Background Documents

Cooling for All

Cooling Solutions for Buildings

MARCH 2018

KIGALI COOLING EFFICIENCY PROGRAM

SUSTAINABLE ENERGY FOR ALL

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ADDRESSING DATA LIMITATIONS

Access to cooling is a new area of investigation and, inevitably, when piloting a new approach not all the data one would wish to examine is neatly lined up, especially when it comes to looking for disaggregated data on vulnerability based on gender, health, and education level.

To support this publication, an extensive data gathering exercise and literature review was undertaken, including a call for data to organizations that may have access to enhanced levels of granularity. The data expressed herein draws on a model produced by SEforALL that is based on data received through that process and data which is publicly available, and given limitations is subject to assumptions and margins of error.

In a nascent field such as access to cooling, it is crucial that organizations be empowered to put concerted efforts in the collection of a more extensive set of **granular and verified data at country level**, as well encouraging organizations with significant non- public datasets to make them available to KCEP and selected partners. This would allow for more detailed access gap quantifications with a lower error margin, in order to inform both discussions with key stakeholders as well as future policy and program design. Organizations that may have the knowledge and capacity to undertake such an effort include: GIZ, CLASP, GAVI, Global Cold Chain Alliance, the Global Food Cold Chain Council, UN Habitat, and the IEA,

COOLING SOLUTIONS FOR BUILDINGS

1. POTENTIAL TECHNOLOGICAL AND OTHER SOLUTIONS

Increasing AC efficiency

Research in 2016 by LBNL found that **shifting toward 30% more efficient AC units,** in combination with a phase-out of HFCs[1] could offset the construction worldwide of as many as 1,550 peak power plants, while avoiding as much as 4 billion tonnes of CO_2-e emissions annually by the year 2050 - more than any single country other than China and the US currently emit. Cumulatively this would add up to an amount of 98 billion tonnes of avoided CO_2-e by 2050, representing about 10% of the carbon budget which scientists estimate remains to keeping global warming below the international target of 2°C.[i]

In most major economies, there is a general trend toward more stringent minimum energy performance standards (MEPS) requirements, with a 2011 study by CLASP showing that Japan had the most stringent MEPS for the most common types of split[2] room ACs. This doesn't take away that the average energy performance of ACs sold in most markets is (considerably) lower than the best in class AC available, pointing towards untapped potential for greater AC energy efficiency. [ii]

In 2016, India's Bureau of Energy Efficiency (BEE) introduced a mandatory 1 to 5 star efficiency rating for ACs, with the average AC sold on the Indian market having an energy performance equivalent to a 3.1 (3 star) rating. This was preceded by a number of (part voluntary) initiatives since 2006 to rate ACs sold onto the Indian market.[iii]

In response to the increasing demand for ACs, Energy Efficiency Services Limited (EESL), a Super ESCO[3] set up under India's Ministry of Power, which is showing success in unlocking the energy efficiency market in India through more efficient fans and the distribution of LED lighting, organized a workshop with stakeholders in early 2017 to launch its **Super-Efficient Air Conditioning initiative**.[iv] This new program focuses on super-efficient cooling systems with a minimum 5.2 (5 star) rating, with the aim of providing ACs that are at least 40% more energy efficient than the best in class AC currently available in the Indian market.

A key component of EESL's strategy is to aggregate demand for ACs under a performance based contracting ESCO model, as well as the issuing of Requests for Proposals (RfP) to spur innovation and create demand in the market, while simultaneously bringing down the price of the new AC units.[v] A different approach is being taken by NGO Rocky Mountain Institute, which aims to launch an extreme efficiency cooling prize, awarding - after a competitive process with multiple stages - a US$1 million prize for the manufacturer that can deliver an AC unit 5 times as energy efficient as the average Indian standard room AC unit (3 star) and costing maximum twice as much per unit.[vi] Further efforts to make ACs more energy efficient are underway through the work currently being undertaken by partners of the Kigali Cooling Efficiency Program under the Program's windows One and Two.

Notwithstanding these promising developments on the AC efficiency front, with the demand for building cooling unlikely to slow pace, solutions need to be identified beyond merely installing AC units with better energy performance in every building and even every room. An important point to keep in mind here is that in the near-future **the price point of ACs is likely to come down as well as the income threshold**.

The price point reduction may be created through economies of scale as manufacturers increase output to meet a market demand that is growing because of the increasing temperatures and higher frequency of deadly heatwaves. This could mean that even low-income households will start

[1] Hydrofluorcarbons, frequently used for AC and refrigeration purposes
[2] Split air conditioners consist of an indoor- and an outdoor-unit, which are installed in fixed locations and linked together with the refrigerant line
[3] An entity that is established by government and functions as an ESCO for implementing projects in public facilities and supports capacity building and project development activities of existing private ESCOs

prioritizing buying an AC next to other essential items such as food, water, and shelter. Reducing the income threshold for owning an AC could be stimulated by new business models such as Pay As You Go (solar) AC or Servitisation models, as has been shown to be effective with solar home systems in East Africa in particular[vii]

Passive cooling

Cooling needs should first be met by focusing foremost on minimizing cooling demand through good building design incorporating passive cooling measures. Thereafter, the remaining cooling needs can be met in the most affordable and efficient manner by use of active cooling solutions.

A plethora of passive cooling design solutions are already available to architects and building designers today, with such measures falling into roughly six different categories, comprising:[viii]

- **Preventive measures** that aim to provide protection and/or prevention of external and internal heat gains, such as taking into account the local microclimate and site design; using solar control; optimizing building form and layout; thermal insulation; as well as using building management policies to influence behavioral and occupancy patterns;
- **Modulation** and **heat dissipation techniques,** allowing the building to store and dissipate heat gain through the transfer of heat from heat sinks to the external climate, either by making use of a building's thermal mass or of natural cooling;
- **Ventilation**, using air to remove heat or provide cooling to occupants, often through cross ventilation or stack ventilation, as well by using the coolness of the night for night flushing;
- **Radiative cooling**, often designing the roof to act as a radiator through direct radiant cooling (roof as a heat sink to absorb the daily internal loads, releasing it during the cooler night), and indirect radiant cooling, using a heat transfer fluid to remove heat from the building structure;
- Reflective cooling, using lighter colored surfaces, such as a roof or wall, to reflect more light away from the building and keep that surface and those around it cooler than a darker one;
- **Evaporative cooling**, using the evaporative process of water to cool incoming air while simultaneously increasing the relative humidity, which works particularly well in dry climates; and
- **Earth coupling,** using the moderate and consistent temperature of soil to act as a heat sink to cool a building through conduction.

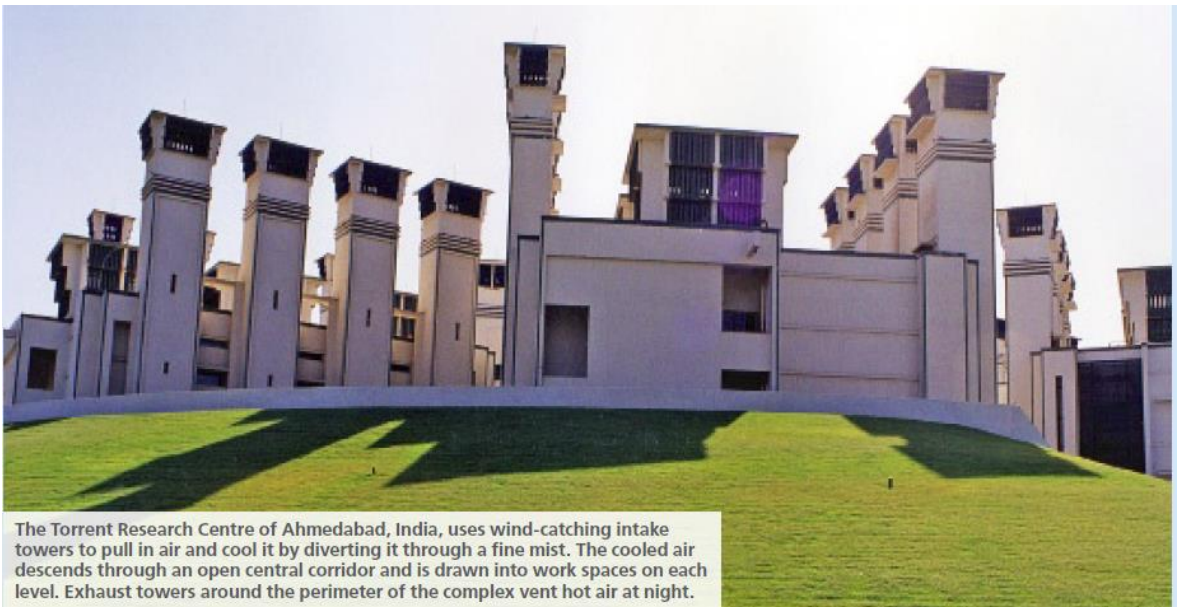

Figure 1 Example of an office building in Ahmedabad, India, using wind towers to naturally cool the building's interior[ix]

In addition, a range of energy efficient active cooling solutions are available that use similar techniques, optimizing the cooling potential by adding elements that require an external energy source. An example is earth coupling. Direct coupling (passive cooling measure) may use earth as a buffer for the building's walls or roof, whereas indirect coupling will generally use earth ducts and a

heat exchanger to circulate air or water between the building and nearby stable-temperature earth layers.[x]

Fans in solar home systems

Fans can be a good, relatively efficient and low-cost solution for grid-connected homes, who cannot afford an air conditioner or would have their cooling needs well served by a fan as well. For those living without access to grid electricity however, fans are usually still off limits. Solar applications are increasingly providing opportunities to bring energy and its services, such as light and broadcasting (radios and TVs) into people's homes. This is for many people living in low-cost, low income housing, solar power creating a new hope – to own a solar-powered electric fan.

Their houses may be poorly ventilated, while extra windows are expensive and on the lower floors can attract burglars. Fans, however, draw a comparatively large amount of current, which can quite quickly drain the battery of a solar panel, while unlike light bulbs, fans have moving parts that can quite easily break if under heavy use.

In most locales, where solar applications have now become available, either through buy-to-own or through Pay-As-You-Go models, solar fans are still absent. Increasingly solar fans are being offered for sale on the global market though, for example through providers in the U.S. and in Dubai, that can be used for 5 to 7 hours at medium-speed if charged for 8 to 10 hours during the day. This does mean that households keen to use a solar fan during the hottest hours of the day, as well as to cool themselves while sleeping at night, will have to make choices as to when to use the fan. [xi]

The challenges in running a fan at a sufficiently high speed and for a sufficiently long period of time without requiring a large array of solar panels, and therefore their **relative absence from solar focused access-to-energy programs**, points to a need for creating mechanisms that incentive the market to spend greater effort on R&D for the development of super-efficient, low-cost and durable fans. This would allow large numbers of people who increasingly are being reached by access to energy programs, to also reap the socio-economic and health benefits of enhanced cooling in their homes, schools and workplaces.

Low-tech coolers using natural cooling

A variety of solutions have entered the market in recent years, which provide low-income households and workshops or small factories with a simple cooling solution that can be installed in a wall or window, basically providing them with a natural 'air-conditioning' system with no or low energy bills and using locally available materials and low-skill construction techniques. Solutions either use evaporative cooling or wind driven cooling (ventilation) to lower the temperature inside by about 5ºC.

An example is the **Eco Cooler,** developed in Bangladesh. This Do-It-Yourself device is quite easy to make at minimal cost, using discarded plastic bottles. The plastic bottles are cut in half, mounted on a sturdy board with bottleneck sized holes and placed over a window with the wider part of the bottles facing outwards. The developers have teamed up with Grameen Intel Social Business[4], to bring this so-called Eco Cooler to villages in Bangladesh. Teams are sent out to villages to teach local people how to make the Eco-Coolers, who are subsequently asked to pay it forward.[xii]

In Delhi, India, an architect recently invented a cooler for a factory that was keen to keep its workers cool but couldn't afford a large electrical AC system. The **cooler uses terracotta tubes** (clay-based ceramic pottery) which are arranged in a spherical shape, held together by a metal structure. Recycled water from the factory is poured or in this case pumped over the porous terracotta, which is absorbed by the clay and then slowly evaporates, lowering the temperature of the surrounding air.[xiii]

To achieve large-scale dissemination and uptake of natural air conditioning systems it is critical for the **right enabling environment** to be in place ranging from the right partnerships to the right policies and business models to reach low-income consumers.

[4] Which is a social business platform, that's a partnership between NGO Grameen Foundation and technology company Intel

Localized/mobile cooling

In addition to more passive forms of localized cooling, such as less restrictive dress codes, a range of products have been developed by manufacturers in recent years that can help cool a person's body without cooling the entire space Examples include the car industry, whereby a number of manufacturers are providing **ventilated or air-conditioned car seats or seat cushions**. Seat cushions are now readily available for example, which use a small fan powered by the car's cigarette lighter, combined with the use of 'porous' microfiber and mesh materials that help circulate air through the cushion and absorb body heat.

Others use passive cooling, by using phase-change materials to create a **gel pad** to use on seats or as backrest with a cooling effect. Body heat gets absorbed by the pad and softens the cooling gel from a solid to a liquid state, creating a cooling effect which can last for several hours. Re-cooling the pad is a matter of removing the heat source for as little as 10-15 minutes, with refrigeration (e.g. fridge, freezer, or a bucket of cold water) being able to speed up the process. Phase change materials are also being used in building walls.

Several companies have also started offering **cooling vests**, which can be worn for example by those with high outdoor exposure such as construction workers. Cooling vests fall into four primary types:

- Evaporative cooling vests have to be submersed in water for a few minutes and lightly wrung out afterwards before being worn;
- Ice chilled cooling vests make use of cooling packs that are frozen first and then placed in pockets inside the cooling vest;
- A phase-change cooling vest makes use of cooling packs with phase-change materials that absorb the body's heat and create a cooling effect for 2 to 4 hours;
- A cool flow cooling vest makes use of a water flow system that pumps water through the vest through tubing;

In addition, small **portable battery or electric powered fans**, available in a variety of sizes and forms as small as handheld/clip-on mini fans, can also provide localized cooling. Finally, researchers from the US and from Hong Kong have independently developed **wearable cooling devices**, that are worn on the wrist and will soon become commercially available. The Embr Wave and the Aircon Watch leverage the physical phenomenon known as the PelTier effect[5] to reduce (perceived) body temperature. They are worn on a wrist strap and powered by a small battery, and when placed against the skin, can make someone feel warmer or cooler pending the settings.[xiv]

Novel use of waste cold

Opportunities also lie with beneficially using **residual or 'waste' cold.** For example, during the re-gasification process of LNG (from a liquefied state at minus 162°C) at import terminals, large amounts of waste cold are being produced which currently mostly go uncaptured. With LNG use on the rise and port terminals often located close to or in urban areas, and with about 40% of the world's population living within 100km from the coast, this could provide opportunities for using this cold for building or other cooling purposes instead. Estimates for the UK point towards a volume of recoverable waste cold from LNG imports of approximately 80 TWh/annum, almost matching the country's current cooling demand for all cooling purposes combined. Even waste heat could be used to provide cooling, through a device known as an absorption chiller, while free cooling opportunities provided by nearby water bodies such as rivers, lakes and seas may also hold considerable potential.[xv]

Green building initiatives

Besides the actual technologies, a proliferation in the past 10-15 years of numerous voluntary **'green building' certification schemes** – including LEED originating in the US, BREEAM originating in the UK, China's 3-Star, Hong Kong's BEAM, Australia's Green Star, and India's IGBC rating to just name

[5] The PelTier effect describes the phenomenon of heating or cooling caused by an electric current flowing across the junction of two different conductors. As the current moves from one conductor to another, the transfer of energy causes one side to heat up and the other to cool down.

a few - as well as the rise of concepts such as Passive House[6], help bring back the focus on passive design, recovery of resources, and low-energy active cooling solutions for buildings. Despite these laudable initiatives, green building efforts however are estimated to currently reach only about 1% of the world's building stock and do usually not affect lower-income housing[xvi], although the International Finance Corporation is seeing a number of low-income housing developers looking to adopt their EDGE standard. For example, the Imperial Homes group has developed a number of green low-income housing schemes in the Phillippines.

Similarly, **policies that promote net zero energy or zero carbon buildings** are likely to have a positive effect on the uptake of more sustainable cooling solutions, to reduce the volume of renewable energy that has to be supplied to the building through on- or -offsite generation. An example is the EU Energy Performance of Buildings Directive, which mandates all new buildings in the EU from end 2020 onward to be designed as Nearly Zero Energy Buildings (nZEB).[xvii] China, in its early 2017 release of the 13th Five-Year Plan on Energy Efficiency and Green Buildings, has now also voted to start working on identifying feasible nZEB pathways at various levels, from individual buildings to districts, and to initiate a nZEB frontrunner program.[xviii]

Thermal storage

Finally, with an increased focus in the (renewable) energy sector on demand-response management, shaving peak loads, and the **storage of renewable energy** when output is higher than demand, cooling could provide part of the solution. The popular Ice Bear energy system on sale in the U.S. for instance acts as a thermal battery, using excess and hence cheap renewable energy to freeze water in an ice tank, which can subsequently be used to deliver cooling to the building's AC systems when such energy is in short supply (and thus expensive), reducing peak demand for grid electricity. [xix] Similarly, solar cooling solutions, in combination with compact storage options, can reduce peak loads on the grid - with peak cooling demand for buildings and maximum solar radiation often coinciding - and help balance energy supply and demand.[xx]

2. POTENTIAL POLICY AND BUSINESS MODEL SOLUTIONS

Alternative cooling solutions for buildings are unlikely to take off at a large enough scale and subsequently become mainstream without the right enabling environment. This includes having a mixture of the right policy and regulation, incentives, access to financing, and attractive business models in order make the solution desirable for both supplier and offtaker and accelerate uptake.

Governments can use a variety of policies and regulations to increase dissemination and uptake of building cooling measures, while an important role can also be played by reaching out to and collaborating with NGOs, community groups and the private sector.

Although limited examples exist of business models focusing exclusively on cooling for buildings, approaches from other sectors such as energy efficiency and renewable energy points towards potential opportunities for the adoption of similar models in building cooling to accelerate market transformation. A concise overview of a number of potential models for consideration and inspiration is provided, focusing on both models that could be used by suppliers to sell *into* an offtaker market, as well as models which offtakers may use to sell *from* suppliers on the market.

Strengthening of Minimum Energy Performance Standards (MEPS)

With both consumer and total energy demand for air conditioners (AC) rapidly surging, an ambitious trajectory for the strengthening of Minimum Energy Performance Standards (MEPS) can help countries mitigate and partially prevent the costly impacts of large increases in consumer-driven energy demand. Window 2 of the KCEP program is focusing, among other things, on the strengthening of MEPs in selected countries.

To effectively rate the energy performance of ACs, the **Energy Efficiency Ratio (EER) and the Seasonal Energy Efficiency Ratio (SEER)** are the two main types of metrics used internationally.

[6] Passive house (German: Passivhaus) is a rigorous, voluntary standard for energy efficiency in a building, reducing its ecological footprint. It results in ultra-low energy buildings that require little energy for space heating or cooling.

The EER is the ratio of the cooling capacity to the electricity consumption when measured at full load, and thus does not take into consideration part load performance. With ACs often running at part load or cycling between on and off for a major part of their operation, the SEER provides a more representative measure of the energy performance of AC units over the cooling season. SEER metrics are increasingly being used by countries as an alternative to the EER to set Minimum Efficiency Performance Standards (MEPS) and labeling requirements.

A 2011 comparison (CLASP) of the minimum energy performance requirements for the most common types of split RACs in major economies - with the U.S., the EU, Japan, China, Korea, Taiwan, India, and Australia included in the analysis – showed that most of them base their test procedures for AC systems on the adaptation of two international standards: ISO 5151 and ISO 13253. **The Japanese "Top Runner" requirements came out as the most stringent existing requirements for split AC units.** The Japanese requirements were between 17% (for more than 6 kW units) and 68% (for less than 3.2 kW units) more demanding than any proposed or present requirements at that time in the other economies considered.

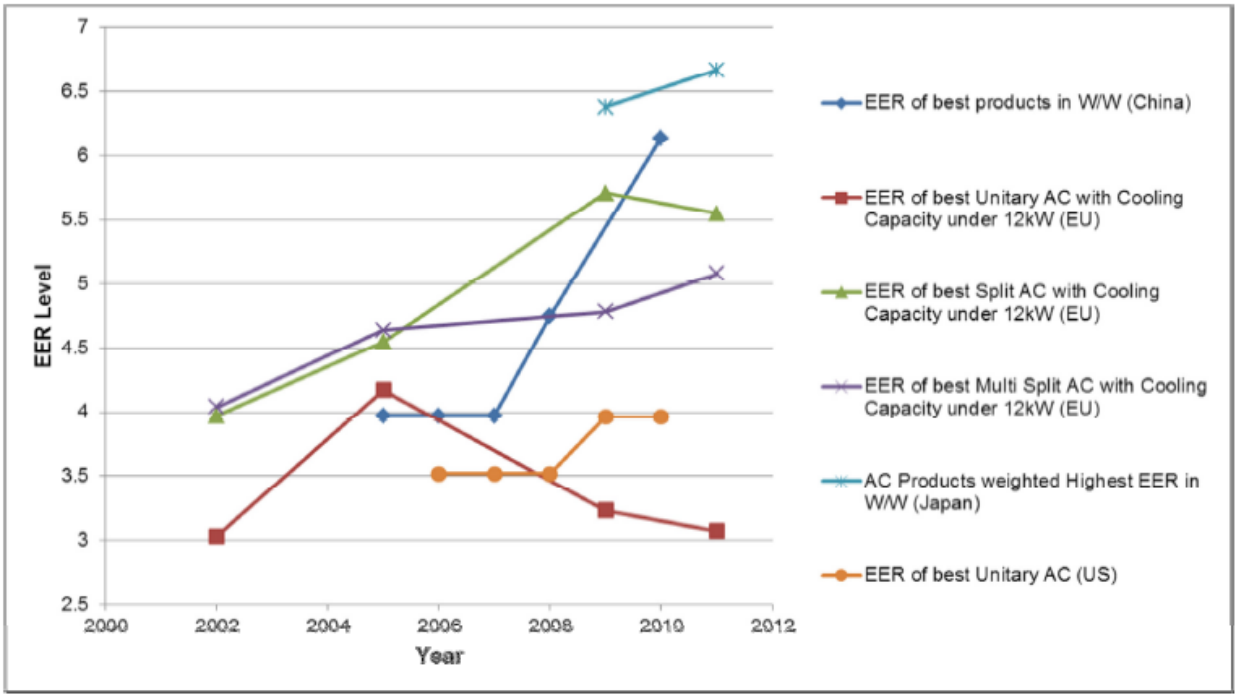

Figure 2 Trends in the EER of the most efficient AC products on the market in EU, China, Japan and the U.S.

Nonetheless, **the EER of the most efficient AC products has improved over the years in most economies**. In the EU, the EER of the most efficient split and multi-split AC products with a cooling capacity under 12 kW improved between 2002 and 2011. In Japan, the EER of the most efficient AC products rose 67% between 2009 and 2011. The same upward trend was observed in the U.S. for the most efficient unitary AC products between 2006 and 2010. And in China, the EER level of the most efficient products increased rapidly between 2005 and 2010, triggered by the implementation of MEPS and an energy label for variable speed ACs. A Chinese high efficiency AC tested according to four different measurement standards (European present as per 2011 and future, Chinese and U.S.) show that the best available technology (BAT) on the European market was comparable to the one in China.

The studied economies used **different approaches in establishing their MEPS levels**, with some establishing different MEPS levels according to the cooling capacity of single split ACs, while others have adopted a single MEPS level for single split ACs regardless of their cooling capacity. Despite the different approaches used, there was a general trend toward more stringent MEPS requirements. Moreover, the planned MEPS levels in economies such as Taiwan and India (as per 2011) were more stringent than current levels in many 'western' economies.

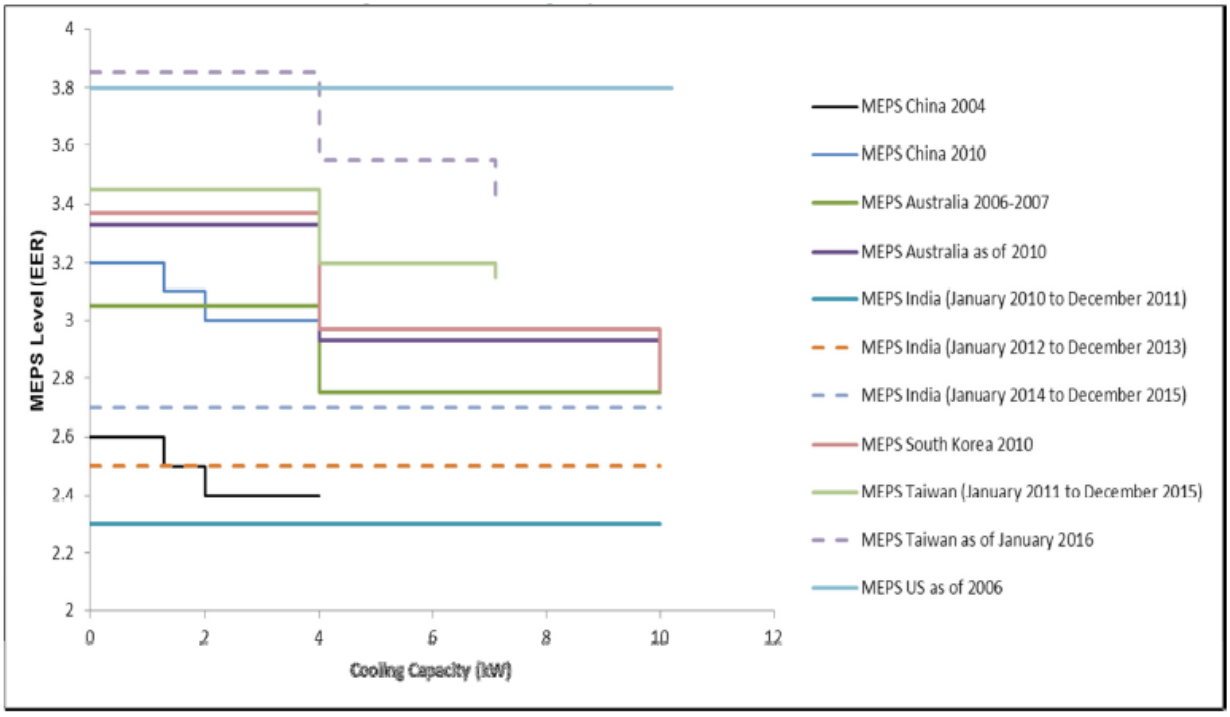

Figure 3 MEPS for Single Split RACs in selected economies

Furthermore, in all the analyzed economies, except the EU, **AC manufacturers or distributors are required to get a certification or registration of their AC products prior to their distribution on the market.** The EU has a voluntary certification scheme instead. Each studied economy had also established a mandatory energy label for room ACs, with some countries initially having started off with a voluntary label.

This all points to buy-in for having MEPS in place for AC units, which gradually strengthen over time, and an ability by manufacturers to deliver ACs which comply with these standards. Nonetheless, many economies driving a large proportion of near-future AC demand, such as Nigeria, Indonesia, and Myanmar have only in recent years started to introduce MEPS or are still working on their introduction. The absence of MEPS or having relatively weak MEPS in place will do little towards curbing rapid increases in energy demand from greater AC uptake.

To considerably improve the average energy efficiency of ACs sold, an **ambitious long-term goal for AC efficiency** will have to be set, with governments (introducing and) tightening corresponding MEPS every few years in order to send a clear signal to the market while gradually raising the bar. As there's still a risk of lock-in to high energy consumption paths from ACs sold in the next decade or so, which would have to comply with relatively low MEPS due to the process of gradual introduction and/or tightening, a case can be made for frontloading where feasible some of the incremental MEPS stringency improvements in markets where manufacturers have shown to have AC models much more efficient than the current average are readily available.

In addition, governments may want to combine this with an **incentive program**, such as a rebate, that creates a strong stimulus for people already owning an AC to upgrade to a more efficient one, especially once more stringent MEPS come into place, while returning their old inefficient AC unit through a collection and dismantling scheme. This could avoid people either holding on to their old ACs or to start reselling them as second-hand on the market, which would keep inefficient ACs with a high probability of leakage of refrigerants with high GWP potential in circulation.

Passive cooling policies

A wide range of measures are available to cool buildings without the use of electricity. Nonetheless, for **existing buildings**, the challenges of retrofitting those buildings to incorporate more passive

cooling measures go beyond the obvious challenge or even impossibility to alter certain components of the existing buildings' design. Some of the barriers for buy-in are very similar to those encountered for building energy efficiency retrofits. To name a few, many people fail to associate the adverse impacts of fossil fuel driven energy generation (whether from a central power plant or via a local diesel generator) – ranging from carbon emissions and local air population to energy security concerns - with high energy consumption in the buildings sector.

Also, the low and at times subsidized electricity prices in many countries, the (perceived) high upfront capital costs of retrofits, split incentives between building owners and tenants, and the general disruption to occupants, have not created sufficient incentives for most building owners/managers to voluntarily pursue building energy efficiency retrofits. Passive cooling retrofits are likely to run into similar challenges.

A plethora of initiatives have been and are trying to address these **barriers to energy efficiency retrofits**, with varying levels. In Europe and the U.S., 75% of today's buildings are expected to still be in existence by 2050. For emerging economies, where the building energy efficiency market has by no means arrived at a stage of maturation yet, a major focus on improving existing stock by incorporating passive cooling measures is likely to require very significant time and financial investments.

This in itself does not rule out implementing passive cooling measures for existing buildings, however requires a sharp focus on measures that come with a relatively low-cost and -effort as well as limited occupant disturbance, in order to allow them to be rolled out at a large enough scale to benefit those who need it most. Examples are 'cool roofs' as well as 'cool walls', to reduce solar absorption, thermal insulation, as well as installing ventilators to increase air flow.

As many developing and emerging countries still add significant volumes of new-built buildings to their total building stock, it would make most sense to take an approach that focuses mainly on incorporating passive cooling in the design of **new buildings**. Key measures include:

- **Working with government bodies** –national, subnational and/or municipal as relevant- and other stakeholders to get them to commit to, develop and implement stretch building energy codes with a very high energy efficiency or even net zero energy/carbon goal in their jurisdictions to ensure that by 2030, or latest 2050, all new buildings meet these specifications. This sends a strong signal to the market of the direction that the industry will have to be heading;
- This will have to go hand in hand with **gradual strengthening of the local building energy codes;**
- Introducing policies, that mandate all new construction and major renovations to be **designed for non-air-conditioned comfort** at times of the year when temperature-wise this is achievable;
- Furthermore, there is a need for support towards the development of **passive cooling design specifications / standards** for key building types across main climate zones – with a preference for performance-based rather than highly prescriptive pathways to avoid locking industry to just a few limited ways of providing passive cooling and stifling innovation;
- As well as catalyzing, **incentivizing and educating the market**, and developing, piloting and implementing **replicable models** that can be easily and feasibly rolled out across larger numbers of new or even existing building stock;

An example could be to appoint and support a collaborative platform of public, NGO, and private sector parties to jointly research, trial and **develop the optimal passive cooling approach for the next generation of mid-rise, low-cost housing**, creating a model to leapfrog to better building design that helps control temperature gains.

This could tie in with large ongoing social housing development programs, also creating the potential to **incentivize construction sector parties** to design for thermal comfort through passive design. India's Housing for All program for example ("Pradhan Mantri Awas Yojana Mission"), which runs from 2015 to 2022 and aims to provide 20 million affordable housing units for the urban poor in more than 2500 cities and towns across 26 states; and Brazil's "Minha Casa, Minha Vida" low-income housing program, which has delivered 2.6 million of affordable housing units since 2009, with another 4.2 million units already authorized for construction. By working with them,

Another option could be to **tie the beneficiary loans (mortgages)** of those qualifying for low-income housing to incorporating a number of easy-to-implement **passive cooling and cooling energy efficiency measures**. A similar approach is taken by Mexico's Green Mortgage program run by Infonavit, Mexico's federally owned social housing institute, which mandates anyone soliciting credit from Infonavit to buy, build, enlarge, or remodel a house to take out a Green Mortgage which helps finance energy- and water-efficient features and technologies.

Behavior change programs

Behavior change can be powerful means of helping curb energy demand from cooling. This can range from setting the right temperature for AC cooling (i.e. not too cold), to e.g. wearing the right clothes including being allowed to 'dress down' when it's hot, and altering working patterns to allow people to work during the cooler hours of the day.

A successful example comes from Japan, which has hot and humid summers. In many countries, excessive cooling of office and retail buildings is quite common, not in the least to allow for office worker to sit in office with suit and tie. This may result in those who dress lighter due to the heat to now needing to put on extra layers when inside a building, even though it's scorching hot outside. in Tokyo however, these buildings rarely put the AC temperature below 28°C – compared to a common 21ºC in US offices over summer. This is the result of a national campaign by the Ministry of Environment, called **Cool Biz** which started in 2005 in order to save energy. It runs every year from May till September or October.

Offices and retailers are asked to keep thermostats at 28°C or above, and to allow employees to shun Japan's cultural norms on how to dress formally for work by coming to work in much less formal attire. Government buildings, including schools, community centers and libraries, are mandated to lead by example. Other recommendations include allowing staff to shift work hours, by coming into work earlier when temperatures are lower; using blinds to keep direct sunlight out; using greenery for cooling and shade; switching off electronics when not in use; and using gel packs with coolants that can be placed under seat cushions.[xxi]

Although met with skepticism - and some resistance, including from the necktie business - at first, 'Cool Biz' has become one of Japan's most successful environmental initiatives. To create more buy-in and raise the profile of the campaign, the government not only requested government workers to dress down and took out large ads in newspapers, Japan's government leaders also regularly take part in Cool Biz and the Prime Minister is frequently being interviewed without wearing a tie or jacket. In 2015 for example, a survey showed that 96.1% of the Japanese population was aware of the initiative. Between 2005 and 2010 the avoided carbon emissions from less energy demand equaled to 9.5 million tonnes. In addition, it may make workers more productive as excessively chilled work places can actually result in a productivity slump.[xxii]

Electricity pricing

Policy solutions could also involve better pricing of electricity in countries where electricity is subsidized, in order to **reflect the real cost of energy generation and associated carbon and ambient air emissions**. In India for example, which is experiencing a boom in AC sales and related energy consumption, electricity is subsidized for residential customers. In Delhi, households pay only about 75% of the cost of electricity generation. Moreover, many households in India are not billed at all, one reason being rampant power theft, or they pay a flat rate for lack of a meter.[xxiii]

An example of electricity pricing reform is the introduction of a carbon or air pollution tax on conventional electricity generation, which would also give a boost to the deployment of renewable energy. In order to avoid such a tax exacerbating inequality, it would have to be combined with a tax rebate or tax exemption for households below a certain income threshold, who due to their limited income means are unlikely to be major energy consumers anyway.[xxiv]

Another option could be pollution fines, such as applied in China, where a national-level regulation empowers provincial authorities to fine cities for high levels of air pollutants. This has resulted locally in accelerated uptake of district cooling systems, further described in the section on urban

environment, as the fines result in a payback period for district cooling as low as three years due to the avoided penalties on pollution and the reductions in coal purchases for electricity generation.

Collaborating with local organizations

In order to reach the (urban) poor and make them aware and create uptake of low- or no-cost solutions available to them, such as DIY coolers and solar fans, considerable engagement efforts are likely to be required. These range from soliciting their active input and co-creating the solutions together with them to using information and marketing channels they can access, such as 'word of mouth'. It can also be of great help to engage with local NGOs and community networks.

An example is the **Mahila Housing Trust**, a grassroots NGO which is a spin-off of the Self-Employed Women's Association. It works to empower underprivileged communities in various Indian states with emphasis on the emancipation of women. It works with a broad range of partners, ranging from government to academic institutions, to international foundations and private companies. The NGO has a variety of programs. Its energy & climate program includes working with slum inhabitants in Ahmedabad to install cool roofs on slum dwellings, disseminate ventilators made from fiber sheet to improve circulation in homes, and promote cooling for auto rickshaws by installing a layer of paddy husk on the roof and outer walls of a rickshaw on a frame of bamboo or plastic pipes. The organization is now expanding to Delhi after winning the Delhi Challenge, an urban innovation contest.[xxv]

A very different approach is being used by **Addressing the Unaddressed**, an NGO which focuses on giving people in the slums of Kolkata, India an address. In those slums where they work, every dwelling is given a unique postal address based on its geo location within the slum. This postal address helps planners map out the area more effectively and makes sure that each household is included. Working with community and local councilors as well as local NGOs and the slum dwellers, data are gathered to help identify the scale of issues these households and dwellings are facing, from access to sanitation and primary health care to the durability of the home. The slum dwellers also use their new postal address for opening bank accounts, getting ID cards and social benefits, and having mail delivered directly to their homes.[xxvi]

In Pakistan, NGO **Saliban** has been assisting slum dwellers earning an average US$3 a day with getting access to plots with secure land tenure and providing them low-cost mortgages to finance the building of a better-quality house. A 20% down-payment (roughly US$175) is required, while the remainder (US$575) can be paid off in installments over a period of 8 years. Its approach has attracted the attention of several local banks.[xxvii]

An energy access and microfinance project by USAID and partners, called Energy Links, focused most of its outreach and collaboration efforts on **community savings groups**, which are quite prevalence in off-grid rural areas, not in the least as the model is being propagated by international and local NGOs. Of the many collaboration opportunities it pursued, it found this to be one of the most useful. Typically, savings groups are composed of 15 to 30 self-selected individuals, mainly women, who meet weekly or fortnightly to save, borrow, and often provide basic insurance services by creating a separate 'social fund'. They can also be a useful channel to create awareness of better access products. An estimated 4 million of such groups operate in Africa alone.[xxviii]

Public-private partnerships

Public-private partnerships have also rapidly gained popularity, combining the strengths of both public sector organizations with those of private sector partners. A wide variety of partnerships between smaller or larger numbers of participants are possible in order to deliver beneficial outcomes.

In Mexico for example, the lack of affordable housing is a serious problem for low-income families. Insufficient access to financing and materials along with a lack of technical skills preclude low-income families from living in safe and adequate conditions. About 34% of Mexican families live in poor-quality homes, the majority relying on self-constructed buildings.

Cemex, one of the largest cement manufacturers in the world, decided therefore in 1998 to move from selling materials to selling solutions to Mexico's low-income urban dwellers. Its **Patrimonio Hoy** program makes housing more affordable by offering low prices on materials, giving would-be home owners consultations with architects to help them design their homes, providing pre-costed housing designs, if desired delivering construction materials through a savings and credit scheme spread out over a typically 70-week period while keeping prices fixed throughout that period, and even offering supervised construction services for those not able to do it themselves, for example because they're temporarily working abroad..[xxix]

Patrimonio Hoy has attained national coverage in Mexico, reaching so far about 600.000 families, and has expanded across Latin-America to Costa Rica, Colombia, the Dominican Republic, Nicaragua and Panama. In doing so, it collaborates with partners such as the Inter-American Development Bank. CEMEX operates local Patrimonio Hoy offices that offer technical assistance, financing and construction services to low-income families, with offices located in 56 Mexican cities in areas that provide easy access to marginalized communities. It also collaborates with local governments and NGOs to manage Self-Employment Production Centers, where local families receive supportive training and materials to better construct their own housing.

In order to attract new customers, the program works with a network of local promoters, usually individuals that are well known and trusted by their communities, the majority of them women and many having used the program themselves. Families that use the program also receive customized financing products according to their financial needs. Overall, the program helps low-income families to build their homes up to three times faster than usual and at one third of the cost. [xxx] The success of the program has also attracted the interest of the World Bank.

In Bangladesh, the Infrastructure Development Company Limited (IDCOL), a government-owned non-banking financial company under the central bank, cooperates with international and local partners to install solar home systems in remote rural areas, which are not easily accessed by the national electricity grid. As of May 2017, over 4 million solar home systems had been installed through the **Solar Home Systems (SHS) initiative** which began in 2003, impacting more than 12% of the entire Bangladeshi population. By providing one channel for dispersing financial support from international donors and multilateral development banks such as the World Bank, and using a network of non-profit and private partners to deliver, a 'wholesale' model has been created that helped unify an otherwise fragmented market, as well as to standardize technology, finance and policy, together resulting in scale. [xxxi]

The program uses selected local partner organizations, 49 of them in 2017, often microfinance institutions, as promoters in light of their existing relationships with customers, engaging with them and helping to establish confidence in the program, as the public was initially quite skeptical. The partner organizations also select low-income customers who need the support most, extend loans and collect payments, and oversee private local partners to install the systems and provide after-sales services. IDCOL provides grants and soft loans as well as the necessary technical assistance. Different finance options are provided to customers, with the poorest qualifying for a repayment scheme under which they make a 10-15% down-payment, with the remainder - including interest of 12-15% used to pay the partner organizations - payable in 36 equal instalments.[xxxii]

It has been shown that the program has beneficial knock-on effects on low-income households, which saw increases in per capita food and non-food expenditure, because of savings derived from using solar instead or kerosene and/or the time freed up for productive activities. It has also generated a

positive impact on the local manufacturing industry, which is now able to produce all components locally at good quality and competitive prices, with the cost of solar home systems having come down dramatically. [xxxiii]

The program has now expanded to also incorporate the provision of solar home systems in Bangladesh; welfare programs targeted at the 40 million citizens still living below the poverty line. Up to 50% of the total allocation under its Food for Work and Test Relief programs has been reallocated to providing mini, micro, and nano grid solar solutions for marginalized communities. With Bangladesh having become self-sufficient in food production, lack of food or inability to buy it is no longer the biggest problem for the poor although lack of energy remains a crippling problem, which is why the government is moving the subsidy in the direction of solar energy provision. Most families receive in return for their labor a 20-watt system which can light up three LED lights. [xxxiv]

Aggregate purchasing models – offtaker to supplier

Recent years have seen a surge in aggregate purchasing models for in particular renewable energy (RE).[xxxv] Similarly, many manufacturers have long united themselves in vertical or horizontal supply chain purchasing consortia to jointly purchase a variety of supplies.[xxxvi]Taking the RE sector example, by aggregating with other parties, companies with smaller (power) purchasing needs can access utility-scale RE projects and thereby take advantage of the better economics as well better terms & conditions, while it also helps enable risk sharing. From the supplier's perspective, the guaranteed offtake provides it with a stable source of revenue, reduced purchaser credit risk, and a chance to lower the cost of investment capital.[xxxvii]

A popular RE aggregation model is the **buyer-syndicate**, uniting a group of companies or organizations to pursue a mutually beneficial RE deal, potentially facilitated by an intermediary and in some cases having an anchor offtaker, which guarantees the purchase of a majority of the total volume, securing the deal.

A closely related model is the **buyer-cooperative**, whereby buyers contribute to a cooperative being established for bulk purchasing and equipped with a lean staff team to conduct the process of researching, negotiating and managing contracts on their behalf. An example is Blue Hawk, an HVAC purchasing cooperative of 215 heating, ventilating & air conditioning distributor members with 939 locations throughout the US.[xxxviii] Many appliance stores also purchase their ACs through aggregate purchasing groups in order to obtain the lowest price.[xxxix]

This model could be suited for PAYG providers or microfinance institutions (both covered later in this section) or other companies or organizations with a similar aim of providing access to cooling products, as by aggregating their demand they will likely be able to reduce the cost, having the purchasing power to ask for solutions better tailored to the urban or rural poor, and may even be able to spur innovation in the suppliers market.

Green or social impact procurement – offtaker to supplier

Governments as well as mayor companies both increasingly deploy **green purchasing and procurement** strategies in order to acquire more sustainable products and services. In turn, they help to create a market for these more environmentally friendly products and services. Purchasing parties have several options available to incentivize suppliers to provide them with more sustainable products and services. For instance, they can create 'demand pull' by specifying the performance and outcomes that need to be met and leave it to suppliers to come up with innovative solutions to meet that need.

An example of this is the procurement by Super-ESCO EESL in India of 100,000 ACs that are at least 40% more energy efficient than the best in class AC currently available in the Indian market. A similar approach could be used to accelerate research and development for solar fans, as current solutions are often poorly tailored towards the reality of low-income, off-grid families who are only able to generate a limited amount of solar energy each day - which is drained quite rapidly by running a solar fan.

Social impact procurement on the other hand uses procurement to affect social impact, either by running a competitive process and/or making a direct award to a social enterprise to deliver goods or services. The approach can be used to marry procurement with outcomes that help meet the SDGs.

The government of Sweden for example and the Renewable Energy and Energy Efficiency Partnership (REEEP) have opened the first financing round of the **Power Africa: Beyond the Grid Fund for Zambia**, which aims to bring clean energy access to 1 million Zambians and jump-start the country's burgeoning markets for energy access services. The Fund will directly support energy access enterprises using a social impact procurement approach, which offers opportunities for the Zambian private sector to contribute to development challenges while directly linking financial payment to on-the-ground results.

Companies are invited to bid for contracts for a range of energy access services, from basic solar systems that provide a household with lightning to more comprehensive offerings suitable for businesses and public facilities. The fund will offer to purchase tens of thousands new off-grid energy connections from the winning energy access providers, who can then use these contracts to leverage more capital and customers in Zambia.

In order to maximize eligibility, the fund offers two types of financing: one being a start-up and incubation component, aimed at allowing firms to establish operations and build a foundation for expansion in the country; and the other a scale-up component, aimed at allowing established companies to grow their customer base such that energy access provision can reach a sustainable investment scale in Zambia. [xl] This approach holds considerable promise for certain cooling access solutions, for example for solar fans once a market offering more suitable to off-grid households becomes available, with many solar energy access companies already receiving request from customers for an affordable, energy-efficient solar fan that can run for longer periods of time.

ESCO and servitization models – supplier to offtaker

Energy Service Companies (ESCOs) generally provide their clients with a more efficient and lower cost energy service by using **performance-based contracting**, whereby the ESCO's payment is directly linked to the amount of energy saved. The savings in energy costs are generally used to pay back the upfront capital and other investment costs over a period typically ranging from a few up to twenty years. If the project does not meet the agreed (minimum) savings, the ESCO is often responsible for paying the difference. ESCO contracts allow facility owners to install or upgrade their assets with efficient equipment, with no need for upfront capital expenditure.[xli]

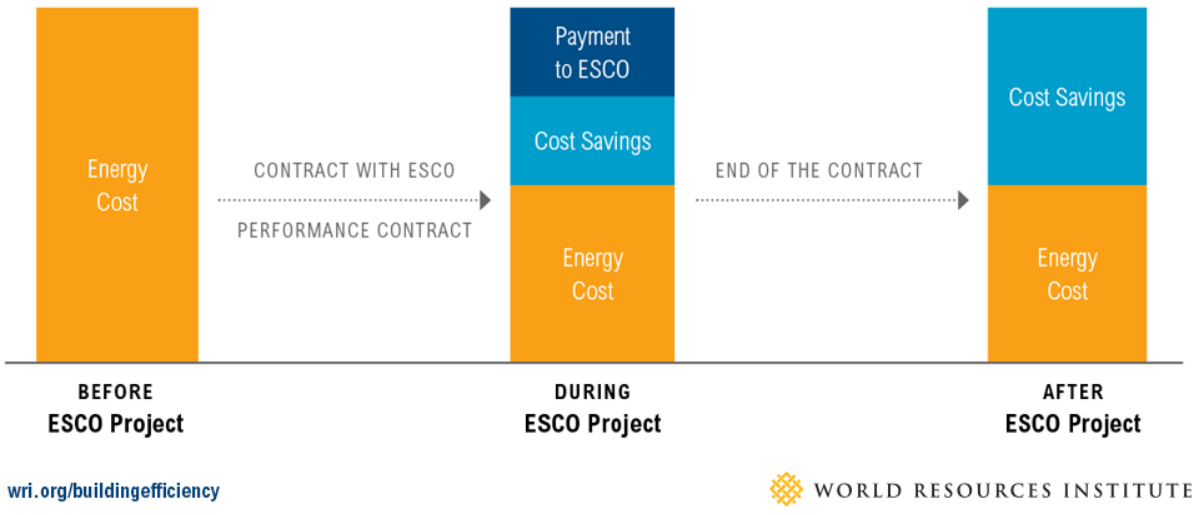

Figure 4 Example of exchanged cash flows before, during and after an ESCO project[xlii]

EESL, the earlier mentioned Super-ESCO in India, aims through its new Super-Efficient Air Conditioning initiative to provide ESCO services for super-efficient ACs. Initially it will focus on the

B2B market, aggregating demand in government buildings to provide them with the first lot of 100,000 units under a performance based model, whereby the capital, installation and maintenance costs borne by EESL are paid back through the energy savings over a period of five years. [xliii]

The pure ESCO model is mainly suited for situations, where people are already connected to grid electricity and could lower their energy bills by having an external service provider make their homes more energy efficient or upgrade inefficient (AC) cooling appliances, as the provider is paid back by the savings on the energy bills.

Nonetheless, variations to the ESCO model using the concept of **servitization** may better suit the access to cooling market where people are unlikely to gain access to electricity soon. An example is provided by Nigerian solar distribution company Rensource, a 2017 finalist in the World Bank's "XL Africa" business accelerator. This start-up is providing Power-as-a-Service solar solutions to both residential consumers and SMEs in urban and peri-urban Nigeria.

Solar systems are installed and commissioned at customers' premises, although continue to be owned and maintained by Rensource in exchange for a monthly subscription fee. If the user moves homes during the subscription period, the company will decommission and reinstall the system for free. Rensource offers four distinct subscriptions to suit a variety of needs, from those simply who wanting to power basic appliances such as lights and radios, to those who even want to run appliances with high power use, like water pumps, water heaters, and washing machines.[xliv]

'Energiesprong' net zero energy building retrofit model – supplier to offtaker

Over a period of 6 years, the Dutch government through a program called Energiesprong challenged industry to come up with solutions for **net zero energy retrofitting of residential buildings owned by social housing corporations**. The solution had to meet four bold requirements: scale (very high volume), speed (construction completed in 2 weeks or less), self-financing (paid for via energy savings), and desirable (residents wanting to participate).[xlv]

This has resulted in Dutch construction companies now providing a host of innovative and quick turnaround solutions, that future-proof aging social housing stock for a 30-year period. The housing retrofit results in energy neutral homes, while providing minimal disruption to tenants with retrofits completed in a matter of days or even less. The total costs of such retrofits in the Netherlands has come down by 60% over the course of just a few years, while offered to tenants through a zero-cost model; that is, paid via their energy savings quite similar to an ESCO model. The Energiesprong model is currently being taken to the UK, France, Luxembourg, and Germany, as well as to New York, and San Francisco.[xlvi]

Although Western-Europe has limited cooling needs for its building stock, the 'rapid makeover' model for the retrofit together with ESCO model for revenue generation, as applied by Energiesprong for relatively low-value housing stock generally occupied by low(er)-income households, may provide valuable lessons on how to incentivize the market to offer innovative, cost-effective cooling demand reduction retrofits to low-income households in hot climate zones.

In Rio de Janeiro, Brazil, for example, the program for **Morar Carioca**, aims to turn its favelas (slums) into proper neighborhoods. Funded by the city, the federal government and the Inter-American Development Bank (IDB), the program not only comprises interventions to provide public services but also to improve people's homes. Morar Carioca is different from many other slum improvement programs in that it also going inside people's houses to improve both the structural quality and the residents' quality of living.

Case by case, improvement plans are made for each house by an architect and a social worker after a series of interviews with the dwellers. For example, increasing the number of windows to improve ventilation and natural cooling, water-proofing or insulating the walls and ceilings, installing sanitary equipment etc. The program also actively incorporates green features, such as installing water or energy efficiency equipment, lamps and devices. The case by case upgrading of homes is a time and cost intensive process, eating up 10% of the total program's budget and costing in total as much as US8900 per house.[xlvii] By adopting elements of the Energiesprong approach, the cost and time

required for upgrading a slum home in the favelas of Rio could come down, while providing residents with a more thermally comfortable home and lower energy costs.

Pay as You Go models - supplier to offtaker

A few dozen companies spread across mainly Africa and Asia are nowadays offering **pay-as-you-go (PAYG) solar energy** options to consumers, thereby overcoming a key obstacle in providing solar to off-grid, low-income households. Through PAYG, energy is converted into a commodity sold through existing retail networks, also simplifying the supply chain for providers selling into regions with limited logistical infrastructure.[xlviii]

Most PAYG options are priced at a price point similar to or lower than a household's weekly cost for purchasing alternative energy, often kerosene.[xlix] PAYG can deliver a degree of payment flexibility to consumers which more traditional financing options don't offer, such as choosing the amount and frequencies to top-up an account that match a consumer's cash flow, as affordability is not merely a matter of how much but also when to pay.[l]

PAYG solar systems are generally offered through **two main types of PAYG business models**, either lease-to-own whereby customers make an initial down-payment –typically between 10-30% of the fully financed cost- and subsequently pay in increments till ownership is transferred to them, or energy-as-a-service (perpetual lease), whereby asset ownership remains with the service provider.[li] PAYG puts these customers more in control – when they're low on cash, not using their system or if it breaks, they can halt payments.[lii] Payment in both cases is usually via either mobile money systems or through other, often mobile-enabled energy credit models.

Success factors for the PAYG solar industry include policy clarity, a well-developed financial sector, an active mobile money market, ready access to foreign exchange, a relatively stable currency and simplified import procedures and tariffs, as exemplified by Kenya which has a thriving PAYG solar market. [liii]

PAYG is being applied to other energy access challenges as well. Also in Kenya, the national utility is bringing safe, reliable and legal grid electricity connections to the Nairobi slums through a 'last mile' approach, going from 5,000 to 150,000 connections in the course of just one year. Most slum consumers use a PAYG scheme to pay for their grid electricity, buying pre-paid chits, available at any corner store, to pay for their electricity in small increments. Many of those who are now selling the Kenya Power units in the slums are in fact former vendors of illegal electricity.[liv]

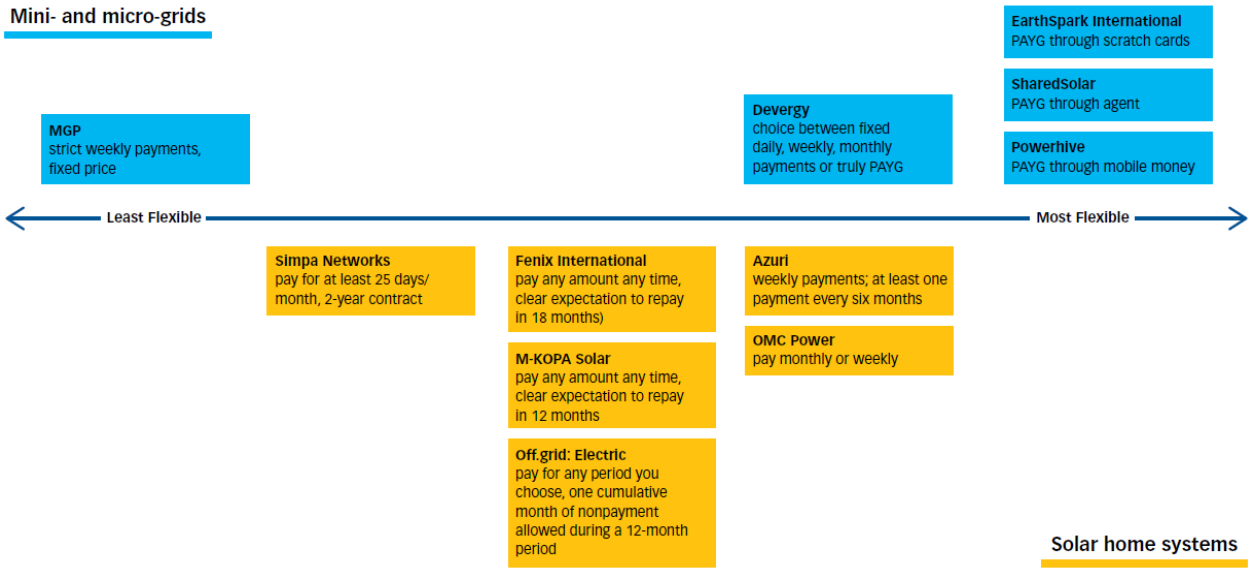

Figure 5 Examples of payment schedules for various PAYG solar providers[lv]

Although PAYG cooling services are at this point mainly speculative, Modulus Design (US) considers in an April 2017 blog a system for **PAYG HVAC** by using mini-split AC systems. Small air handlers

are strategically placed in various locations throughout someone's home, which in combination with in-room thermostats only deliver the amount of heating or cooling that the room needs at any given time, providing greater efficiency than conventional systems with a central air handler. Users would pay monthly only for the minutes they use the system, similar to a PAYG cell phone subscription.[lvi] This offering, similar to PAYG solar, could provide customers with access, affordability and efficiency, integrated into a desirable package.

For those without electricity, solar fans are clear candidates for a PAYG model, in particular as they can be added to existing PAYG solar offerings, which usually offer a number of different systems to their customers, ranging from small, portable solar devices mainly to power a light; solar plug-and-play systems known as 'pico' for powering lighting, radios, and mobile phone charging; and larger solar home systems, which can charge a TV, fridge, and so on.

Microfinance for energy access – supplier to offtaker

In the past decade, several micro-finance institutions (MFIs) and similar providers of small financial grants have experimented with **clean energy end-user finance**, such as solar lamps and clean cook stoves. Few programs have scaled though, a key reason for which lies with the fact that the offered financial solutions help solve the demand-side problem of consumers not having enough cash to purchase these products, but generally do nothing to solve fundamental supply-side challenges, such as the product's distribution ('last mile') and after-sales service. Without a local ecosystem that can reliably provide, service and replace the products when needed, microfinance is unlikely to make a lasting impact in providing low-income households with access to energy.[lvii]

To some extent MFIs may actually be better positioned than PAYG providers to finance a servitized proposition, as they tend have greater capital availability, an existing vetted customer base and loan distribution network. This can also help overcome PAYG providers some of their financing challenges. That is, since customers pay for their products over several years and in in local currency, PAYG start-ups may face significant working capital shortages as well as foreign exchange risks with products often purchased from abroad. In Uganda for example, the shilling fell 30% against the US dollar in 2015 alone.

As a result, there is now an increase in **synergistic partnerships between PAYG and MFI providers**, solving the local ecosystem component. Such partnerships have a potential to deliver PAYG to customers at greater scale and lower cost, for example by offering microfinance customers access to an add-on loan that can be added to their existing loan to access non-financial products such as a PAYG solar energy system.

Many MFIs however are still reluctant to offer energy products to new clients who have not yet proven their creditworthiness. This limits the degree to which PAYG energy loans can create more equal energy access. In addition, PAYG loans may enhance people's ability to earn a living or to save money, but in general the solar products are not income-generating as more traditional micro-finance loans are, which makes a PAYG loan in fact simply a form of consumer financing.[lviii]

MicroCred, which works in Senegal, Madagascar, Cote d'Ivoire and Mali, is one of the MFIs that allows customers to top up their loan to access other products and services. Its subsidiary, Baobab Plus, uses the MicroCred network to sell a variety of products that improve people's life on credit, financed by MicroCred. Recently it has also started selling them to new customers, using dedicated PAYG software which records activation and payments for a product and comes with lockout technology, which enables it to lend to clients with no credit history. By building up a good PAYG payment history, these clients can also qualify themselves over time for microfinance loans, while the solar lamp can be used as a guarantee. [lix]

Nonetheless, as the energy access market continues to expand rapidly, some MFIs have looked for different ways of **supporting the development of a local ecosystem**. MFIs can for example enter into a partnership with an energy access enterprise to offer financing for their products and for technical assistance, as many rural communities have had little experience with electricity. Energy lending can also be provided to intermediaries for on-lending. MFIs can offer conventional loans to provide working capital for energy access enterprises and for local retailer-service agents. Or they can purchase energy access products in bulk at reduced prices and on-sell them to partners.

Several MFIs have also started working with social enterprises specialized in **distributing and servicing products for the poor**. These include Project Dharma, Boond and Frontier Markets, all in India, which distribute a variety of customized products and services sold at a socially affordable price point to low-income rural households, ranging from water purifiers to pest control to solar lighting and efficient cookstoves.[lx]

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