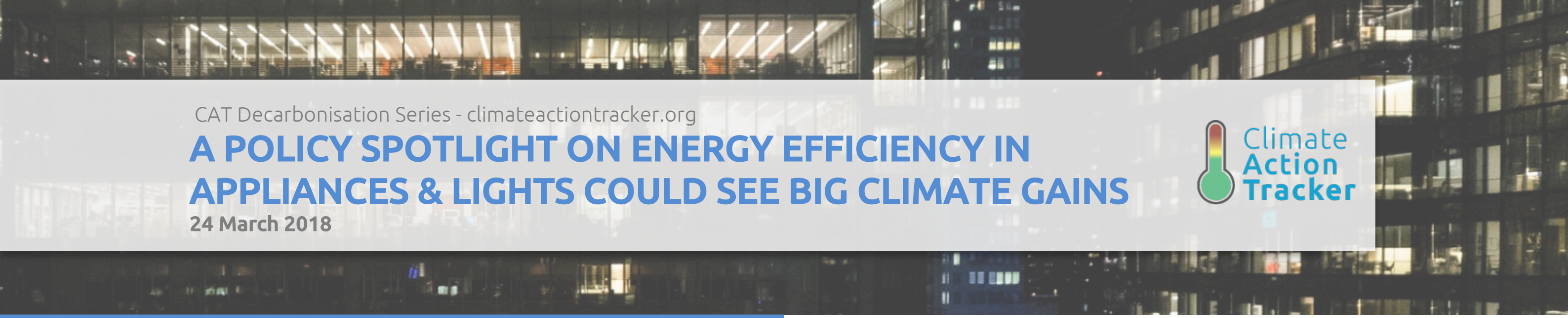

CAT Decarbonisation Series - climateactiontracker.org

# A POLICY SPOTLIGHT ON ENERGY EFFICIENCY IN APPLIANCES & LIGHTS COULD SEE BIG CLIMATE GAINS

24 March 2018

Climate Action Tracker

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## KEY MESSAGES

- Energy efficiency improvements for appliances and lighting is one of the key short term measures to support deep and rapid decarbonisation of the building sector[1] by 2030.
- Coupled with a low carbon power supply, existing highest energy performance and labelling standards for appliances and lighting could bridge the emissions gap required in the sector by 2030 to achieve the Paris Agreement temperature goal.
- Increasing the energy efficiency of appliances and lighting decreases final energy demand and will help to attain faster overall decarbonisation of the power sector, a crucial enabling factor to stay within a 1.5˚C warming limit
- The highest existing energy performance and labelling standards for appliances and lighting, applied globally, could save about 4,500 TWh in 2030, the equivalent of closing 1,140 average coal-fired power plants (600MW). Coupled with low carbon electricity, applying the standards globally could reduce emissions by 5.2 GtCO2 (-60%) in 2030 compared to a business-as-usual scenario. This is higher than the annual emissions of the entire European Union.
- To be effective, minimum energy performance standards need to be enforced, harmonised across regions and continually strengthened to keep up with technological progress. Adoption can be increased through labelling standards and incentives through public procurement.
- Policy design is crucial; both public and private actors need tailored initiatives that specifically address barrier(s) for energy efficiency uptake (financial, behavioural, market failures, etc.).

## INTRODUCTION

Energy efficiency in buildings is key to achieving early energy demand and emission reductions, in line with a 1.5°C long-term warming limit. Indeed, enhanced energy efficiency measures can tip the balance towards a successful implementation of the Paris Agreement, as one of the main differences between 1.5°C and 2°C emissions pathways is that 1.5°C pathways reduce emissions faster in the building sector (Rogelj *et al.*, 2015).

Indirect emissions (emissions from the use of heat and electricity) need to drop by 65–75% by 2030, and be phased out completely by 2050 (Rogelj *et al.*, 2015). Direct emissions also need to drop by 60–70% by 2030 and 80–90% by 2050 (Rogelj *et al.*, 2015), primarily through reductions in emissions from space heating, as we have discussed previously (Climate Action Tracker, 2016).

In this memo we focus on energy use for appliances and lighting[2], which today represent 55% of total emissions in the building sector, with the majority coming from the indirect emissions associated with electricity use. Reducing emissions from these end uses is a key contribution to decarbonising the overall building sector at the pace needed to achieve the Paris Agreement warming limit.

Technology development could play an important role in decreasing energy use and emissions, especially when looking at the potential of smart technologies and the Internet of Things (IoT). But a recent study (United Nations Environment Programme (UNEP), 2017b) has demonstrated that applying *existing* energy efficiency standards in buildings globally are among the most important measures to bridge the emissions gap in 2030.

Lighting and appliance energy efficiency is not only key to compensating the expected increase in electrical energy demand[3] by 2030 (+51% for appliances and +18% for lighting), it is also instrumental in supporting the transition towards a decarbonised energy system (with more and new electricity demand from electrification of transport and heating) and helping to achieve faster overall decarbonisation of the power sector as required

[1] By building sector, we refer to residential and services buildings. We do not include the full building life-cycle (material consumption, construction, wastes, etc.)

[2] Lighting end-use here includes energy consumed for interior or exterior lighting of dwellings today mainly powered by electricity. Appliances end-use here encompasses large (or major) appliances (sometimes also called white appliances or white goods), other (usually much smaller) appliances and air-conditioning equipment. (IEA, 2017a)

[3] 92% of energy used by appliances and lighting is electricity. The remining 8% should also be electrified

NEW CLIMATE INSTITUTE ECOFYS A Navigant Company CLIMATE ANALYTICS for a 1.5°C pathway. Energy efficiency measures also entail co-benefits such as fuel-cost savings that will significantly reduce the mitigation costs.

Our analysis assesses the potential impact if all governments were to adopt the highest existing energy performance and labelling standards for appliances and lighting by 2030.

## MINIMUM ENERGY PERFORMANCE STANDARDS & LABELLING

To stimulate the uptake and continuous development of efficient appliances and lighting, the combination of energy performance and labelling standards adjusted over time are the policies of choice.

Applying Minimum Energy Performance Standards (MEPS) is a policy measure that can be implemented at country or regional level to specify performance requirements for an energy-using device to reduce its life-cycle costs. They effectively limit the maximum amount of energy that may be consumed by a product, or the minimum level of efficiency in performing a specified task. By specifying the minimum acceptable efficiency levels, MEPS define which products can be marketed and sold (Molenbroek *et al.*, 2015).

Energy labelling standards can include a description and/or rating of the product energy use/efficiency. The goal of these labels is to better inform those purchasing the product, so that energy use (and resulting running costs) are taken into account, allowing a holistic comparison between products (Molenbroek *et al.*, 2015)


*Figure 1 Examples of MEPS and Energy Labelling standards in different regions*

Over 60 countries have pledged to adopt energy efficiency measures in the lighting and appliances sector (United Nations, 2016). For highest impact, these policies should aim at achieving net negative or (at least) zero costs for consumers (Siderius, 2014).

To further maximise the effects of MEPS and labelling standards, governments should also:

- Support capacity building and the institutional set-up required for implementation and enforcement of MEPS and labelling policies (to avoid mislabelling and check efficiency claims)
- Ensure monitoring of the resulting savings and continuous strengthening to incentivise technological improvement by manufacturers
- Make collective regional efforts to establish and harmonise standards, certifications and accreditation applying to appliances and lighting. Harmonisation allows to avoid the costs of duplicating testing and of non-comparable performance information and requirements (e.g. the Regional Efficient Lighting Strategy for Central America (United Nations Environment Programme (UNEP), 2017a)
- Ensure public procurement rules include energy performance and labelling standards so that the public sector sets an example to show how efficient products can eventually save money.

## SAVING ENERGY IS A KEY MEASURE TO REDUCE EMISSIONS

To understand the potential for emissions reductions from adopting the highest MEPS and labelling standards for appliances and lighting, we have developed three different energy use and emissions scenarios in four regions (World, European Union, South Africa and United States), and two building types (residential and commercial).

The three scenarios are defined as follows[4]:

- A “Business-As-Usual scenario” (BAU) which projects emissions evolution **in the overall building sector** in an unchanged policy context that would lead to a global 2.7°C increase[5].
- A “MEPS and Labelling Standards scenario” (Efficiency scenario), which projects emissions evolution based on how much energy would be consumed if highest existing MEPS and labelling standards regulations were enforced at global level by 2030[6].
- A “Efficiency and Decarbonising Electricity scenario”, which projects emissions evolution based on the above scenario and assumes the emissions factor of the electricity used is in line with the global “Beyond 2°C Scenario” (B2DS)[7]. While the definition of the B2DS scenario is not

[4] Detailed modelling methodology is included in Annex A
[5] Based on the energy use and emissions from the IEA Energy Technology Perspective’s (ETP) 2017 Reference Technology Scenario
[6] Based on assumptions from European Commission study (Molenbroek *et al.*, 2015)
[7] Based on the energy use and emissions factors from the IEA Energy Technology Perspective’s (ETP) 2017 Beyond Two Degrees Scenario

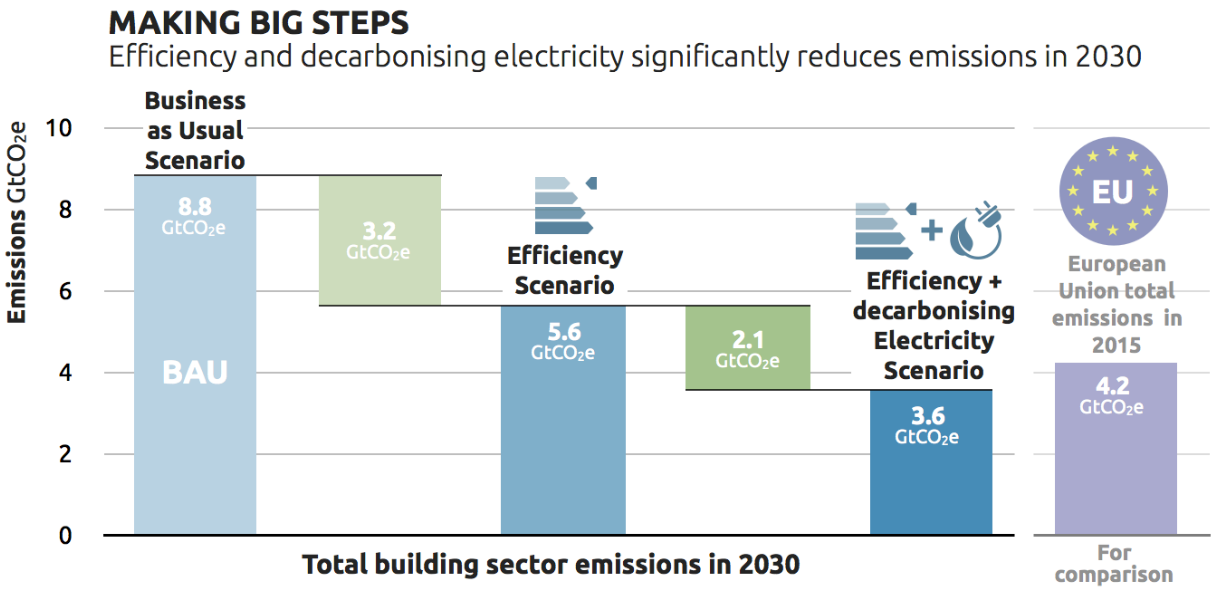


*Figure 2 Impact of $CO_2$ emissions reductions to the buildings sector in 2030 from different scenarios*

consistent with the Paris Agreement's 1.5 °C temperature limit, its $CO_2$ emissions trajectory for the global power sector is roughly in line with the least-cost 1.5 °C-consistent emission pathways (>50% chance by 2100) from integrated assessment models[8] (Rogelj et al., 2015).

In the BAU scenario, the total annual emissions in the building sector will remain at the same level (around 9 $GtCO_2$) in 2030. Applying highest existing MEPS and labelling standards globally for lighting and appliances in both residential and commercial buildings (Efficiency scenario), could save about 4,500 TWh of energy in 2030, the equivalent of closing 1,140 average coal-fired power plants[9]. This represents a decline of global building emissions to 5.6 $GtCO_2$ (-36% compared to BAU).

With decarbonisation of the electricity used (Efficiency and Decarbonising Electricity scenario), a further decrease is possible down to a level of 3.6 $GtCO_2$ in 2030 (-60% compared to BAU). This is similar to the annual emissions of the entire European Union. The reductions could be larger if the power sector decarbonises faster than assumed in the scenario.

Figure 3 shows the expected development of $CO_2$ emissions of the overall building sector at world level in the three scenarios as described above. See also Annex B for additional scenario results.

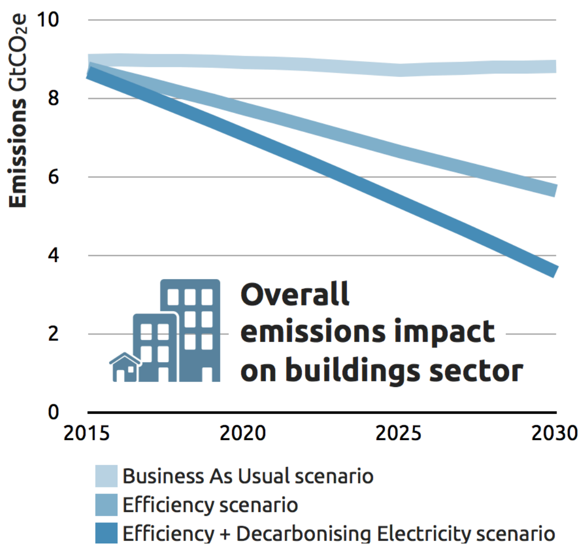


*Figure 3. Impact of $CO_2$ emissions savings in appliances and lighting on the overall building sector at world level ($GtCO_2$)*

## APPLIANCES

Our analysis shows the urgency of rapidly scaling-up action, as energy use linked to appliances is expected to increase by 51% at world level in a BAU scenario.

In both our efficiency scenarios, the assumption is that appliances-related efficiency improvements of 58% for residential buildings and 18% for commercial buildings at world level are possible by 2030. The scenarios consider the minimum realistic period it would take for all economies to adopt and implement the highest existing MEPS and labelling standards for appliances (typically assumed to be about five years i.e. from 2020 onwards), and the degree to which the stock of equipment in 2030 would be influenced by these regulations (resulting in differences of efficiency improvements at regional level).

[8] Global direct (end-use) emissions from buildings under a B2DS scenario are reduced by more than half compared to 2°C scenario by 2050 (equivalent to -83% below 2014 levels), in line with IAM results. Also global indirect emissions from electricity go below zero by 2050, in line with 1.5C pathways (Rogelj et al., 2015)

[9] With a capacity factor of 75%, a 600 MW power plant would produce 3.94 TWh in a year

Applying highest existing MEPS and labelling standards for *appliances alone* at a global level would enable a decrease in $CO_2$ emissions from buildings by 30% in 2030 (Efficiency scenario). With additional measures to decarbonise the power sector, the potential reduction reaches 54% (Efficiency and Decarbonising Electricity scenario).

At national level, appliance efficiency measures would have a diverse impact on building emissions (see table below). Building emissions in the EU and the US are expected to decrease by 34% and 23% by 2030 in a BAU scenario, respectively. Energy savings linked to MEPS and labelling standards in appliances could further decrease emissions of the sector by nearly 25% in the EU, and 30% in the US (Efficiency scenario). The Efficiency and Decarbonising Electricity scenario could decrease emissions by another 20% below BAU for the EU and 12% for the US.

In contrast, in South Africa, building emissions are expected to grow by nearly 10% by 2030. MEPS and labelling standards (Efficiency scenario) could help to stabilise and decrease emissions by more than 15% below BAU. Decarbonising the power sector would achieve greater results, with another 35% emissions reduction below BAU (Efficiency and Decarbonising Electricity scenario).

Table 1. Impact of CO2 emissions savings in appliances on the overall building sector for EU, United-States and South-Africa in 2030 compared to BAU scenario

| 2030 | Unit | Efficiency scenario | Efficiency + Decarbonised Electricity scenario |
|---|---|---|---|
| European Union | $GtCO_2$ | -0.18 | -0.33 |
| United States | $GtCO_2$ | -0.46 | -0.65 |
| South Africa | $GtCO_2$ | -0.02 | -0.06 |

## LIGHTING

In both our efficiency scenarios, the assumption is that, by 2030, it is possible to achieve lighting-related efficiency improvements of 60% for residential buildings and 14% for commercial buildings. Again, the scenario takes into account the minimum realistic period it would take for all economies to adopt and implement the highest existing MEPS and labelling standards for lighting (resulting in differences of efficiency improvement at regional level).

Applying highest existing MEPS and labelling standards for *lighting alone* at a global level would enable a 6% decrease in buildings' $CO_2$ emissions by 2030 (Efficiency scenario). With additional measures to decarbonise the power sector, the potential reduction would be 33% (Efficiency and Decarbonising Electricity scenario).

At a national level, the impact of the efficiency measures in lighting on building emissions is limited. But coupled with decarbonising electricity, the impact is important (even though results of the scenario include some overlap with appliances measures results). MEPS in lighting could decrease emissions of the lighting sector by 5% in the EU, 3% in the US and 5% in South Africa (Efficiency scenario compared to BAU). The Efficiency and Decarbonising Electricity scenario could decrease emissions of the sector by 27% in the EU, 20% in the US and 44% in South Africa below BAU.

Table 2. Impact of CO2 emissions savings in lighting on the overall building sector for EU, United-States and South-Africa in 2030 compared to BAU scenario

| 2030 | Unit | Efficiency scenario | Efficiency + Decarbonised Electricity scenario |
|---|---|---|---|
| European Union | $GtCO_2$ | -0.04 | -0.20 |
| United States | $GtCO_2$ | -0.05 | -0.31 |
| South Africa | $GtCO_2$ | -0.005 | -0.05 |

## CHALLENGES FACING UPTAKE OF EFFICIENT APPLIANCES & LIGHTING

Barriers to adopting more efficient appliances and lighting can be broadly grouped into:

- **financial barriers** (higher upfront costs for more efficient appliances and lighting, often accompanied by lack of access to finance to allow purchase of higher priced appliance),
- **market failures** (such as imperfect information about energy savings) and
- **behavioural and organisational barriers** (tendency to ignore small opportunities for energy savings).

### Case Study: zero subsidy program in India

The UJALA program in India aims to address the financial barrier of higher cost of LEDs: it is a zero-subsidy program that has sold more than 230 million LED bulbs to Indian households since its launch in 2014, by procuring bulbs through competitive bidding, thereby enabling it to bargain and obtain significant discounts from manufacturers. It has resulted in electricity savings of more than 30 TWh annually and an avoided peak demand of 6 GW. The demand for LED bulbs has increased by 50 times since 2014, accompanied by a drop in retail market price by over 60% (Chunekar, Mulay and Kelkar, 2017).

Energy access is also a decisive factor determining the uptake of efficient lighting solutions in some regions.

Personal preference for the warmer, natural light from inefficient, incandescent lamps has been a barrier for the uptake of LEDs initially, although newer LEDs now come in a range of 'warm' colours. A consumer preference for the *shape* of incandescent lights is being addressed through innovative so-called filament LEDs, whose market is valued at $20 billion globally by 2020 (Bloomberg, 2018).

Rebound effects [10] of energy efficiency measures can be as high as 10–30% of projected energy demand reduction (Directorate General for Internal Policies (European Parliament), 2016). Economy-wide cap-and-trade systems as well as energy and carbon taxes, when designed appropriately, appear to be the most effective policies in setting a ceiling for emissions and thus addressing energy use across the economy (van den Bergh, 2015; Vivanco, Kemp and van der Voet, 2016).

## PLAY ON EMOTIONS: BEHAVIOURAL AND TECHNOLOGY SOLUTIONS CAN UNLOCK EFFICIENCY POTENTIAL

To unlock the large efficiency potential and overcome the barriers spelt out above, both public and private actors need tailored initiatives/undertakings.

As a first guidance, successful policymaking and business initiatives should account for human cognitive biases, i.e. natural tendencies to ignore rules, regulations, incentives, and penalties.

[10] "The rebound effect – the phenomenon that an increase in energy efficiency may lead to less energy savings than would be expected by simply multiplying the change in energy efficiency by the energy use prior to the change"

Emotions are an often-overlooked area of economics and, by extension, also policymaking.

The UK government, which established its own behavioural insights team, used insights and evidence from behavioural economics and psychology to help its internal departments successfully meet the Prime Minister's pledge to reduce their energy emissions by over 10% in just one year (Behavioural Insights Team, 2011). Among other tactics, they used social norms as motivation, e.g. by publishing monthly performance league tables that were discussed by the Cabinet Secretary, or by launching a competition among HQ buildings to see who could save the most energy, and circulating details of how the winning department achieved savings.

Egypt also used behavioural insights for a successful communications campaign, making consumers aware of energy use (World Government Summit, 2018).

The examples highlight the crucial role of policy design and make it clear that any public awareness and acceptance campaign should take these insights into account to optimise impact.

Beyond public buy-in, enforcement is also key to ensure success of the energy performance and labelling standards policies. As an example, EU regulation on energy performance makes it obligatory to display energy labels for all appliances as prominently on a website as they are in shops. But a study found that up to 10% of Europe's expected energy savings by 2020 could be lost as a result of non-compliant products (ECOS, 2017).

Technology innovations and smart appliances may also positively contribute to saving energy.

Companies such as San Francisco-based OhmConnect operate as "choice architects". They run an app which capitalises on behavioural insights, rewarding California utility customers who dial back energy usage during times of peak demand to avoid the switch on of old fossil fuel based reserve plants. When the energy demand on the grid is high, it sends users messages inviting them to cut down on energy use for an hour.

Aside from the monetary reward (users earn between $70 and $150 a year) (Yale Climate Connections, 2018), OhmConnect uses "loss aversion," building on the insight that people are more likely to try to avoid losses than strive for gains. Mechanisms include slightly guilt-inducing messages or deducting points for non-participation.

E.ON and First Utility also make use of behavioural insights to nudge[11] their consumers into saving energy (see box below).

**E.ON and First Utility: smart meters and nudges[12]**

- E.ON and First Utility use information collected from smart meters to allow customers to compare their energy usage with others from their neighbourhood
- This nudges customers towards optimising their energy consumption
- Smart meters also can help to communicate the price of using energy dynamically, incentivising customers to use power during off peak hours where possible

As highlighted above, smart meters can significantly contribute to demand side management. However, there are potential drawbacks that need to be considered:

- Security vulnerabilities of smart devices
- Lack of standardisation in communication protocols across different companies
- Privacy concerns for real-time measurements
- Potential increase of energy use due to the standby consumption of new "smart" (automation and control) devices.[14]

## BEYOND EFFICIENCY 1: SWITCHING OFF THOSE UNNECESSARY LIGHTS

Beyond energy efficiency measures, policies that target the usage of energy offer tremendous savings potential, as can be illustrated in particular for lighting.

In France, lighting installations of non-residential buildings must be switched off at night, to reduce both energy waste and light pollution. It is estimated that this measure's energy savings are comparable to the annual electricity consumption of 750,000 households, lowering $CO_2$ emissions by 250 kt and saving French businesses EUR 200 million in energy costs (European Commission, 2017).

The concept of switching off lights when they're not needed is also interesting for municipalities. In conjunction with technological advances, smart street lighting is becoming increasingly attractive across the world, enabling the management of street lights remotely, including failure notifications, and measurement of energy use (Philips, 2018).

Cities as diverse as Los Angeles, Buenos Aires, Cardiff, Jakarta, Toronto and many more are currently experimenting with smart lighting (ibid.).

With sufficient financial support to allow leapfrogging to clean technologies, in this case LEDs, this is also a viable option for least developed countries and small developing islands states – as illustrated by Jamaica, where the Smart Light Emitting Diode (LED) Street Light Programme aims to reduce energy costs and smart LED lighting technology offers remote reading of consumption of each lamp. (Caribbean Development Bank, 2017).

## BEYOND EFFICIENCY 2: 'OFF-GRID' NO LONGER EQUALS 'LIGHTS OFF'

Over a billion people worldwide remain without access to electricity, with half of these people living in sub-Saharan Africa (Sustainable Development Knowledge Platform, 2017).

For lighting in particular it is estimated that "1 in 3 people worldwide obtain light with kerosene and other relatively pricey fuels, paying 15% of total global lighting costs but receiving only 0.2% of resulting lighting energy services" (CLASP, 2017).

Kerosene not only is expensive, using it for lighting is very inefficient, and also has significant negative health impacts.

Off-grid energy solutions, in particular solar lighting, have - and continue to offer - tremendous opportunities in avoiding GHG emissions, while stimulating social and economic development.

These lighting solutions can be combined with micro-grids with 100% renewable energy supply to increase energy access, in particular (but not limited to) to remote rural areas, as well as small developing islands states (SIDS).

[11] Nobel prize winner Thaler defines a nudge as "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives." (Thaler and Sunstein, 2009)

[12] http://www.telegraph.co.uk/finance/personalfinance/energy-bills/11491757/Four-ways-your-energy-firm-nudges-you-to-be-more-green.html

[14] The IEA estimates an increase in standby consumption from 7 to 36 TWh between 2015 and 2025 from smart devices (Friedli *et al.*, 2017)

**Solar Microgrids – Nigeria and India**[15,16]

- Community Energy Social Enterprises Ltd and Renewvia Energy Corporation have signed an MoU to provide solar power to 25 communities across Nigeria using local microgrids.
- CESEL and Renewvia aim to sell electricity to microgrid customers at a less expensive price than current generation using diesel.
- Freyr Energy, an Indian solar provider firm has set up more than 50 solar microgrids for rural tribal inhabitations.
- Microgrids power the entire inhabitation with sufficient battery backup for three days.

## CO-BENEFITS

The selling points for energy efficiency measures are manifold: they deliver energy and $CO_2$ reductions while also reducing total costs (IEA 4E, 2016).

Reduction in energy use also results in reduced power sector impacts, such as air pollution, especially from coal-fired power plants. Ambient, or outdoor, air pollution accounted for 3 million premature deaths in 2012 (Asia and the Western Pacific accounted for almost 90% of these), with this number being expected to grow to 4.5 million by 2040 (UNDP, 2016). Reducing energy needs for appliances and lighting can contribute to reducing these premature deaths in addition to phasing out fossil fuels in this timeframe.

More efficient appliances conserve not just energy but also other natural resources, such as water. It is estimated that the EU's Eco-design and labelling programmes for washing machines and dishwashers will save 336 million $m^3$ of drinking water by 2020, equivalent to 1.2% of the EU residential total use (IEA 4E, 2016). In the US, it is estimated that the standards for residential clothes washers in effect since 2015 will save 11,470 million $m^3$ of water from 2015 to 2044 (US Department of Energy, 2008).

Energy efficiency programmes create incentives for innovative solutions within competitive markets, leading to market expansion and/or growth. In the EU it was estimated that by 2014, energy efficiency programmes created 0.8 million direct jobs, with a further 3–5 times the number of indirect jobs created (IEA 4E, 2016).

Improving energy efficiency is a key element of achieving the Sustainable Development Goal 7 (SDG 7) of affordable and clean energy access. SDG 7 explicitly calls for doubling the energy efficiency improvement rate by 2030 (World Bank, 2016).

The SDGs provide a different view on the rebound effect in regions where the effect is linked with the alleviation of energy poverty. "A rebound effect which is driven by a household's choice to increase comfort and improve conditions for health, well-being and productivity is unlikely to be considered a negative effect overall" (International Energy Agency (IEA), 2014). This is also an important means to ensure *good health and well-being*, and *access to affordable and clean energy* (SDG 3 and 7 respectively).

## CONCLUSION

To keep global warming within the limit specified by the Paris Agreement, both direct and indirect emissions from energy use in buildings need to be phased out by 2050.

Energy efficiency of buildings is one of the key short-term measures that will enable deep and rapid decarbonisation. Based on measures that can be achieved at net zero costs for consumers and substantial co-benefits, it is an obvious business case with tremendous opportunities for both manufacturers as well as customers.

Coupled with a decarbonising power supply, existing highest energy performance and labelling standards for appliances and lighting are a key element to achieving the Paris Agreement goals. The scenarios modelled in this study show a potential to reduce global emissions between 3.2 and 5.2 GtCO2 in 2030 compared to a business-as-usual scenario. This represent a reduction of between -36% and -60% of the building sector's in 2030.

Increasing appliance and lighting energy efficiency contributes to limiting final energy demand and will help achieve faster overall decarbonisation of the power sector, a crucial enabling factor to meeting the Paris Agreement's 1.5°C limit.

Efficiency improvements, together with renewable energy, are a key strategy for providing access to affordable and clean energy for all (SDG 7). This includes the potential for off-grid and micro-grid renewable energy options.

[15] https://cleantechnica.com/2017/03/02/10000-nigerian-homes-get-electricity-solar-microgrids/
[16] http://www.newindianexpress.com/cities/hyderabad/2018/feb/21/give-us-today-our-daily-energy-1776353.html

## ANNEX A: METHODOLOGY

Our analysis of appliances and lighting in buildings related energy use and emissions is based on the following approach:

- The model considers CO2 emissions only, both direct and indirect (electricity and heat). The base year is 2014.
- The model tracks energy use and emissions up to 2030 for the following categories:
    - Appliances (inc. Air Conditioning) and Lighting;
    - Residential and commercial buildings;
    - World, EU, USA and South-Africa.
- Reference energy and emissions (the "Business-As-Usual scenario") are based on ETP 2017 reference technology scenario, which is in line with a 2.7-degree pathway (according to IEA ETP).
- The "Efficiency scenario" calculates energy and emissions evolution of the building sector based on how much energy would be saved in appliances and lighting when energy efficiency measures are applied for products used at the level equal to the most ambitious currently promulgated Minimum Energy Performance Standards (MEPS) or at the level equal to the most ambitious currently promulgated energy label threshold (i.e. the so-called "High Label" requirement) in 2030, whichever is most ambitious (assumptions based on European Commission study (Molenbroek *et al.*, 2015)). This is modelled separately for all regions, end-uses and type of buildings in 2030, assuming a linear reduction from the 2014 baseline.
- The "Efficiency and Decarbonising Electricity scenario" calculates energy and emissions evolution of the building sector based on the same energy efficiency assumptions but applying the emission factor of a decarbonising power sector based on ETP 2017 beyond-two-degree scenario, which is in line with a 1.5 to 2-degree pathway.
- In both our low carbon scenarios, we use the marginal emission factor to calculate emissions savings from electricity reductions. To define the marginal emission factor, we use the weighted-average emission intensity of fossil-fuel based power plants, as these are the emissions that are commonly avoided when emission reduction measures are taken (Blok and Nieuwlaar, 2016). Since fossil-fuel power plants are higher on merit order curve (higher variable costs) than other plants including nuclear and most renewables, these plants will be taken out of operation first when demand decreases. This approach is still valid even in a power system with a very high share of renewable energy generation of the total electricity demand. It has been demonstrated that even with 80% renewable share, the conventional power plants still drive the marginal emission factor in most of the case (BEE, 2013).

## ANNEX B: ADDITIONAL RESULTS

Applying highest existing MEPS and labelling standards for *appliances* at a global level would enable a decrease in $CO_2$ emissions from buildings by 30% in 2030 (Efficiency scenario). With additional measures to decarbonise the power sector, the potential reduction reaches 54% (Efficiency and Decarbonising Electricity scenario).

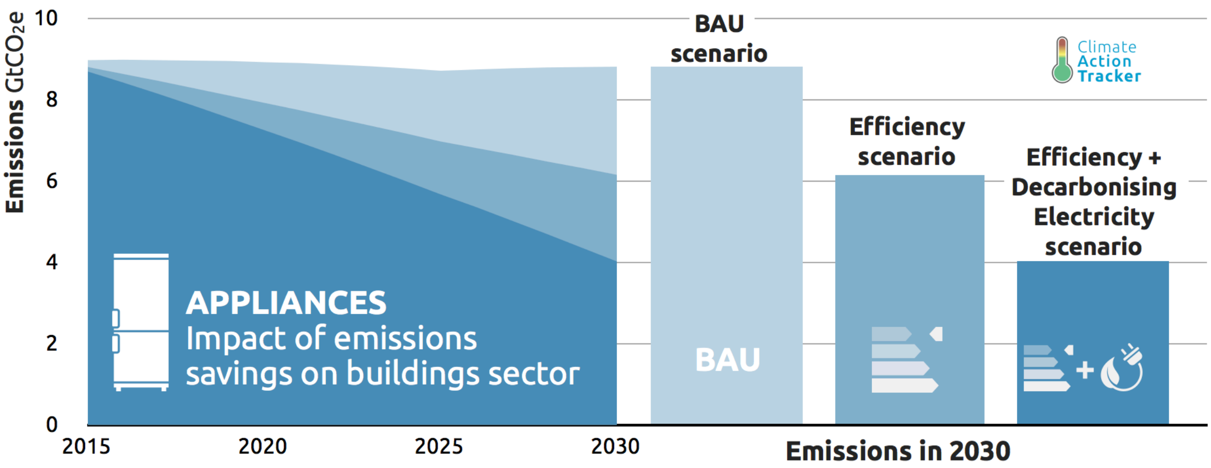


*Figure 4 Impact of $CO_2$ emissions savings in **appliances** on the overall building sector at world level ($GtCO_2$)*

Applying highest existing MEPS and labelling standards for *lighting* at a global level would enable a 6% decrease in $CO_2$ emissions of buildings by 2030 (Efficiency scenario). With additional measures to decarbonise the power sector, the potential reduction would be 33% (Efficiency and Decarbonising Electricity scenario).

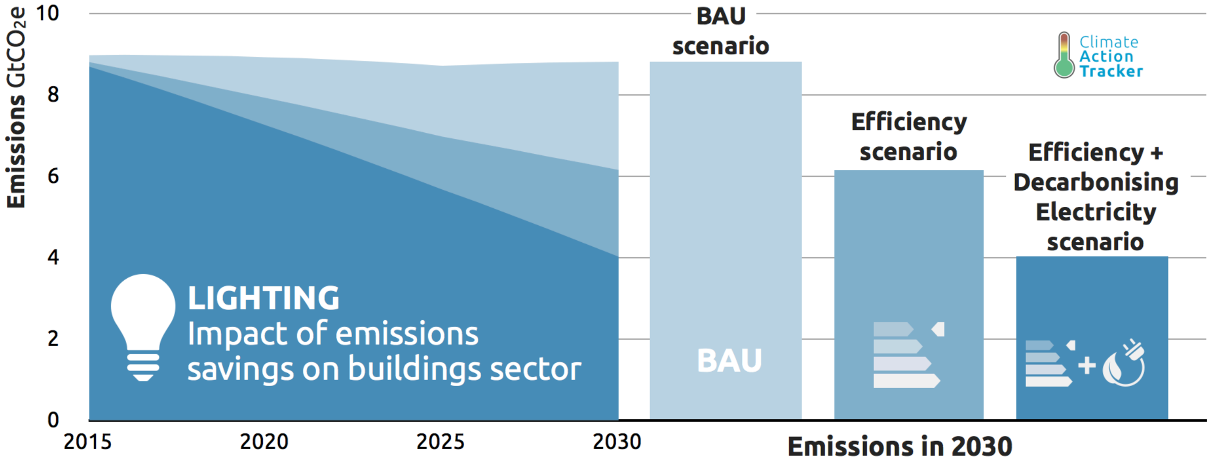


*Figure 5 Impact of CO2 emissions savings in **lighting** on the overall building sector at world level ($GtCO_2$)*

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