# Second Batch of Domestic TOP TENs List

## U.S. Building BAT List

### BAT1:Condensing gas tankless water heaters

This type of water heaters provides end-users with instantaneous,on-demand hot water. To meet end-user demand in hot water,condensing gas tankless water heaters require larger burners.Compared to conventional,storage water heaters,this type of water heaters does not require water storage and thus eliminate standby losses (York,2014).

In our modeling assumptions,tankless water heaters affect water heating demand in single and multi-family residential houses. Results show that on a national level,tankless water heaters can save about 34% of residential water heating demand. This accounts for about 0.4 Quads of both technical potential and maximum adoption scenarios,which is consistent with other sources (Navigant,2017b reports technical potential for tankless water heaters as 0.459 Quads in 2030).

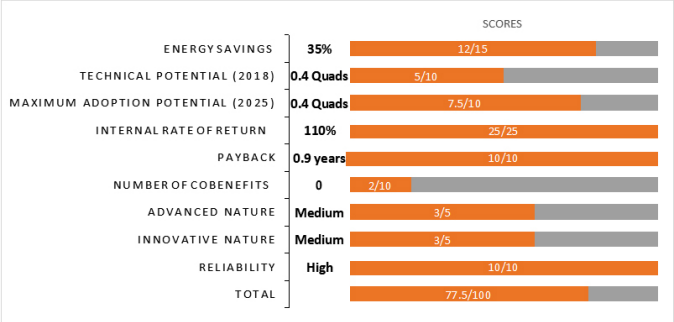


Figure: Results of evaluation of Condensing Tankless Water Heaters

### BAT2: Occupant responsive lighting

Responsive lighting systems improve the energy efficiency of office buildings. Using various sensors,management systems,and control components,these systems allow facility managers of commercial buildings to provide high-quality lighting services that meet individual preferences and

light needs while reducing energy demand and costs (GSA,2012a).

Occupant responsive lighting technologies affect lighting electricity consumption in commercial buildings. We estimate that under technical potential adoption scenario,occupant responsive lighting technologies can save 0.6 Quads. In case of Maximum adoption potential scenario,the savings potential is about 0.4 Quads in 2025. Overall,deployment of these technologies can reduce lighting consumption by 44% with a simple payback period of about 8.5 years. These results are consistent with those reported in our reference sources (for example,(DOE/EERE,2017a).

In addition,Occupant Responsive Lightning can improve occupant comfort,improve lifetime of other components,and provide demand response capabilities.

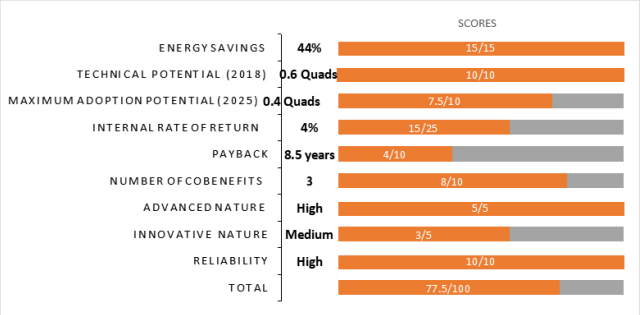


Figure: Results of evaluation of Occupant Responsive Lighting

## BAT3: Heat pump water heaters

Heat pump water heaters work as a refrigerator in reverse. Accumulating heat from surrounding environment,a heat pump moves this heat into a tank to heat water. Since heat pump water heaters move heat rather than generating it,they are 2-3 times more energy efficient compared to traditional electric resistance water heaters (DOE,2018b). We consider only air-source heat pumps in this study.

Heat pump water heaters affect water heating electricity consumption in single and multi-family houses. We estimate that heat pump water heaters can reduce residential energy consumption for water heating by 59%. Under the technical potential adoption scenario,we estimate potential energy savings as 0.7 Quads in 2018 and 0.4 Quads in 2025 under maximum adoption scenario. Our estimated energy saving potential under the maximum adoption scenario is lower than reported in other sources ((Navigant,2017a) reports the annual saving potential for this technology as 0.8 Quads source energy in 2030). The difference in estimates can be due to different energy efficiency indicators used for modeling in our study and other sources.

However,our estimated simple payback period (4.1 years) is consistent with payback reported in other sources ((Navigant,2017a) reports a payback period of less than 5 years for heat pump water heaters). The literature does not mention co-benefits for this technology,which led to a low score for this component in scoring.

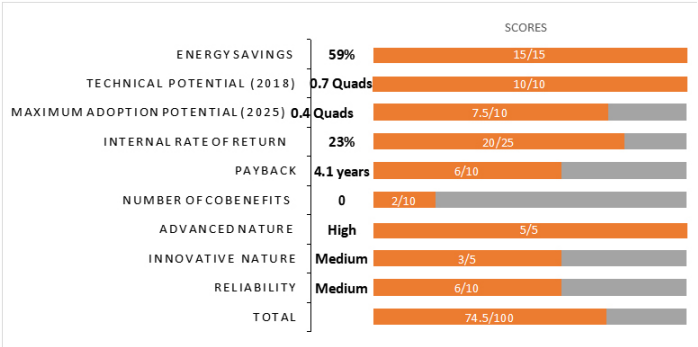


Figure : Results of evaluation of Heat Pump Water Heaters

## BAT4: LED downlight luminaires

In our study,we assessed LED downlight luminaires as a replacement for incandescent and fluorescent technologies in the residential sector. Advanced LED technologies,readily available on the commercial market,can deliver significant energy and cost savings to end-users.

We estimate that LED downlight luminaries can reduce residential electricity consumption for lighting by 82%. This constitutes 0.18 Quads of savings in 2018 under the technical potential adoption scenario and 0.13 Quads in 2025 under maximum adoption scenario. Perrin and Davis (2015) reported that LED downlight luminaires adopted nationwide in both the commercial and residential sectors can save 0.278 Quads. Given that we only assessed the residential sector,which accounts for 46% of total lighting consumption in 2015 (EIA,2017c),our savings estimates are similar to other studies. High savings and a short simple payback period led to an attractive internal rate of return (IRR) and hence high scores for these parameters. In addition to energy and cost savings,LED downlight luminaires improve occupant comfort.

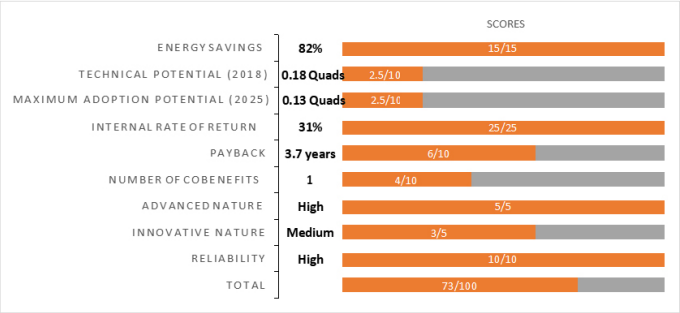


Figure: Results of evaluation of LED Downlight Luminaires

## BAT5:Building energy management and information systems

During the literature review stage,we identified three similar and potentially overlapping technologies: 1) Cloud-based energy information systems,2) Traditional building automation systems,and 3) Web-based lighting management systems. BTO staff suggested combining these specific technologies into one category.

Building energy management and information systems provide building facility managers with the ability to monitor and control the energy performance of various systems such as heating,ventilation,air conditioning,and lighting.

Among co-benefits for this technology,we identified the following: 1) Improved lifetime of other components;2) Peak demand reduction. 3) Reduced maintenance needs.

The modeling results show that simple payback period of this technology can be about 3.7 years,which in turn also lead to attractive IRR value.

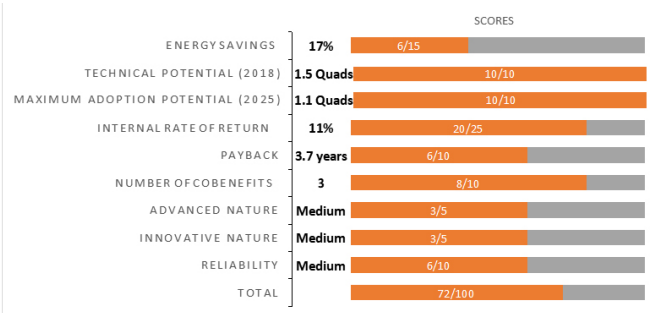


Figure: Results of evaluation of Building Energy Management and Information Systems

## BAT6:Fixed window attachments

During the re-categorization stage,we merged three

separate technologies (Hi-R window panel[1],Switchable film,and Window attachments[2]) into one category,"Fixed window attachments".Fixed window attachments affect the heating and cooling loads of buildings.

We estimate that this technology can reduce heating and cooling needs of buildings (both residential and commercial) by about 40%. The technical energy savings potential of this technology exceeds 1.78 Quads (1.22 Quads for residential and 0.56 Quads for commercial sectors).

We estimate that fixed window attachments are on average 40% more efficient than the baseline energy performance of building windows. The total technical savings potential is more than 1.7 Quads in 2018,and the maximum adoption potential is 0.77 Quads in 2025. The large share of heating and cooling energy use in total building energy demand can explain such relatively large savings potential. However,a long payback period and negative IRR resulted in low scores for these parameters.

We identified the following co-benefits of fixed window attachments: 1) Improved occupant comfort 2) Improved lifetime of other components 3) Noise reduction,and 4) Peak demand reduction.

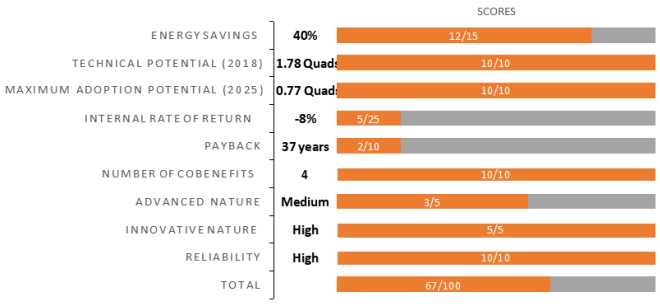


Figure : Results of evaluation of Fixed Window Attachment

## BAT7:Advanced rooftop unit controls

Advanced rooftop unit (ARU) controls allow facility managers of commercial buildings to monitor,control and adjust heating,cooling and ventilation services provided by packaged rooftop HVAC systems. Specifically,using advanced control and monitoring strategies ARU controls allow building managers to improve occupant comfort while reducing operation and maintenance costs and delivering significant energy savings.

We estimate that ARU controls can save 56% the energy use compared with standard packaged HVAC systems with constant speed-supply fans. Our estimate is consistent with a savings rate of ARU controls provided by DOE/EERE (2017b). Our modeling also shows that when deployed,ARU controls can reduce HVAC energy use of commercial buildings by almost 0.5 Quads in 2018 under Technical potential adoption scenario and by 0.26 Quads in 2025 under Maximum adoption scenario. Co-benefits of ARU controls include improved comfort,indoor air quality,an improved lifetime of other components,and reduced peak demand.

Notes:

[1] These are often referred to as storm windows.

[2] These are window exterior and interior products that are designed to improve energy efficiency,daylighting quality,optical and thermal performance as well as overall occupancy comfort.

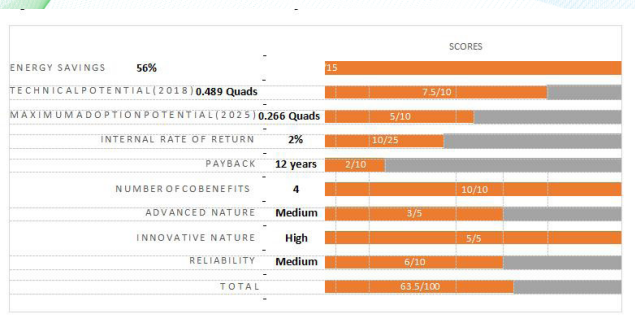


Figure: Results of evaluation of Advanced Rooftop Unit Controls

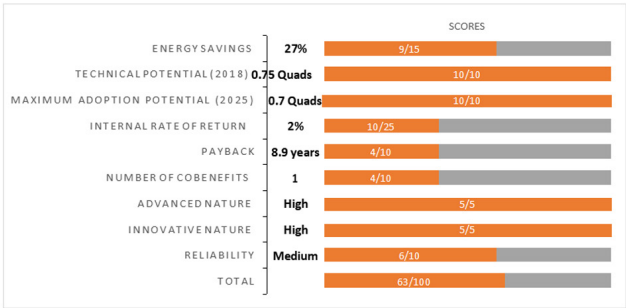


Figure: Results of evaluation of Plug Load Control Devices

## BAT8:Plug load control devices

Plug load control devices help facility managers and building owners in managing the energy consumption of various devices and office appliances powered by the traditional plug. Limited information is available on the energy consumption of plug load control devices in the residential and commercial sectors (Metzger,2012). In addition,Scout 0.2 does not include applicable baseline data. For that reason,we were not able to model this technology. Instead,we prepared our own estimates on potential energy savings,IRR and payback period in the residential and commercial sectors.

We used advanced power strips as a proxy here for plug load control devices to estimate the technology's energy savings potential. We estimated that plug load control can result in 0.75 Quads of savings under the technical potential scenario and 0.7 Quads in 2025 under the maximum adoption scenario. In addition to their relatively high energy savings,plug load control devices can reduce peak demand.

## BAT9:Comprehensive attic update

Attic insulation and other attic weatherization measures can significantly reduce the heating and cooling load of residential buildings. In our modeling,we assumed that existing residential houses upgrade their attic to meet the requirements of 2012 International Energy Conservation Code. Specifically,when attic insulation completed,the attic should achieve following R-values:

- Climate Zone 1: R-30.
- Climate Zone 2-3: R-38
- Climate Zone 4-8: R-49 (ENERGY STAR,2014).

We estimate that roof insulation of existing residential houses will deliver 15% of energy savings and decrease energy use by almost 0.2 Quads under Technical Potential scenario and by 0.08 Quads in 2025 under Maximum adoption scenario. These estimates are lower than reported in the literature. For example,Navigant (2017b) reports technical potential savings of attic insulation and sealing as 0.7-1.1 Quads per year. The difference can be due to different baseline assumption in Scout modeling tool and methods to estimate savings potential by other sources.

Apart from energy and cost savings,comprehensive attic update measures improve occupant comfort,extends the lifetime of other components and reduces noise.


Figure: Results of evaluation of Comprehensive attic update

## BAT10:Dynamic solar control systems

Dynamic solar control systems in residential and commercial buildings provide occupants with multiple benefits. These systems adjust lighting,prevent overheating of surface area inside premises while improving comfort and delivering cost and energy savings. Dynamic solar control systems include automated shades,as well emerging technologies such as dynamic glass glazing. As noted before,this report focuses only on commercially available technologies,even though we recognize the potential future market for emerging technologies.

Deployment of dynamic solar control systems primarily affects heating and cooling load of buildings. We estimate that dynamic solar control systems on average can save almost 20% of the energy used in both commercial and residential buildings. Our modeling shows that the technical potential for the residential sector is 1.2 Quads and 0.8 Quads for commercial. The maximum adoption potential in 2025 is 1.1 Quads. However,the long payback period and negative IRR resulted in lower scores for these evaluation categories. Regarding co-benefits,dynamic solar control systems can improve the lifetime of other components,reduce peak demand and improve occupant comfort. ■

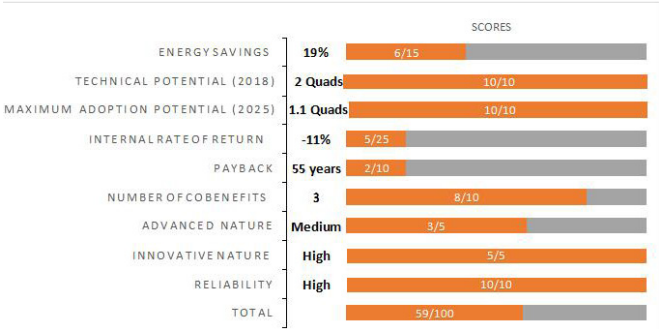


Figure: Results of evaluation of Dynamic solar control systems