VERMONT
DEPARTMENT OF PUBLIC SERVICE

# 2016 Vermont Comprehensive Energy Plan

HEAT

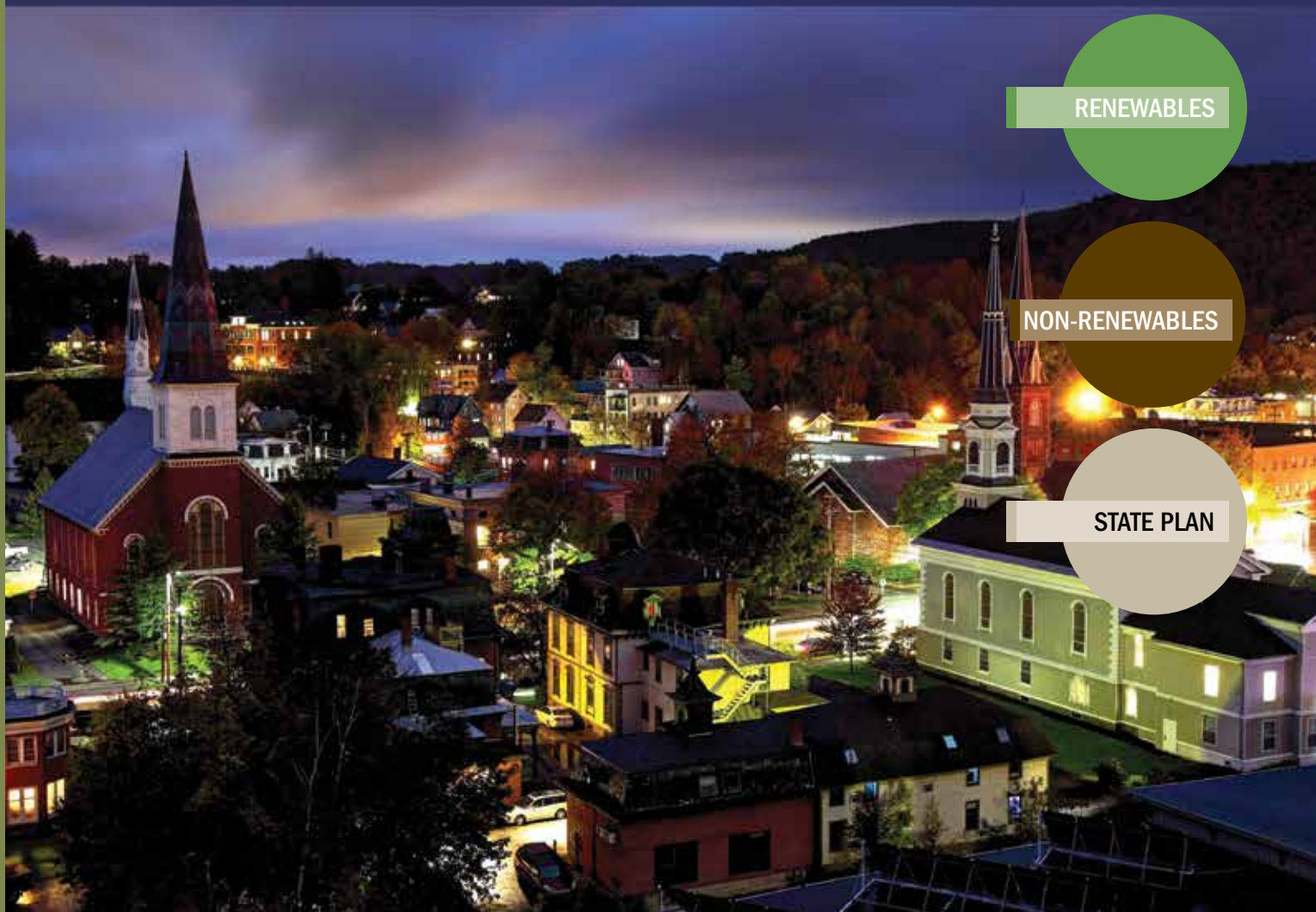
TRANSPORTATION

ELECTRICITY

RENEWABLES

NON-RENEWABLES

STATE PLAN



VERMONT
DEPARTMENT OF PUBLIC SERVICE

Dear Fellow Vermonters:

Five years ago, under the leadership of Governor Peter Shumlin, we embarked on a new energy future for Vermont. The goal of achieving 90% of Vermont's total energy needs from renewable sources by 2050 was visionary, but just that — a goal. Since then, Vermont has shown not only the worthiness of that goal for our energy security and environmental benefit but also its achievability and affordability. Not only can Vermont be a leader in global climate change efforts, but we can do so while increasing our energy security, improving our economy, protecting ratepayers, and reducing our total energy costs.

**"I believe there is no greater challenge and opportunity for Vermont and our world than the challenge to change the way we use and produce energy."**

— Governor Peter Shumlin
December, 2011

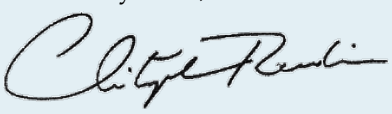
In the last five years, Vermonters have embraced this effort with enthusiasm, expanding our in-state renewables by over 250 megawatts of electric capacity. We've improved on our already nationally recognized work in electric efficiency, and expanded efforts to advance thermal efficiency. We added over 100 MW of new wind generation, and repowered hydropower at several existing Vermont dams in an environmentally sound manner. By far, the greatest growth has been in solar — with net metering at homes, farms, businesses, and throughout communities accounting for nearly 90 MW alone. All this while keeping the cost of electricity at or below the rate of inflation and securing electric bill reductions in three of the last four years for a vast majority of Vermonters.

Our list of accomplishments includes updated building codes for energy efficiency and renewable energy preparedness; expanded financing opportunities to help improve the efficiency of our housing, and to roll out advanced new technologies such as heat pumps; plus the addition of almost 100 electric vehicle charging stations and — perhaps the best demonstration that Vermonters are fully committed to this effort — the fast-paced adoption of electric vehicles, with more than one out of every 100 new vehicles purchased in Vermont over the last two years being a plug-in or fully electric vehicle. In addition, our land-use policies have been strengthened to encourage smart growth and its associated energy savings; in Montpelier, we added Vermont's first community district energy system fueled by sustainable forest resources; and finally, Vermont created the nation's first truly integrated Renewable Energy Standard through Act 56, which integrates increasing renewable energy with reducing total energy use and costs. In the next pages, you will see our joint vision to advance our goals in a specific way that shows how we can do so responsibly and affordably.

None of this would have been possible without partnerships and countless citizens stepping forward to do their part. Vermont now has over 16,000 jobs in the clean energy sector, which accounts for almost 5% of our workforce. Lenders, including Vermont banks, credit unions, and the Vermont Economic Development Authority, have made millions of dollars in loans to Vermonters who have sought financing to advance these goals. Homeowners and other electric customers have rocketed through two net metering caps and continue to demonstrate an appetite for more.

Formulation of this plan would also not have been possible without the dedication of Vermonters from all over the state. Hundreds of comments helped make this plan better. Other participating state agencies, stakeholders, and the Department's dedicated staff deserve recognition for completing this tremendous effort. In the end, without active citizen participation, the plan is just a plan. While we can and should all be proud of Vermont's progress to date, I so much value the commitment Vermonters have shown to implement the vision embodied in this plan. If we continue on the path we have been on for the last five years, Vermont will be well on our way to meeting our goals, and we will leave our state more beautiful and much stronger for the next generation.

Thank you all,



Christopher Recchia, Commissioner

# Executive Summary

Vermont stands at a moment of great promise for a clean energy future. Over the four years since the publication of the last Comprehensive Energy Plan, Vermonters have built a foundation of infrastructure, policies, and programs on which to construct an increasingly renewable energy economy. We must build upon this foundation to accelerate progress toward the goals included in this plan. Vermont's energy transformation will take many years to fully implement; along the way it will enhance the vitality of our state's economy, improve our health, and improve the quality of our local and global environment. This 2016 Comprehensive Energy Plan provides a framework to advance those goals, along with specific plans and recommendations for action by the public and private sectors.

This Comprehensive Energy Plan (CEP) is built around these themes and cross-cutting insights:

- Vermont develops and pursues energy policy, not for its own sake but as a tool to advance economic, environmental, and health objectives.
- Our energy future is largely a product of infrastructure, both public and private.
- Vermont is well-positioned to thrive in the transition to distributed energy resources, linked and coordinated through enhanced communications.
- Energy system innovation provides an opportunity for Vermont to foster entrepreneurship, while also keeping more of our energy spending in-state.

## Guiding economic, environmental, and health goals

Vermont's energy policy, as codified in 30 V.S.A. § 202a(1), establishes these state goals:

> *To assure, to the greatest extent practicable, that Vermont can meet its energy service needs in a manner that is adequate, reliable, secure, and sustainable; that assures affordability and encourages the state's economic vitality, the efficient use of energy resources and cost effective demand side management; and that is environmentally sound.*

Energy adequacy, reliability, security, and affordability are essential for a vibrant, resilient, and robust economy. Energy efficiency is a driver of productivity. Environmentally sound energy policy rises in prominence in the context of our urgent need to mitigate the global climate change that is resulting from greenhouse gas emissions while also advancing local environmental sustainability. Vermonters' health is a necessary consideration, shaped by infrastructure and by both economic and environmental forces.

Chapter 3 of the CEP identifies and describes the policy objectives of this plan, which are summarized in the box on the next page. It also explicitly addresses the fact that those goals may at times be in conflict, and makes explicit this CEP's attempt to identify and promote those recommendations that advance all objectives over those options that produce conflict.

This CEP advances these guiding goals, both through the detailed recommendations found throughout the plan and by building on the state's goal, established in the 2011 CEP, of meeting by mid-century 90% of Vermont's energy needs from renewable sources while virtually eliminating reliance on oil. **Expanding upon the statutory goal of 25% renewable by 2025 (10 V.S.A. § 580(a)), this CEP establishes the following set of goals:**

- **Reduce total energy consumption per capita by 15% by 2025, and by more than one third by 2050.**
- **Meet 25% of the remaining energy need from renewable sources by 2025, 40% by 2035, and 90% by 2050.**
- **Three end-use sector goals for 2025: 10% renewable transportation, 30% renewable buildings, and 67% renewable electric power.**

Taken together, meeting these goals will increase affordability and economic security for both residents and businesses by increasing energy efficiency and relying on more stably priced resources than alternative paths offer. Meeting them will also strengthen Vermont's economy and enhance our state's capital infrastructure by shifting energy expenditures from fuels produced out of state to in-state infrastructure and fuel supplies. Increasing the use of fuels produced on Vermont's farms and forests can enhance the security of those critical sectors of the state's economy while also improving their environmental stewardship.

Since the last CEP was published in 2011, Vermont has added more than 100 MW each of in-state wind and solar photovoltaic (PV) electric generation. Implementation of Act 56 and the Renewable Energy Standard (RES) will further drive Vermont toward meeting our interim and overall goals. We are doing all this while keeping electric

# Guiding Goals When Developing and Evaluating Energy Policy

## A Vibrant and Equitable Economy

- **Ensure an affordable and stable cost of living** through improving the energy fitness of Vermont homes, strategic electrification, focusing development in compact villages and urban centers, and substituting fossil fuels with renewable alternatives that have lower long-term costs.
- **Ensure an affordable and stable cost of doing business** through improvements in commercial and industrial building and process energy efficiency, strategic electrification, and the substitution of renewable alternatives for fossil fuels.
- **Increase entrepreneurship opportunities** by supporting market demand for renewable energy and energy efficiency services, as well as encouraging research and commercialization of new energy services and technologies.
- **Improve labor market conditions** by creating well-paying jobs in industries that supply renewable energy commodities and energy efficiency services.
- **Ensure an equitable distribution of benefits and burdens** by assisting those least able to pay the increasing costs of energy and the upfront costs for investments in efficiency and fuel switching.
- **Maintain revenue to support government functions** by replacing the reduction in income from the sale of taxable fuels, such as motor fuels, with appropriate new revenue sources.

## Healthy Ecosystems and a Sustainable Environment

- **Reduce greenhouse gas emissions,** consistent with the state's emission-reduction goals, by reducing fossil fuel use and efficiently using renewable energy sources.
- **Reduce local air pollutants**, including particulates and toxins, by using efficient and clean combustion technologies, along with shifting away from fossil fuels.
- **Bring a global and life-cycle perspective** to the analysis of costs and benefits.
- **Retain healthy, functional forest and agricultural systems** through responsible use of forest and agricultural resources for energy and non-energy-related applications.
- **Maintain water quality throughout Vermont's ecosystems** through responsible land and water use.
- **Optimize land use choices** to minimize local and global environmental impact, including balancing land use among competing needs in the state for energy, non-energy development, housing, transportation, working lands for agriculture and forestry, and other purposes.

## Healthy Vermonters

- **Encourage active lifestyles** and reduced energy use through compact development and by providing safe opportunities for walking, biking, and using public transit.
- **Improve outdoor air quality** by reducing emissions from transportation, home and business heating and energy usage, and energy production.
- **Improve the health of indoor environments** and reduce energy bills through improved building weatherization and the use of advanced heating and ventilation technologies.
- **Reduce negative health impacts** expected to occur as a result of climate change.
- **Assess health impacts of our energy system** in order to avoid or mitigate potential negative impacts, especially for the most vulnerable population groups such as the elderly, low-income households, and those with chronic or pre-existing medical conditions.

rates stable and low. Electric rates in Vermont have increased only 3.7% since 2011, which is slower than overall inflation, while New England average rates rose 12.3% and U.S. average rates have increased 5.6%. Vermonters on average now pay the second-lowest electric rates in New England.

The plan emphasizes the importance of efficiency and conservation. This includes continuing improvements in demand-side thermal and electric efficiency and conservation. It includes efficiencies gained by using new electric technologies (heat pumps, electric vehicles) that are substantially more efficient than previous technologies. It also includes efficiency in electric generation that comes from shifting toward cost-effective wind, solar, and hydroelectric power, and away from wasteful power plants that send heat up smokestacks. The focus on strategic electrification reinforces the shift toward distributed energy resources that support our grid, increase resilience, and reduce infrastructure costs.

Meeting these energy goals will also set the state on a path to meet its greenhouse gas emission reduction targets. We have a moral and economic imperative to take substantial and consistent action to reduce greenhouse gas emissions to mitigate global climate disruption, while also preparing Vermont for its impacts. **This CEP establishes two goals for reduction in greenhouse gas (GHG) emissions from Vermont's energy use, both of which are consistent with the renewable energy and energy use goals:**

- **40% reduction below 1990 levels by 2030, and**
- **80% to 95% reduction below 1990 levels by 2050.**

The Renewable Energy Standard (RES) in Act 56 of 2015 has set Vermont on a path to better alignment among the growing sources of renewable energy generation, along with the right to claim that renewable energy toward Vermont's objectives. Responsible land use choices will enable us to meet our energy goals while advancing the state's land use goals of compact centers surrounded by working lands. Local energy supply from farms and forests also supports the financial sustainability of our working landscape.

Finally, this CEP recognizes that energy and land use choices directly impact Vermonters' health, through both environmental and economic means. Meeting these energy goals will require infrastructure that enables active lifestyles, coupled with improved air quality from reduced combustion of fossil fuels combined with increased use of advanced wood heat technologies. Energy affordability also means increased winter comfort, with profound health benefits.

Continuous assessment of the performance of energy programs and policies against these goals will inform the state's energy policy development.

## Infrastructure matters

Energy use in homes and businesses is overwhelmingly determined by the physical characteristics of those buildings and the appliances or industrial processes they contain. Transportation energy use is fundamentally driven by the locations of homes and businesses, along with the public, private, and commercial infrastructure that includes our roads, sidewalks, transit systems, and vehicles. Electric generation facilities are themselves substantial physical infrastructure, as is the engineering feat of the electric grid that connects them.

Infrastructure choices are therefore in many cases energy choices; and many energy policies and programs become effective by shaping those choices. The long-lived nature of most of the built environment makes it more challenging to quickly transform our energy system. Initial choices in construction of roads, buildings, and other infrastructure have outsized impacts compared with subsequent modifications to that infrastructure. Getting it right the first time matters.

Chapter 5 of the CEP identifies and discusses the land use impacts of energy choices, and the energy impacts of land use choices.

When compared to legacy infrastructure, clean energy infrastructure tends toward options that reduce operating costs but cost more to construct or purchase up front. Examples include solar, wind, and hydroelectric generators, which have no fuel cost; building retrofits, which improve the quality of a building shell while lowering its operating costs; and locating a new building in a compact center, which can have higher land costs while lowering transportation energy needs. These investments can pay off over their lifecycle — but they require financing tools to show that advantage over legacy options. Financing tools can also better align the interests of those developing infrastructure with those who will pay to operate it.

Chapter 6 of the CEP identifies and discusses cross-cutting actions and approaches to clean energy finance.

## A distributed and connected energy future

Our legacy fossil-fuel-based energy system is also a centralized system. Large central electric generators produce power that flows great distances along power lines to consumers; fossil fuels are produced in a few locations around the world, then shipped or piped to wholesalers and then to consumers. This CEP embraces a different vision: a distributed energy future in which a significant portion of Vermont's energy is produced near where it is consumed, and which is shaped by many coordinated actions by distributed energy users, rather than through singular central control. This alternate vision is possible thanks to the increasing availability of cost-effective distributed electric generation technology, such as solar PV, along with the increasing opportunity to store electric and thermal energy, and the communications overlay that comes from near-universal broadband and smart grid deployment combined with "smart" appliances and other

end-use energy control technologies. Wood energy use for heat is the original distributed energy, and advanced wood heat technologies rejuvenate this option as well.

This shift to a more local and distributed energy system is apparent throughout this CEP, but the shift's most prominent impact is in the electric sector. As energy efficiency and demand response have matured as resources, we have seen that efficiency can change long-term forecasts, while demand response can be dispatched — like a generator — to meet peak loads. New generation has come online from resources like wind and solar power that have no operating costs, are generally smaller in capacity, and are distributed in many locations around the distribution grid. Electric-energy storage technologies are maturing quickly, as are technologies for automating and aggregating control of many different kinds of end uses (beyond the water heater controls that have been deployed for decades). Electric vehicles and heat pumps present new challenges and opportunities. The proliferation of information technology tools throughout the grid provides the opportunity to optimize operations, with significant yet uncertain potential to contain costs. Regulatory transformation may also be required in order to reduce costs and improve system performance by capturing value from diverse distributed resources.

### Fostering innovation and entrepreneurship

Vermont has the opportunity to capitalize on its leadership in clean energy. We are already home to the largest number of clean energy jobs, as a fraction of all jobs, of any surveyed state: 4.8% of Vermont employees (16,231 people) participate in the clean-energy economy .[1] Companies that get their start here are well-positioned to expand and compete in other states and countries as the economies in those locations also shift toward clean energy. This CEP embraces the idea of Vermont as a starting point, and as a test bed for new technologies.

Vermont's scale is conducive to assembling the parties needed to try something new, earning approval, and proceeding to action quickly. Even Vermont's largest energy companies are small on a national scale and retain the nimbleness that small size can bring; and Vermont's recent energy history is one of collaboration between firms, state and federal agencies, and non-governmental partners. At the same time, we have a cutting-edge energy industry and infrastructure that entrepreneurs and innovators can engage with — including a statewide smart grid, thousands of distributed electric generators, world-leading efficiency and regulatory expertise, and a burgeoning advanced wood heat industry.

## Where we've been, where we are, and where we're going

The 2011 CEP established a goal of meeting 90% of the state's energy needs through renewable sources by 2050. It also proposed taking steps to virtually eliminate our dependence on petroleum. The 2011 plan spurred vibrant and ongoing discussion statewide, along with significant actions. These actions include:

- Passage of Act 56 establishing a Renewable Energy Standard;
- The Thermal Efficiency Task Force and two Clean Energy Finance Summits;
- Updated building energy codes and a Vermont residential building label;
- Pilots of new financing programs, including the Heat Saver Loan;
- Signing of the multi-state Zero Emission Vehicle memorandum of understanding;
- Strengthening the state's land use designation programs;
- Expansion of the Standard Offer program, while lowering the cost of new contracts by more than 60%; and
- Expansion of net metering to 15% of peak load, and an ongoing process to design a sustainable net metering program.

Chapter 2 of this CEP discusses each of these successes in more detail.

Energy is a substantial portion of home and business expenses. Vermonters will spend about $2.4 billion this year on energy. This total cost is split between electricity (35%), fuels for heat and industrial processes (25%), and fuels for transportation (40%). This total reflects today's relatively low oil and natural gas prices. To the extent that Vermont remains dependent on those fuels, if and when their costs rise, our total energy costs will rise as well, especially for heat and transportation.

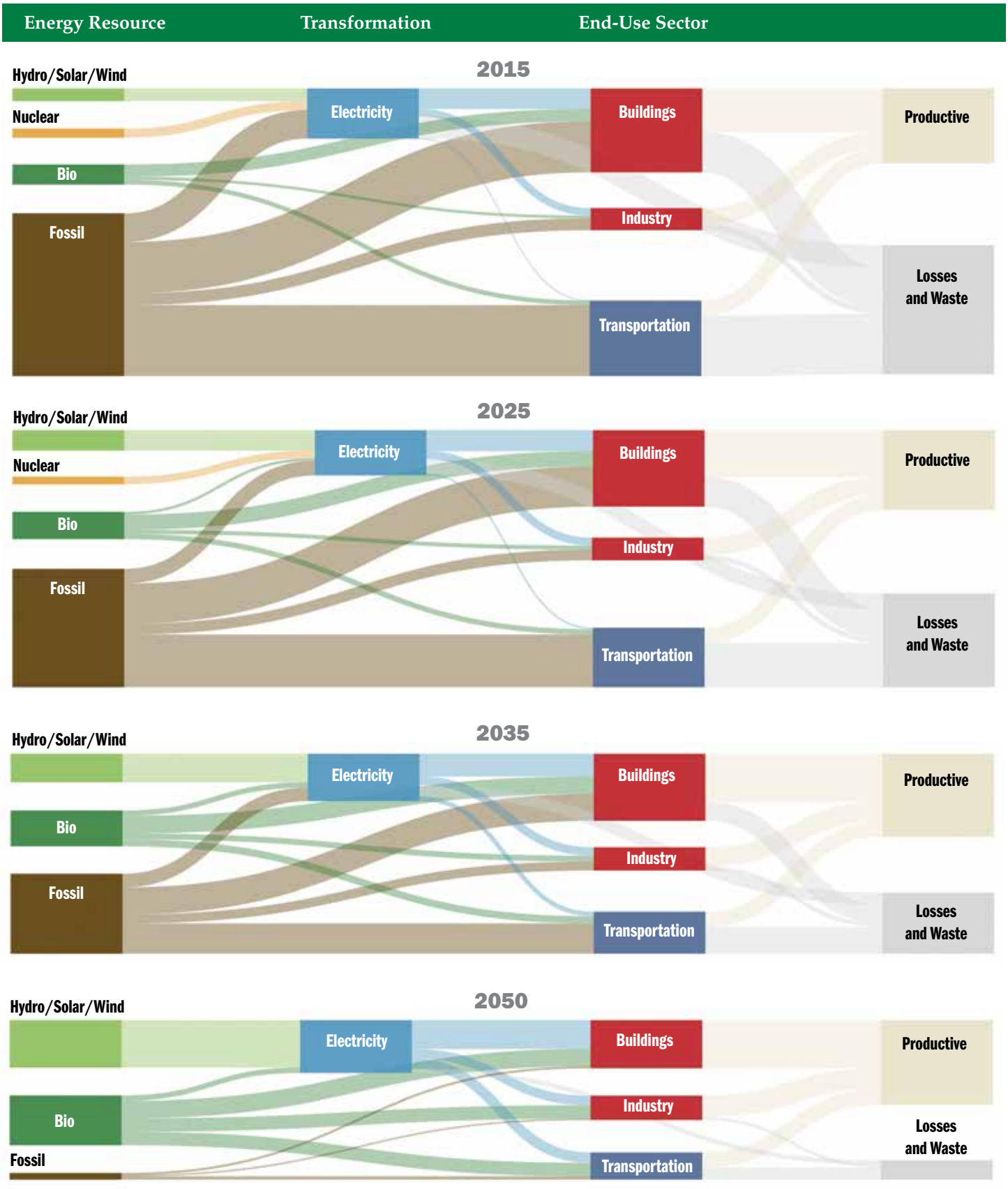
Energy is also the dominant source of Vermont's greenhouse gas emissions — 80% of our emissions result from energy use. Here transportation dominates, with 47% of all GHG emissions. Reducing our emissions, and maintaining affordability, go hand-in-hand with a transition to renewable energy and a reduction in energy waste.

In 2015, Vermont will get about 16% of our total energy from renewable sources. Renewability varies by sector: electric power is about 45% renewable, while building heat is about 20% renewable, and transportation is only about 5% renewable. Figure ES-1 shows the estimated total energy flows for 2015, 2025, 2035, and 2050. Each portion of this graphic begins with primary energy on the left side, divided into four types: hydro/wind/solar (non-combustion-based renewable resources); bio (combustion-based renewables); nuclear electricity; and fossil fuels. The height of each band corresponds to the amount of energy from each source. Some of each resource then flows to

1 *Vermont Clean Energy Industry Report 2015,* (Department of Public Service), publicservice.vermont.gov/sites/psd/files/Topics/Renewable_Energy/CEDF/Reports/VCEIR%20 2015%20Final.pdf

*Figure ES-1*

## Vermont energy flows in 2015, with an illustrative path forward to 2025, 2035, and 2050.



be transformed into electricity, while some combustible resources are used directly in each end-use sector (buildings, industry, and transportation). Losses and waste from electric generation are totaled on the far right, along with losses and waste from each of the end-use sectors: buildings, industry, and transportation.

Figure ES-1 illustrates one path forward that would meet of the CEP's quantitative energy use, renewability, and GHG emission goals for 2025, 2035, and 2050. The productive energy at each time period increases, reflecting Vermont's growing economy and improving quality of life. Meanwhile, total energy use declines significantly as waste and losses are reduced. Fossil fuel use falls throughout, but is particularly displaced between 2035 and 2050 by the combination of electricity and bioenergy (which is concentrated in uses where electrification is not possible or cost-effective). Electric end-use energy increases significantly, while primary energy used to generate electricity grows only slightly.

This figure illustrates three ways to reduce total energy use without compromising energy service:

1. **Continuing improvements in demand-side thermal and electric efficiency and conservation.** Efficiency and conservation neutralize the increase in energy demand associated with increases in population, the growth in building-space square footage, and the growth in industrial output, all of which are assumed to increase at historically consistent rates. The largest efficiency impact comes from improvements in building shells which reduce the need for building heat delivered by any means.

2. **Fuel switching away from combustion technologies to more efficient electric-powered technologies.** Heat pump and electric vehicle technology is capable of supplying the same level of energy service as its combustion-based counterparts, with a third or less of the site energy requirements.

3. **Declining source energy requirements of electricity generation.** As more of the state's electric power supply is generated by solar, wind, and hydro resources, which do not produce the unusable waste heat associated with combustible generation fuels, the overall source-energy requirements to power new heat pump and electric vehicle loads also decline. Thus, even with growing consumption of electricity, per capita consumption of primary energy declines even faster.

## Strategies to meet our goals

There are four general types of policies that work together to drive change: market-based policies, information and access, strategic investment, and codes and standards.

**Market-based policies** (also called price-based policies) establish a new market, or shape the prices in an existing market, in order to harness market forces to achieve a policy goal. Examples include cap-and-trade systems, renewable portfolio standards, and carbon taxes. Such policies are intended to align market forces and societal objectives by sending a price signal to end-use consumers that would encourage consumption of a renewable or efficiency alternative that is societally preferred, but would otherwise be less cost-competitive.

**Information and access policies** address the real-world shortcomings of a market-based policy instrument. These policies enhance markets by providing information, technical assistance, or access to capital, including financing. They also address problems of misaligned incentives, such as between landlords and tenants. They are aimed at ensuring that consumers have access to efficient markets, where they can easily identify and act on options that offer the lowest lifecycle costs.

**Strategic investment** may be required to spur and shape the early adoption of new technologies and their markets. Research and development may yield examples on which to build. Policies can build markets for nascent technologies. Strategic investment that is directed at the highest-cost necessary technologies for achieving Vermont's goals can reduce those costs. This allows price-based policies to drive optimization without unreasonable direct price impacts.

**Codes and standards** — such as building energy codes, appliance efficiency standards, vehicle fuel economy rules, and land use plans — serve to avoid lost efficiency opportunities in long-lived products and infrastructure, using established technology. Codes and standards are appropriately applied only when cost-effective on a lifecycle basis.

The RES established by Act 56 of 2015, combined with Vermont's participation in the Regional Greenhouse Gas Initiative (RGGI), has built a foundation of market-based policies in the electricity sector, while leveraging the progress being made here to reduce fossil fuel use in other sectors. The RES is expected to reduce the state's GHG emissions by an amount approximately equal to a quarter of the emission reductions required to meet the state's 2050 goals, while saving Vermonters hundreds of millions of dollars in energy costs — significantly advancing our economic and environmental goals.

The recommendations established in this CEP reflect integration across the four policy approaches to driving sustainable energy system change. Of particular note is a recommendation, further detailed in chapter 4, regarding market-based GHG emission reduction policy:

> *Vermont should work with other states and provinces in our region, building upon existing regional initiatives, to investigate and pursue options for market-based GHG emission policies that integrate with the other*

## Public engagement, education, and support

Vermont can only meet the goals established in this plan with the support and active involvement of individuals, businesses, non-governmental organizations, and all levels of government. Individual decisions — about where to live, what car to buy (or whether to buy a car at all), what appliances to buy, whether and how to weatherize your home or invest in renewable energy — will have a significant impact in shaping Vermont's energy future. The same is true of business decisions. While public policy has affected and will continue to affect these choices, and they have real public impact, they are fundamentally private decisions.

Public support for utility energy supply choices is also essential for these organizations to make the necessary investments on behalf of their customers. Those choices need to reflect the state's policy of least cost energy planning – including economic and both local and global environmental costs – in order to build and sustain public support. The pace of growth of in-state renewable electricity development has not produced unanimous support, and there is more work to be done to foster processes and choices that will engender greater support in the future. The land use principles identified in chapter 5, along with the specific recommendations in chapters 11 and 13, are intended to help shape the path forward. This path will involve continuous refinement as we learn from experience, develop best practices, and accommodate new technologies.

This plan encourages public education and opportunities for local engagement and action from a total energy perspective. Beyond the siting-related recommendations just mentioned, key recommendations include:

- Learning from and expanding on the Regional Planning Commission energy planning pilot now underway to develop robust and comprehensive regional energy plans that build from a shared set of goals and reflect local knowledge and preferences;
- Creating and supporting creation of public information resources on renewable energy and energy efficiency in Vermont;
- Growing and strengthening local energy expertise, particularly through support of town energy committees and energy coordinators who play an essential role in driving local energy engagement and action; and
- Supporting K-12, higher education, and vocational education initiatives to bring energy into the classroom, including learning from successful efforts in other jurisdictions.

*approaches described in this CEP, and consistent with the principles regarding revenue recycling, pace, equity and competitiveness detailed in this plan.*

The structure of the CEP reflects the energy flows shown in Exhibit ES-1, moving right to left. Sections address the challenges, opportunities, and strategies for each topic, consistent with the guiding goals. The CEP concludes with the incorporation of the State Agency Energy Plan, which identifies the state's path forward as an energy consumer and producer who can lead by example.

## Heat in buildings and industry

One fifth of the energy used to heat Vermont's buildings and to provide process heat in industrial applications comes today from renewable sources, primarily wood. The CEP establishes a goal of increasing that portion to 30% by 2025, through both efficiency and increased use of renewable fuels. Achieving this goal is compatible with efforts to meet the state's existing statutory building efficiency goals — including weatherizing 80,000 of the state's homes by 2020. This particular goal looks increasingly out of reach, but the efforts to meet it have spurred development of new tools that will help the state meet similar objectives: reduced energy costs combined with increased value and quality of the state's building stock. The technological and programmatic tools exist to transform new construction so that all new buildings are "net zero" by 2030.

Meeting 30% of the remaining heat demand from renewable sources, including wood and other solid biomass, liquid or gaseous biofuels, and heat pumps powered by renewable electricity, means significantly increasing the use of both bioenergy and heat pumps. One sample pathway involves increasing the use of solid and liquid biofuels by 20% by 2025, on the way to doubling wood's share of building heat by 2035. Meanwhile, installing about 35,000 cold-climate heat pumps by 2025 would begin the transformation of remaining building heat to renewable electricity.

Vermont's primary challenges to achieving these goals are:

- Market failures such as lack of information, lack of access to capital, lack of valuation of building efficiency in the real estate market, and split incentives between landlords and tenants.
- Lack of consistent public or private funding at the quantities required to meet the statutory goals.
- An older building stock, 30% of which was built before 1940.

These challenges are particularly steep for low-income Vermonters, many of whom rent housing in older buildings, have no or almost no ready capital, and have no appetite for or ability to borrow money.

Vermonters also face a lack of fuel choices — although here as elsewhere there is real progress. This progress includes improved wood heating technologies and availability of locally produced wood pellets; increased availability and understanding of cold-climate air-source and ground-source heat pumps; and expanding access to natural gas via pipeline and truck. New biomass-powered district heating systems are being demonstrated in Montpelier, in the new Waterbury state office complex, and in other building complexes around the state.

Critical tools and recommendations moving forward include:

- Take a whole-building approach to buildings as systems, recognizing the interaction of all their components and the value of partnerships between experts who would address buildings in different ways: electric and thermal, heating systems, building shells, controls, and access to capital through financing.
- Develop a seamless "one-stop shop" for customer information and coordinating projects. Improve customer and market information regarding building heat through a statewide information clearinghouse, and building-specific information through building labels.
- Continue to work with stakeholders to develop the path to all new buildings being built to net-zero design by 2030.
- Fully fund and maximize the effectiveness of existing thermal efficiency programs, particularly those serving low-income populations, as well as new utility programs to meet RES Tier 3 obligations.

## Transportation

As a rural state, Vermont's economy and its people depend on reliable transportation. This requires energy – about one-third of Vermont's total energy – and its associated economic, environmental, and health consequences. Transportation is responsible for nearly half of Vermont's greenhouse gas emissions, and in 2013 more than $1 billion per year left the state to buy fuel. The primary challenges in transportation transformation include:

- The long lifetime of the built environment, so impacts on land use are both slow and essential.
- Vehicle and fuel markets are national, and there are few proven state policy or programmatic levers to shape customers' vehicle choices, especially in the face of customer uncertainty regarding new fuels and vehicle technology.
- Electric vehicle technology is advancing rapidly, but there are not yet EVs to meet all Vermonters' diverse vehicle desires (especially in view of concerns over EV range, and many Vermonters' desire for four-wheel or all-wheel drive).
- Vermont's rural communities lack the density to support frequent and affordable public transit service.

Only 6% of transportation energy is renewable today, and this is primarily in the form of corn-based ethanol blended in gasoline. Sustainably increasing this fraction significantly, while reducing overall energy use, will require a different approach. Meeting a goal of 10% renewable energy in transportation by 2025, on the way to at least 80% by 2050, will depend on four primary strategies:

- **Reduce transportation energy demand through smart land use.** Striving toward Vermont's land use goal of maintaining the historical settlement pattern of compact centers surrounded by rural countryside is highly compatible with a goal of keeping vehicle miles traveled per capita below 2011 levels.

- **Shift transportation away from single-occupancy vehicles** through the promotion of other options, including transit, walking, biking, carpooling, and telework.

- **Electrify and increase the efficiency of light-duty vehicles.** Plug-in vehicle registrations in Vermont have grown by a factor of 10 in three years, but the market is still in its early stages. The plan sets a goal of 10% of the vehicle fleet powered by electricity by 2025. Vermont's Zero Emission Vehicle (ZEV) Action Plan includes evaluating potential ways to incentivize the purchase and lease of EVs, promoting consumer awareness and understanding of the benefits of EVs and fuel efficient vehicles, and deploying charging infrastructure at workplaces and key public locations. The State of Vermont's own vehicle fleet already includes more than a dozen plug-in vehicles. That number will continue to grow, and the state is hosting public charging infrastructure.

- **Increase the efficiency of heavy-duty vehicles and power them with renewable fuels**, such as advanced liquid or gaseous biofuels. Expanded fueling infrastructure and increasing fuel availability are the primary immediate required steps. Improving the lifecycle renewability of biofuels will be essential to securing their long-term place in Vermont's renewable future.

## Electricity

Vermont has made consistent progress in recent years on reducing the environmental impacts of our electricity consumption while maintaining stable and affordable electric rates. Electric rates in Vermont have increased by 3.7% since 2011, slower than overall inflation, while New England average rates rose by 12.3% and U.S. average rates have increased by 5.6%. Vermont's electricity is currently 45% renewable; with the RES that fraction will increase to

55% in 2017, and it will continue to climb to 75% renewable in 2032. Vermont will also be home to an increasing portion of the generation that serves our load, with the RES requiring 10% of 2032 electricity to come from small, renewable generators connected to our state's electric grid.

As discussed earlier, the electric grid is in the midst of a transformation away from a centralized, one-way electric grid to an integrated grid where both demand and supply adjust moment by moment to maintain balance on the grid. This paradigm offers new opportunities to optimize grid infrastructure decisions and to allow for significant increases in electric use while lowering both overall energy costs and electric rates. Electricity is expected to play a major role in the clean energy transformation of both heating and transportation — and the hardware, software, and regulation of the grid need to be ready.

The primary recommended strategies for electric power in this CEP are:

- Continue to acquire all reasonably available cost-effective energy efficiency.
- Manage electric load using active means, including new control technologies in concert with expanded access to and adoption of smart rates.
- Plan carefully to meet all three tiers of the RES in a least-cost manner. Strive to lower both energy bills and electric rates.
- Engage actively in regional grid planning and policy-making, recognizing the significant impact that regional choices can have on Vermont.
- Maximize opportunities to encourage siting of renewable energy on the built environment, in already disturbed areas, or co-located with other uses in order to minimize conflicts with other land uses and users.
- Take advantage of opportunities to incrementally transform our utility regulations to reflect the reality of distributed energy resources and an integrated grid. This includes explicitly welcoming innovation and entrepreneurship by utilities and their partners.

## Energy Resources

Chapters 12 and 13 of this CEP describe in detail each of the energy resources – renewable or not – that powers Vermont. End-use energy efficiency is a key resource that can meet demands without the use of any supply resources, often at lower cost and with fewer environmental and health impacts. As such, it is and should remain the first option for meeting energy service demands. But energy efficiency cannot meet all energy needs — so supply resources are required.

***These two chapters examine these resources:***

- Solar
- Wind
- Wood and other solid biomass
- Liquid biofuels
- Methane from on-farm and non-farm digesters as well as landfills
- Hydropower
- Coal
- Petroleum
- Nuclear
- Natural gas

***For each resource, the chapter examines these aspects:***

- Overview
- State of the market
- In-state resources
- Out-of-state resources
- Siting and permitting
- Benefits
- Challenges
- Strategies and recommendations

*This CEP recognizes that there is no single path for Vermont to attain the goals, or to enact the strategies identified here or discussed in detail within the rest of the plan. Required instead will be incremental policy changes, along with progress on education, finance, and innovation. Vermont must work with both public and private sectors, including with utilities, to advance these objectives in cost-effective, affordable, efficient, and innovative ways, and to encourage each and every citizen to do what they can to help all of Vermont achieve a transformative energy future.*

To access the full Comprehensive Energy Plan, please visit
http://publicservice.vermont.gov/publications/energy_plan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