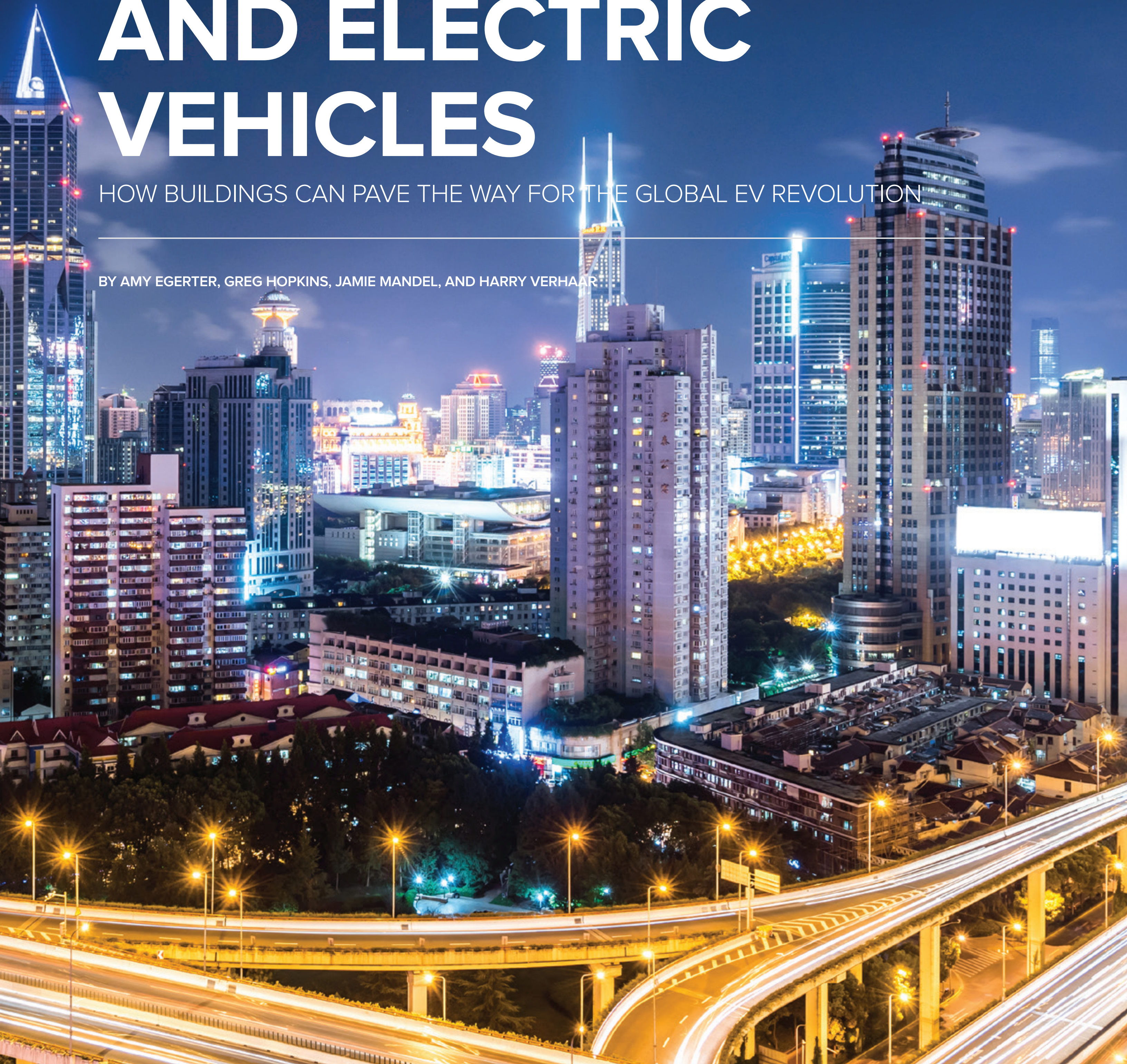
ENERGY EFFICIENCY AND ELECTRIC VEHICLES

HOW BUILDINGS CAN PAVE THE WAY FOR THE GLOBAL EV REVOLUTION

BY AMY EGERTER, GREG HOPKINS, JAMIE MANDEL, AND HARRY VERHAAR



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ABOUT US

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Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has offices in Basalt and Boulder, Colorado; New York City; Washington, D.C.; and Beijing.

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EXECUTIVE SUMMARY

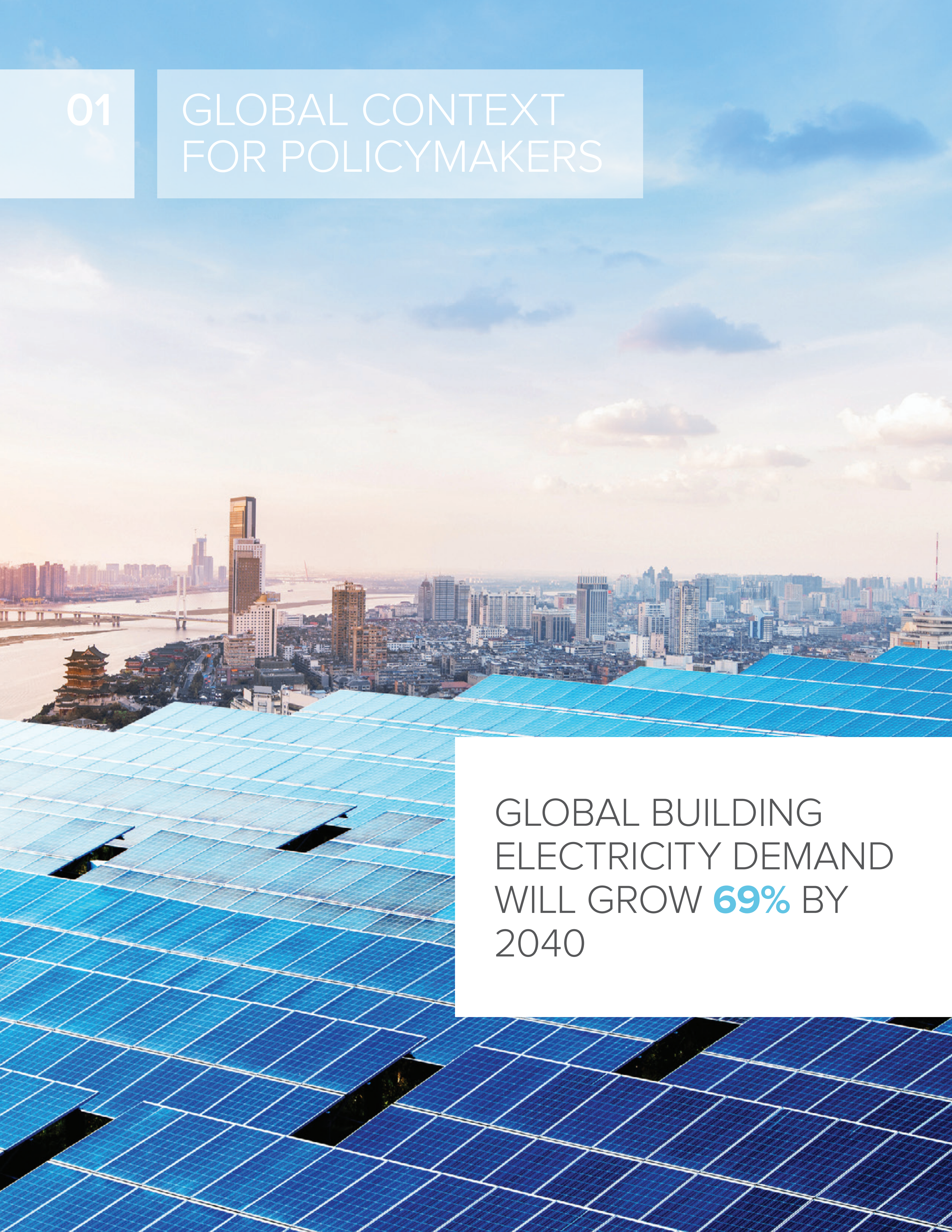
- Globally, the electric vehicle (EV) revolution offers tremendous climate benefits, but the resulting electricity demand growth can and should be managed by policymakers; this report suggests that the accelerated deployment of energy efficiency technologies in buildings is the most cost-effective avenue to achieve this goal.

- By increasing the current global energy efficiency retrofit rate in buildings from approximately 1% per year to just over 5% per year using cost-effective, market-ready technologies that can achieve at least 30% energy savings, we can accommodate baseline adoption of 550 million EVs on the road through 2040 without increasing generation capacity dramatically and while successfully meeting the 2°C target set by the Paris Agreement.

- Not only does energy efficiency represent the lowest-cost energy supply resource, but it also offers benefits including local economic development, load-balancing capabilities, and improvements in building stock quality, productivity, and public health.

- Capturing these benefits will require a step change in policy approaches that primarily target the point of building renovation as a trigger to integrate energy efficiency, smart EV charging technologies, and demand flexibility to minimize costs and to support a high-penetration renewable energy future.

01 GLOBAL CONTEXT FOR POLICYMAKERS



GLOBAL BUILDING ELECTRICITY DEMAND WILL GROW **69%** BY 2040

GLOBAL CONTEXT FOR POLICYMAKERS

Worldwide, electricity use is projected to increase by more than two-thirds through 2040 across all sectors. As the global population grows and gross domestic product (GDP) increases, buildings—including residential, commercial, and public buildings—will be responsible for over half of that additional load growth. At the same time, growing adoption of EVs is expected to further increase electricity generation demand. With momentum behind the EV revolution and current trends in building electricity use, one has to wonder: where will all of this electricity come from? And furthermore, how will all of this impact climate goals?

With that in mind, we set out to explore the following questions:

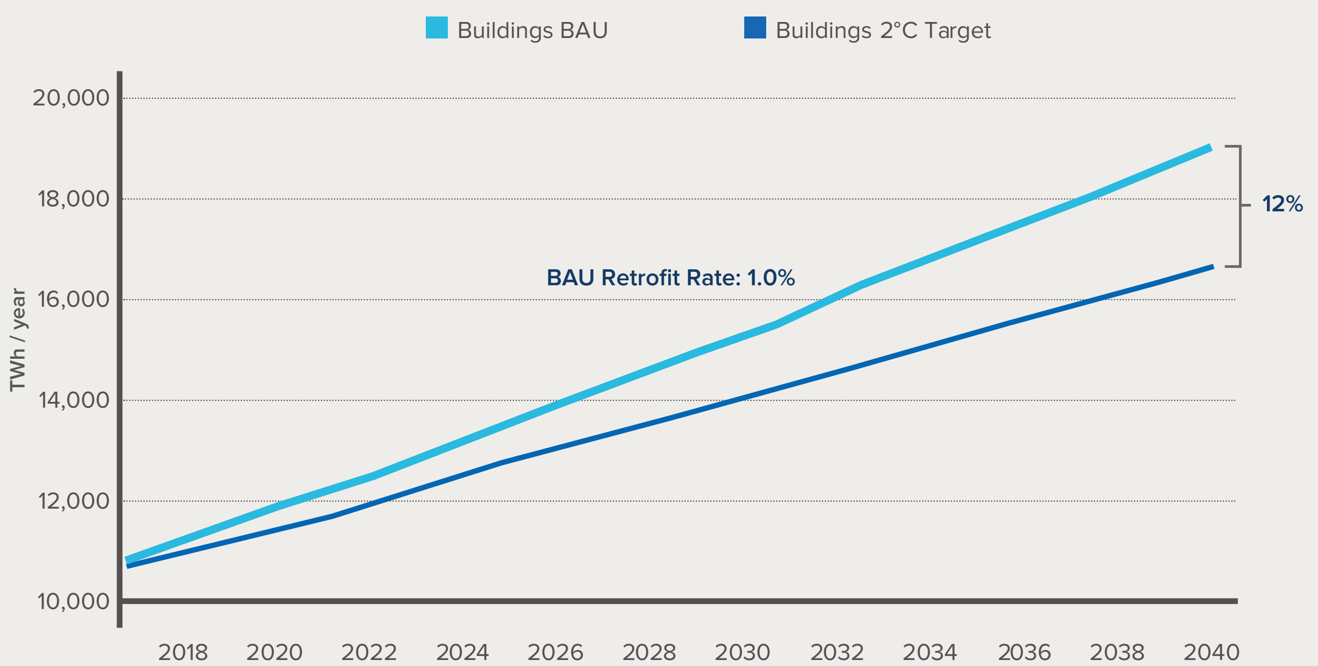
- How much electricity demand should we expect from EVs worldwide, and what could that mean for grid infrastructure?
- Given the cost-effectiveness of energy efficiency relative to new generation infrastructure, is it possible for existing buildings to offset that predicted demand for EV electricity through increased deployment of energy efficiency retrofits?
- How would a warming limit of 2°C change these target retrofit rates?
- What policy actions can be taken at a national and/or local level to achieve the building retrofit rates necessary to offset EV demand and meet climate goals?

Buildings Outlook

The International Energy Agency (IEA) predicts that **global building electricity demand will grow 69% by 2040.**[1] If left unchecked, this will require electricity infrastructure investment of $2.5 trillion by 2040 in the United States alone to accommodate increasing demand (although recent trends suggest this load growth might not fully materialize, the associated infrastructure expense is often already planned).[2]

Based on predictions made by the IEA, even without the addition of EVs to the grid, a **12% absolute reduction in building electricity use versus business as usual (BAU) will be required by 2040 for the buildings sector to meet its contributions to a 2°C global warming target**. This is a total electricity reduction of nearly 2,300 TWh in 2040, **equivalent to taking 684 million households off the grid.**[3] Current energy efficiency trends in the buildings sector are not sufficient to meet this goal, as shown by the BAU curve in Exhibit 1 (next page), which accounts for existing and expected building energy policies globally and incorporates a **BAU building retrofit rate estimated at only 1.0%** of the global building stock per year.

Exhibit 1: Global Building Electricity Demand: Business as Usual vs. 2°C Scenario



Source: International Energy Agency (IEA), *Energy Technology Perspectives 2017*

While certain countries have made progress in establishing strong energy policies for buildings, nearly two-thirds of countries still do not have any mandatory building energy codes in place, according to the IEA.[4] Achieving 2°C targets within the buildings sector will require an increase in the retrofit rate to 3.2% per year, suggesting a need for much more aggressive deployment of highly efficient building technologies, driven in part by mandatory and progressively tightening building energy policies.

EV Outlook

The momentum behind the EV revolution has been gathering over the past year, with countries like Canada, China, France, and Japan committing to increase their use of EVs, and companies like Volkswagen, Volvo, and Ford setting targets to significantly increase production of EVs within the next five to 10 years.[5] Some cities are enacting increasingly ambitious policies, such as Paris' and Mexico City's bans on diesel engines by 2025, or Oslo's and Austin's mandates that city fleets be all or partially electric by 2020.[6] In fact, the Bank of Finland has noted that not responding to this shift in mobility technologies could even pose a systemic risk to the European Union's economy.[7]

This growth in EV use, while undoubtedly good for the environment as electricity sourcing moves toward renewables, will need to be thoughtfully planned to minimize increasing capacity needs on the electric grid. Because the vast majority of EVs are charged at home or at the workplace, this growth in EV adoption represents incremental growth in building electricity use.

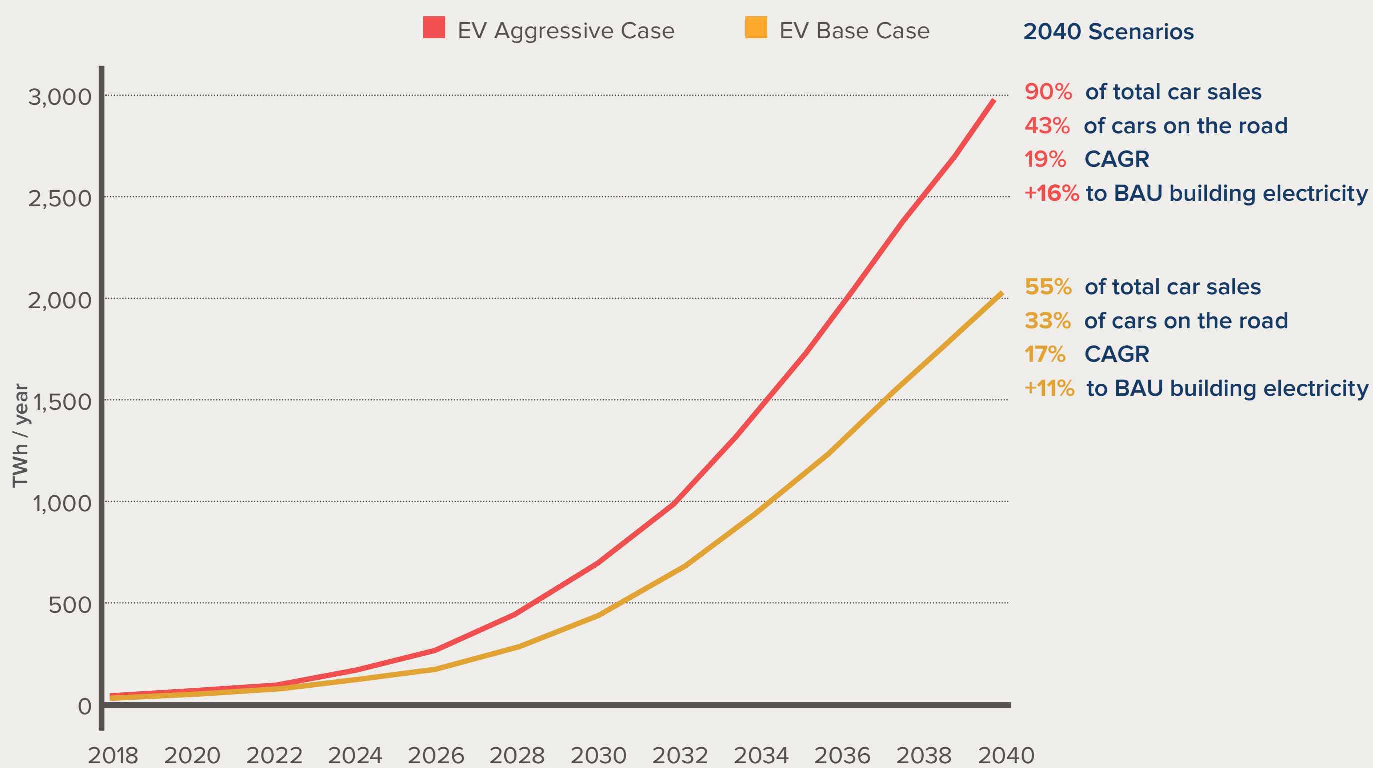
We looked at a range of scenarios for EV uptake through 2040 to gauge the potential impacts that EVs will have on the electric grid.

- **The base case scenario predicts that EVs will comprise 55% of annual vehicle sales by 2040 (with 50 million EVs sold in the year 2040) and 33% of total cars on the road worldwide (reaching 550 million total EVs).** This case represents Bloomberg New Energy Finance's (BNEF's) 2018 EV outlook,[8] which is based on current projections of EV adoption from public goals, targets, and sales trends. We view BNEF's prediction as a realistic representation of EV adoption based on current trends.

- To determine the upper limits of EV adoption, Rocky Mountain Institute designed an aggressive scenario to represent what effect rapid adoption of EVs would have on electricity demand. EV adoption rates are much higher in this scenario and reach 90% of annual vehicle sales by 2040 (with 63 million EVs sold in the year 2040) and 43% of total cars on the road worldwide (reaching 830 million total EVs). This scenario represents RMI's most aggressive outlook based on internal research looking at continued commitments, cost declines, and infrastructure rollout goals.

EVS WILL COMPRISE **55%** OF ANNUAL VEHICLE SALES BY 2040

Exhibit 2: Global EV Electricity Demand: Base Case vs. Aggressive Case

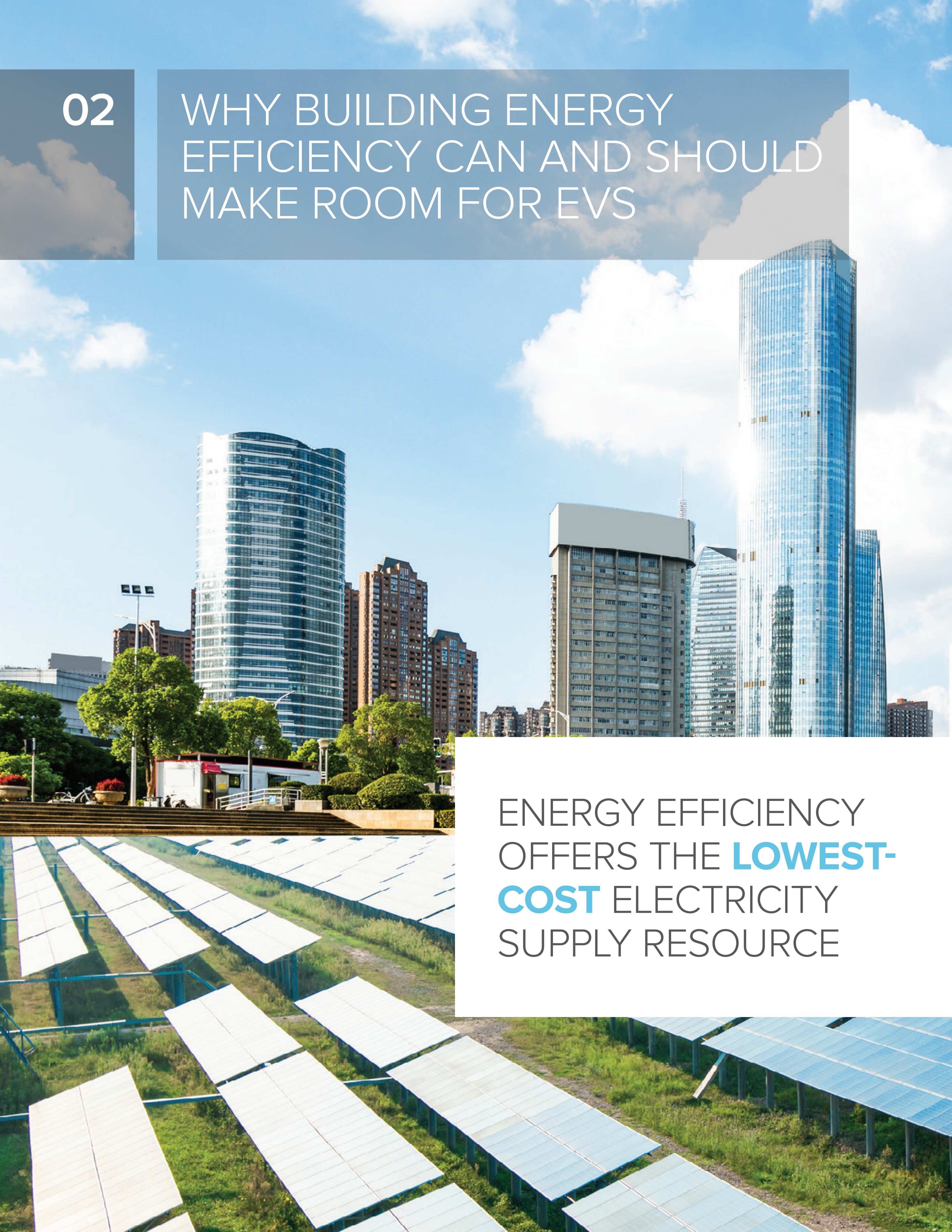


Source: Bloomberg New Energy Finance, *Electric Vehicle Outlook 2017;* and Rocky Mountain Institute projections

These predictions represent an 11%–16% increase in building electricity load by 2040 due to the addition of EVs. Although these numbers might seem relatively small, the aggressive case reaches roughly **3,000 TWh** per year of electricity use—more than the European Union's total electricity consumption in 2013.[9]

Despite these increases, the EV revolution should be seen as an opportunity to strengthen and improve grid functioning in countries around the world. A report prepared for the World Wildlife Fund demonstrates that, with proper implementation of smart charging and vehicle-to-grid controls, a full phaseout of internal combustion engines in the UK by 2030 would not only be possible, but would offer significant value to the overall electricity grid.[10]

02 WHY BUILDING ENERGY EFFICIENCY CAN AND SHOULD MAKE ROOM FOR EVS



ENERGY EFFICIENCY OFFERS THE **LOWEST-COST** ELECTRICITY SUPPLY RESOURCE

WHY BUILDING ENERGY EFFICIENCY CAN AND SHOULD MAKE ROOM FOR EVS

Energy efficiency in buildings represents the most cost-effective opportunity to support the EV revolution, given that it offers the lowest-cost option for meeting future energy needs compared to constructing new generation infrastructure (whether from conventional or renewable sources). We believe that **the current global building retrofit rate, estimated at 1.0% per year, can be increased dramatically based on existing, cost-effective, and widely available energy efficiency technologies in combination with supportive policy and emerging business and financial models.** Additionally, these retrofits can be used as a means to install smart charging EV infrastructure to ensure future grid stability and renewable energy penetration.

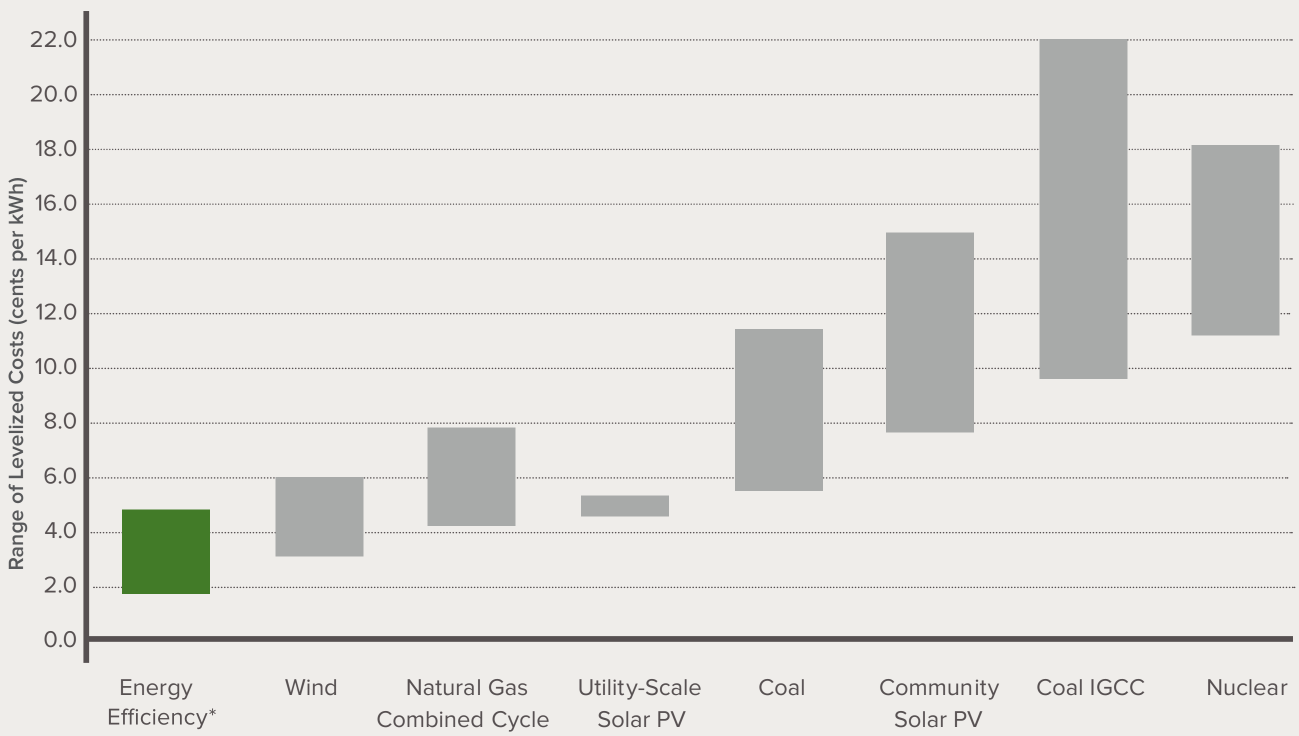
Economic Benefits

The economic argument for increasing building energy efficiency retrofits rests on the fact that there are numerous market-ready technologies that can be deployed with short payback periods, and that building retrofits create more local economic development than the construction of additional power generation. RMI's Reinventing Fire analysis suggests that US buildings can cut projected energy use by 38% over the next few decades using existing and emerging technologies (even as of 2010–2011), requiring an investment of $0.5 trillion to generate total savings of $1.9 trillion in present value with an average return on investment of 24% per year.[11] Additionally, many of these technologies do not even require invasive construction (e.g., LED lighting, variable frequency drives, low-E glass coatings, smart building controls, retrocommissioning).

In contrast with the anticipated need to invest $2.5 trillion in US grid infrastructure mentioned previously, the $0.5 trillion investment in market-ready technologies for building energy efficiency comes with the added benefit of creating sustained local jobs. For reference, according to a 2013 Ecofys report,[12] investing in energy efficiency measures could create 380 jobs per TWh of electricity saved, whereas investing in coal-fired power plants creates 110 jobs per TWh of electricity generated. Job creation from energy efficiency can happen both directly (e.g., in manufacturing and implementation) and indirectly (e.g., by freeing up disposable income). Investments in local construction enable direct capture of energy cost savings and returns on retrofit investments by local residents and businesses, whereas investments in electricity generation facilities will divert returns elsewhere, with less immediate benefit to the community. The American Council for an Energy-Efficient Economy (ACEEE) found that energy efficiency investments in the United States since 1990 have helped avoid building the equivalent of 313 additional large power plants and generated $790 billion of cumulative savings to consumers across the country.[13]

Additionally, recent data from Lazard and the ACEEE confirms that **energy efficiency offers the lowest-cost electricity supply resource.**[14] At 2 to 5 cents per kilowatt hour, efficiency is two to three times less expensive than fossil fuel alternatives. And although renewable sources are critical to making the grid cleaner over time, energy efficiency investments currently make more financial sense and should be maximized first as an electricity supply resource.

Exhibit 3: Levelized Cost of Electricity Resources



* Notes: Energy efficiency program portfolio data from Molina 2014. All other data from Lazard 2017. High-end range of coal includes 90% carbon capture and compression.

Source: Annie Gilleo, "New Data, Same Results—Saving Energy is Still Cheaper than Making Energy," ACEEE, December 1, 2017, http://aceee.org/blog/2017/12/new-data-same-resultssaving-energy

If the financial case is not compelling enough, investments in building energy efficiency also provide meaningful non-energy benefits, such as higher productivity for businesses, improved thermal comfort and indoor air quality, reduced employee sick days, and increased resilience and energy security (i.e., lower likelihood of supply interruptions and, for certain countries, reduced reliance on imported energy).[15]

Load-Balancing Benefits

Energy efficiency retrofits have the benefit of reducing overall load on the electric grid and can increasingly (in the case of grid-interactive efficiency investments in building controls, smart LEDs, and smart appliances, among others) make demand flexible, thereby promoting grid stability. When paired with the deployment of smart EV charging infrastructure to enable EVs as distributed energy resources, this can help to balance loads and better harness renewable energy generation.

EVs and grid-interactive efficiency investments are responsive loads that can be timed based on numerous signals, including:

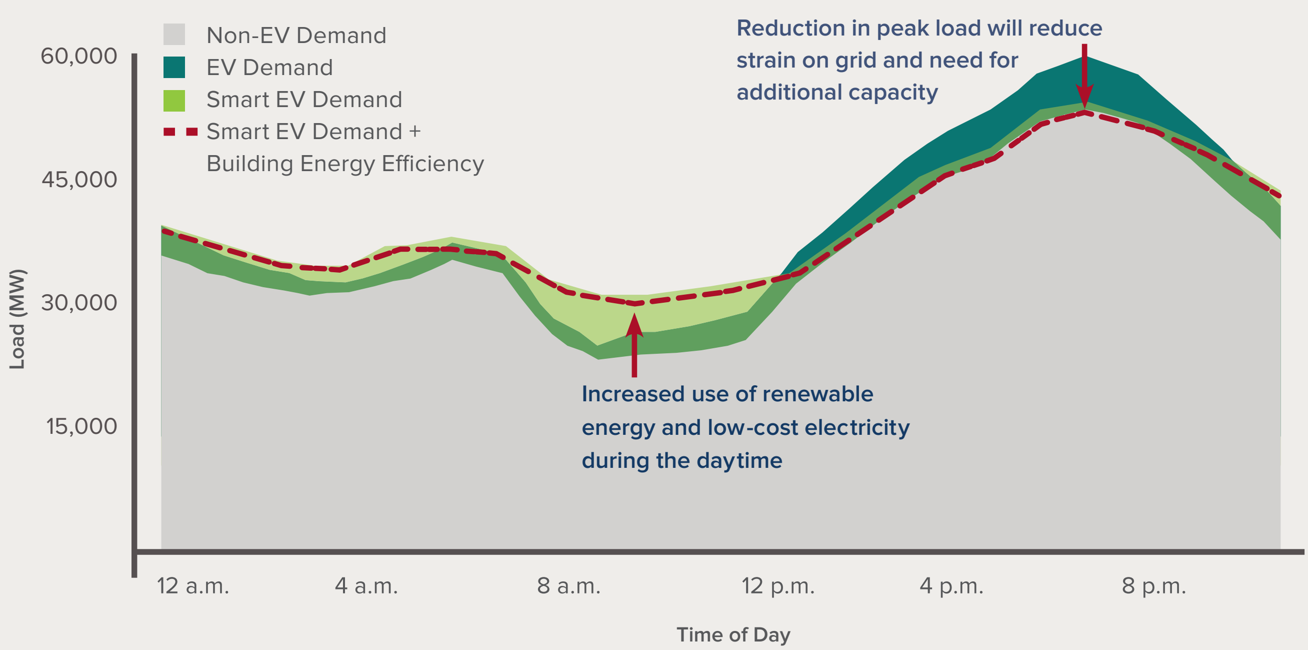
- Grid utilization: Charging when the grid is underutilized and power is cheap.

- Renewable energy: EVs can store electricity from renewable energy generation when the generation is high, reducing curtailment of renewable energy.
- Building electricity use: At the building level, EV charging could respond to building electricity consumption schedules and ramp up accordingly to ensure that excessive demand charges are not incurred.

Leveraging smart EV charging with demand flexibility can lead to a more balanced electric grid and minimize excessively large increases in peak load. Smart EV charging could consist of right-timing the charging based on a cost or emissions signal, or it could mean charging and discharging the battery to the grid (i.e., two-way charging). Exciting new technologies such as two-way EV chargers are already being developed and tested across Europe.[16] Smart charging technologies, either for timing or two-way charging, when paired with energy efficiency technologies and energy management systems, can allow for communication between end uses to further reduce peak load.

As an example, Exhibit 4 illustrates the impact of widespread deployment of fast payback measures, including LED retrofits, appliance replacements, and retrocommissioning across the state of California. These measures have a payback of less than four years and achieve about a 7% reduction in statewide hourly electricity use. Paired with smart EV charging controls to control charging times, the peak evening load can be reduced to entirely offset EV electricity use.

Exhibit 4: Hypothetical Effect of Smart EV Charging and Building Energy Efficiency on Peak Electric Load



Source: CAISO projections and CA EV projections; Energy analysis of LED lighting, appliance replacements, and retrocommissioning across 50% of the existing building stock in CA at an average hourly savings of 7%; assumes 50% of non-EV load is from existing buildings

A separate RMI analysis demonstrates in more detail how demand flexibility technologies not only cost-effectively reduce peak loads but are essential to achieving high-penetration renewable grids.[17] The IEA projects that 37% of total electricity generation worldwide will come from renewable sources by 2040 (59% if 2°C targets are met), but reaching and surpassing these levels will be challenging without the use of smart demand flexibility technologies that can shift loads to better match variable renewable energy generation, limiting curtailment and improving value. While smart EV charging is a critical component to this strategy, a new generation of automated building communication and control technologies (including smart thermostats to control air conditioning, dryer timers, grid-interactive water heaters, and battery energy storage) can further enable demand flexibility for building loads that do not require fixed schedules.

Implementing these measures across a country or across the globe, as guided by smart integrated policies, would go a long way toward not only reducing the need for additional power generation but also setting energy use on a path to 2°C targets. EVs and energy efficiency, when considered in unison, can create a cost-optimized path to achieving peak load and energy goals.

Quantifying the Required Retrofit Rate

While the rationale for relying on building retrofits to curb load growth is clear in theory, we sought to address a few important practical questions:

- What would retrofit rates need to look like to meet building-sector 2°C goals in addition to offsetting predicted EV electricity demand?
- What type of policy actions can accelerate deployment to these levels while creating economic and quality-of-life benefits for constituents?

We calculated several scenarios to determine how much building retrofit rates would need to increase to avoid constructing additional power generation capacity (i.e., offset all building and EV load growth between 2018 and 2040), based on the EV uptake scenarios and expected building electricity demand trends. The analysis that determined these retrofit rates did not consider carbon impacts associated with generation changes in the grid over time, but focused instead on the goal of reducing excessive power grid infrastructure build-out due to increasing electricity demand. Additional details can be found in the Appendix.

For this analysis, we have defined these incremental retrofits to save 30% of site electricity use per building. RMI has observed through previous project experience that this level of savings is achievable in most building retrofits without significant up-front cost when market-ready technologies are deployed. Such whole-building energy reductions can be accomplished through a variety of retrofit scopes, including combinations of envelope upgrades, heating and cooling system replacements, appliance and lighting upgrades, and the integration of smart controls or energy management systems. Depending on their existing conditions, some buildings can achieve savings well above 30%, whereas others will achieve savings closer to or slightly under 30%.

The results of this analysis show that **global average retrofit rates will need to increase by approximately three to six times beyond their current rates to offset the predicted load additions through 2040 and limit global warming:**[18]

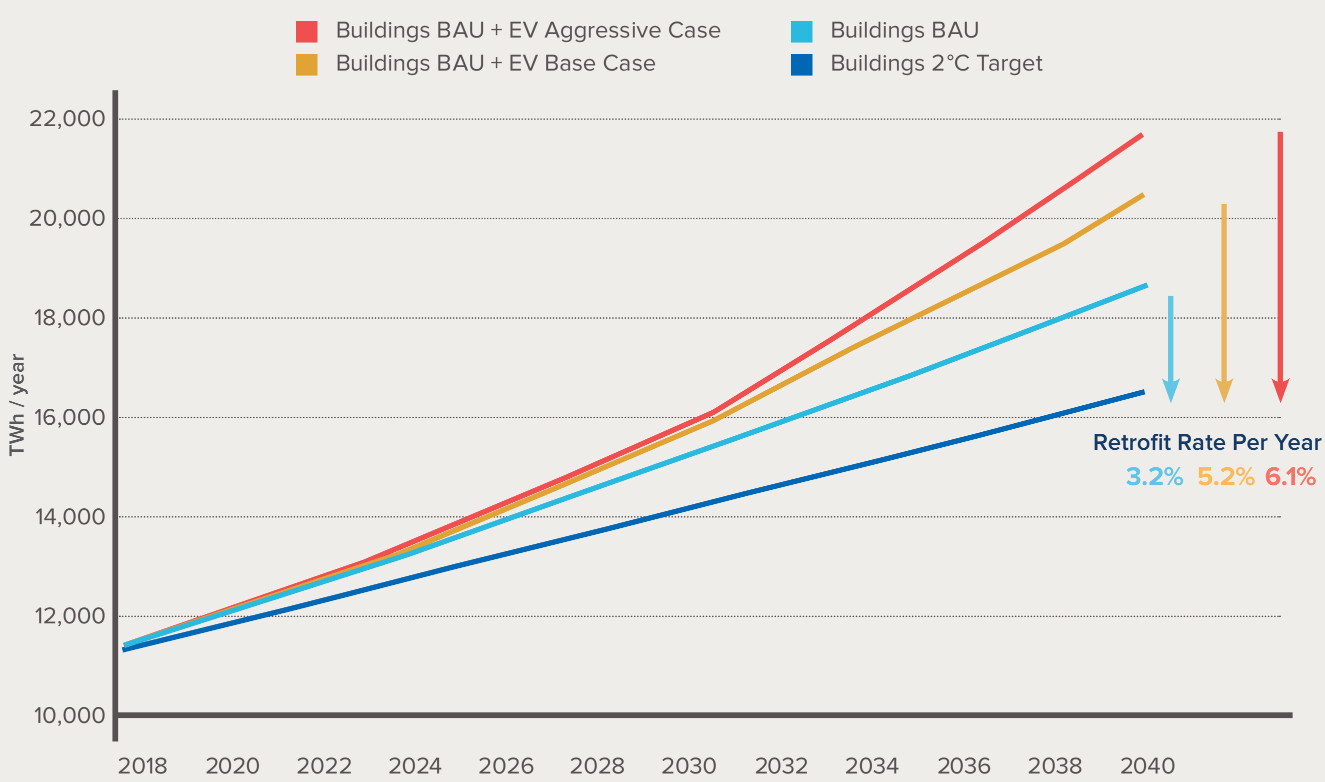
- ~3x higher retrofit rates are needed to meet 2°C targets within the buildings sector in 2040 (before accounting for EVs); a cumulative 43% of the 2040 global building stock would need to be retrofitted over BAU.

- ~5x higher retrofit rates are needed to meet 2°C targets and to offset EV demand predicted in the base case scenario; a cumulative 80% of the 2040 global building stock would need to be retrofitted over BAU.

- ~6x higher retrofit rates are needed to meet 2°C if the most aggressive EV forecast is borne out; a cumulative 98% of the 2040 global building stock would need to be retrofitted over BAU (i.e., nearly the entire building stock would need to be retrofitted to achieve additional 30% electricity reductions over BAU to hit 2°C targets by 2040).

With deeper retrofit scopes (e.g., saving 50% of site electricity per building versus 30% above), global retrofit rates would need to increase only two to four times (as opposed to three to six times) their current rates to achieve the same 2040 targets without significant infrastructure build-out. Realizing these retrofit rates and associated energy savings would take the equivalent of 684 million to 1.6 billion households' annual electricity use off the grid by 2040, based on current global average electricity use per household.

Exhibit 5: Building Retrofit Rates Required to Offset EV Demand and Meet 2°C Targets



Note: Retrofit Rate Per Year reflects the estimated 1.0% BAU global building retrofit rate plus calculated incremental retrofit rates needed to offset each scenario's electricity demand gain (TWh) in 2040, based on the additional global built floor area assumed to achieve 30% site electricity savings. Share of Stock Retrofitted reflects the cumulative global built floor area undergoing incremental retrofits through 2040 in each scenario as a proportion of the 2040 global building stock.

03 PUTTING ANALYSIS INTO ACTION

WE CAN MEET **2°C TARGETS** BY BETTER INTEGRATING POLICIES

PUTTING ANALYSIS INTO ACTION

What will catalyze the buildings sector to accelerate retrofit deployment? These retrofit rate increases will require a step change in policy approaches to the energy efficiency of buildings and smart charging EV technologies. Ultimately, local, regional, and national governments will need to determine how best to handle their increasing loads efficiently and cost-effectively. By capturing the full value of economic building energy efficiency retrofits, these stakeholders can make room for exciting new technologies like EVs, which have the potential to transform global transportation systems and reduce carbon emissions, likely at a net savings rather than at a net cost. As with any disruptive technology, there will need to be changes to the status quo, and instead of stakeholders seeing this as a burden, they should see this as an opportunity to update the existing building stock and improve quality of life.

Developing and strengthening policies for building and mobility sector electricity use can be an effective way to manage this transition. Globally, it is estimated that approximately 68% of residential buildings and 55% of commercial and public buildings are not subject to mandatory codes and standards.[19] With the EV revolution drawing nearer, policymakers should consider the impact this will have on electricity use in their region, and how building and mobility policies can work together to enhance the stability of grid infrastructure.

We can successfully avoid massive grid infrastructure expansion costs and meet 2°C targets only by better integrating policies that account for and align buildings, EVs, and renewables. When considering new policies and incentives for EV charging and time-varying rate structures, for example, policymakers should also consider the role of building equipment and appliances and how they collectively relate to the growing supply of renewable energy coming online in their jurisdictions. Demand flexibility technologies, like those mentioned above, should be viewed as a core asset at all levels of grid and policy planning—particularly to support renewable energy supply targets.

Core Policy Recommendations

- Consider **building and EV policies in tandem** to lower the costs associated with both; EVs can be an effective policy driver for building efficiency, and perhaps more importantly, building efficiency is likely to provide the lowest-cost option to address EV grid infrastructure needs (or render those needs unnecessary).

- Furthermore, EVs and building efficiency measures can together support a **high-penetration renewable future** by allowing demand to respond dynamically to supply.

- The energy transition must be part of an **integrated policy framework**, with mobility, buildings, and renewables all supporting each other within a regional context to maximize cost-effectiveness and grid flexibility.

Policy Recommendations to Accelerate Building Efficiency Deployment

- For existing buildings, establish and enforce **benchmarking and disclosure policies** that make building energy performance information publicly available. Although such policies do not improve energy efficiency in and of themselves, they are highly effective because they raise awareness, drive demand, promote competition between building owners, and provide the data needed to inform and facilitate energy upgrade decisions. Benchmarking and disclosure policies are most effective when the reporting tools and ratings provide recommendations for efficiency improvements in addition to performance information.

- State and local benchmarking and disclosure policies alone have led to 3%–8% reductions in energy consumption or energy use intensity in commercial and multifamily buildings across several major US cities.[20]
- The EU's Energy Performance of Buildings Directive (EPBD) establishes building energy rating schemes and associated energy performance certificate labels for residential, private commercial, and public buildings that are mandatory in most EU member states, ensuring that building energy performance information is provided to prospective tenants and buyers as part of the transaction process.[21]

- For existing buildings, establish **performance-based building ordinances** that phase in energy efficiency requirements over time. While the efficiency requirements of these policies can be sequenced over predefined timelines applicable to all owners (e.g., every two years after sufficient lead time), they can, alternatively, leverage key transactional triggers, such as point of sale or point of rental licensing.
  - In the commercial sector, New York City, among other cities, has established a building ordinance that phases in energy efficiency requirements over time for buildings over 25,000 square feet.[22]
    - Consider aligning building ordinances with local utilities to ensure that supporting mechanisms such as incentives, historical utility data for affected buildings, and contractor training programs are put into place in conjunction with ordinance implementation.
  - In the residential sector, minimum efficiency standards for rental properties require building owners to meet certain performance levels before receiving their rental licenses. Boulder, Colorado's SmartRegs program has successfully rolled out such a policy,[23] establishing several replicable best practices, as documented in a recent RMI report.[24]
    - Efficiency standards for rentals can be particularly impactful for cities with existing rental licensing programs in place and a large proportion of rental housing.

- For new construction, establish and/or expand coverage of **mandatory building energy codes** (where currently there are voluntary or no codes in place) that address building envelopes; systems for heating, cooling, and ventilation; and EV charging infrastructure.
  - The most holistic way to address all end uses as a system is to implement a performance- or outcome-based code, as countries such as Germany and the UK have done.
  - New construction codes that push for net-zero energy should be a key focus in non-OECD countries, where 82% of global floor area additions through 2040 are expected (totaling 110 billion square meters).[25] New constructions that are net-zero energy will dramatically reduce the need for future energy efficiency retrofits.
  - Building codes with progressively tightening energy performance requirements over time should be a key focus in OECD countries, where most of the 2040 building stock already exists.
    - For reference,[26] cities in the United States with decade-old building energy codes can achieve

17% energy savings in residential buildings and 30% energy savings in commercial buildings by updating to the newest codes (i.e., 2015 IECC and ASHRAE 90.1-2016).

    - Cities with even older or no codes can achieve 29% energy savings in residential buildings and 33% energy savings in commercial buildings.

  - Expanding building codes to address EV charging and load management is a key entry point for holistic policy solutions.

    - The EU's EPBD requires ducting infrastructure or full EV charging stations for certain building types when newly built or undergoing extensive renovations.[27]

      The EPBD also mandates that the European Commission develop a "smart readiness indicator" rating the capabilities of buildings to integrate into the grid (including EV charging) and optimize energy performance.

    - California's Title 24 has included mandatory criteria for EV charging stations and goes further to incorporate demand management technology to help control peak loads.[28]

- Establish and/or expand coverage of **minimum energy performance standards for appliances and equipment** used in residential and commercial buildings.

  - Consider phasing in bans on outdated/inefficient technologies (e.g., incandescent light bulbs or high-energy-efficiency-ratio air conditioners), just as certain municipalities have started phasing in bans on internal combustion engines.

- Mandate smart meter rollouts and high-speed internet in new and existing buildings to prepare the building stock for grid communication.

- Encourage and support research, development, and deployment of building energy management systems that are designed to manage load flexibility.

- Support implementation of energy efficiency by rolling out **financing mechanisms and incentives** as well as investing in research and development for new technologies.

  - Green bonds, white certificate markets, and utility on-bill financing are some examples of effective yet underutilized financial support mechanisms.

- To address noneconomic barriers to retrofits, build up training and educational programs, standardize retrofit procedures where possible, and raise occupant awareness around energy efficiency.

These policies should be implemented and tailored to the ultimate goal of increasing the frequency and efficacy of building retrofits. To multiply the global retrofit rate by three to six times what it is now, and to ensure that these retrofits are paving the way for EV integration, a mix of proven practices paired with innovative approaches to incentivizing retrofits will be needed.

Policy Recommendations to Plan for the EV Revolution

It is absolutely critical to get right the methods and infrastructure for vehicle electrification from the start, with appropriate tariffs, well-planned charging infrastructure, and the ability to manage chargers either directly or through aggregators. Policies will be most effective when the integration of smart EV charging infrastructure is timed to coincide with broader building renovation efforts.

- **Time-of-use pricing signals** can be used to shape load and incentivize EV charging at off-peak times.
  - Buildings with EV charging infrastructure should automatically be placed on such rate structures.
  - EV charging access at workplaces and shopping locations can **encourage daytime, off-peak charging.**
- Chargers should be **demand-response enabled** to further incentivize and default to off-peak charging.
- Encourage the bundling of demand-reduction measures at the time of installing EV charging infrastructure as part of a standardized retrofit solution.
  - This could include baseload components such as insulation, and also dynamic capabilities such as dimmable lighting, automated controls, energy storage, and demand-response systems at the building level.
  - The dynamic demand control elements should also be integrated with the building solar photovoltaic charging system to minimize building demand and maximize system-wide benefits.
- **Emerging two-way charging technologies** that allow for EV batteries to supply electricity to buildings or the grid should be investigated and included in demonstration projects.
- Include EV loads in building code compliance modeling to increase awareness of additional electricity use caused by EVs.
- Collect and share data about the utilization of charging station infrastructure to aid in further policy guidance on charging station rollouts and impacts to the local grid.

All signs point to the beginning of an EV transition that will continue gaining momentum in the near term. The swift adoption of well-designed policies at a local and/or national level can preempt long-term infrastructure consequences and avoid significant cost outlays while creating more comfortable, productive, and resilient places to live and work.

04 CONCLUSION

CONCLUSION

Although EVs and their regulatory implications are relatively new and untested, they offer forward-thinking policymakers a unique opportunity to "get it right" from the outset. When it comes to building energy policies, on the other hand, policymakers do not have to reinvent the wheel—best practices and lessons learned can and must be shared internationally given the vast technical and practical experience accumulated to date. Policymakers should focus heavily on the interactions between EVs, buildings, and the grid. Building codes and EV policies have yet to define these interactions and, as EVs will become a critical load in buildings, the issue should be addressed sooner rather than later.

Through this analysis, we hope to convey the urgent need to economically address growing electricity loads across the globe and to equip policymakers with the context and insights necessary to pursue and implement innovative policies that tie together two sectors essential to meeting climate goals. Given the accelerating EV revolution and the very slow pace at which the building stock turns over, poor planning or a lack of policy action altogether will lock in inefficient technologies and the associated costs and emissions for decades to come. **Concerted action is required to increase the building retrofit rate from 1.0% to at least 3.2% and as much as 5.2%–6.1% globally if we aim to achieve a 2°C future.**

Fortunately, energy efficiency offers significantly more benefits and fewer costs than its alternatives, efficiency technologies can more effectively harness the growing supply of renewable energy through demand flexibility, and efficiency policy frameworks are not new (although they need to be adapted to the urgency and magnitude of the opportunity). The technologies, policy mechanisms, and supporting investment structures already exist to take our built environment where it needs to go—the only impetus needed is leadership.

05 APPENDIX: METHODOLOGY

APPENDIX: METHODOLOGY

This report focuses on reducing grid infrastructure needs and therefore considers the implications of EVs in terms of load growth using the reference and 2°C scenarios from the IEA, as described below. These forecasts assume varying rates of renewable energy penetration. However, RMI's analysis does not consider carbon emissions impacts associated with generation changes in the grid over time in the context of building retrofits.

Data Collection

Buildings

Annual projections for global final electricity demand (converted to TWh) in residential and commercial/public buildings and for floor area are from the International Energy Agency Energy Technology Perspectives (ETP) 2017 using the reference scenario and 2 degrees scenario from 2018 through 2040. Starting from socioeconomic assumptions (including population, GDP, income, and urbanization and electrification rates), IEA ETP's global buildings sector model determines demand drivers and related useful energy demands, which are applied across building end uses and technology choices to calculate final energy consumption across 35 model countries and regions.[29] Whenever possible, historical data and buildings sector information, such as building energy codes or minimum energy performance standards for end-use equipment, are applied within the model. Depending on the end use or technology, multiple categories are included (or estimated) within the model; for example, the global building stock is broken down into three categories, including near-zero energy buildings, code-compliant buildings, and buildings that do not meet code or do not have an applicable building energy code.

IEA's reference scenario takes into account today's commitments by countries to limit emissions and improve energy efficiency, including the Nationally Determined Contributions pledged under the Paris Agreement. IEA's 2 degrees scenario lays out an energy system pathway and CO_2 emissions trajectory consistent with at least a 50% chance of limiting the average global temperature increase to 2°C by 2100.

This work is partially based on the Energy Technology Perspectives 2017 developed by the International Energy Agency, copyright OECD/IEA 2017. The resulting work was prepared by Rocky Mountain Institute and does not necessarily reflect the views of the International Energy Agency.

Electric Vehicles

Annual base case predictions for EV electricity use were based on analysis done by Bloomberg New Energy Finance (BNEF) in the Electric Vehicle Outlook 2018 report. Aggressive case targets were set based on RMI professional experience and observed market trends. Note that IEA ETP does project EV electricity demand, but considers it as part of the transport sector (not the buildings sector), so EV demand is not being double-counted; this analysis leverages only the ETP global buildings sector model described above.

Data Analysis

Buildings

The business-as-usual global building retrofit rate estimate of 1.0% is based on guidance from the IEA to assume a retrofit rate of about 0.9% leading to around 1.1% in 2050/60 in the ETP buildings reference scenario. RMI calculated incremental retrofit rates as an additional percentage of global built floor area assumed to achieve 30% site electricity savings on an annual basis to offset the scenario-specific total electricity demand gain (in TWh) in 2040. Although building retrofits can achieve savings well above or below 30%, RMI selected 30% average savings based on project experience, suggesting that 30% is achievable in most retrofits using market-ready technologies without significant up-front costs. The calculated incremental retrofit rates were then added to the business-as-usual 1.0% rate to determine total required retrofit rates.

Electric Vehicles

The base case scenario for global EV uptake presented in this report is the base case projection published by BNEF in June 2018. RMI's aggressive case assumes that, in 2040, 90% of total vehicle sales are EVs. Working backward from 2040 using goal-seek analysis, RMI modeled EV uptake trends after those modeled by BNEF in the base case to create a similar EV adoption curve.

06 ENDNOTES

ENDNOTES

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