Massachusetts 2050 Decarbonization Roadmap

January 15, 2021

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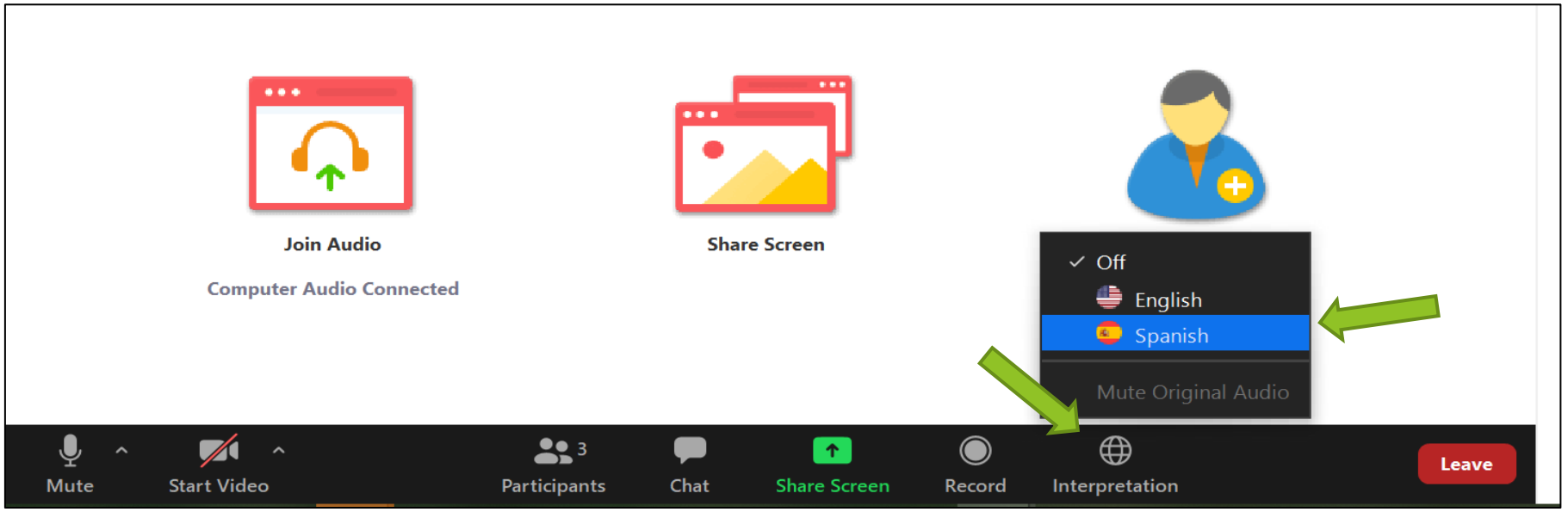
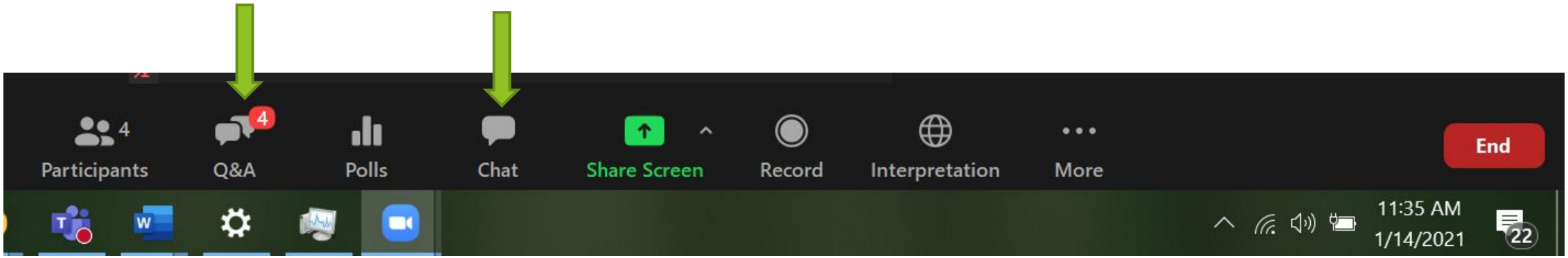
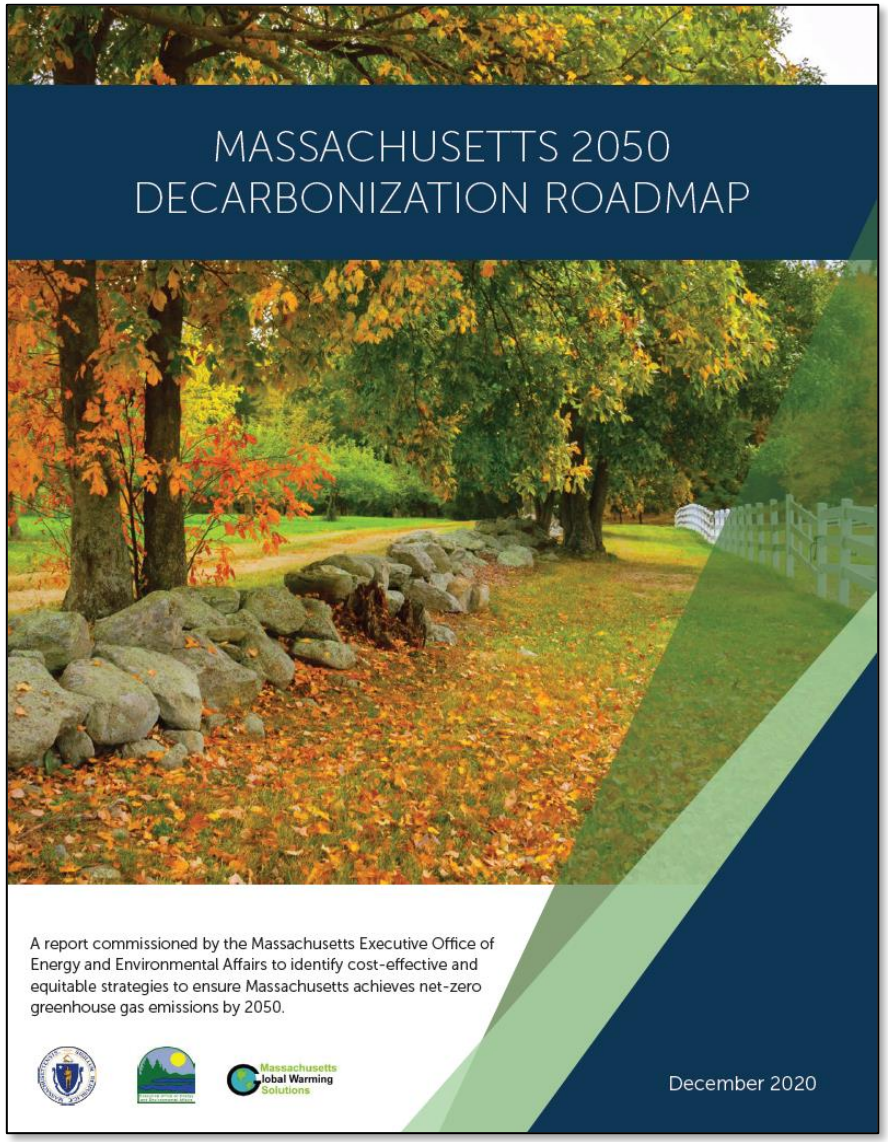


Webinar logistics

- This webinar is being recorded and will be posted online afterwards.
- All lines will be muted.
- Poll
- Question & Answer session will take place after the presentation.
  - If you have a question during the presentation, you can type it into the Q&A Box. If you have a logistical issue, please type it into the Chat box.



- What is the 2050 Roadmap?
- Approach
- Top Findings
- Sector Snapshots
- Next Steps: www.mass.gov/2050Roadmap

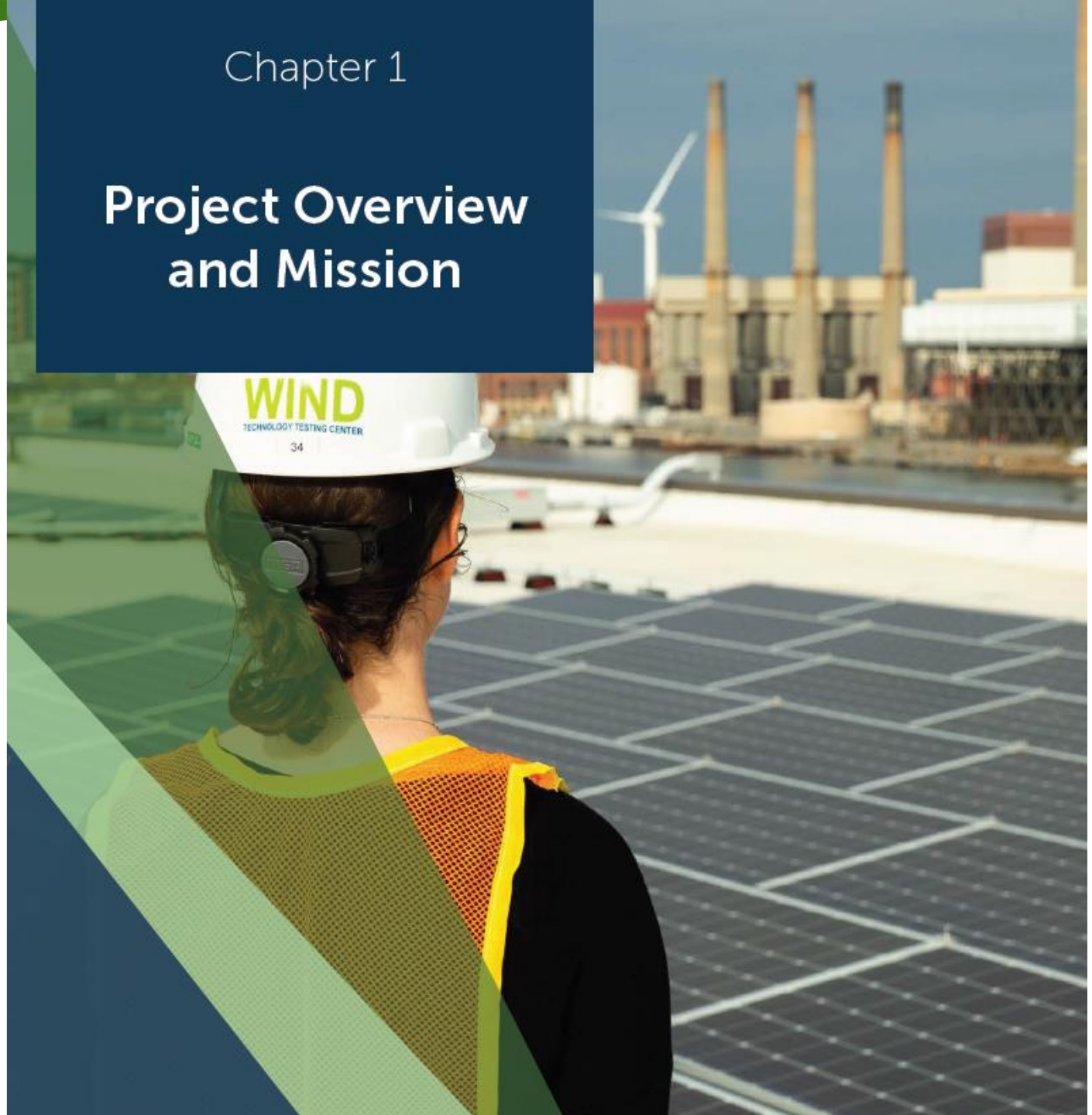


- Two Year Research Effort
- Comprehensive Understanding of 30-year Transition to Net Zero
- Focused on Implementation
- Inform Near-Term Decision-Making
- Results Published Dec. 30, 2020

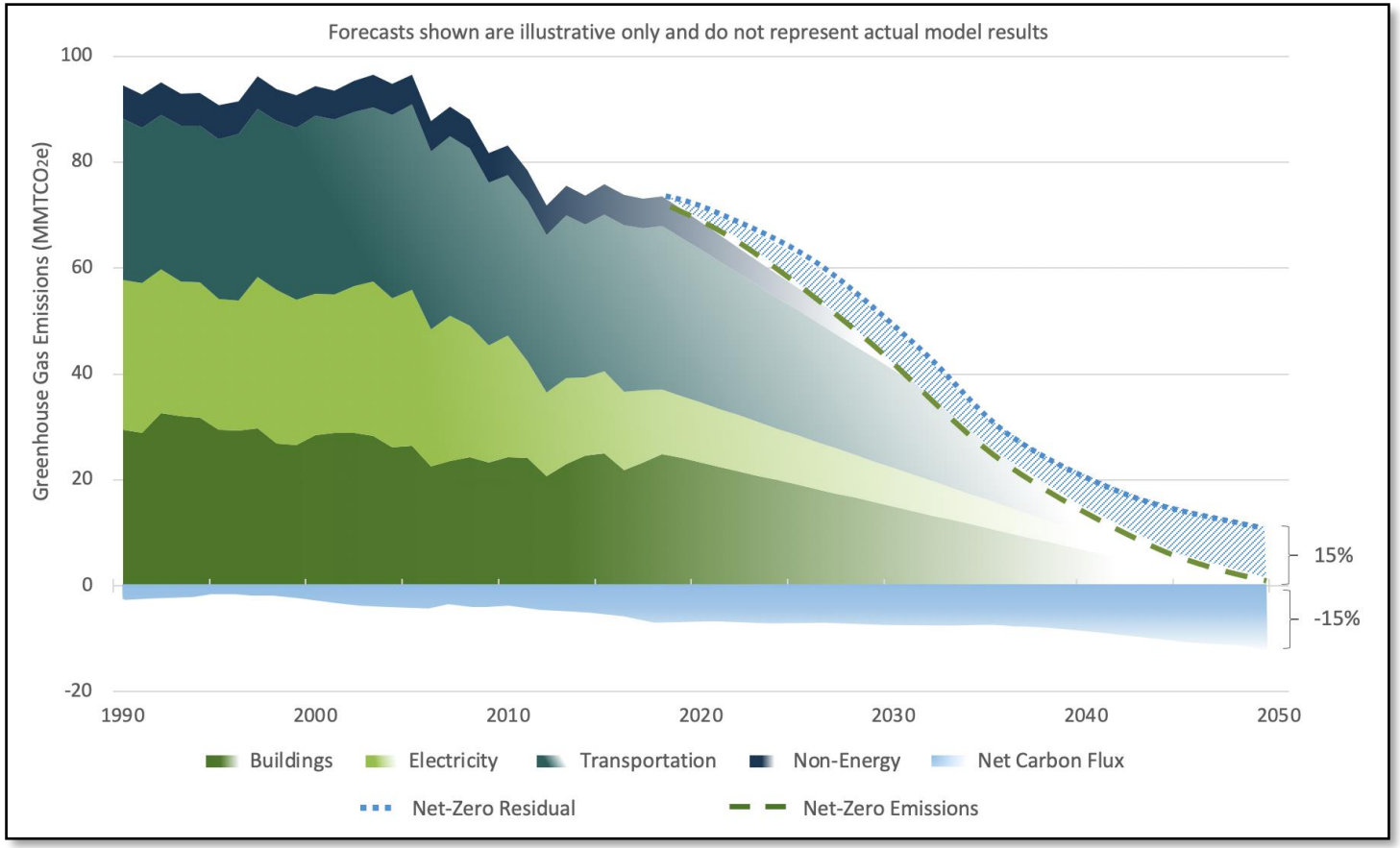
For More Information: www.mass.gov/2050Roadmap

Chapter 1

Project Overview and Mission



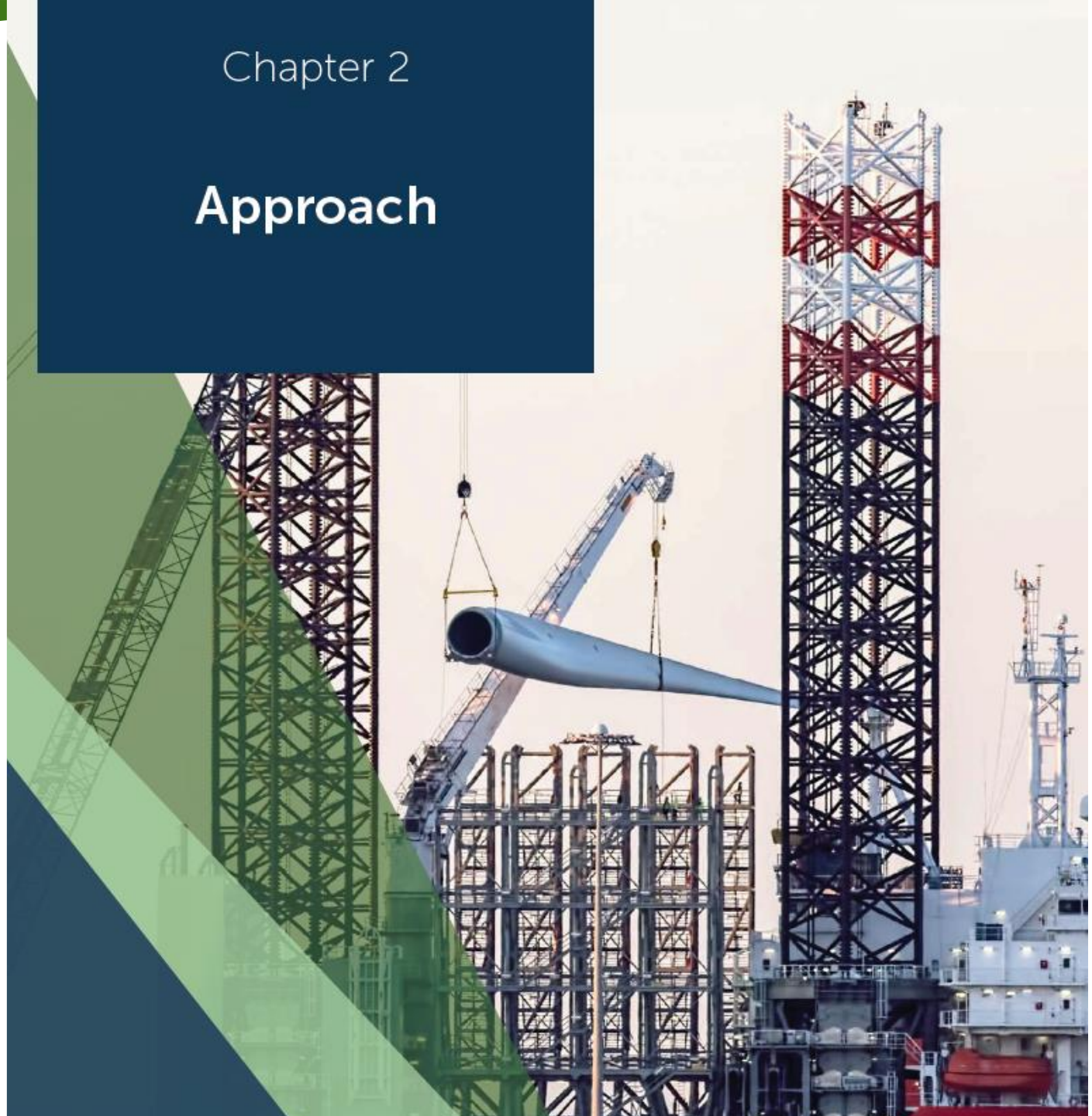
How can the Commonwealth achieve Net Zero GHG emissions while maintaining a healthy, equitable, and thriving economy?



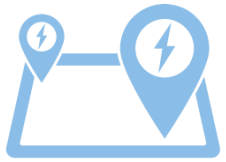
For More Information: www.mass.gov/2050Roadmap

Chapter 2

Approach



Start with the technical to enable policy and implementation



Explore multiple pathways to support the development of robust and resilient decarbonization strategies

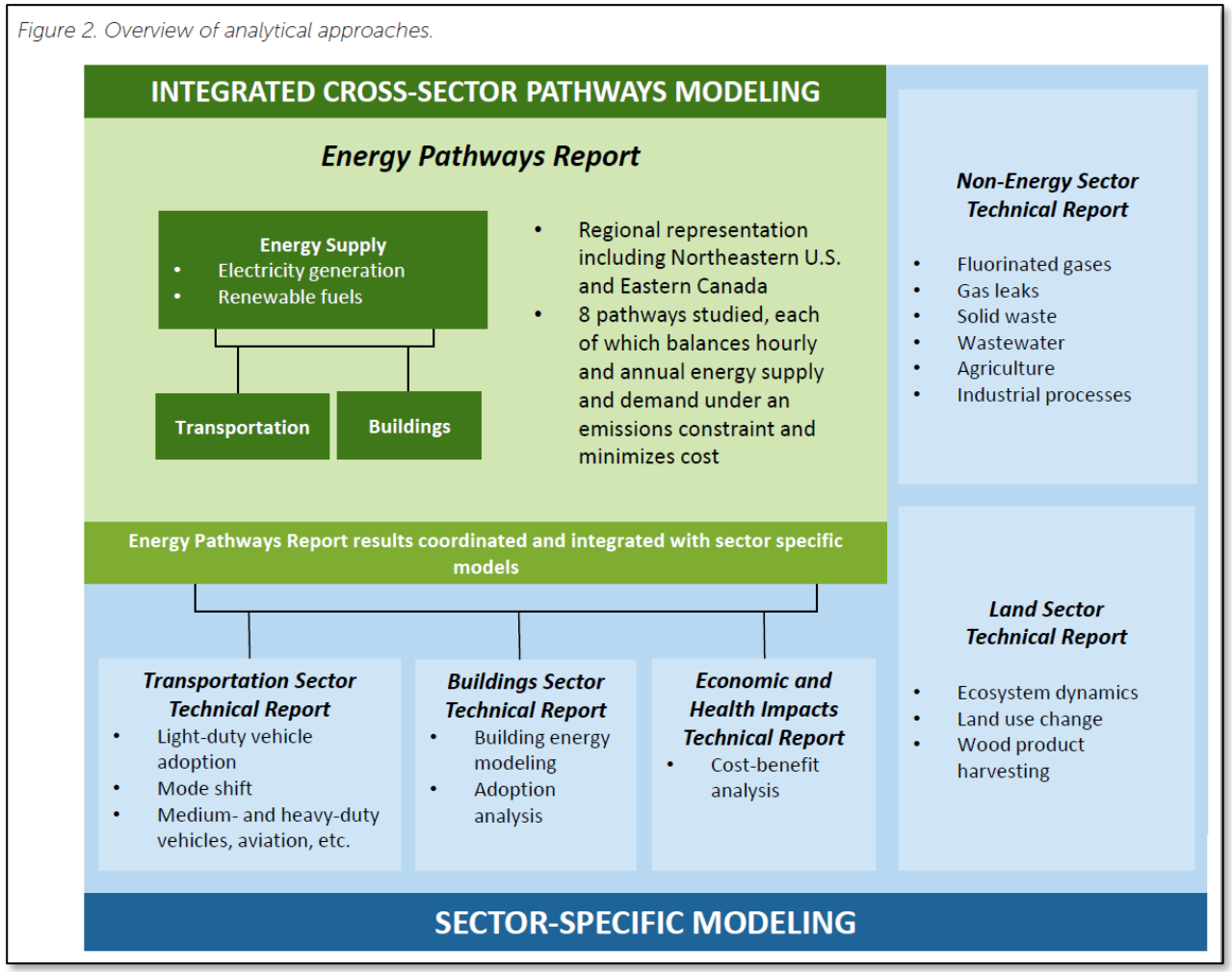
Create optionality for the Commonwealth

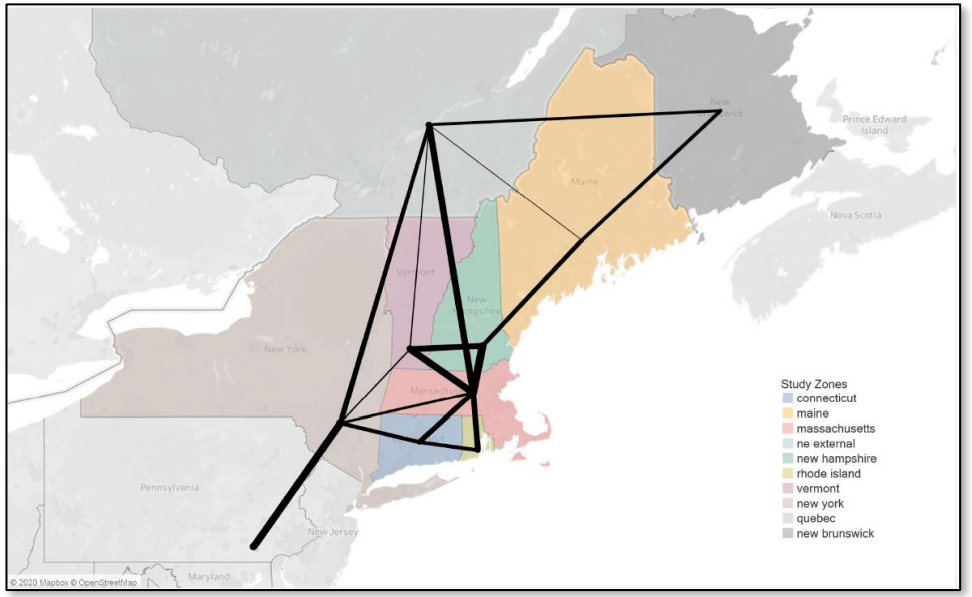
Use “back-cast” modeling to best understand the transformations needed to get to 2050

Produce granular data to unlock and enable policy implementation and market action

For More Information: www.mass.gov/2050Roadmap

Figure 2. Overview of analytical approaches.





- Regional
- Integrated
- Cross-Sector
- All Sectors
- All Emissions

For More Information: www.mass.gov/2050Roadmap

Each *Pathway* is a complete, annual portfolio of reliable energy supply – the "what do we need" and "by when do we need it" – to meet future energy needs across the economy while achieving required 2050 emissions reductions (at least an 85% reduction below 1990 levels).

	Pathways Analyzed	*Key Characteristics / Distinguishing Features*
	All Options	**Baseline analysis** – model selecting most economic resources to meet emissions limits using baseline cost assumptions.
Variations applied to *All Options*	**DER Breakthrough**	High deployment of behind-the-meter solar + battery storage
	Decarbonized Gas	Regional access to low-carbon pipeline gas product
	100% Renewable	Fossil fuels fully replaced throughout economy with carbon neutral fuel; nuclear retired
	Regional Expansion	Lower-cost electric transmission + export of captured CO_2
	No Thermal	Forced retirement of all gas and oil electricity generation
	OSW Constrained	Region constrained to 30GW of offshore wind (near-shore siting difficult; high price; approvals delayed; etc.)
	Limited Energy Efficiency	Envelope efficiency gains remain at current levels.

For More Information: www.mass.gov/2050Roadmap

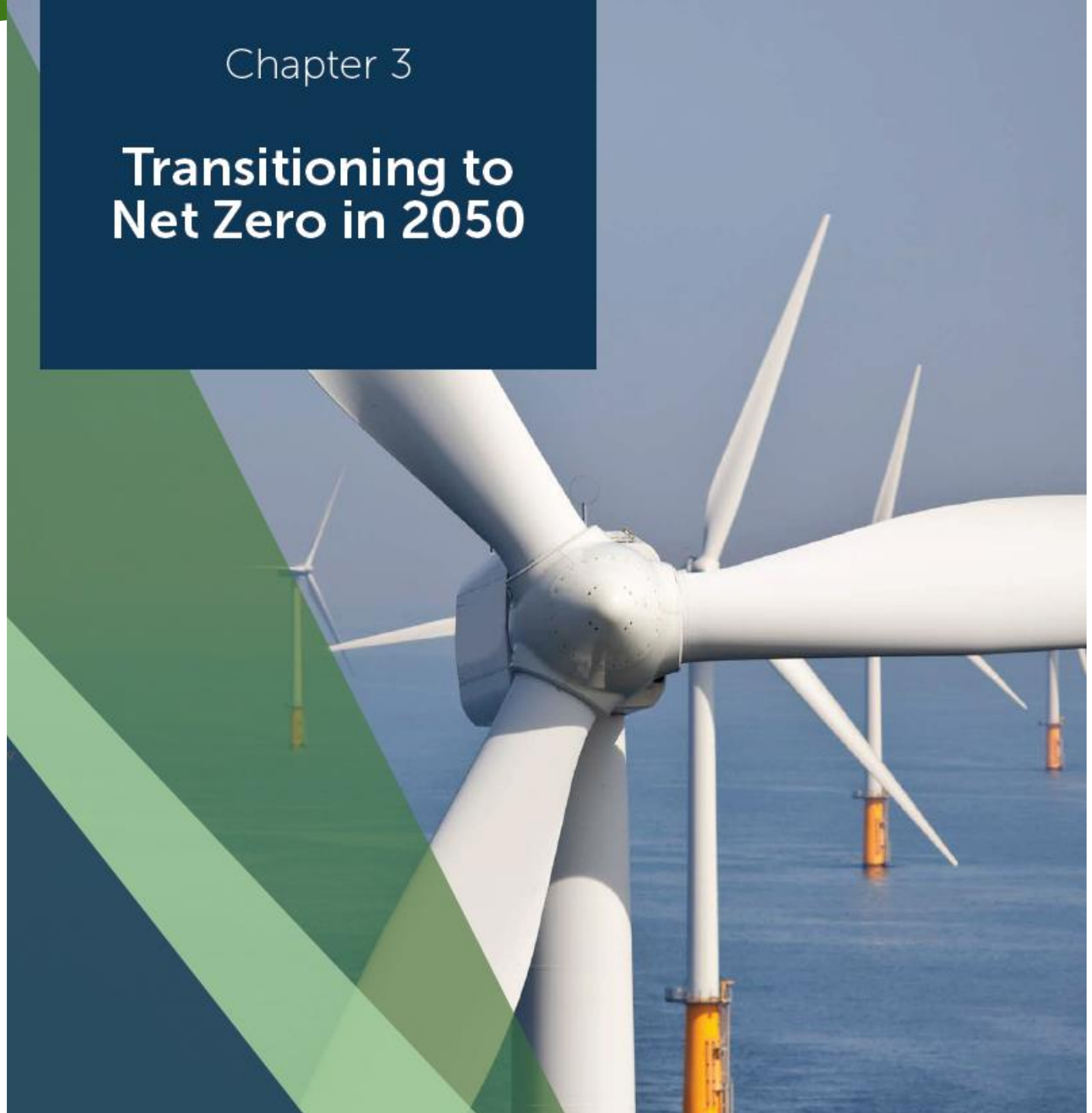
Equity Considerations for Deep Decarbonization

Stakeholder Engagement

For More Information: www.mass.gov/2050Roadmap

Chapter 3

Transitioning to Net Zero in 2050



Massachusetts can achieve Net Zero in 2050 while continuing to thrive

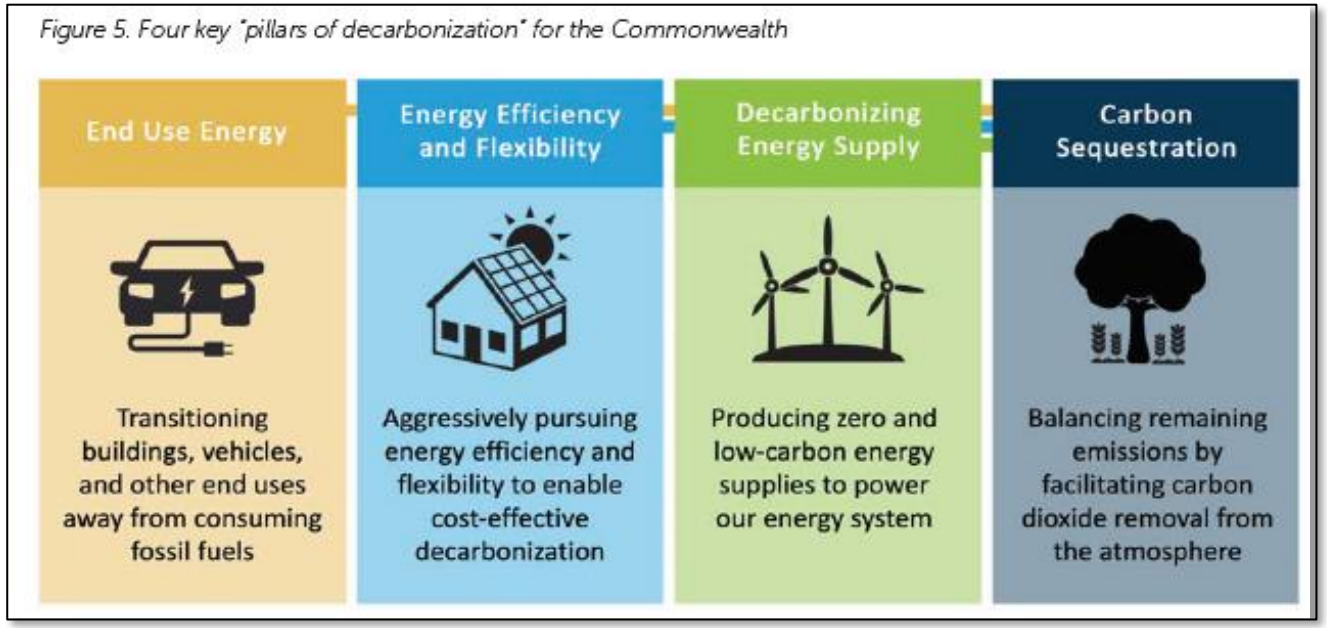
- Affordably
- Investment Delivers Savings
- Health and Equity Benefits

For More Information: www.mass.gov/2050Roadmap

Strategies to Achieve Net Zero

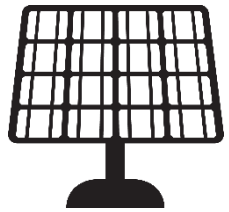
4 key components of deep decarbonization guided development of implementation strategies:

Figure 5. Four key "pillars of decarbonization" for the Commonwealth



To reduce emissions from energy demand in end uses through electrification, fuel switching, efficiency, and flexibility.

To reliably supply low-to-zero carbon energy resources to Massachusetts residents.



To minimize residual emissions and maximize cost-effective carbon dioxide removal and storage.

For More Information: www.mass.gov/2050Roadmap

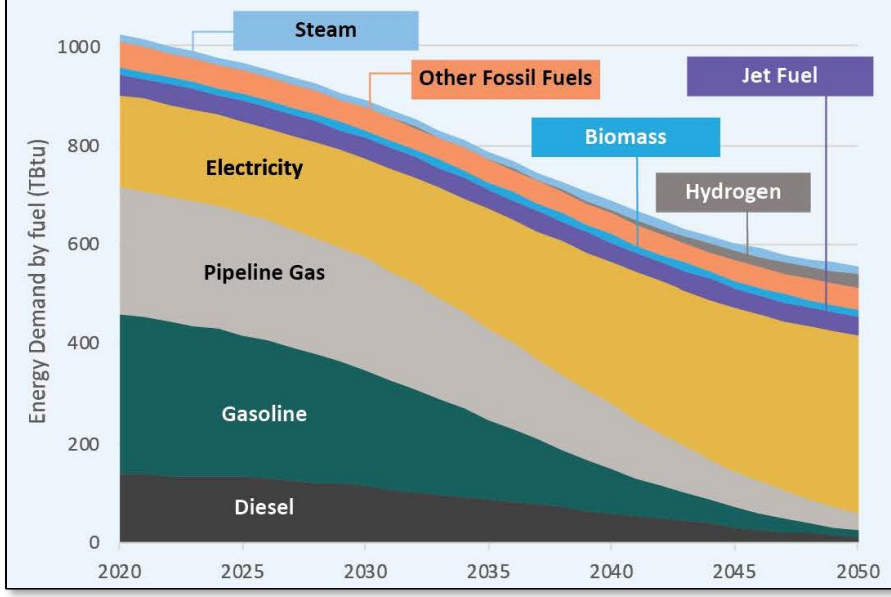
Energy Demand and Supply

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

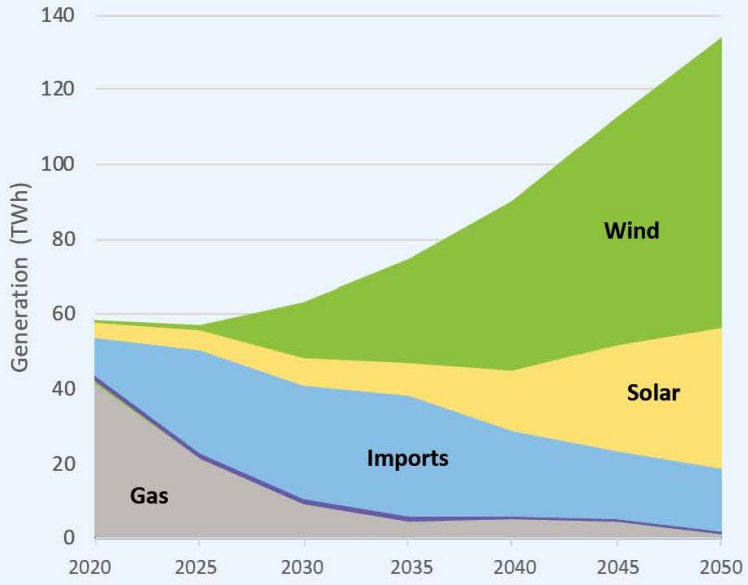
Over time, most building and transportation end uses are electrified resulting in monthly savings

Solar and wind generation increase dramatically through 2050

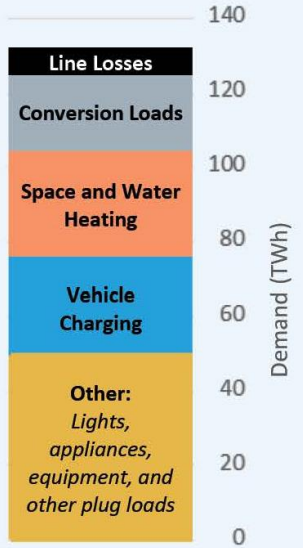
Energy Demand by Fuel



Electricity Generation by Source

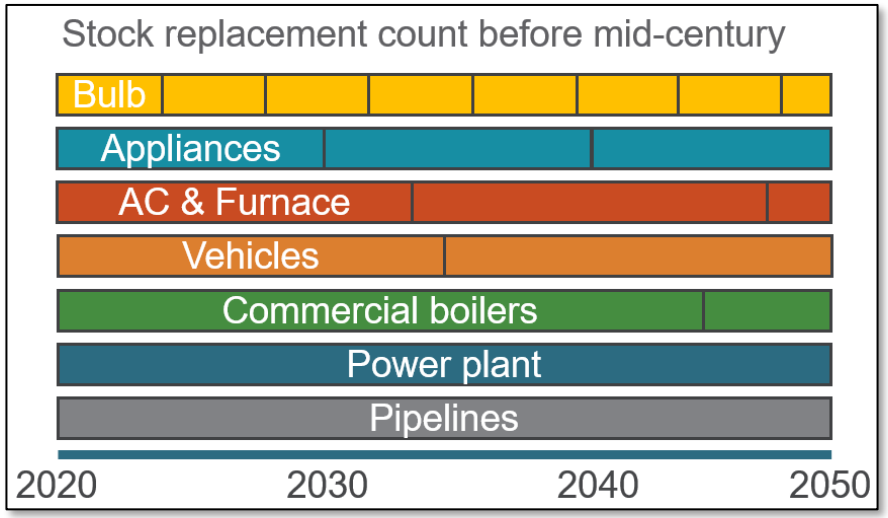


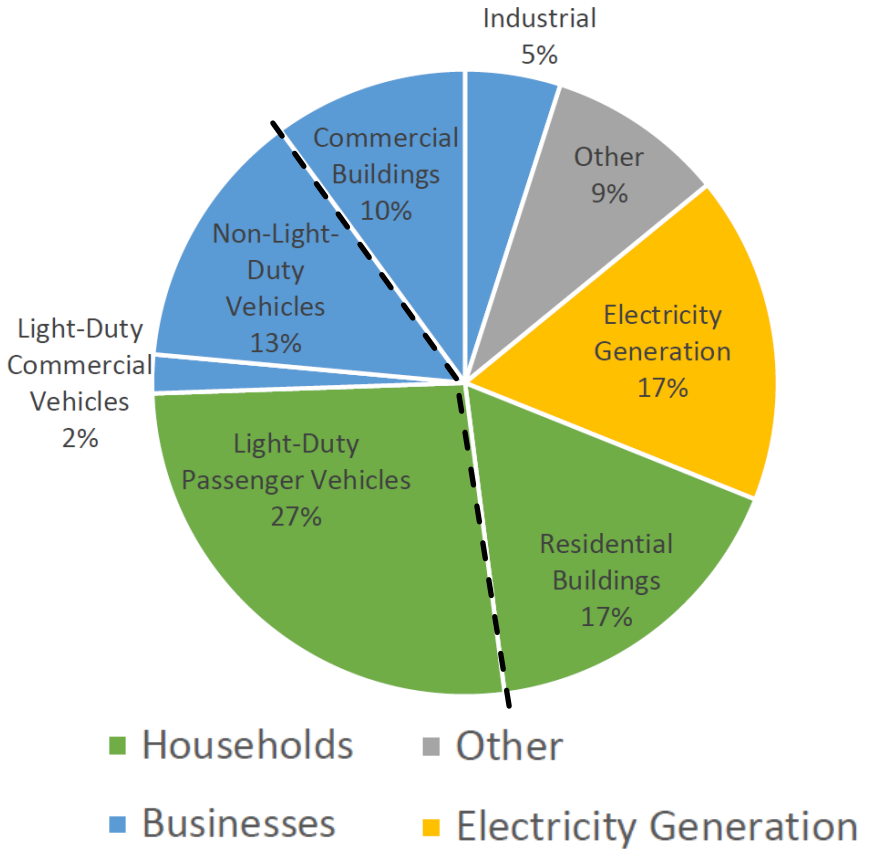
2050 Electricity Demand



For More Information: www.mass.gov/2050Roadmap

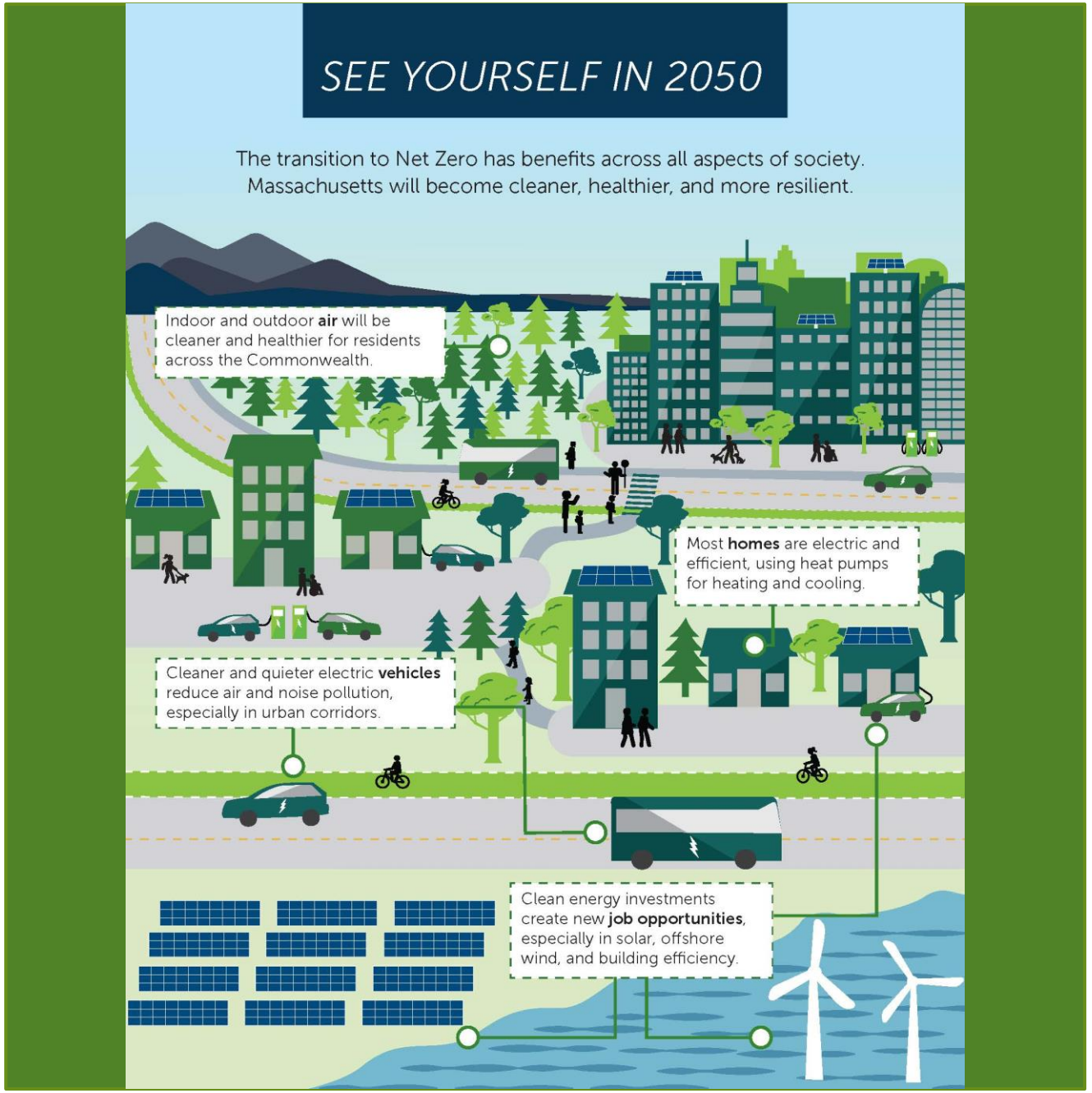
Pace is the Key to Maintaining Affordability





- 4-5 million passenger cars, cross-overs, SUVs and trucks
- 3 million buildings (weatherization + heating systems)

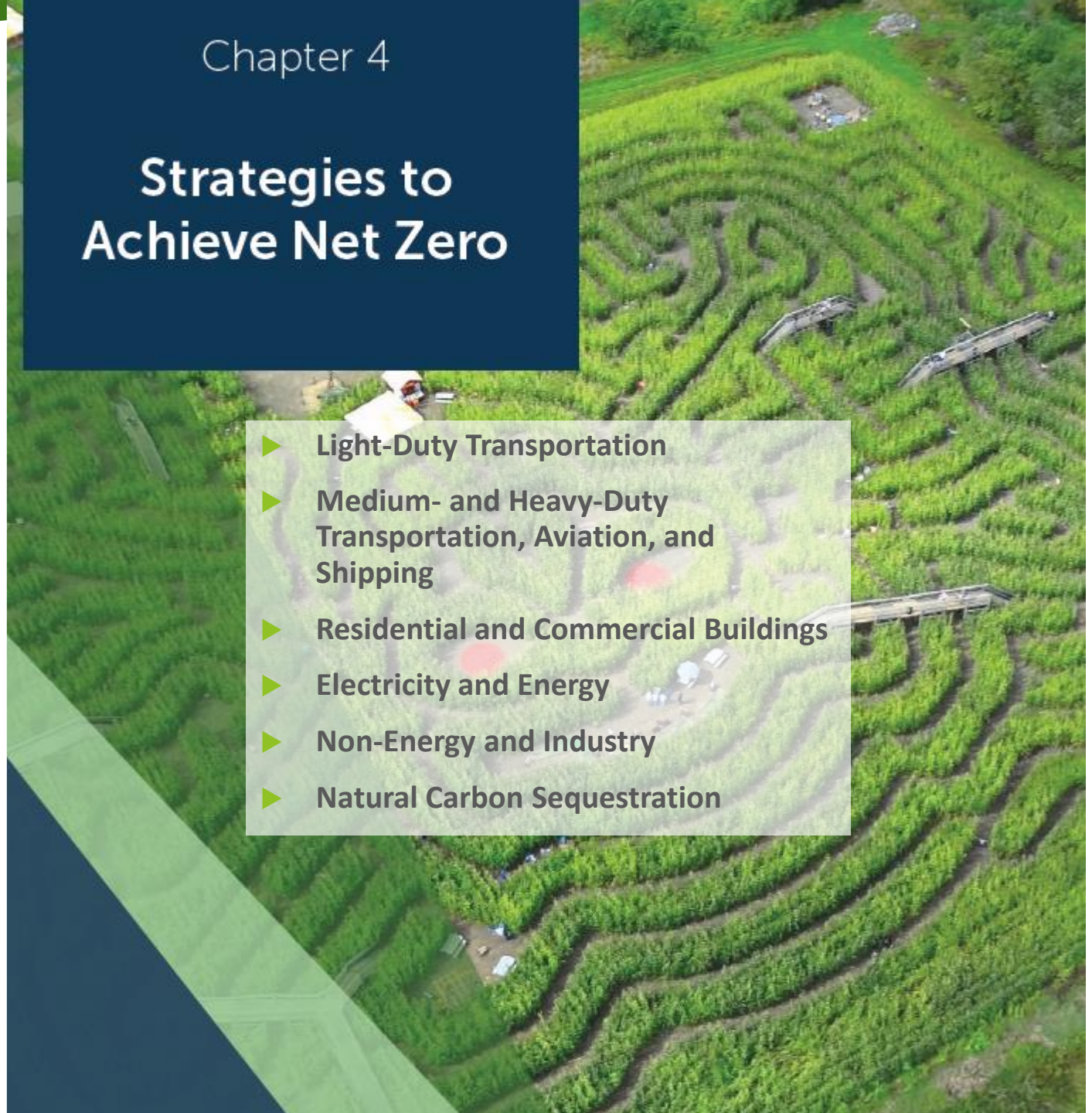
For More Information: www.mass.gov/2050Roadmap



For More Information: www.mass.gov/2050Roadmap

Chapter 4

Strategies to Achieve Net Zero



- Light-Duty Transportation
- Medium- and Heavy-Duty Transportation, Aviation, and Shipping
- Residential and Commercial Buildings
- Electricity and Energy
- Non-Energy and Industry
- Natural Carbon Sequestration

Light-Duty Transportation

Contributions to Massachusetts Emissions

- Light-duty vehicles (LDVs) are currently responsible for about 27% of statewide emissions.

Transition Needed for Decarbonization

- By 2050, emissions from light-duty transportation will need to be reduced to nearly zero.
- The primary strategy to reduce light-duty transportation emissions is switching from fossil-fueled vehicles to zero emissions vehicles.
- This is supported by maintaining and supporting existing public transit systems, reducing single occupancy vehicle use where possible, making complementary land use decisions, and supporting active transportation infrastructure such as bike lanes and sidewalks.

Near Term Implications

- Given the expected pace of all new vehicle sales, the near term need to achieve significant emissions reductions, and the less-than-15 year average lifetime of most LDVs, it is critical that this transformation accelerate to scale as soon as possible.
- Deployment of EVs will require the development of dependable and accessible charging infrastructure throughout the Commonwealth and in residents' homes.

Continued Areas of Research and Further Investigation

- Development and deployment of policies and systems to enable and ensure managed charging, and
- Deployment of a statewide vehicle charging infrastructure strategy.

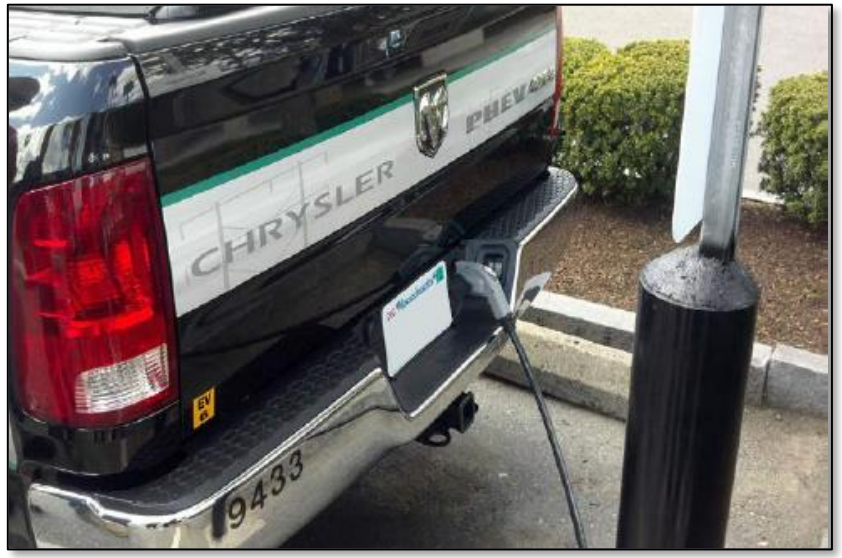
Complete adoption of zero emissions LDVs in 2050 would have public health benefits, including an estimated annual impact of:

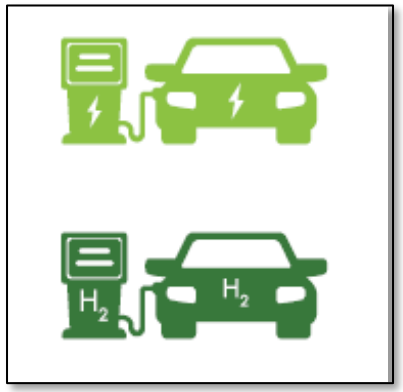
27
avoided deaths from cardiovascular and respiratory illness.

1,700
days of work absences avoided.

$295 MILLION
in total health benefits.

NEARLY 4,000* JOBS
by 2050 will be created to support vehicle electrification and charging infrastructure.
*Deployed across the light, medium- and heavy-duty fleets.





For More Information: www.mass.gov/2050Roadmap

Medium- and Heavy-Duty Transportation, Aviation, and Shipping

Contributions to Massachusetts Emissions

- Medium- and heavy-duty vehicles (MDHDVs), rail, and aviation are currently responsible for about 14% of statewide emissions.

Transition Needed for Decarbonization

- Battery-electric technology is emerging as a viable strategy for many MDHDVs classes. Given the diversity of duty-cycles and performance requirements, it is likely that an array of solutions, including hydrogen fuel cells and zero-carbon fuels, will complement electrification.
- Deployment of battery electric vehicles (BEVs) and hydrogen fuel cell electric vehicles (FCEVs) in the MDHDVs classes will require retrofits to depots and fueling stations to provide charging and/or hydrogen services.
- Given limited options for decarbonizing most commercial aviation, this sector will likely be a source of residual emissions in 2050, unless zero-carbon aviation fuels are rapidly scaled and become cost-effective.

Near Term Implications

- Decarbonizing this sector requires forward planning due to infrastructure needs and limited stock turnover points between now and 2050.
- Addressing issues including siting, permitting, interconnecting, rate design, and distribution system improvements are required to increase adoption.

Complete adoption of zero emissions medium- and heavy- duty vehicles in 2050 would have public health benefits, including an estimated annual impact of:

45

avoided deaths from cardiovascular and respiratory illness.

2,800

of work absences avoided.

$490 MILLION

in total health benefits.

NEARLY 4,000* JOBS

by 2050 will be created to support vehicle electrification and charging infrastructure.
*Deployed across the light, medium- and heavy-duty fleets.

25

For More Information: www.mass.gov/2050Roadmap

Residential and Commercial Buildings

Contributions to Massachusetts Emissions

- On-site combustion of fossil fuels in the residential and commercial buildings sectors – primarily for space and water heating – is currently responsible for about 27% of statewide GHG emissions.

Transition Needed for Decarbonization

- 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 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.

Near Term Implications

- Existing buildings: electrification and efficiency strategies rely on infrequent opportunities to change out heating, ventilation, and air conditioning (HVAC) equipment, such as equipment end-of-life or major renovation. Leveraging these opportunities early is essential for keeping costs low.
- New Construction: Buildings erected after 2025 less likely to be remodeled or have equipment reach end of life, which underscores the importance of enacting a high-performance code for new construction.
- Small residential buildings (<4 units) and single-family homes are relatively easy to modify and comprise over 60% of statewide building emissions. Residences built before 1950 have the most potential to lower occupant costs through energy efficiency upgrades.
- Larger, more complicated building typologies may necessitate more flexibility in both timing and technological solutions.

Complete electrification of heating in 2050 would have public health benefits including an estimated annual impact of:

200
avoided deaths from cardiovascular and respiratory illness.

12,400
days of work absences avoided.

$2.2 BILLION
in total health benefits.

OVER 5,400 JOBS
by 2050 will be created to support building electrification and efficiency.

For More Information: www.mass.gov/2050Roadmap

Electricity and Energy

Contributions to Massachusetts Emissions

- The electricity system is currently responsible for about 19% of statewide emissions.

Transition Needed for Decarbonization

- As more end uses rely on the electricity system, the carbon intensity of emissions from the electricity system will need to approach zero at the same time as installed generating capacity more than doubles.
- Offshore wind and solar are the lowest cost low-carbon energy resources and will comprise the bulk of the Commonwealth's and the region's electricity generation in 2050; both must be deployed at scale (15-20 GW of each installed) in the Commonwealth over the next 30 years.
- A balanced range of complementary resources and technologies, including imported hydropower and additional high-voltage 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

Near Term Implications

- Decarbonization requires a comprehensive plan focused on a rapid deployment of renewables—the siting and construction of offshore wind and ground-mounted solar generation at scale, reliable balancing, and planning for limited land and bioenergy resources.
- Coordination across the Northeast will be necessary to transition to a clean, affordable, and reliable low-carbon, 21st century grid, including system planning and development of new markets by the grid operation

27

Near complete adoption of renewable electricity generation in 2050 would have public health benefits including an estimated annual impact of:

18

avoided deaths from cardiovascular and respiratory illness.

1,000

days of work absences avoided.

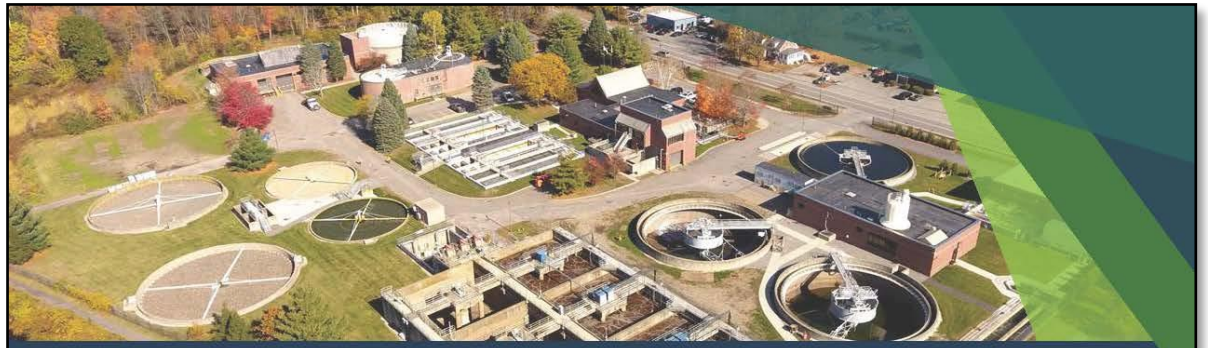
$190 MILLION

in total health benefits.

MORE THAN 10,000 JOBS

will have been created annually to support the development of a low carbon grid.

For More Information: www.mass.gov/2050Roadmap



Non-Energy and Industry

Contributions to Massachusetts Emissions

The subsectors referred to as Non-Energy and Industrial emissions include:

- industrial energy and process emissions,
- fluorinated greenhouse gases (F-gases),
- solid waste management,
- wastewater treatment,
- natural gas transmission and distribution, and
- livestock and agricultural soils.

Non-energy and industrial emissions account for about 12.5% of statewide emissions.

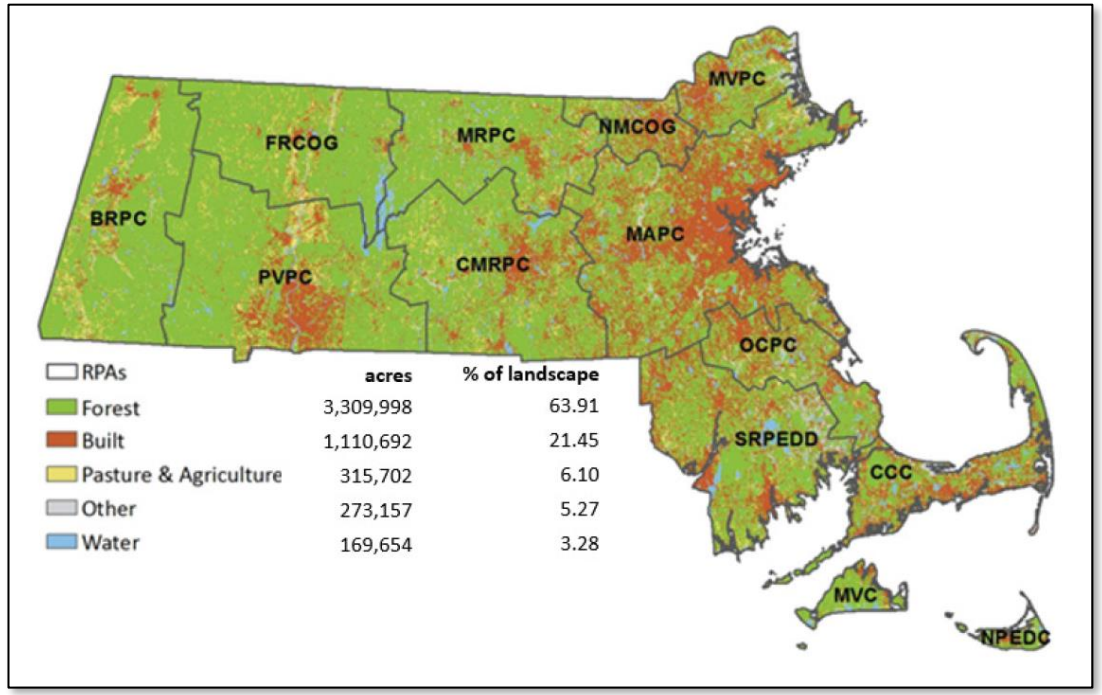
Transition Needed for Decarbonization

- While a relatively small source of emissions collectively, emissions from industrial and non-energy sources are likely to be a significant portion of the Commonwealth's residual emissions in 2050 (3-5 $MMTCO_2e$ or about one-third of 2050 statewide emissions).
- These sources are among the most challenging to decarbonize and their emissions are intrinsically linked either to basic economic activity or to the population and are thus expected to remain in 2050.

Near Term Implications

- Despite the difficultly of emissions reductions in some of these subsectors, active management and best practices are necessary to achieve Net Zero.
- Phasing out high-global warming potential (GWP) fluorinated gases will reduce potential non-energy emissions substantially, but requires early action due to stock-turnover dynamics of equipment, particularly with increasing use of heat pumps.

For More Information: www.mass.gov/2050Roadmap



RPAs	acres	% of landscape
Forest	3,309,998	63.91
Built	1,110,692	21.45
Pasture & Agriculture	315,702	6.10
Other	273,157	5.27
Water	169,654	3.28

Natural Carbon Sequestration

Contributions to Massachusetts Emissions

Massachusetts forests are projected to have the capacity to sequester about 5 $MMTCO_2e$ per year from now through 2050. This is equivalent to roughly 7% of the Commonwealth's current emissions and roughly half of allowable residual emissions in 2050.

Transition Needed for Decarbonization

- Ensuring the viability and health of the Commonwealth's existing 3.3 million acres of forested land is the primary strategy to ensure this sequestration potential is available in 2050.

Near Term Implications

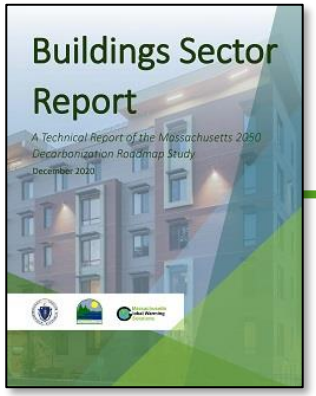
- Encouraging dense development and best management practices for commercial timber harvesting can increase forest carbon sequestration, but only minimally; neither has the potential to significantly alter the 2050 sequestration potential of Massachusetts forests.

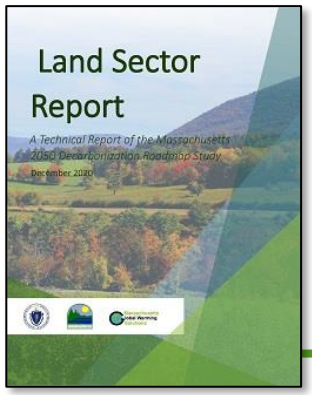
Continued Areas of Research and Further Investigation

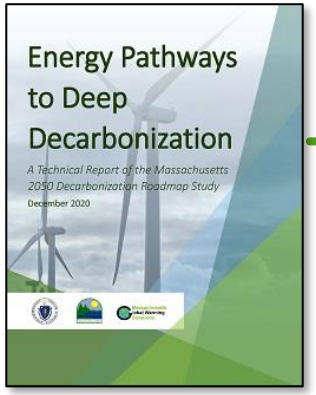
1. Gaining a more complete accounting of land use impacts on human and natural systems to understand the long-term systemic effects and the balance of ecosystem benefits, and
2. Exploring the treatment of atmospheric carbon removals outside of Massachusetts' borders.

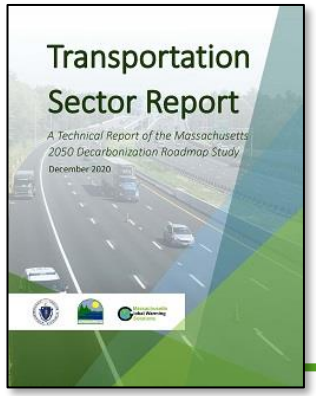
For More Information: www.mass.gov/2050Roadmap

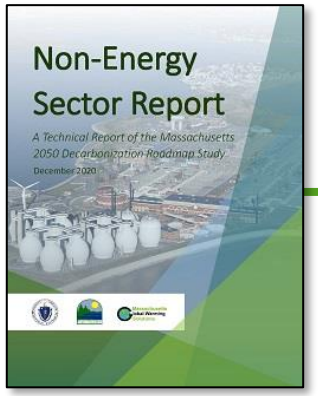
Long-Term Analysis Informing Near-Term Action



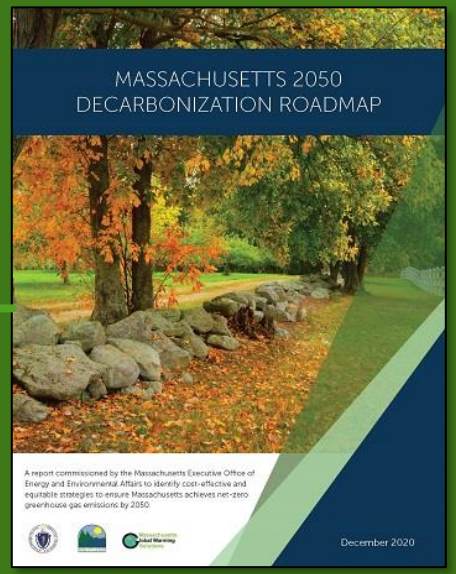








MA 2050 Roadmap



Long-range, comprehensive analysis of cost effective and equitable pathways to reduce greenhouse gas emissions by at least 85% and achieve Net Zero in 2050.

2030 Emissions Limit:

45% below 1990 level

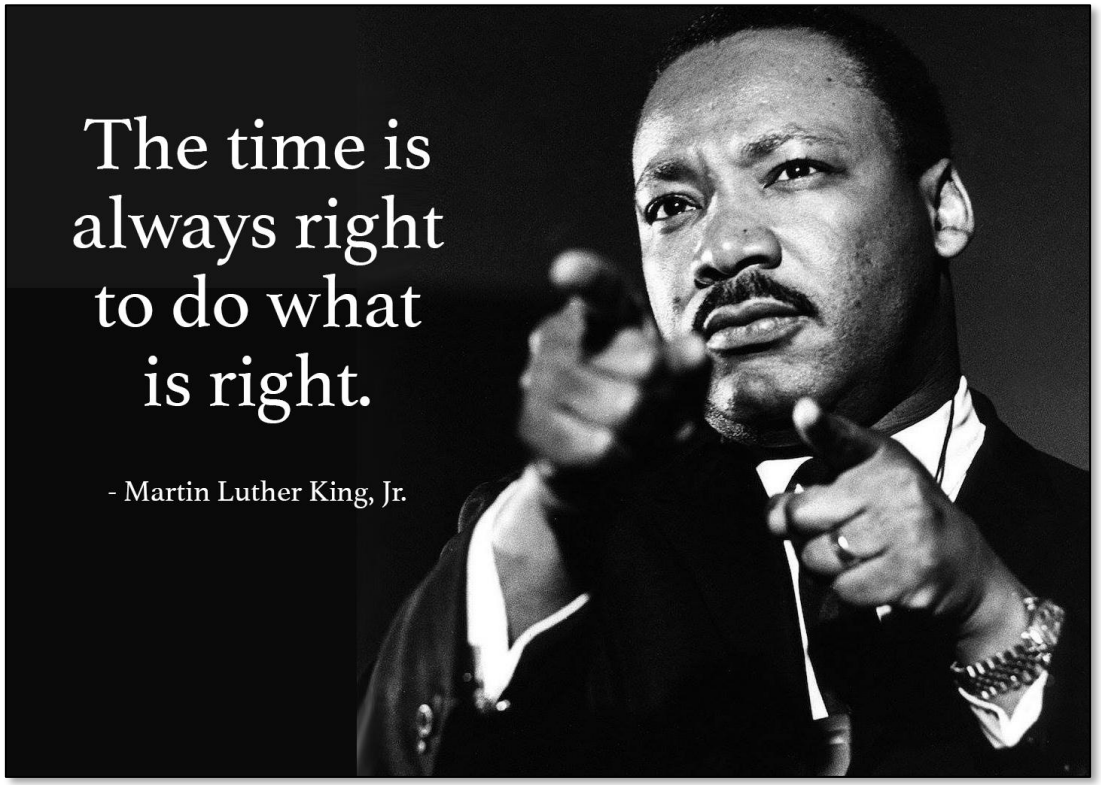
Clean Energy & Climate Plan for 2030

Implementation plan outlining strategies, policies, and actions for how the Commonwealth can achieve the 2030 emissions limit affordably and equitably.

Released Dec. 30

Open for public comment through Feb 22

For More Information: www.mass.gov/2050Roadmap



We have decided not to aim for what we know to be possible, but what we know to be necessary. Our task is now to make the necessary possible.

Dan Jørgensen, Danish Minister for Climate, Energy and Utilities

Next Steps:

- Read the 2050 Roadmap & Technical Reports:
  - www.mass.gov/2050Roadmap
- Engage with the Interim Clean Energy and Climate Plan for 2030
  - www.mass.gov/2030CECP
  - Public comment period open through Feb. 22
  - Two hosted Q&A webinars

Question & Answer

- Thank you for those who submitted questions in advance.
  - We will be answering those first.
- If you have additional questions, please submit using the Q&A Box.