Mitigation Working Group's Buildings Sub-Group:
Collection of Resources
April 28, 2021

1. New and Existing Home Costs

- **The Economics of Electrifying Buildings** (report) - this 2018 report looked at economics for all-electric new construction and space and water heating electrification retrofits, across four cities (Providence RI, Chicago, Houston, and Oakland). The report quantified a number of areas that present an economic proposition. Most notably, that there are immediate economic benefits to all-electric new construction, retrofits of customers with oil, propane, or electric resistance heating today. The main typology of study was detached, single family homes.
- **New Economics of Electrifying Buildings** (blog and report) - RMI released a 2020 report with updated analysis of economics of all-electric new construction vs mixed fuel construction, for seven cities (Boston, New York, Columbus OH, Minneapolis, Austin, Denver, and Seattle). All-electric homes were cheaper to build than the new, mixed fuel homes in all seven cities, on a net present cost and first cost basis.
- Cost and Other Implications of Electrification Policies on Residential Construction for the National Association of Home Builders by the Home Innovation Research Labs. Released February 2021.

2. New and Existing Commercial/Institutional

- ClimateMaster Water-Sourced Heat Pump System Case Studies (K-12 Education, Multi-Family, Offices, Higher Education, etc)
- Higher Education: University of Maryland economy-wide analysis for 51% reductions by 2030. Paper and Technical Appendix.
- Net Zero Schools: Torcellini, Paul A., Nathaniel Allen, and Maureen McIntyre. 2020. Plowing through the Cost Barrier: Zero Energy K-12 Schools for Less: Preprint. Golden, CO: National Renewable Energy Laboratory. NREL/CP-5500-77414..
    - "Research findings indicate that not only can zero energy schools be designed and built on conventional school budgets, they can cost less. In an integrated design and construction process, the cost of zero energy measures can be offset by, for example, downsizing heating, ventilating, and air-conditioning systems, reducing both life cycle and first costs….Successful strategies for achieving zero energy at no initial cost are presented."

3. Electricity Supply / Grid Integration

- Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio: A Cost-Benefit Analysis. "This report quantifies the significant, untapped value that the General Services

Administration (GSA) could unlock by investing in grid-interactive efficient buildings (GEBs). A GEB is an efficient building with smart technologies characterized by the active use of energy efficiency, solar, storage, and load flexibility to optimize energy use for grid services, occupant needs and preferences, and cost reductions"

4. Natural Gas Distribution System

- Washington DC - Climate Business Plan by WGL
    - Sierra Club opposing comments, including expert witness report that reviews WGL's Climate Business Plan (expert review is Exhibit A) https://edocket.dcpsc.org/apis/api/filing/download?attachId=105083&guidFileName=457f5067-9b4b-49d4-b74f-61e5da32a7e5.pdf). In Washington D.C. Washington Gas and Light filed a Climate Business Plan which includes a series of assumptions regarding the availability of "renewable natural gas" and the company's plans to meet climate goals in the District." District Department of the Environment testimony.

5. Cleaner Technologies (renewable gas, district energy, etc)

- Renewable Gas
    - **Building Electrification: A Key to Safe Climate Future** (RMI blog) – this write-up covers a number of relevant recent studies on least cost solutions to achieve climate goals, covering building electrification as well as some of the critical considerations tied to proposals around Renewable Natural Gas.
    - Rhetoric Vs. Reality: The Myth of "Renewable Natural Gas" for Building Decarbonization. This report from Sierra Club and Earthjustice examines the potential for FGAs to decarbonize buildings and refutes the claim that FGAs are a viable alternative to building electrification.
- Other renewable fuels
    - Evaluating District Energy Options Workshop Session. This presentation by GLHN Architects & Engineers, Inc. introduces different district energy concepts.
    - State of the Science and Issues Related to Heat Recovery from Wastewater. "The research confirms that sewage is, in fact, a viable source/sink for heat, and that advances in heat pump technology make it the best-developed, and as it happens, the most practical and efficient method for accessing sewage thermal energy. More than 500 facilities worldwide can and do capture and recycle this abundantly available resource, but beneficial application requires care in evaluating local conditions and selecting and siting appropriate components, collaboration beyond utility fence lines, and a triple-bottom-line (TBL) approach. There also is a growing public and industry appetite for this technology."

6. Policy Plans and Frameworks

International

- Buildings Sector Solutions by Project Drawdown -"*How can we retrofit existing buildings and create new buildings to minimize energy use? How can we stop other, on-site sources of emissions?* These questions are at the heart of making buildings not only better for the planet, but also more affordable to operate and healthier, better places for the people inside and around them. Building solutions orient around energy efficiency, energy sources, and refrigerants."
- Policy Solutions by Breakthrough Energies. "To reduce building emissions, we need policies that drive deployment of new technologies, such as low-GHG building materials and ultra-efficient heat pumps, and that create incentives for the electrification and improved efficiency of clean technologies that already exist. These policies should also seek to incentivize emission reductions in low-income and historically disadvantaged communities where maintenance issues and split incentives between tenants and landlords have hampered efficiency gains."

National

- ULI Blueprint for Green Real Estate - "Building on the leading sustainability work that ULI Greenprint member organizations have been implementing since 2009, the *ULI Blueprint for Green Real Estate* report helps real estate owners and investors create or accelerate a sustainability program, and developers looking for ways to integrate sustainability into their overall development strategy. The resource is focused on real estate addressing environmental areas—energy, water, waste, and greenhouse gas (GHG) emissions—while acknowledging that the role of a real estate sustainability program is much broader than it once was, now encompassing topics like resilience, health and wellness, and social equity."
- The Tower Companies Corporate Responsibility Report
- Building Decarbonization Code by New Buildings Institute. "The overlay is focused on codes for new construction with the potential of adding code language for existing buildings in a future version. While not an all-electric code, the language does prioritize efficient electric equipment and is designed to be flexible."
- Net-Zero America: Potential Pathways, Infrastructure, and Impacts by Princeton University. "The Net-Zero America study outlines five distinct pathways that could decarbonize the entire U.S. economy over the next 30 years, using existing technology and at costs aligned with historical spending on energy. The research is the first to describe at a high degree of granularity (at a state-by-state level or better) what needs to be built — and when and where — across key sectors. It also is the first to provide comprehensive models of the resulting costs, changes to the job market, implications for the energy sector, and impacts on air pollution and public health for each state, sometimes down to the county."
    - NY Times Article
- Accelerating Decarbonization of the U.S. Energy System by the National Academies of Sciences, Engineering, and Medicine. "In order to reach net-zero carbon by 2050, the United States must begin taking action now to accomplish five main technology goals. Meeting these objectives over the current decade (2021-2030) will be essential to making the net-zero transition possible on a 30-year timeframe, so that long-lived energy infrastructure can be replaced with zero-carbon alternatives."
- Building Electrification: A Key to a Safe Climate Future (RMI blog)

- Building Electrification Action Plan for Climate Leaders by Sierra Club - this 30-page report is oriented primarily to California but presents a robust set of principles for building electrification that can be carried forward to other states.
    - The California PUC found that full electrification (buildings and transportation) would save an average customer around $100 a month on energy costs
- State Plans
    - Massachusetts climate plan highlighting the need for deep decarbonization and electrification in the building sector: https://www.mass.gov/doc/interim-clean-energy-and-climate-plan-for-2030-december-30-2020/download (beginning on page 27)
    - California report on building electrification and decarbonization: https://ww2.energy.ca.gov/2019publications/CEC-500-2019-055/index.html
    - California Housing Partnership Affordable Housing Decarbonization Report - the report is focused on CA but it identifies barriers and challenges for decarbonization of affordable housing, the themes of which can likely be transferred to Md: https://chpc.net/resources/ah-building-decarb-report-2021/
    - Washington DC DOEE Carbon Free DC Draft Plan: https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/Carbon%20Free%20DC%202050_Buildings%20Overview.pdf
- Equitable Building Electrification: A Framework for Powering Resilient Communities by the Greenlining Institute
- US Environmental Protection Agency: Benchmarking and Building Performance Standards Policy Toolkit. "EPA's Benchmarking and Building Performance Standards Policy Toolkit aims to inform and support state and local government decision makers who are exploring adopting policies focused on reducing energy use and greenhouse gas (GHG) emissions from existing commercial and multifamily buildings in their communities."
- All-Electric New Homes: A Win for the Climate and the Economy by RMI (2020)
    - "states and cities across the country won't meet their climate goals if new buildings in their jurisdiction include fossil fuel systems that lock in carbon emissions over the 50 to 100-year building lifetime. The cost of such an ambitious transition is often the first consideration. Thus, to help inform these crucial decisions, Rocky Mountain Institute updated and expanded our 2018 analysis, *The Economics of Electrifying Buildings.* We examined the economics and carbon emissions impacts of electrifying residential space and water heating, now with seven new cities and additional methodology changes."
- Rewiring America Households Savings Report. "But our new report shows that the average American household can both fight climate change *and* save money at the same time. We can do it using existing technology, without sacrificing any comforts of home. In other words, we'll have the same number of cars, ovens, dryers, refrigerators, air conditioners and heaters, but at dramatically lower cost and without the indoor and environmental pollution that accompany burning fossil fuels. If done right, we would create millions of new, good-paying jobs in every zip code, save each household on average between $1,050 to $2,585 *per year* on its energy bills, and dramatically reduce economy-wide greenhouse gas emissions — all the while enjoying zippier cars and smarter appliances."
- HELIX is a NEEP tool available to states and communities to track home energy labeling

in their jurisdiction, as well as connect to the local multiple listing service to integrate home energy information into the real estate market.

- **Regulatory Solutions for Building Decarbonization** (RMI report) – this report outlines recommendations and considerations for utility business model reform to enable decarbonization. Focus areas include: aligning the utility system with the imperative to swiftly address climate change by decarbonizing the entire economy, building a market for new clean energy solutions, like efficient, modern heat pumps, and stopping the expansion of new gas infrastructure and creating a path to wind down gas systems safely and affordably.
- **It's Time to Align Housing Finance** (RMI blog and associated report) – this 2021 blog and report proposes practical solutions to reduce friction in originating and securitizing single-family green mortgage products already offered by the government-sponsored enterprises (GSEs) Fannie Mae and Freddie Mac to create a new $2+ trillion market within a decade.
- **Best Practices for Achieving Zero over Time for Building Portfolios** (RMI report) – this report has details on best practices to decarbonize multifamily and commercial building portfolios over time.
- Home Innovation Research Labs, List of Incentives for National Green Building Standard Green Certification. "The National Green Building Standard™ (ICC/ASHRAE 700) is approved by the American National Standards Institute (ANSI) as an American National Standard. The NGBS provides criteria for rating the environmental impact of design and construction practices to achieve conformance with specified performance levels for green residential buildings. Federal agencies and local/state jurisdictions recognize the NGBS on par or superior to other residential green rating systems. Below is an alphabetical list by state of all known incentives for NGBS Green-certified projects."
- 2020 Long-Term Reliability Assessment, December 2020, by the North American Electric Reliability Corporation. "NERC is a not-for-profit international regulatory authority whose mission is to assure the reliability of the bulk power system (BPS) in North America. NERC develops and enforces Reliability Standards; annually assesses seasonal and long-term reliability; monitors the BPS through system awareness; and educates, trains, and certifies industry personnel. NERC's area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico."
    - "Because PJM has extensive capacity resources, risk for capacity shortages during nonpeak periods are minimal. The highest risk periods are the end of the spring and fall outage seasons when numerous outages are taken to maintain generation and transmission. Some outages can take longer than planned and extend into the beginning of the peak period (June 1 through September 15 and December 1 through March 15). Careful planning and operational time frame outage denial minimize the risks of possible capacity shortages."
    - "The goal of the PJM capacity market is to provide enough capacity to meet the PJM load forecast and the PJM reserve requirement at the lowest possible cost. It is anticipated that the PJM capacity market will continue to support compliance with PJM reserve requirement in the future."
- **Northeast Energy Efficiency Resources:**

· Building Decarbonization Public Policy Framework

· The Smart Energy Home: Driving Residential Decarbonization
· Action Plan to Accelerate Strategic Electrification in the Northeast
· CAPEE- Community Action Planning For Energy Efficiency
· HELIX- Home Energy Labeling Information eXchange
· Benchmarking Toolkit
· Energy Codes are Life Safety Codes
· Construction Codes: Myths and Realities
· Attributing Building Energy Code Savings to Energy Efficiency Programs
· Building Energy Codes for a Carbon Constrained Era: A Toolkit of Strategies and Examples · NE CHPS
· Home Buyer Energy Efficiency Checklist
· Renter's Guide: Creating Lower Cost, Energy Efficient Apartments and Homes. Both the renter's checklist and the home buyer's checklist are available for co-branding.

Maryland

- DSIRE: Maryland Financial Incentives. "DSIRE is the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States. Established in 1995, DSIRE is operated by the N.C. Clean Energy Technology Center at N.C. State University and receives support from EnergySage."
- American Council for Energy Efficiency: Maryland Database."Every year, ACEEE ranks states on their energy efficiency policy and program efforts and provides recommendations for ways that states can improve their performance in a variety of policy areas. The *State Scorecard* serves as a benchmark for state efforts, encouraging states to continue strengthening their efficiency commitments as a pragmatic and effective strategy for promoting economic growth, securing environmental benefits, and increasing their communities' resilience in the face of the uncertain costs and supplies of the energy resources on which they depend."
- Maryland Benefits: Examining the Results of EmPOWER Maryland through 2015 (2017). "In 2008 Maryland passed an energy efficiency resource standard requiring the state to reduce per capita energy consumption by 10% by 2015. In this report we review the costs and benefits of Maryland's EERS policy with a focus on statewide benefits from utility-sector programs. We discuss and quantify several key benefits including avoided utility infrastructure, reduced harmful air emissions from power plants, increased statewide jobs and gross state product, and wholesale market price reductions caused by reduced demand."
- MD Executive Order 01.1.2019.08: Energy Savings Goals for State Government (2020). "On June 25, 2019, Governor Hogan issued Executive Order 01.01.2019.08, Energy Savings Goals for State Government, which created a new energy savings initiative and goal for Stateowned buildings. The "Maryland Leads by Example" initiative, to be developed and managed by the Department of General Services (DGS) and the Maryland Energy Administration (MEA), has a goal to reduce the energy consumption of State-owned buildings 10% by the year 2029, compared to a fiscal year 2018 baseline."

- Maryland Office of People's Counsel - Low-Income Market Characterization Report (2018). "The purpose of the Maryland Low-Income Market Characterization Study is to furnish data that can be used to understand the energy affordability issues faced by Maryland's low-income population and to inform the design of existing and future programs. By providing baseline data to OPC, state agencies, utilities, and other interested parties, the study seeks to inform the discussion of how to best meet the energy needs of low-income households."
- Reaching 90% Compliance: Maryland Building Code Compliance Roadmap by Maryland Energy Administration (2012). "The primary purpose of adopting and complying with a more stringent energy code is to reduce lifetime energy consumption in new construction and extensive remodels. Reduced energy consumption in a new energy efficient building saves money for owners every year that a building exists, paying for any added construction costs many times over. This Plan, which is a collaborative effort between state agencies, local building officials, private firms, and other stakeholders, describes a path to reach 90% statewide compliance with the adopted code by 2017."

7. Technologies

- **Prefabricated Zero Energy Retrofit Technologies: A Market Assessment** (report) -- explores the current state of technology and market gaps for industrialized retrofits as demonstrated by Energiesprong in the Netherlands and provides key recommendations for how the United States might develop its own capacity for such retrofits.
- **Heat Pumps**
  - Heat Pumps Slow Climate Change in Every Corner of the Country - the Sierra Club conducted a detailed analysis of our current and future electricity grid and assessed the impact of converting homes heated by gas to electricity in every state. The answer is clear: Installing clean, electric heat pumps to replace gas water heaters or furnaces in every corner of the country cuts climate and health pollution. This is even true in states where coal and gas plants still power part of the electricity grid, and the climate benefits of electrification only improve as the grid continues to get cleaner over time.
  - Applied Economic Clinic found that even in a cold climate like Massachusetts with relatively high electricity rates, the operational cost over the lifetime of an air source heat pump is lower than that of a gas furnace: https://aeclinic.org/publicationpages/2021/01/13/inflection-point-when-heating-with-gas-costs-more
- **Residential Appliances and Health Costs**
  - Gas Stoves: Health and Air Quality Impacts and Solutions (report) - this 2020 report compiles existing research on the indoor air quality and health impacts of gas stoves. There has been considerable attention to this health research in the last year, including a planned randomized trial on health impacts of stove electrification via the California Electric Commission and an indoor air

quality study on stove electrification project in New York (Out of Gas project, with WeAct for Environmental Justice and PUSH Buffalo)

- Health Effects From Gas Stove Pollution (available for download here) - this report from Sierra Club, RMI, Mothers Out Front, and Physicians for Social Responsibility evaluates and summarizes existing literature and research that details the negative health impacts from gas stoves in homes and closes with recommendations for policymakers.
- Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California - this report from UCLA is focused on California, but a number of the findings are relevant for work in other states, including Maryland.
- Combustion Pollutants & Indoor Air Quality - this landing page for information and additional resources from the California Air Resources Board identifies indoor air pollutants and their sources, including gas appliances, and provides links to further research and information resources.
- Pollution in the Home: Kitchens Can Produce Hazardous Levels of Indoor Pollutants - this news story from Lawrence Berkeley National Lab summarizes a series of studies on indoor air quality issues associated with gas stoves.

- **Battery Storage**
  - The $2.5 trillion reason we can't rely on batteries to clean up the grid, https://www.technologyreview.com/2018/07/27/141282/the-25-trillion-reason-we-cant-rely-on-batteries-to-clean-up-the-grid/. "Fluctuating solar and wind power require lots of energy storage, and lithium-ion batteries seem like the obvious choice—but they are far too expensive to play a major role."
- **Natural Gas**
  - Direct Measurements Show Decreasing Methane Emissions from Natural Gas Local Distribution Systems in the United States. Brian K. Lamb, Steven L. Edburg, Thomas W. Ferrara, Touché Howard, Matthew R. Harrison, Charles E. Kolb, Amy Townsend-Small, Wesley Dyck, Antonio Possolo, and James R. Whetstone. Environmental Science & Technology 2015 *49* (8), 5161-5169. DOI: 10.1021/es505116p
  - Analysis of the Role of Gas for a Low-Carbon California Future. Prepared for the Southern California Gas Company. "This report quantifies the amount of RG that would need to be supplied to SoCalGas' retail customers to decarbonize gas at similar pace as the electric supply..."
    1. "Based on RG supply availability at the costs assumed in this study, the research indicates that RG delivered to residential and commercial buildings could reach similar GHG emissions reduction targets in 2030 as appliance electrification. When comparing the cost-effectiveness of different GHG emissions reduction strategies, RG scenarios have comparable or lower costs to electrification scenarios when considering the range of possible RG and electricity rate projections, and uncertainties around appliance purchase, installation,

and upgrade cost estimates."

- Gas for climate: How gas can help to achieve the Paris Agreement target in an affordable way by Ecofys, a Navigant Company. "We conclude that it is possible by 2050 to scale up renewable gas (biomethane and renewable hydrogen) production in the EU to a quantity of 122 billion cubic metres by 2050. We also conclude that using this gas with existing gas infrastructure, smartly combined with renewable electricity in sectors where it adds most value, can lead to €138 billion societal cost savings annually compared to decarbonisation without a role for renewable gas."