ClimateWorks FOUNDATION

2050 Today

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Deep decarbonization: electrification across end-uses

Pre-read packet

Background

Large-scale electrification of three sectors—transport, buildings, and industry—is an essential component of moving the world onto a low-carbon pathway and achieving net-zero emissions by mid-century. Furthermore, if done right, end-use electrification can be a boon to increased integration of clean renewable power, especially for those applications that have flexibility as to when they consume power. Beneficial electrification that maximizes climate benefits requires a strategic framework including which end-use activities should be targeted for wide-scale electrification now or later (or never) and which types of policies and interventions provide the greatest potential for scaling on a timeframe consistent with climate goals.

Last year the ClimateWorks Foundation initiated a project to explore priorities for climate action and philanthropy in light of the need to achieve net-zero emissions by mid-century. Among the five priorities identified was the simultaneous pursuit of power generation decarbonization and wide-scale end-use electrification. While the former accelerates, attention is turning to the latter, which requires a nuanced approach, one that recognizes that some sectors are ready for scaling today, while others need further development and some will remain hard or even impossible to electrify and thus will need other low-carbon alternatives.

Session objectives

1. Understand the rationale for electrifying (almost) everything and by when
2. Understand barriers and opportunities at the intersection across end-uses (transport, buildings, industry)
3. Understand the role of philanthropy and what strategies/tactics/venues are the most promising

Electrification Scale-up Timing

Switching from direct fossil fuel use in end-use sectors (buildings, industry, and transport) to electricity allows those end-use sectors to benefit from a decarbonizing power sector and the power sector to benefit from the flexible load that end-use electrification can provide. Two dimensions are important to consider when determining when this switching is advantageous for a particular activity including emissions intensity of the grid (Figure 1) and technological

readiness.

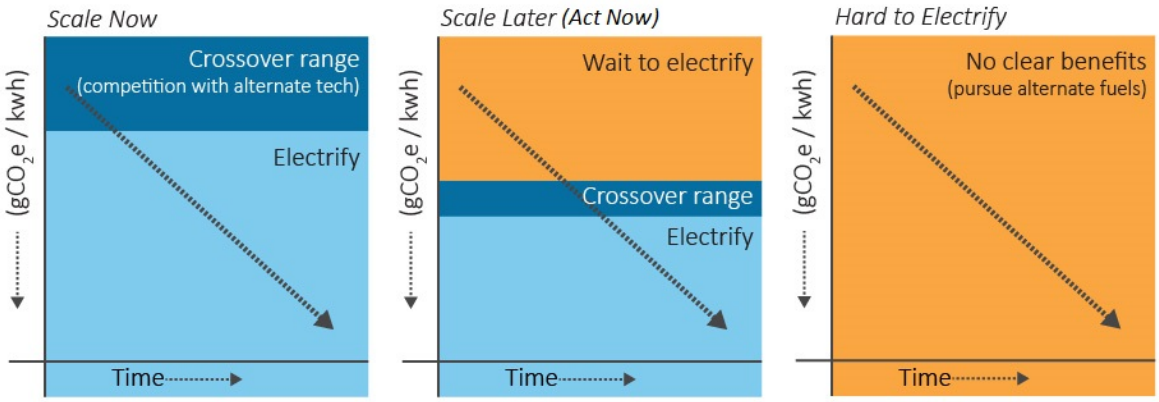

Figure 1: Conceptual framework as it relates to a declining emissions intensity of power generation and time needed to further develop the technological/market readiness

Because the emissions intensity crossover point and technological and process readiness varies across end-use applications, it makes sense to group activities according to their current amenability to scale electrification:

> *Scale now* those activities that can quickly and cost-effectively benefit from electrification with available technologies at current or expected levels of emissions intensity.
>
> *Scale later (Act Now)* those activities that (1) will benefit from electrification at future expected emissions intensity levels and/or (2) rely on technologies or processes still under development. Near-term action is still required to bring these opportunities to a point where they can eventually scale.
>
> *Hard to Electrify* activities require alternative approaches because at present they face very high barriers to electrification and those that (1) might never benefit from electrification in terms of emissions reductions or (2) lack a counterpart technology or application that is readily electrified.

According to this framework, certain end uses would be prioritized for scaling electrification now, other end uses would be pursued/scaled as technological readiness and cost-effectiveness warrant, and yet other end uses would require alternative development of non-electric low-carbon strategies (Table 1).

	Scale Now	Scale Later (Act Now)	Hard to Electrify*
Transport	Light duty vehicles, buses, two & three-wheelers	Medium-duty trucks (incl. short/ medium-haul freight)	Long-haul applications for freight, marine transport and aviation
Buildings	End-use heat in new construction	End-use heat in older buildings	Some district heat
Industry	Heat pumps for low heat industries, elec-arc furnace, paint curing, 3-d printing	More options for medium heat industries	Some high-heat processes

Table 1: Simplified set of end-use electrification options based on electrification category and sector.

Scale Now

Climate philanthropy has multiple near-term strategies to promote electrification, most notably in the transport sector, where progress is already taking advantage of decreasing emissions intensities in the power sector and smart charging provides the opportunity to increase the value of fixed grid assets and facilitate additional renewable integration. The relatively high vehicle efficiency of electric vehicles (3X more efficient than combustion) will only improve the GHG benefits as grid decarbonization continues.

End uses in the buildings and industry sectors are important to get started but more complicated. In the buildings sector, emphasis has been on new construction, where cost-effective technologies exist to leapfrog to electrified devices while avoiding the buildout of additional natural gas infrastructure.

In the industry sector, the bulk of fossil fuel use is for process heat, and electrified counterparts come with technological and cost barriers. However, low-heat (<100^{o}C) processes used in the production of food and beverages, textiles, and some pharmaceuticals and some medium/high-heat (<400^{o}C) processes are already being electrified with efficient heat pumps and resistance heating (e.g. drying, paint curing, carbonizing carbon fiber).

Scale Later (Act Now)

Some end uses have path dependencies that can be addressed by waiting until emissions intensities of generation reach the crossover point OR by working today to overcome geographic, structural, cultural, financial, and technological barriers in anticipation of future scaling. Especially where technological readiness is a barrier, interventions such as RD&D, pilot or demonstration projects, and the creation of early niche markets can be effective ways to build confidence in the solutions.

For an example, take space heating in existing buildings. A switch from natural gas to electricity for heating might already make sense in terms of emissions reductions but because of high costs or the lack of a competitive retrofit industry it may require an extended period of pilot retrofit programs to build confidence in larger-scale interventions.

The transport sector offers clearer scale-later cases. In the freight subsectors, the challenge is the lack of commercially available and rapidly deployable technology. Electrified freight is in the pilot testing and early commercial stage, and already we are seeing factors that might make a straightforward scale-later (or even scale now) case for some kinds of freight – for example, short -haul delivery and drayage trucks.

The time it takes for stock turnover and market development plays a large role in all end-use sectors. Even for scale-later opportunities, it will be important to get started now developing the technologies, addressing market barriers, and building confidence in the solutions in preparation for scale adoption.

Hard to Electrify* (but watch closely)

Finally, some end-use technologies—from an emissions, technological, or cost standpoint—will likely continue to be difficult to electrify well into the future; either the barriers are too great to overcome or these end uses might be better addressed through other means.

In the transport sector, long-haul commercial shipping and aviation will be very difficult to electrify as will some forms of industrial high-heat. These modes may be better suited to energy carriers such as advanced low-carbon biofuels, hydrogen, and/or fossil-energy with carbon-capture and sequestration (CCS). In addition to low-carbon fuels, these hard-to-electrify sectors can benefit from other mitigation opportunities like additive manufacturing and greater materials efficiency.

It's important to note that we should reassess these categories and what is included in them on a regular basis, especially as technologies continue to improve. Things that were once thought difficult to electrify (e.g. buses) are now here and ready to scale today.

Key Philanthropic Opportunities

Climate philanthropy has many opportunities to support wide-scale decarbonization and electrification. To take advantage of them, the following actions are recommended priorities:

- Shift emphasis from renewables deployment to grid integration. The rapid pace of renewables deployment in the power sector in many geographies suggests that philanthropic resources could be redirected to scaling up beneficial electrification and integrating clean electrons onto the grid, especially in China, India, the EU, and the United States.

Power Generation Decarbonization

As our Faster and Cleaner 2 report illustrated, decarbonization of the power sector turns on several factors, including a region's capacity to integrate clean power onto the grid. The literature suggests that most systems can reliably operate with 80 or 90 percent of their generation coming from wind and solar, especially as more end-uses become electrified and flexible loads, such as electric vehicle charging, can be dispatched to follow generation. Given costs, the last 10–20 percent of power sector decarbonization will likely need to come from other sources: carbon capture and sequestration, advanced bio-energy, advanced nuclear, and storage (e.g., chemical, pumped hydro). These technologies remain in development, and given increasing energy demand, they will needed to be deployed on a large scale for the world to hit Paris Agreement temperature targets.

- Continue building philanthropic support for transportation electrification. Dramatically moving the transport sector onto a climate-safe path is within reach. Support should go to expanding regional policies and programs where government ambition outpaces local capacity and to building politically powerful local and global coalitions among governments, labor, consumers, corporations, utility companies, and groups working on equity and social justice.
- Advocate for innovation. Electrification of end uses depends in large part on continued technological innovation, yet public (and philanthropic) funding for innovation activities is

relatively low. Promotion of increased innovation spending and policies that encourage private sector innovation is critical to move technologies from the lab to commercial scale.

- Support carbon removal strategies. To meet 2050 emissions mitigation targets, carbon removal must accompany other mitigation strategies. Resources are needed to study the tradeoffs associated with removal approaches and to advocate for market developments and finance. Better understanding tradeoffs will show when pursuit of CCS is advantageous, especially in hard to electrify, high-heat sectors.
- Avoid natural gas lock-in. Cheap natural gas threatens to displace zero-carbon power generation, requiring examination of the role of accelerated depreciation of old natural gas units. Beyond the power sector, natural gas is a feedstock to the chemicals industry and a source of energy in the buildings and industry sectors, creating cost barriers for a transition to electrified technologies or use of advanced low-carbon biofuels or hydrogen.
- Support carbon pricing. Carbon pricing, either in the form of carbon taxes or cap-and-trade, can be a powerful policy to drive decarbonization and beneficial end-use electrification. This is especially true where the challenges and solutions are highly heterogeneous such as industrial processes. By including a meaningful carbon-price in decision-making, private-sector players can make intelligent market-based decisions about when it makes sense to electrify or take other actions to reduce emissions.
- Don't forget to address the difficult to electrify sectors. Many large, energy-intensive, high-heat industries require support for low-carbon alternatives. In the context of aviation and other hard to decarbonize industrial applications, support is needed for low-carbon liquid fuels, hydrogen, and continued efficiency improvements.

Further reading

1. NREL Electrification Futures Study: A Technical Evaluation of the Impacts of an Electrified U.S. Energy System. https://www.nrel.gov/analysis/electrification-futures.html
2. EPRI "Efficient Electrification"

   https://www.epri.com/#/pages/sa/efficientelectrification?lang=en
3. E3, "Utilities' Role in Transport Electrification: Capturing Benefits for All Ratepayers" https://www.fortnightly.com/fortnightly/2016/04/utilities-role-transport-electrification-capturing-benefits-all-ratepayers