What was the motivation for this project?

The purpose of this project was to quantify the potential health impacts of transportation strategies proposed to reduce greenhouse gas (GHG) emissions in Vermont.

Rates of many leading causes of chronic disease in Vermont are affected by our transportation system and transportation behaviors. For example, using physically active transportation modes, like walking or biking, decreases the risk for heart disease, stroke, diabetes, and dementia. Conversely, air pollution from motor vehicles may increase the risk of lung cancer and respiratory illnesses. Medical costs to treat these and other chronic diseases exceed $2 billion each year in Vermont and continue to rise. Additionally, transportation infrastructure and human factors contribute to traffic injuries and deaths.

The 2016 Comprehensive Energy Plan (CEP) set goals to reduce GHG emissions by 40% by 2030 and by 80-95% by 2050 (as compared to emissions levels in 1990).[1] However, as of 2015, GHG emissions in Vermont have actually increased by 16% since 1990.[2] The transportation sector accounts for 43% of all GHG emissions in Vermont, so it is a major focus of the state's GHG emission reduction strategies. The CEP set specific transportation goals for 2025 and 2050, including increases in walking, biking, transit, carpool, and use of electric vehicles. Changing transportation behaviors, technologies, and infrastructure to meet these goals can also help to improve the health and safety of Vermonters while reducing the costs of chronic disease and accidents.

How did the Health Department estimate the health impacts of transportation changes?

To quantify the potential health co-benefits of the transportation goals in the CEP, the Vermont Department of Health adapted and applied the Integrated Transport and Health Impacts Model (ITHIM).[3] ITHIM was developed by researchers at Cambridge University and in California to evaluate the air quality, physical activity, and road safety impacts of future transportation scenarios. ITHIM uses peer-reviewed research to estimate how changes in transportation behaviors and technologies will affect health. ITHIM has been used for projects in California, Oregon, Tennessee, and internationally.[4]

The Health Department used the California Spreadsheet Version of ITHIM. Health Department staff entered data describing baseline conditions in Vermont and assumptions about future transportation scenarios, both of which are described in more detail below. The ITHIM spreadsheet automatically calculated the estimated changes in health outcomes, health-related monetary impacts, and vehicle emissions for each future scenario.

What data did we enter into ITHIM?

To calibrate the transportation and health relationships for the Vermont population, ITHIM requires the user to input Vermont-specific data about population characteristics, health status, transportation behaviors, and air quality. To best match the 2011 baseline used for the CEP transportation goals and the most recent availability of Vermont transportation survey data in 2009, we used baseline data from as close to 2010 as possible for all inputs.

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[1] Vermont Department of Public Service, Comprehensive Energy Plan, 2016.
[2] Vermont Department of Environmental Conservation, Greenhouse Gas Emissions Inventory Update, 2018.
[3] University of Cambridge, MRC Epidemiology Unit, Integrated Transport and Health Impact Modelling Tool
[4] University of Wisconsin-Madison, Global Health Institute, Integrated Transport and Health Impacts Model Overview.

Population characteristics

1. **Population by age and gender** – 2010 U.S. Census data were used to input Vermont population data divided into two genders and eight age groups.[5]

Health characteristics

2. **Mortality** – 2010 U.S. Global Burden of Disease data for Vermont were used to estimate mortality rates for 12 different groups of diseases.[6] Vermont vital records data from 2005-2016 were used to estimate the proportion of colon cancers from all colorectal cancers.[7]
3. **Physical activity** – National Health and Nutrition Examination Survey data from 2007-2014 were used to estimate the amount of transportation-related and all other physical activity.[8] National data were used for this measure as Vermont-specific data were not available

Transportation characteristics

4. **Travel behaviors** – 2009 National Household Travel Survey data for Vermont were used to estimate the average daily time and distance traveled for eight different transportation modes.[9] Non-metropolitan New York data was also included to increase the sample size for estimating the average daily time spent walking and biking by age and gender categories.
5. **Vehicle miles of travel** – Vermont Agency of Transportation data from 2018 from the Highway Performance Management System and the Automatic Vehicle Classification Report were used to estimate vehicle miles of travel (VMT) for three different categories of vehicles and three different categories of roadways.[10,11] 2018 data were used as 2018 VMT data were similar to 2010 while vehicle classification data were not readily available for older years.
6. **Bus occupancy** – Vermont Agency of Transportation and Agency of Education data were used along with peer-reviewed, published research to estimate the average number of occupants per public transit and school bus in Vermont.[12]
7. **Injuries and fatalities** – Vermont Agency of Transportation crash data from 2006-2015 were used to estimate the frequency of crashes resulting in injuries or fatalities for seven different transportation modes.[13]
8. **Electric vehicle fleet** – The 2017 Vermont Transportation Energy Profile report provided data on electric vehicle registrations in Vermont, with the earliest data available for 2012.[14] The Public Utility Commission's report on Promoting the Ownership and Use of Electric Vehicles in the State of Vermont was used to estimate the total number of light-duty vehicles in Vermont.[15]

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[5] Vermont Department of Health, Vermont Population Estimates and Census Data, Population of Vermont Counties by single year of age and sex, 2010.
[6] Institute for Health Metrics and Evaluation, Global Health Data Exchange, GBD Results Tool.
[7] Vermont Department of Health, Vital Records & Population Data.
[8] Centers for Disease Control and Prevention, National Health and Nutrition Examination Survey.
[9] U.S. Department of Transportation, Federal Highway Administration, 2009 National Household Travel Survey.
[10] Vermont Agency of Transportation, Vermont Mileage and Vehicle Miles of Travel Report, 2018.
[11] Vermont Agency of Transportation, Automatic Vehicle Classification Report, 2018.
[12] Additional details are available by request.
[13] Vermont Agency of Transportation, Vermont Public Crash Data Query Tool.
[14] Vermont Agency of Transportation, 2017 Vermont Transportation Energy Profile.
[15] Vermont Public Utility Commission, Promoting the Ownership and Use of Electric Vehicles in the State of Vermont.

Air quality and emissions characteristics

9. **Particulate matter** – National Environmental Public Health Tracking data from 2008-2012 were used to estimate the average ambient concentration of fine particulate matter ($PM_{2.5}$) in Vermont.[16] The Environmental Protection Agency's Co-Benefits Risk Assessment (COBRA) model was used to estimate the proportion of fine particulate matter attributable to light-duty vehicle emissions.[17] Peer-reviewed data about vehicle emissions (including emissions from the tailpipe, tire, break, and road wear, and dust resuspension) were used to estimate differences in $PM_{2.5}$ emissions per mile for conventional, electric, and plug-in hybrid vehicles.[18]
10. **Carbon dioxide** – Peer-reviewed data about lifecycle GHG emissions of passenger vehicles were used to estimate the average carbon dioxide (CO_2) emissions per mile from different types of passenger vehicles.[19] CO_2 emissions from electricity generated for use in electric vehicles were not included in CO_2 calculations, as 99.7% of Vermont's electricity generation is already fueled by renewable sources.[20]
11. **Fuel efficiency** – The Vermont Transportation Energy Profile Report was used to identify average fuel efficiency of light-duty vehicles in Vermont in 2011, the earliest year that such data were available.[14]

What assumptions did we make about future transportation scenarios?

We developed three different future scenarios corresponding to the 2025, 2030, and 2050 transportation objectives identified in the Comprehensive Energy Plan. ITHIM uses assumptions about future transportation behaviors and technologies to estimate the health impacts for each scenario. ITHIM does not require us to provide specifics on what infrastructure changes, transportation policies, or programs will be needed to achieve the future changes.

1. **Electric vehicles only**
    a. By 2025, 10% of light-duty vehicles are electric, or 55,000 electric vehicles
    b. By 2050, 80% of light-duty vehicles are electric, or 440,000 electric vehicles
2. **Behavior change only** (by 2030, compared to 2011)
    a. Two times the number of walking and biking trips
    b. Increase public transit ridership by 110%
    c. Increase carpooling by 20%
3. **Both electric vehicles and behavior change**
    a. All of the above

All scenarios assumed linear progress towards the relevant objective from 2011 to the target year for each objective.

[16] Centers for Disease Control & Prevention, National Environmental Public Health Tracking, Data Explorer.
[17] Environmental Protection Agency, Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool.
[18] Timmers V, Achten P. Non-exhaust PM emissions from electric vehicles. Atmos Env. 134; 2016: 10-17.
[19] Elgowainy A, Han J, Ward J, et al. Current and Future US Light-Duty Vehicle Pathways: Cradle-to-Grave Lifecycle Greenhouse Gas Emissions and Economic Assessment. Environmental Sciences & Technology; 52(4): 2018.
[20] U.S. Energy Information Administration, Vermont State Profile and Energy Estimates, 2019.

Other scenario assumptions

The following assumptions were applied to all scenarios:

1. Population
    a. The 2025 and 2050 populations were assumed to be the same to allow for direct comparisons across these two scenarios. The total population size and the distribution of population by age was based on the average of the two official Vermont population projections for 2030.[21] The gender distribution was based on 2010 U.S. Census data, as the 2030 projections did not provide gender-specific population estimates.
2. Vehicle miles of travel
    a. Total per capita miles of travel for all transportation modes were held constant over time, to be consistent with the CEP objectives. Increases in travel by walking, biking, and public transit were offset by equivalent reductions in travel by personal vehicle.
    b. The distribution of vehicle miles of travel by vehicle types and roadway types were held constant over time.
3. Electric vehicles
    a. The total number of light-duty vehicles were held constant over time.
    b. New electric vehicles were assumed to be 50% all-electric and 50% plug-in hybrid,[22] with plug-in hybrids running on electric 55% of the time.[14]
    c. The bike fleet was assumed to include 50% e-bikes for all future scenarios, which provide slightly less physical activity than a conventional bike.
4. Fuel efficiency
    a. Average light-duty vehicle fuel efficiency was assumed to increase linearly to 24.1 miles per gallon by 2025 and 32.4 miles per gallon by 2050.[23]

What information did ITHIM provide to us?

ITHIM provided the following outputs for each scenario, for a 2050 target year, compared to baseline (2011) conditions:

Health outcomes

Estimated health impacts are based on projected changes in physical activity (associated with walking and biking), ambient fine particulate pollution, and miles of travel for each transportation mode. The following health outcomes are provided for 13 different categories of diseases and overall, per year:

1. **Change in premature deaths** – the number of deaths occurring before the expected age of death within a given population.
2. **Change in years of life lost** – the number of years lost to premature death within a given population
3. **Change in years lived with disability** – the number of years lost to illness or disability within a given population
4. **Change in disability-adjusted life years** - the number of years lost to illness, disability, or premature death within a given population

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[21] State of Vermont. Vermont Population Projections – 2010 - 2030. 2013.
[22] American Lung Association, Clean Air Future: Health and Climate Benefits of Zero Emission Vehicles, 2016.
[23] Energy Action Network, 90% Renewable by 2050.

Health-related economic impacts

Two health-related economic outputs are provided:

1. **Costs of illness** – these include both direct (e.g., health care expenditures) and indirect (e.g., lost productivity associated with illness, disability, or premature death) costs. Costs were derived from national estimates published in peer-reviewed research and inflation adjusted (using the Consumer Price Index) to 2018-dollar equivalents. The change in direct and indirect health costs is based on the change in disability-adjusted life years for each of 11 diseases.
2. **Value of life** – the cost of each premature death is valued at an amount that people are willing to pay to reduce their risk of death. A value of $9.6 million per life was used in this analysis, which is the most recent value used by the U.S. Department of Transportation.[24]

Carbon dioxide emissions

Change in carbon dioxide emissions from passenger vehicles was estimated based on the expected proportion and type of electric vehicles in the statewide passenger vehicle fleet, life-cycle carbon dioxide emissions of passenger vehicles, expected changes in vehicle miles of travel, and estimated future average light-duty vehicle fuel efficiency. Emissions estimates were based on a simplistic model and intended to give a rough estimate only. Emissions estimates produced by ITHIM should not supersede emissions estimates conducted using more sophisticated analytical tools.

What other impacts should we expect but could not be quantified?

In addition to the items that ITHIM was able to quantify, we would also expect future transportation scenarios to affect:

1. **Affordability** – Walking, biking, and public transit are all cheaper modes of travel than owning and operating a private vehicle. Although upfront costs for electric vehicles are currently higher than for comparable internal combustion vehicles, the operating costs for electric vehicles are cheaper over time. On average, Vermonters spend about 25% of income on transportation, with low-income and rural households bearing the largest burden.
2. **Accessibility** – Compact land use patterns that support a safe and diverse transportation system helps to improve access to jobs, healthcare, services, and recreational opportunities.
3. **Equity** – Having robust transportation options provides more equitable access to all Vermonters, as some individuals are unable to or choose not to drive a private vehicle. About 17,000 Vermont households do not have access to a vehicle. This is especially important for older Vermonters who may become isolated if they are unable to drive.
4. **Community** – A people-focused transportation system provides more local social and economic opportunities than a vehicle-focused transportation system.

What's next?

We hope that the findings from this assessment provide motivation for making changes to the transportation system and to individual transportation choices that will also provide health benefits. Do you have any suggestions for how we can help improve health through our transportation system? Please let us know at ClimateHealth@vermont.gov!

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[24] U.S. Department of Transportation, Revised Departmental Guidance on Valuation of a Statistical Life in Economic Analysis, 2016.