Guiding principles to decarbonize energy systems

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Introduction

Electric and gas utilities are increasingly placed on the front lines of the fight to address climate change. While the U.S. government struggles to forge a comprehensive legislative solution, many states and cities are charging ahead with climate action and clean energy plans that hold major implications for utilities. Meanwhile, many utilities are already experiencing the impacts of climate change through increasingly extreme wildfire, hurricane, heat, flood, and drought conditions.

This paper draws on ICF's decades of experience working across North America with utilities and with governments at all levels to help illuminate pathways that can achieve ambitious climate policy goals while taking into account the practical, regulatory, and financial issues utilities face. Based on our experience working with cities, counties, states, utilities, and private sector companies across the country, we offer this paper as a distillation of insights to guide future strategies.

There is no one silver-bullet solution to decarbonizing the massive and complex U.S. economy. Electrification, low-carbon fuels, and other strategies will likely be needed in various mixes for different regions. No one strategy accommodates competing interests while providing affordable, reliable, and resilient energy services for all. Strategies must also be realistic regarding timing and geography. Today's ambitious climate plans will take

decades to fully implement, raising questions on how best to phase actions, and how to minimize risks in a "no-regrets" approach. Solutions that work in a specific geography, market, and regulatory context may not be the right solution for others.

The complexity of climate solutions, combined with their timing and geographic dimensions, calls for more robust and comprehensive analysis. As governments and utilities move to make major changes in energy infrastructure, yesterday's simpler "black box" models will not be adequate to the task. Climate planners and analysts must use better tools and suspend preconceived views based on what may work elsewhere, what may serve one set of interests, or what may seem to be the path of least resistance. They must also grapple with promising solutions that are yet unproven, and so must study their options while working to minimize risks to the reliability, resilience, and affordability of energy services.

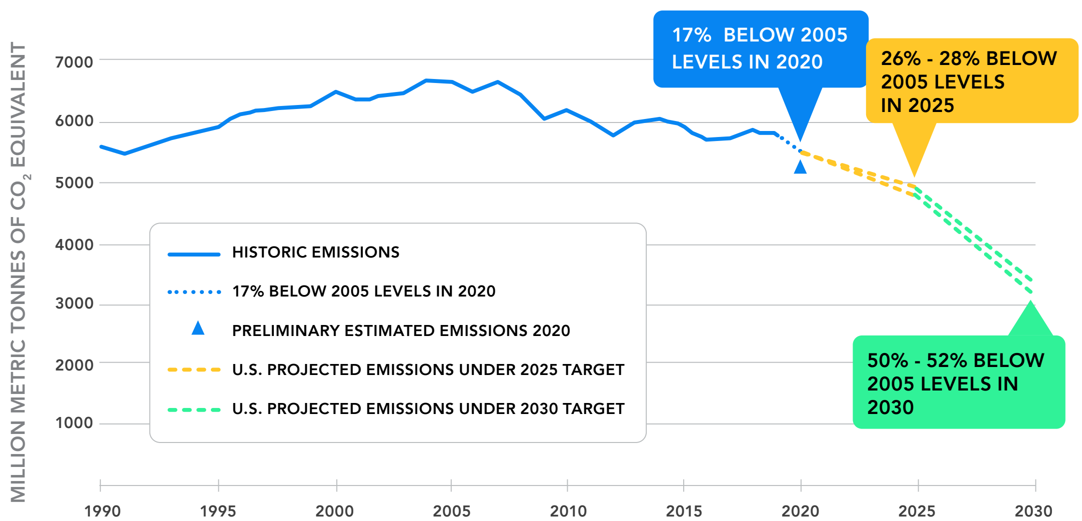
The climate problem requires accelerated action

The climate landscape continues to intensify while also growing in complexity. In April 2021, the U.S. reestablished its commitment to achieve ambitious greenhouse gas (GHG) emissions reduction goals of 26% to 28% by 2025 and 50% to 52% by 2030 compared to 2005 emissions, almost a doubling of reductions within five years (see Figure 1). When the UN's Intergovernmental Panel on Climate Change released its AR6 Climate Change 2021 report[1] in August 2021, UN Secretary General Antonio Guterres said its dire assessment amounted to a "code red for humanity" that would require the world to "combine forces now" to avert climate catastrophe. A month later, at the UN's annual summit in New York, U.S. President Joe Biden proclaimed the United States would up its commitment to fight climate change at home and abroad. Accelerated action is clearly likely, especially in the long term, but figuring out the right set of solutions and how they are prioritized for a given jurisdiction or company is difficult.

FIGURE 1. U.S. GREENHOUSE GAS EMISSIONS

United States historic emissions and projected emissions under 2030 target

Source: The United States of America Nationally Determined Contribution. Reducing Greenhouse Gases in the United States: A 2030 Emissions Target report.



There is growing momentum toward electrification as a solution to decarbonization as the electric grid becomes increasingly clean through renewable power. Just like switching vehicles from petroleum to electric, switching home heating, water heating, and cooking from oil and natural gas to electric appliances can reduce the direct use of fossil fuels by substituting increasingly cleaner electricity. However, electrification is not the sole answer in every situation. The need for balanced decarbonization strategies is driven by maintaining the reliability of energy supply and delivery systems, especially in preparation for increasing weather extremes; finding alternatives to practical limitations on fuel conversions; and limiting transition costs.

[1] https://www.ipcc.ch/report/ar6/wg1

These strategies must be regionally specific, meeting the needs of all energy supply and demand sectors through a diverse mix of solutions ranging from efficiency to electrification to low-carbon fuels. Also, communication of these strategies must realistically address the challenges as well as the opportunities to manage expectations and ensure stakeholder support.

Climate solutions must fit their locations

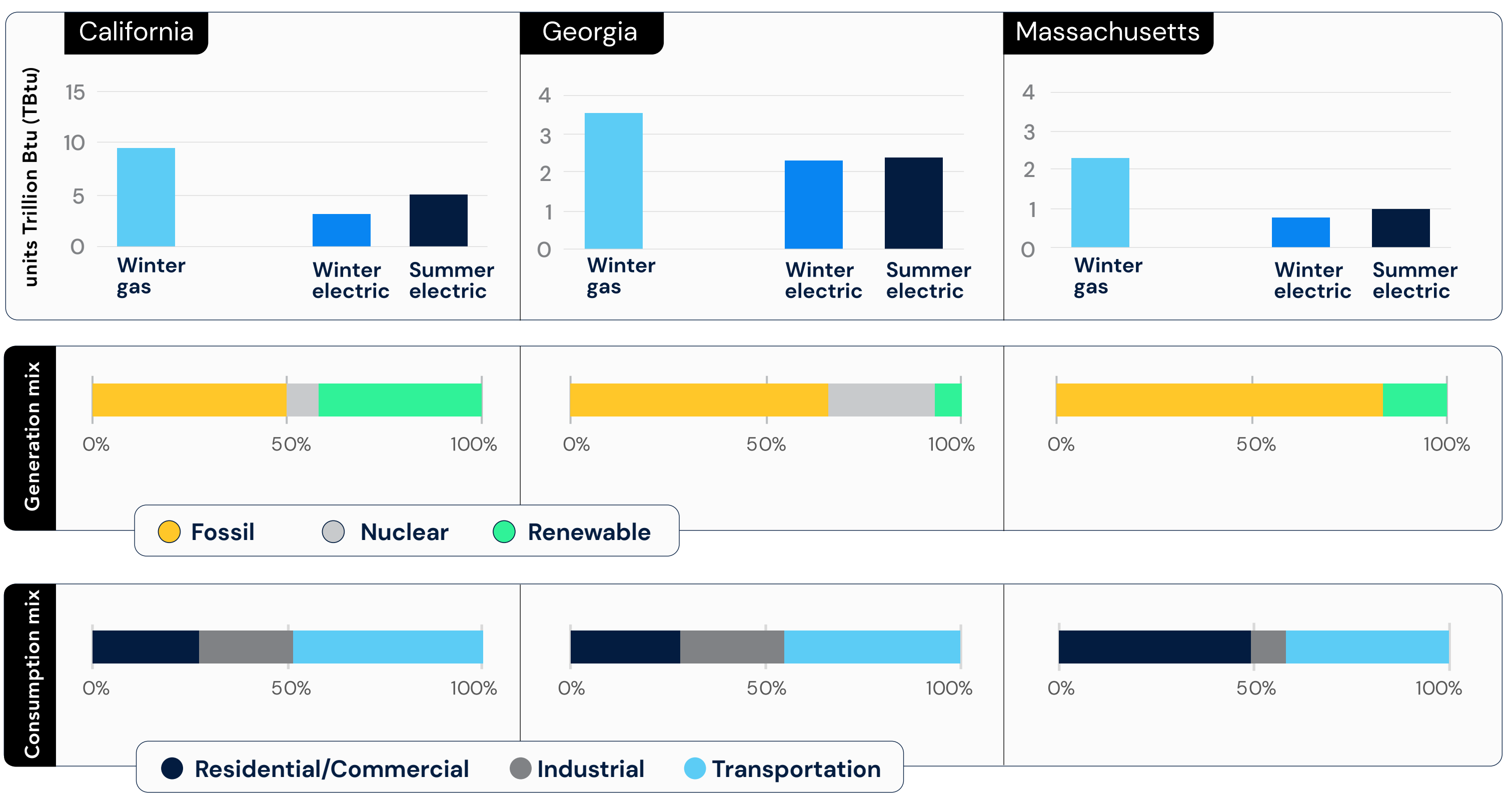
Emission-reduction strategies must be formulated to be viable for their geographic location. States and provinces differ widely in their heating and cooling seasons, the associated fuel and electric loads, the mix of building types and ages, major industries, transportation options and needs, economic trends, and access to clean energy resources such as offshore wind or solar.

Figure 2 compares key determinants of energy use in three states: California, Georgia, and Massachusetts. The first chart compares each state peak electricity use in summer and winter to peak natural gas use in winter, used primarily for heating.

The second chart shows the 2020 generation mix, and the third chart shows the 2019 sectoral breakdown of where all energy—not just electricity—is consumed.

For all three states, winter gas use, in trillion British Thermal Units (TBtu), exceeds the equivalent electricity demand peaks in winter and in summer, meaning the states can meet summer demand with an electric system that has much less energy delivery capability than the gas system. Winter gas demand in Massachusetts is more than double summer peak electricity demand as a result of winter heating needs. The ratio is lower in Georgia and California, which have lower winter heating loads and higher summer peaks due to warmer temperatures. In all three states, however, electrification as a sole decarbonization strategy could require considerable investments to expand generation and the transmission and distribution systems to serve the winter heating demand currently met by natural gas. Investments in low-carbon fuels delivered through the existing gas distribution system, on the other hand, might be more cost-effective strategies in some cases. A mix of electrification and low-carbon fuels could thus make up the right overall strategy mix for some jurisdictions.

FIG 2. STATE ENERGY PROFILES – PEAK ENERGY USE



The states' ability to reduce GHG emissions through electrification is also a function of their electricity generation mix. Of the three states shown, California had the lowest-carbon power supply in 2020, with about 50% of generation coming from nuclear and renewables. Georgia has a much lower share of renewables, due in part to its limited wind resources, but has a large amount of nuclear generation. Massachusetts' in-state generation mix is over 80% fossil (natural gas), but it also relies on clean energy imports from Canada (not shown) and is aggressively pursuing offshore wind to reduce its reliance on fossil-fired power generation. Decarbonizing the grid thus presents different resource, timing, and regional challenges in each state, which suggests that the nature and timing of electrification and low-carbon fuels strategies should be geared to these realities.

Such differences in generation mix and sectoral energy consumption don't tell the entire story—demographic trends, energy demand growth, state and local policies and incentives, and other factors must be considered in shaping and implementing decarbonization pathways that make the most sense for a particular locale.

Decarbonization solutions differ across sectors

The range of regional differences strongly affect the relative merits and downsides of decarbonization alternatives; and they also affect sector-specific emission reduction opportunities. Each major energy end-use sector faces very different opportunities and challenges in seeking to reduce greenhouse gas emissions.

Transportation

Transportation may have the clearest, most commonly understood path to decarbonization in areas where the transition to a cleaner electric grid is progressing. Policymakers and automakers alike are coalescing around a strategy to transition light-duty vehicles from gasoline-fueled internal combustion engines (ICE) to electric vehicles (EVs).

Typical passenger EVs already have lower fuel and maintenance costs than ICE counterparts, and falling battery costs suggest cost parity is near. Manufacturers are betting that this tipping point will give them products that provide superior performance, cost less to build and run, and support sales growth. While EVs are becoming more available, challenges remain around planning for charging infrastructure, ranging from the supply and location of charging stations to the grid upgrades needed to power them. However, utilities and city and state planners are already considering how to manage charging to use electricity when it is most beneficial for the grid, such as off-peak hours and during excess renewables, minimizing strain on the grid while improving system economics.

While widespread electrification of light-duty vehicles seems likely, the future appears more multi-fueled for medium- and heavy-duty vehicles, which may be more feasible and economic to run on hydrogen or renewable natural gas than battery power. Each of these options has its pros and cons, but they share the core challenge of delivering low-carbon energy through massive new infrastructure and technology investments.

Buildings

Every building performs differently. Design elements may be similar for specific building types, but occupant behavior, appliance use, and renovations cause wide variations in energy use. And the mix of building types in every community is different, as are the climates in which those buildings operate. New York City's densely packed 5.12 billion square feet of building space, for example, comprises buildings that are relatively old, large, multitenant, and built with fuel-fired heating but no central electric cooling systems. Phoenix, Arizona, on the other hand, spreads across the hot desert valley with buildings using primarily electricity to run ducted cooling systems. In Phoenix, converting central AC systems to heat pumps works for a large fraction of the

building stock, making electrification relatively straightforward. In New York, installing electric heating (and cooling) can be more complex.

Those differences make planning for building decarbonization difficult enough: add the fact that building stock turnover is measured in decades, if not centuries, and that a diverse range of people and organizations own and occupy these buildings, and the obstacles to implementing major decarbonization strategies are daunting.

The building electrification discussion is sometimes oversimplified as an "either/or" debate, which has the potential to bias analysis and policy toward more convenient—but more costly—one-size-fits-all solutions. In reality, electrification is likely a "yes, and" discussion, as detailed in ICF's white paper, *Building electrification: Steps to start now amid an uncertain future.*[2]

Industry

Each industrial sector faces unique opportunities and challenges on the path to decarbonization. Individual factories and production processes vary greatly in their needs for process heat, motor power, compressed air, lighting, and many more specialized uses. The most common end uses, such as lighting, motor systems, and compressed air systems, which are typically electric-driven, can be improved through efficiency measures. Forklifts and other non-road vehicles and engines can often be electrified cost-effectively. But many industrial processes, especially those requiring high-intensity heat, will require tailored technical solutions and may continue to need liquid or gaseous fuels, suggesting that renewable fuels and hydrogen may be part of industrial sector strategies. Some energy-intensive industrial sectors, such as iron, steel, cement, or petrochemicals, will require technology and business-model innovation to reimagine their operations for a low-carbon future.

[2] https://www.icf.com/insights/energy/building-electrification-steps-start-now

Gas and electric utilities face different challenges

Utilities and their customers are front and center on the path to a decarbonized future because power generation and natural gas use across the residential, commercial, and industrial sectors accounts for most of North America's energy-related GHG emissions. Utilities also hold the greatest opportunities for a clean energy transition. Creating decarbonization strategies that account for local factors is already challenging utilities; these challenges will only grow after the low-hanging fruit reductions are achieved.

Most North American utilities have already established goals to reduce emissions. However, these goals are typically longer term and aspirational, rather than near term and operational. Utility regulators and stakeholders will be asking for firmer plans, with real dollars and emissions targets.

After more than a century serving as the nation's main energy providers for buildings and industry, electric and gas systems typically work side by side as owners and operators of critical energy supply infrastructure across most of the U.S. and Canada. Electric and gas utilities have historically served specific end uses within individual customer homes and businesses, providing—and often competing to provide—energy for heating, cooling, hot water, cooking, lighting, and appliances.

Decarbonizing the power sector presents quite different challenges than those facing the gas sector—even though some technologies and strategies cut across sectors. On the power side, price-competitive wind and solar, complemented by hydroelectric and battery storage, have already made major inroads in some regions' power generation mix. The intermittency of renewables creates particular challenges, requiring not only storage solutions but also demand flexibility in customer devices like water heaters and HVAC systems. On the gas side, low-carbon solutions have not yet reached competitive price levels, though the potential for renewable natural gas (RNG) from wastewater treatment, landfill methane, and agricultural waste shows significant potential, as does the potential for "green" hydrogen.

When renewable power resources exceed grid demand, they can be used to create green hydrogen through electrolysis, which can then be used as a blended pipeline fuel or for peak grid generation support.

The complementary value of electricity and gas systems serving the same communities has provided substantial energy resiliency benefits, which need to be carefully assessed in considering decarbonized futures with a single energy infrastructure. Analogous to the way EV owners fared better than ICE drivers during the recent East Coast gasoline shortages from a pipeline ransomware attack, utility customers may benefit from having choices in fuel as well as electric options. Phasing is also important in decarbonization planning; abandoning energy resource or infrastructure options prematurely can create major risks with unintended consequences. As decarbonization proceeds in the coming decades, it will thus be important to make best use of all available energy supply and demand options, for the time periods they continue to provide value.

Significantly reducing gas usage in the U.S. and Canadian economies presents major cost and timing challenges and could put energy system reliability and resilience at risk because gas units provide much of the baseload and "load following" flexible generation capacity that keeps the grid stable from hour to hour and moment to moment. Gas also serves as seasonal energy storage in North America, ensuring that supplies are available for weeks and months as well as moments and hours. For these reasons, gas supplies and infrastructure will need to play critical roles for years to come, even as end-use electrification strategies begin to reshape the power sector.

In the face of such challenges and complexities, there is ample good news on both the power and gas sides of utility systems. The rapid deployment and falling costs of renewable power and battery storage; increasing smarter grids and customer devices; the large potential for low-carbon gas resources; the emerging willingness of regulators to enable the needed utility investments; and the new collaborations occurring among utilities, state and local governments, and other stakeholders hold the promise of successful decarbonization pathways.

Finding the right mix of electric- and gas-system solutions for a given city, state, or utility system will be the central energy transition challenge of the coming decades.

Finding the new energy balance

As we begin to pay the costs of climate change impacts, new energy systems thinking is needed to realize the benefits of decarbonization solutions. But solutions presented as one-size-fits-all fixes fall prey to the "silver bullet" fallacy. Serious analysts agree that real solutions require consideration of multiple elements, whole-system thinking, and a "no-regrets" risk management approach. For a challenge as complex as decarbonizing the U.S. economy, "silver bullets" are actually more like red herrings for several reasons:

- Geographic, technological, and sectoral differences create immense complexity, and the more complex a challenge, the more customized the solutions must be.
- Preserving system reliability and energy-resource diversity is key while achieving the goal of decarbonization. Much as overreliance on oil triggered energy and national security crises in the 1970s, overreliance on any single energy resource, technology, or delivery system will likely lead to regret-prone risks and unintended consequences.
- Technology development is uncertain, and a "fringe" technology can quickly explode to a market-leading position. A "no-regrets" planning approach is thus needed to keep the flexibility to pivot to new technologies, to manage risks from extreme events, and to allow for evolving environmental justice needs.

While every decarbonization plan will be different, the right approach will have several themes in common:

- It will be built on robust analysis and assessment of all options without presupposing the answers.
- It will pursue low-hanging fruit first, testing and reviewing different approaches to more complex solutions via pilot programs and phased initiatives.

- It will avoid committing to specific paths sooner than necessary. Flexibility is essential as solutions develop over time. New technologies will change the balance, and utilities can take part in advancing their development by testing and piloting alternative technologies. However, the long lead times associated with some strategies may require that decisions are made before all technology uncertainties are resolved.
- It will consider the potential trade-offs between investing in low-carbon options and system reliability and resiliency.
- It will consider multiple scenarios because every scenario forecast will be wrong in certain respects. This allows organizations to avoid getting tunnel vision, so that they can adjust their strategies when conditions on the ground change.
- It will rely on collaboration, often with new and non-traditional stakeholders. Policymakers, innovators, utilities, financiers, building owners, skilled trades and unions, environmental justice advocates, and citizens are all essential to reach such ambitious goals.
- It will ensure energy equity, refusing to leave behind the most vulnerable populations and disadvantaged communities who often have the most to gain or lose, depending on the cost and effectiveness of climate solutions.

To understand the complex interdependencies of today's energy systems, economic sectors and geographic realities, utilities pursuing decarbonization strategies will need science-based research, data analysis tools, and market insights to design policies that don't delay action while accommodating longer-term change.

Rigorous analysis, guidance on exploring pathways, and a repeatable process that can move with you as situations on the ground change are key to unbiased scenario planning grounded in fundamentals.

Learn more about ICF's decarbonization insights.

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Deb works with a broad range of domestic and international clients. Examples include the Commonwealth of Pennsylvania, Delaware, New York City, the City of Philadelphia, Arlington County, Fairfax County, the City of Los Angeles, and various utilities. She also supports the U.S. Environmental Protection Agency, the U.S. Department of Homeland Security, the U.S. Agency for International Development, the UK Department of Energy and Climate Change, the Global Carbon Capture and Storage Institute, the Western Climate Initiative, and the World Bank Partnership for Market Readiness, among others.

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Chris supports member states of the Regional Greenhouse Gas Initiative and states considering participation in the program, analyzing the program's impacts on electricity markets and emissions, and evaluating next steps. He performs similar work for other states and companies, assessing allowance trading as a mechanism to reduce carbon dioxide emissions. He has also reviewed California's cap-and-trade program, state-level policies under the Clean Power Plan, and other state efforts in New York, North Carolina, and elsewhere.

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About ICF

ICF is a global consulting services company, but we are not your typical consultants. We help clients navigate change and better prepare for the future.

The ICF Climate Center offers compelling research and unique insights that help organizations establish clear, practical pathways forward through the combination of climate science and predictive analytics. The Center builds upon the work of 2,000+ climate, energy, and environment experts worldwide—making us one of the world's largest science-based climate consultancies. ICF works with business, government, and nonprofit organizations to design and implement programs and policies that drive low-carbon transitions and build resilience against the effects of climate change.