03 Net Zero Heroes: Efficient Appliances

CEO of GreenScene Rekik Bekele standing in front of solar water pump, Ethiopia. *Credit: CLASP | Duncan Moore*

03

Inefficient appliances and large appliance access gaps severely hinder efforts to lower emissions and build climate resilience. Sections 1 and 2 of this report highlight the urgent need to radically reduce the negative impacts of inefficient appliances while simultaneously expanding the positive impacts from more efficient appliances to everyone.

Efficient appliances are a climate solution that uniquely sits at the nexus of climate mitigation and adaptation. Efficient appliances lower final energy demand and resulting emissions in a cost-effective manner and can expand access through lower operating costs. Unfortunately, appliance efficiency is often ignored in favor of other mitigation solutions, and therefore has not been utilized to its full potential. As a result, appliance emissions are expected to exceed what is needed to achieve NZE in 2050 by 9 Gt CO_2.

This section presents a series of ambitious efficiency targets that would put appliances on a pathway to NZE by 2050 and help close critical appliance access gaps.

CLASP advocates for urgent climate action focused on ten "Net Zero Heroes"—the appliances essential for reducing GHG emissions and building climate resilience globally.

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Women using solar water pump. *Credit: Futurepump*

THESE TEN APPLIANCES[xxxi] ARE:

- LED lighting
- Air conditioners
- Comfort fans
- Refrigerator-freezers
- Heat pump space heating
- Heat pump water heaters
- Industrial motors
- Electric cooking
- Televisions
- Solar water pumps

Appliances currently account for roughly 40% of all energy-related CO_2 emissions. Promoting the Net Zero Heroes by achieving the targets set forth in this section would deliver significant CO_2 reductions by 2050.

Achieving the efficiency targets for all ten Net Zero Heroes would avoid 9.2 Gt of CO_2 in 2050 relative to BAU. Achieving CLASP's Net Zero Hero targets would also improve the quality of life for millions of people by helping households and communities stay comfortable and connected during emergencies and natural disasters, reap the health and wellness benefits of enhanced food security, unlock opportunities for income generation, and foster more equitable outcomes for marginalized groups.

Meeting Net Zero Hero appliance efficiency targets would expand access to critical appliances to hundreds of millions of people while reducing exposure to climate risks through improved access to cooling technologies, enhanced food and water security, and new income-generating activities.

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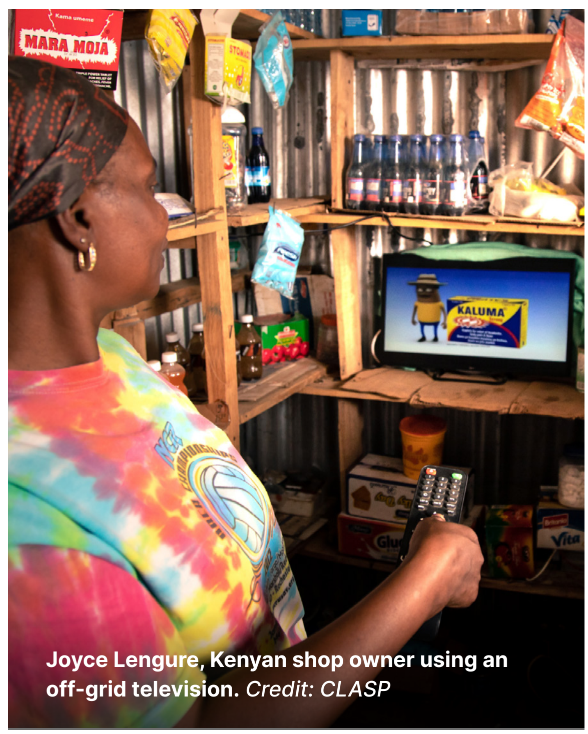
This section is divided into two parts. Part one introduces the ten Net Zero Heroes, presents targets for each, and forecasts climate mitigation impacts of meeting those targets. Part two quantifies the additional adaptation, resilience, and sustainable development benefits of meeting the efficiency targets shared in part one.



Joyce Lengure, Kenyan shop owner using an off-grid television. *Credit: CLASP*

xxxi. CLASP's ten Net Zero Heroes differ from the ten climate appliances essential to building climate resilience in Sections 1 and 2. The Net Zero Heroes are the ten appliances most critical to reducing the energy demand and GHG emissions needed to achieve NZE by 2050. However, many Net Zero Heroes are also critical climate resilience and adaptation benefits, particularly for households gaining access to these products for the first time.

3.1 Mitigation Potential

Achieving the CO_2 emissions reductions necessary to reach NZE by 2050 and limit global warming to 1.5 °C will require ambitious appliance policies and regulations, implemented promptly, and revised frequently.

As discussed in Section 2.1, new, ambitious efficiency policies are necessary to reduce appliance electricity consumption and make room within the renewable electricity budget for the electrification of fossil-fueled end uses, providing access and resilience, and accommodating future population and economic growth. BAU, and even some of the best policies in play today, are insufficient to stay within the emissions budget and achieve net zero.

CLASP calls for a concerted effort and renewed focus on ten energy end-uses—the Net Zero Heroes. The energy efficiency of these Net Zero Heroes must be greatly increased this decade. Table 6 identifies a specific energy efficiency target for each end-use that, if met, will allow appliances to remain within the budgets for both energy and emissions, resulting in significant CO_2 reductions compared to today's best policies.[xxxii]

TABLE 6: NET ZERO HEROES: TARGETS & MODEL IMPACTS

End-use	Target	2040 Mitigation Relative to BAU	2050 Mitigation Relative to BAU
LED LIGHTING	▪ Completely phase out fluorescent and incandescent lighting by 2025 ▪ Double the luminous efficacy of new LEDs by 2030 to take advantage of rapid technological improvement	0.2 Gt CO_2	0.03 Gt CO_2
AIR CONDITIONERS	▪ Double the efficiency of new units by 2030 ▪ Transition to low-GWP refrigerants in accordance with the Kigali Amendment to the Montreal Protocol	0.8 Gt CO_2	1.1 Gt CO_2

xxxii. As some of the Net Zero Hero targets do not begin until 2030, the modeled impacts include today's best policies as a stepping stone between now and 2030.

COMFORT FANS

TARGET

- Require permanent-magnet motors in new table, ceiling, and pedestal fans by 2025

2040 MITIGATION RELATIVE TO BAU

0.04 Gt CO_2

2050 MITIGATION RELATIVE TO BAU

0.03 Gt CO_2

REFRIGERATOR-FREEZERS

TARGET

- Double the efficiency[xxxiii] of new units by 2030[119]

2040 MITIGATION RELATIVE TO BAU

0.1 Gt CO_2

2050 MITIGATION RELATIVE TO BAU

0.2 Gt CO_2

HEAT PUMPS

TARGET

- Stop sales of fossil fuel equipment to fully transition stock to heat pumps by 2050

2040 MITIGATION RELATIVE TO BAU

1.2 Gt CO_2

2050 MITIGATION RELATIVE TO BAU

1.8 Gt CO_2

HEAT PUMP WATER HEATERS

TARGET

- Stop sales of fossil fuel equipment to fully transition the stock of storage water heaters to heat pumps and solar thermal by 2040

2040 MITIGATION RELATIVE TO BAU

0.2 Gt CO_2

2050 MITIGATION RELATIVE TO BAU

0.3 Gt CO_2

ELECTRIC MOTORS

TARGET

- Double the efficiency[xxxiv] of new industrial motor systems (controls, motor, and motor-driven equipment) by 2030[120]
- Greatly accelerate the replacement rate of existing stock by 2030 to achieve full replacement by the most efficient motors (IE5) by 2035

2040 MITIGATION RELATIVE TO BAU

3.4 Gt CO_2

2050 MITIGATION RELATIVE TO BAU

5.1 Gt CO_2

xxxiii. A doubling of efficiency would mean a 50% reduction in the average energy consumption of new units.

xxxiv. A doubling of efficiency would mean a 50% reduction in the average energy consumption of new units.

ELECTRIC COOKING

TARGET

- Fully transition to electric cooking worldwide[xxxv]

2040 MITIGATION RELATIVE TO BAU

0.4 Gt CO_2

2050 MITIGATION RELATIVE TO BAU

0.4 Gt CO_2

TELEVISIONS

TARGET

- Require European Union (EU) Tier 3 efficiency levels everywhere by 2025

2040 MITIGATION RELATIVE TO BAU

0.03 Gt CO_2

2050 MITIGATION RELATIVE TO BAU

0.02 Gt CO_2

SOLAR WATER PUMPS

TARGET

- Fully transition to electric water pumping for irrigation[xxxvi]

2040 MITIGATION RELATIVE TO BAU

0.4 Gt CO_2

2050 MITIGATION RELATIVE TO BAU

0.4 Gt CO_2

TOTAL

2040 MITIGATION RELATIVE TO BAU

6.7 Gt CO_2

2050 MITIGATION RELATIVE TO BAU

9.2 Gt CO_2

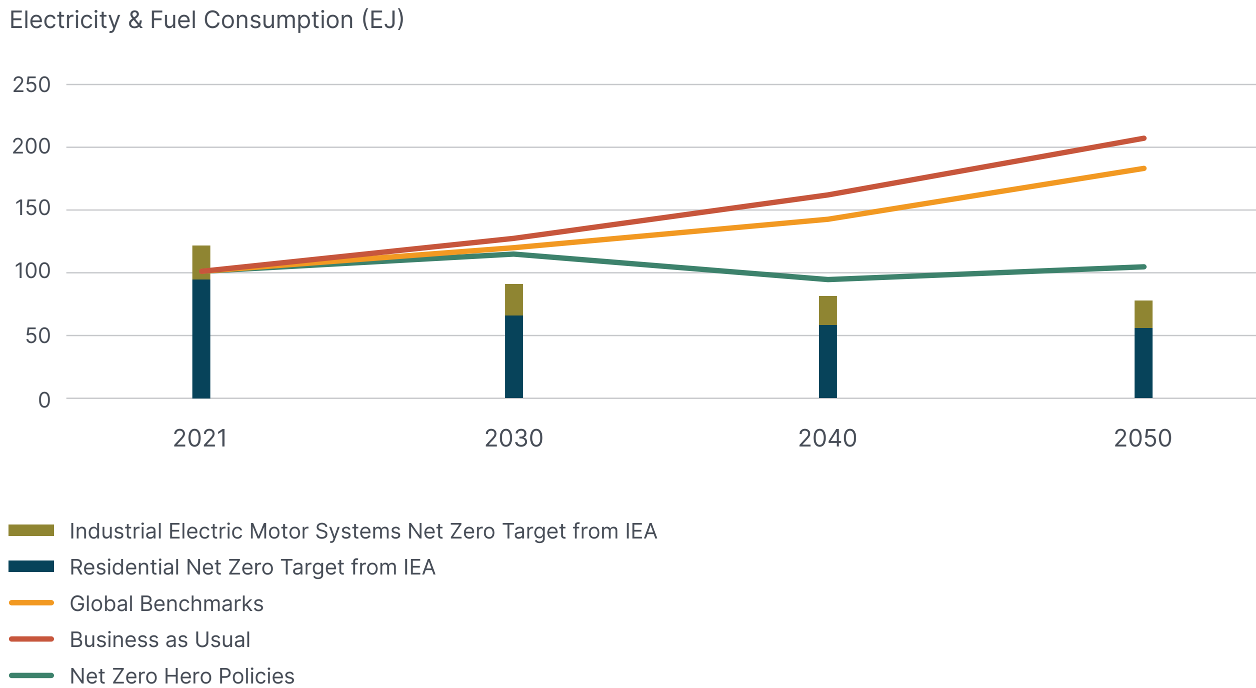
xxxv. For electric cookers, the benefits shown here are in the year the target (a full transition) is achieved. The mitigation potential provided is a conservative estimate. The CO_2 reductions represent the emissions that could be mitigated annually from reduced fuelwood harvest in 84 countries, sourced from the Clean Cooking Alliance's report, Accelerating Clean Cooking as a Nature-Based Climate Solution. Likewise, the mitigation potential does not include CO_2 reductions from transitioning from fossil fuels to electricity nor the reductions in methane emissions from leaks in gas infrastructure because other GHG emissions were not included in the scope of this analysis.

xxxvi. For solar water pumps, the benefits shown here are in the year the target (a full transition) is achieved. The mitigation potential provided is a conservative estimate. The 0.4 Gt potential represents the avoided CO_2 emissions that we would expect in a single year if the access gap were closed with solar water pumps rather than diesel pumps in 11 countries. It does not include the additional emissions reductions that would be achieved by transitioning the existing stock of diesel irrigation pumps to solar-powered or electric water pumps. If we were to expand our analysis to include all countries and the replacement of diesel pumps with solar or electric pumps, the mitigation potential would be significantly higher.

In Figure 16 below, we graph the energy for the appliances analyzed in Mepsy under the Net Zero Hero scenario as well as the Global Benchmarks and BAU scenarios, analyzed earlier. While the energy consumption starts out the same across all scenarios in 2021, the energy in the Net Zero Hero Policies scenario starts diverging after 2030 and stays within 25% of the budget based on the IEA Net Zero Emissions by 2050 scenario. In contrast, the energy consumption continues to climb in the BAU and Global Benchmarks scenarios.

While this energy consumption does exceed the budgets, we assumed that the excess could be further mitigated through behavioral change or additional efficiency improvements (discussed below) such that the eventual energy consumption would fall within the budget. For example, IEA expects behavior change to be a large share of the transition to NZE, contributing about half as much in the transition off of methane gas as efficiency does.[121]

FIGURE 16. ELECTRICITY & FUEL CONSUMPTION UNDER BAU, GLOBAL BENCHMARKS & NET ZERO HERO SCENARIOS

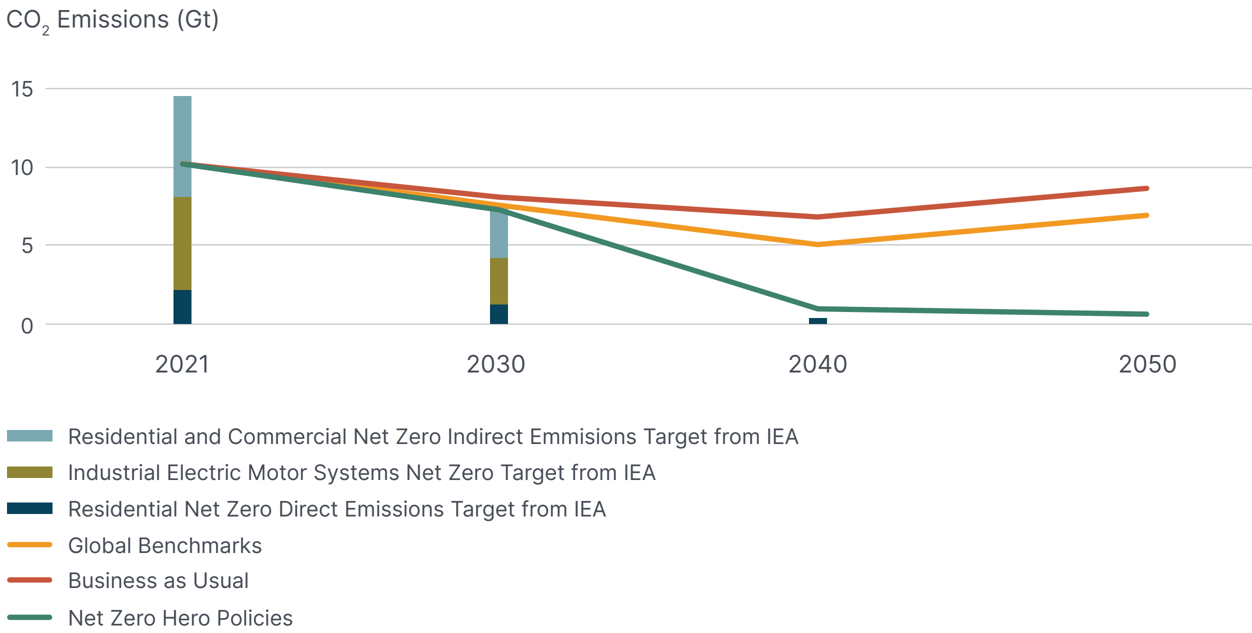


Note: *Modeled using Mepsy for 162 countries and eight appliances, with adoption in 2025-2030. Modeled electricity and fuel consumption under BAU, Global Benchmarks, and Net Zero Heroes appliance efficiency policies for major residential appliances and industrial electric motors systems (lines); overlaid with IEA's energy budgets for the relevant sectors (bars).*

In contrast, because of continuing high energy demand under the BAU and Global Benchmarks scenarios, a significant portion of the demand cannot be met by renewables or mitigated through other means, resulting in continued indirect emissions past 2040.[xxxvii] As a result, Figure 17 shows the size of these emissions along with those from any unelectrified fossil fuels. It is clear that we can only reach NZE if we increase ambition beyond even some of the most ambitious policies adopted today.

xxxvii. We assume that any energy consumption beyond that in the Net Zero Heroes cannot be met with renewables. The IEA's Net Zero Roadmap requires renewable energy capacity to triple by 2030. This is an ambitious target. Annual capacity additions have risen an average of 11% between 2015 and 2020.

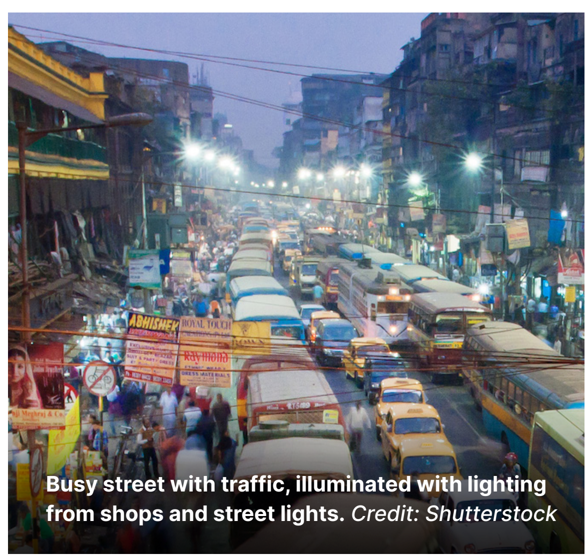
FIGURE 17. CO_2 EMISSIONS UNDER BAU, GLOBAL BENCHMARKS & NET ZERO HEROES SCENARIOS



Note: *Modeled CO_2 emissions from appliance efficiency policies for major residential appliances and industrial electric motors systems (lines); overlaid with IEA's Net Zero Emissions by 2050 trajectory for the relevant sectors (bars). Assumes electric grid decarbonization in line with the Net Zero by 2050 Roadmap. Modeled using Mepsy for 162 countries and eight appliances, with adoption in 2025-2030.*

Only the Net Zero Heroes program outlined in Table 6, characterized by a doubling of the efficiency of some products and urgent electrification of others, can sufficiently drive down energy use and emissions. Further ambition beyond what we have seen to date will be needed to achieve this agenda, both in terms of the frequency and stringency of policy updates and the use of complementary policies, including those that yield behavioral changes and building envelope improvements.

First, it will be important for countries to revise policies frequently to cement efficiency gains and continue taking advantage of technological improvement. Once an efficiency policy is adopted, manufacturers have to redesign some of their products to meet it. When these new products enter the market, policymakers should reevaluate whether further gains are possible. For example, in one country that CLASP recently analyzed, all the air conditioners on the market are twice as efficient as the minimum standard, meaning that the standard is not serving its function and should be revised. Another country revises its air-conditioner policies every two to four years to keep up with market efficiency improvements, but is nevertheless behind the world's best MEPS levels.[122] In other words, frequent updates must be paired with ambition to meet net zero targets.



Busy street with traffic, illuminated with lighting from shops and street lights. *Credit: Shutterstock*

Two people cooking fresh vegetables in pan on induction stove. *Credit: Shutterstock*

CLASP has modeled a series of such revisions in a country with a fast-growing economy, and found that it would be possible to meet a 50% energy reduction (an efficiency doubling) for new AC, refrigerators, industrial motor systems, and lighting by 2030. This would be consistent with the country's commitments under the Product Efficiency Call to Action (see Section 2.1), as well as contribute to achieving NZE by 2050. Efficiency policies would be revised every two to five years, leveraging resources such as U4E model regulations and IEA's policy ladders[123] to maintain pace and ambition.

The policies noted above would result in CO_2 mitigation once the stock turns over. However, to start reducing CO_2 emissions *before* 2030, the doubling efficiency and decarbonization policies would have to be complemented by additional policies and programs such as:

- Incremental efficiency requirements prior to 2030 (e.g., 25% reduction in energy in 2025);
- Incentives for early replacement (especially for long-lived products such as heating and air conditioning, and commercial and industrial equipment such as motors);
- Programs targeting other components of the system (e.g., efficiency gains from incremental improvements in motor efficiency are relatively small; much larger gains can be achieved by using variable speed drives and more efficient end-use components, such as pumps, compressors, and fans, as well as by digitization);
- Labeling or purchasing guidelines that encourage even higher efficiencies for a subset of customers, which can help drive investment into higher efficiency and pave the way for subsequent standards revisions.

Section 4 summarizes a range of policy options available to governments, donors, and other market actors to both improve the efficiency of appliances and promote the production and sale of more efficient models.

3.2 Adaptation, Resilience & Development Potential

Yet another reason to make appliance efficiency a priority now is that people urgently need access to appliances and the resilience and adaptation benefits they deliver. One sure way to make appliances accessible to more people is to make them more affordable. Improving efficiency is an effective way to drive down lifecycle costs, making appliances more affordable. Later in this section, we will present evidence that this mechanism works and estimate what impact improved efficiency could have on affordability and access.

Older woman standing in front of fan in a home. *Credit: Unsplash*

ENERGY EFFICIENCY DRIVES APPLIANCE ACCESS

Climate mitigation potential is reason enough to focus on improving the efficiency of appliances, but improved efficiency can also lead to greater climate resilience and adaptation by improving affordability and, thereby, bringing appliances within reach of more people.

Energy efficiency catalyzes access to appliances by lowering running costs as well as first costs.

The evidence connecting increased efficiency with improved affordability is compelling. It is well established that more efficient appliances cost less to operate due to their lower electricity or fuel consumption. This is a central tenet of most appliance standards programs, which are designed to reduce energy consumption and save consumers money on their utility bills (see Section 4).

Increased efficiency not only reduces energy costs; it can also drive down the total cost of ownership (TCO), i.e., first cost plus operating cost. A comparison of the estimated incremental prices of appliance standards in the US found that these costs were routinely overestimated. When developing standards for nine products,[xxxviii] the US government predicted a manufacturer selling price increase of $148 USD; the actual average was a *decrease* in price by $9 USD.[124] A similar analysis found that product prices often decrease over time, even as efficiency improves. For example, the average (quality-adjusted) price of a new refrigerator in 2015 was actually 35% *lower* than it was in 1987, despite large improvements in efficiency.[125] Similar price trends have been reported for the same period for clothes washers (45% lower) and dishwashers (30% lower).[126]

A 2018 study sought to determine the optimal levels of energy conservation (efficiency) standards for refrigerators and freezers in Uganda. The researchers calculated the TCO of baseline units and more efficient units and found that standards could reduce the TCO by $173 USD for freezers, $35 USD for refrigerators, and $21 USD for refrigerator-freezers. The researchers concluded that implementing standards and making refrigeration products more affordable in Uganda, where the average household spends 22% of its annual income on energy, would help to expand access to these appliances.[127]

This same dynamic is also at play in off-grid contexts, where the energy system must be sized to meet the requirements of the connected appliances. Efficiency for Access compared the costs of purchasing and operating efficient and inefficient solar-powered refrigerator-freezers using price data collected between 2017 and 2019. When considering the purchase price of the appliance, together with the solar energy system needed to power it, they found that the efficient refrigerator-freezers were between $300 USD and $900 USD less expensive than inefficient models, depending on the size of the food compartment and other features.[128] Even though the energy-efficient solar refrigerator-freezers are more affordable than inefficient models, they remain out of reach for many low-income families. Additional interventions, such as the consumer financing options discussed in Section 4.3, are needed to ensure that all families can access refrigerator-freezers. Nevertheless, energy efficiency remains a necessary ingredient in expanding access to refrigeration to off-grid populations.

Man gesturing toward water tank and hose in rural India. *Credit: CLASP*

xxxviii. The nine standards included: refrigerators, clothes washers (2x), electric water heaters, non-electric water heaters, central ACs (3 tons), room ACs, commercial ACs (15 tons), and ballasts.

ENABLING A JUST ENERGY TRANSITION

Achieving the efficiency targets in Section 3.1 (see Table 6) for the Net Zero Heroes is not only critical for climate mitigation, but it will also yield huge benefits for the health and wellbeing of people all over the world. We identified some of the other benefits (beyond climate mitigation), including climate resilience, adaptation, health, environmental, economic, and human development benefits, that would accrue from reaching the Net Zero Heroes Targets. These other benefits are described briefly below and summarized in Table 7.

Air conditioners and refrigerator-freezers: Doubling the efficiency of new units by 2030 would make these important cooling appliances more affordable. We adapted SEforALL's analysis and estimated that these efficiency improvements would make air conditioners accessible to 123 million more people and refrigerators accessible to 262 million more people. In addition, these efficiency improvements would enable millions of consumers to save money on their electricity bills. For more detail, see our Spotlight on Cooling Appliances.

Electric cookers and solar water pumps: We quantified the adaptation, resilience and other human development benefits from expanding access to solar water pumps and enabling universal access to electric cooking. Details are provided in the Spotlight on Electric Cooking and the Spotlight on Solar Water Pumps.

LED lighting, space heating, water heating, and cooking: A full transition to LED lighting would eliminate toxic mercury pollution from the production, breakage, and disposal of fluorescent lighting. A transition from fossil fuel-powered equipment to heat pumps for space heating and water heating and to electric cooking appliances would eliminate methane leakage from these end uses and reduce air pollution. See our Spotlight on Air Pollution for more on how appliance efficiency can help to reduce air pollution levels and improve human health.

Electric motors: Improved electric motor efficiency in industry is associated with increases in industrial competitiveness and productivity and with improved quality control.[129]

LED lighting, comfort fans, and televisions: As with air conditioners and refrigerators, a sustained focus on improving the availability of good-quality, energy-efficient, and affordable LED lighting, comfort fans, and televisions will also serve to increase access to these three Net Zero Heroes. It would also allow consumers to save money on their electricity bills, an especially important benefit for low-income households.

Woman installing LED lightbulb. *Credit: Shutterstock*

In Section 3.1, we identified an efficiency target for each Net Zero Hero and quantified the climate mitigation potential for each. In Table 7 we show the same targets again and summarize some of the other benefits of meeting these targets.

TABLE 7. NET ZERO HEROES: TARGETS & OTHER BENEFITS

LED LIGHTING

TARGET

- **Completely phase out fluorescent and incandescent lighting by 2025**
- **Double the luminous efficacy of new LEDs by 2030 to take advantage of rapid technological improvement**

OTHER BENEFITS

- Eliminate mercury pollution from production, breakage, and disposal of fluorescent lighting
- Reduce waste due to longer LED lifetimes

AIR CONDITIONERS

TARGET

- **Double the efficiency of new units by 2030**
- **Transition to low-GWP refrigerants in accordance with the Kigali Amendment to the Montreal Protocol**

OTHER BENEFITS

- 123 million people with first access[xxxix]
- 116 million people with improved thermal comfort
- 93 million people with improved health and wellbeing

COMFORT FANS

TARGET

- **Require permanent-magnet motors in new table, ceiling, and pedestal fans by 2025**

xxxix. For air conditioners and refrigerator-freezers, we extended SEforALL's analysis to forecast the number of households benefiting from first access and assumed an average household size of 3.74 persons to estimate the number of people benefiting.

REFRIGERATOR-FREEZERS

TARGET

- **Double the efficiency[xl] of new units by 2030[130]**

OTHER BENEFITS

- 262 million people with first access
- 39 million people with improved quality of life
- 26 million people with improved food security and nutrition

HEAT PUMP SPACE HEATERS

TARGET

- **Stop sales of fossil fuel equipment to fully transition stock to heat pumps by 2050**

OTHER BENEFITS

- Eliminate methane leakage from space heating
- Reduce outdoor air pollution from space heating

HEAT PUMP WATER HEATERS

TARGET

- **Stop sales of fossil fuel equipment to fully transition the stock of storage water heaters to heat pumps and solar thermal by 2040**

OTHER BENEFITS

- Eliminate methane leakage from water heating
- Reduce outdoor air pollution from water heating

ELECTRIC MOTORS

TARGET

- **Double the efficiency[xli] of new industrial motor systems (controls, motor, and motor-driven equipment) by 2030[131]**
- **Greatly accelerate the replacement rate of existing stock by 2030 to achieve full replacement by the most efficient motors (IE5) by 2035**

OTHER BENEFITS

- Improved industrial competitiveness, productivity, and quality control

xl. A doubling of efficiency would mean a 50% reduction in the average energy consumption of new units.

xli. A doubling of efficiency would mean a 50% reduction in the average energy consumption of new units.

ELECTRIC COOKERS

TARGET

- **Fully transition to electric cooking worldwide[xlii]**

OTHER BENEFITS

- 3.7 million premature deaths avoided annually
- 0.7 million fewer children with asthma
- Improved respiratory and heart health
- Time savings and reduced deforestation by eliminating the need to gather firewood
- Eliminate methane leakage from cooking

TELEVISIONS

TARGET

- **Require European Union (EU) Tier 3 efficiency levels everywhere by 2025**

SOLAR WATER PUMPS

TARGET

- **Fully transition to electric water pumping for irrigation[xliii]**

OTHER BENEFITS

- 98 million people with improved food security
- 15 million smallholder farmers with yield increases >30%
- 0.85 million new jobs in the agricultural sector
- $100 USD billion in fuel cost savings annually

Note: *For electric cookers and solar water pumps, the benefits shown here are in the year the target (a full transition) is achieved. For air conditioners and refrigerator-freezers, we extended SEforALL's analysis to forecast the number of households benefiting from first access and assumed an average household size of 3.74 persons to estimate the number of people benefiting. Additional detail can be found in the Spotlight on Air Conditioners and Refrigerators.*

Source: *CLASP analysis.*

To support those most affected by climate change and end energy poverty, CLASP advocates for an expanded definition of energy access that includes ten essential appliances critical to building resilience. To date, most efforts to build climate resilience within the energy sector have focused on expanding access to the 2.9 billion people that lack access to clean cooking solutions, and the 675 million people that lack access to electricity.[132]

Expanding the focus of the existing energy access agenda from new connections and kWh to include access to appliances and equipment would unlock the development impacts of expanded power supply. At the same time, the energy efficiency community must broaden its priorities from climate mitigation and avoided CO_2 emissions to include appliance access and climate adaptation and resilience.

xlii. For electric cookers, the benefits shown here are in the year the target (a full transition) is achieved.

xliii. For solar water pumps, the benefits shown here are in the year the target (a full transition) is achieved. The mitigation potential provided is a conservative estimate. The 0.4 Gt potential represents the avoided CO_2 emissions that we would expect in a single year if the access gap was closed with solar water pumps rather than diesel pumps in 13 countries. It does not include the additional emissions reductions that would be achieved by transitioning the existing stock of diesel irrigation pumps to solar-powered or electric water pumps. If we were to expand our analysis to include all countries and the replacement of diesel pumps with solar or electric pumps, the mitigation potential would be significantly higher.