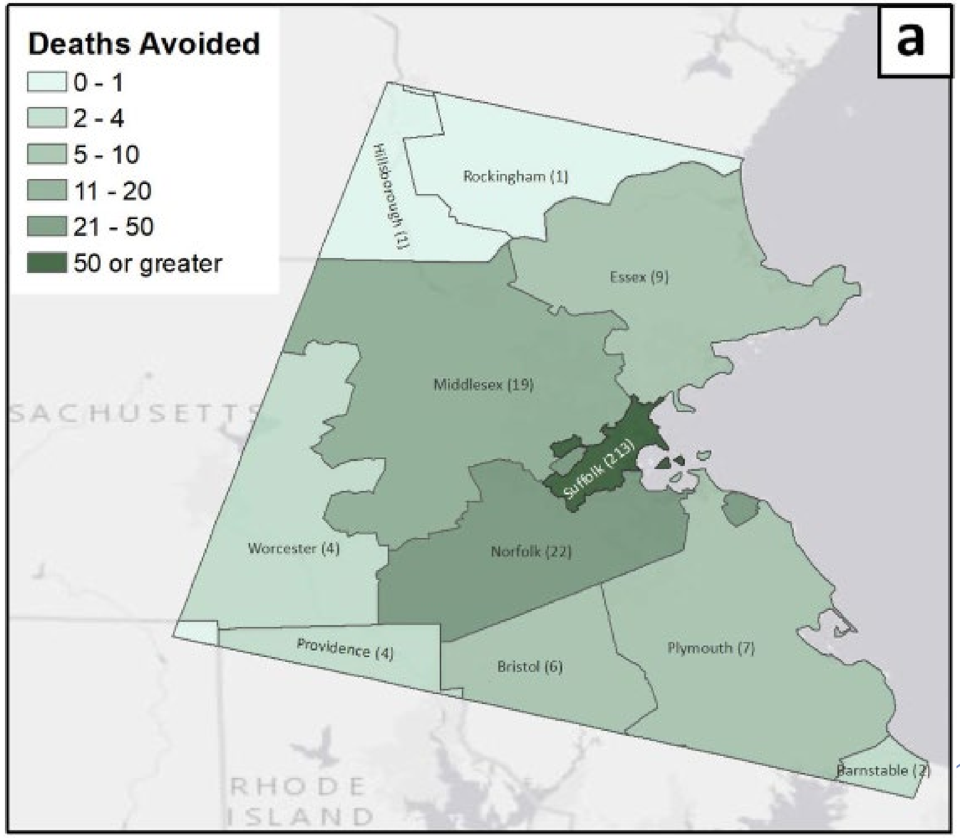
Pathway	*Total Net Cost above Ref. Case*	Change in Out-of-State Spending	Change in In-State Spending	Employment	Return on Investment		
					Labor Income	Value-Added	Output
	30-year total (billions $2018)			*jobs per million $ spent*	*$ per $ spent*	*$ per $ spent*	*$ per $ spent*
All Options	$29.2	-$55.4	$84.7	16.2	1.16	1.99	3.35
DER Breakthrough	$21.4	-$61.1	$82.5	18.8	1.32	2.32	3.97
Regional Coordination	$28.1	-$43.4	$71.6	15.1	1.06	1.83	3.02
Pipeline Gas	$33.2	-$45.3	$78.6	15.4	1.10	1.69	2.87
Offshore Wind Constrained	$34.7	-$45.0	$79.7	13.5	0.96	1.63	2.72
Limited Efficiency	$37.8	-$47.7	$85.5	12.8	0.98	1.71	2.84
100% Renewable Energy Primary	$40.5	-$50.6	$91.1	12.6	0.90	1.53	2.60
No Thermal	$56.2	-$54.2	$110.4	12.8	0.93	1.51	2.56

Rapid build-out of renewables required to reach net zero target



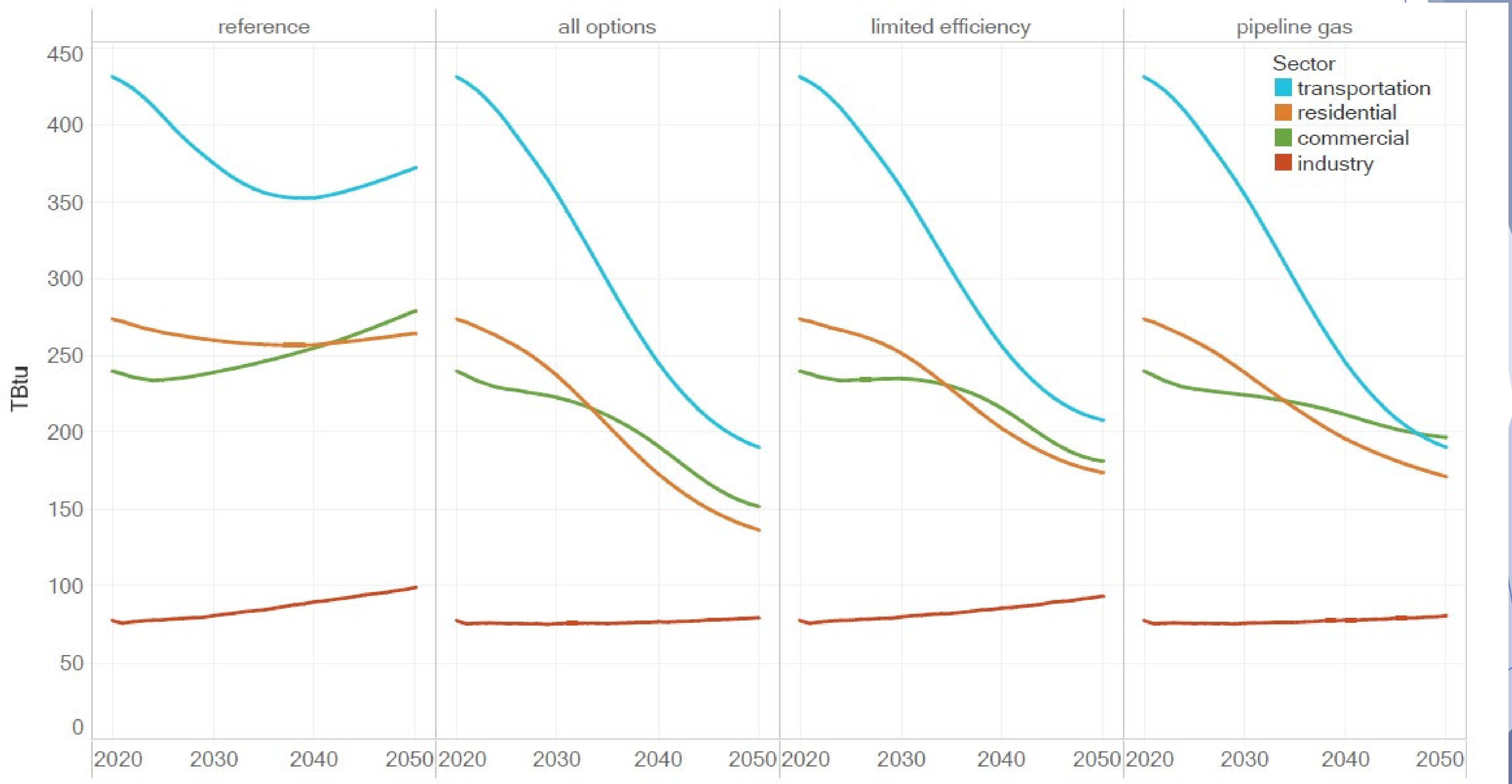
Health Benefits Accrue to the Most Vulnerable

- $2-4.5 Billion in health benefits annual
- Highest benefits are seen in Suffolk and Barnstable county

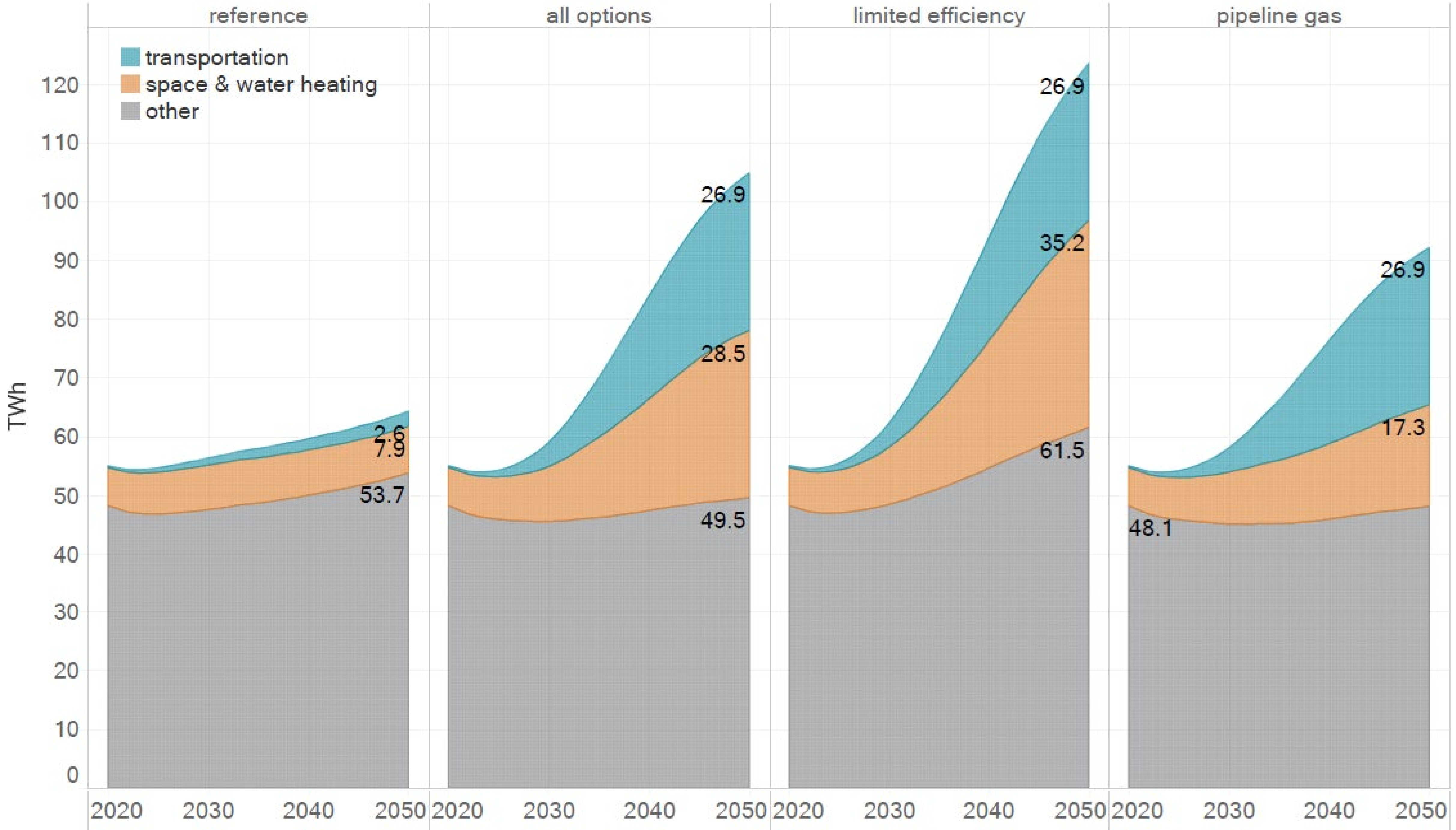


Raifman et. Al Env. Research Letters, 2020

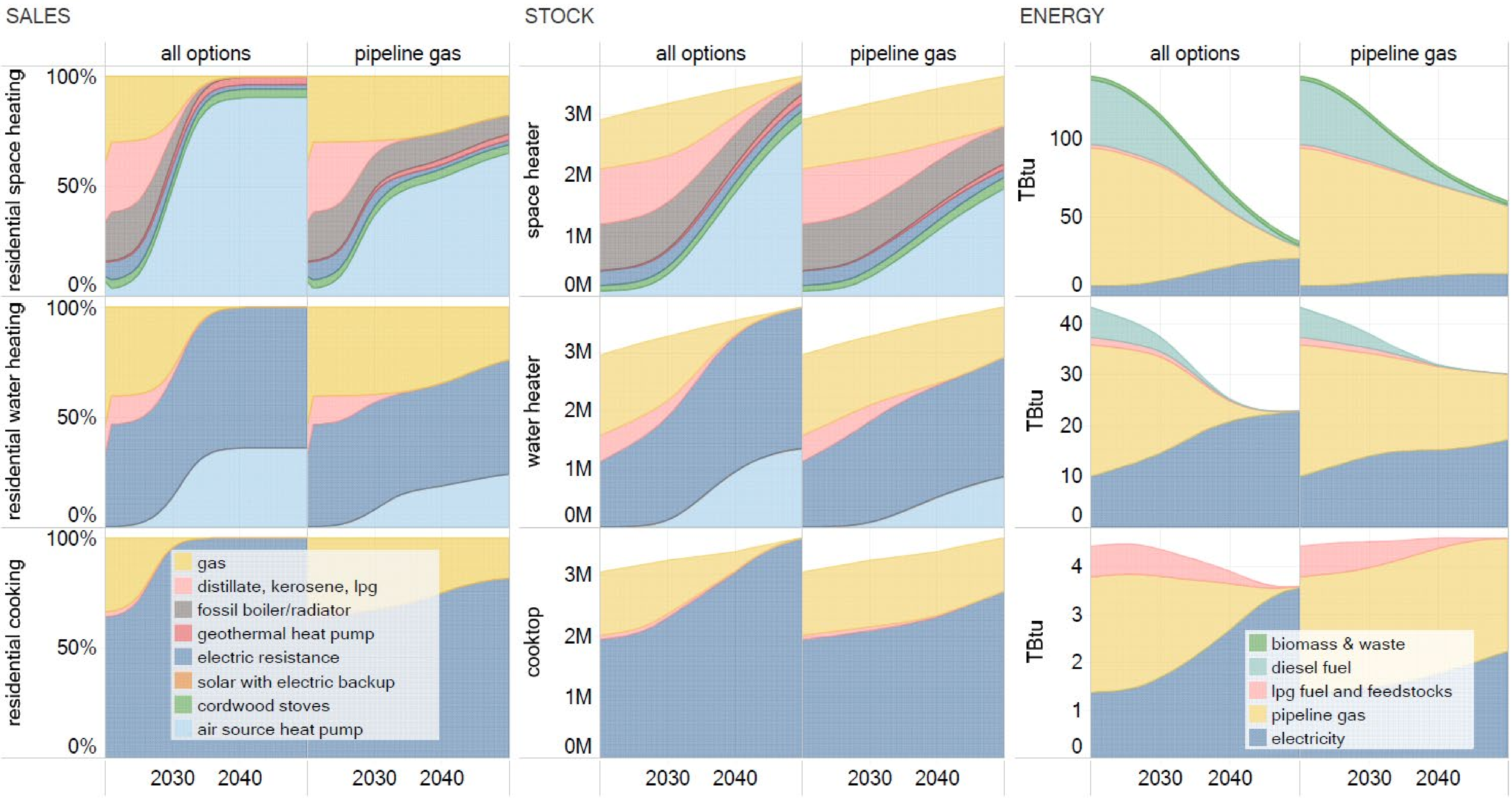
Questions & Discussion



reference
all options
limited efficiency
pipeline gas
TBtu
450
400
350
300
250
200
150
100
50
0
2020
2030
2040
2050
Sector
transportation
residential
commercial
industry



reference
all options
limited efficiency
pipeline gas
transportation
space & water heating
other
TWh
2.6
7.9
53.7
26.9
28.5
49.5
26.9
35.2
61.5
26.9
17.3
48.1


SALES
STOCK
ENERGY
all options
pipeline gas
residential space heating
residential water heating
residential cooking
space heater
water heater
cooktop
TBtu
100%
50%
0%
0M
1M
2M
3M
2030
2040
gas
distillate, kerosene, lpg
fossil boiler/radiator
geothermal heat pump
electric resistance
solar with electric backup
cordwood stoves
air source heat pump
biomass & waste
diesel fuel
lpg fuel and feedstocks
pipeline gas
electricity