**Energy Demand Reduction**

# ENME 489X

# Group 1

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## Background and Purpose of the Report

The first part of this report deals with the ideas that can be incorporated in a household to reduce energy usage and increase the energy savings as efficient energy use is one of the most important aspects of energy sustainability. The primary objective of this report is to come up with ideas that to reduce energy usage. The energy savings can be realized through increased efficiency or by energy generation to reduce energy bills.

The second part of the report deals with identifying the impact of adding an electric vehicle to the findings in Part A. The objective is to analyse whether the saved electricity can be used to charge an electric car leading to energy and gas savings and how it will impact the cost/benefit of the ideas suggested in Part A. The secondary objective is to analyze the change in $CO_2$ emissions due to these savings.

The motivation of this report and behind our selection of ideas is our awareness of increasing energy demand and consumption both in the US and globally. Having learned about the growth of energy demand in the next few decades, solutions must be developed to reduce household demand. While no single household action will effectively reduce energy demand, each action sums to a greater collective. If 10% of US households adopt one of these following ideas, a significant portion of energy consumption can be curbed. This report seeks to explore solutions further and make readers aware of those solutions.

## Structure of the Report

Part A- Energy Demand Reduction

The four ideas that can be incorporated to reduce energy demand are :

- Idea 1: Programmable Thermostats
- Idea 2: Geothermal Heat Pump
- Idea 3: Window Attachments for shade

Part B- Identifying the impacts of adding an electric car

- Can the saved energy being used to power the car?
- Impacts on the cost of the ideas suggested in part A
- Impacts on the economics of the system
- Lastly the amount of $CO_2$ emissions due to the use of an electric car

## Part A - Energy Demand Reduction

In 2014, the International Energy Agency predicted estimates of world electricity generation by source in the *World Energy Outlook 2014*. Among continued growth in coal and natural gas usage, the most surprising statistic is the overall energy generation. In 2012, global generation was 22.7 million TWh. In 2020, global generation is expected to jump to 27.7 million TWh. Finally, it will nearly double over the next 20 years to 40.1 million TWh. Electricity demand will rise along with and cause a rise in electricity generation. This justifies efforts in energy demand reduction. As a global population, any action that lowers energy demand must be taken. Energy demand reduction leads to cost savings and a reduced carbon footprint in households. It also offers peace-of-mind to those that choose to use more efficient systems.

Without the improvements in global energy efficiency over the last 40 years, global carbon emissions would be 30 to 50% higher. But the achievement of global carbon targets requires a much faster rate of improvement - up to six times faster than has been achieved over the last decade. Similar changes are required in the USA, since current projections of the required rate of demand reduction have no historical precedent. This demonstrates the need for a coherent programme of research into energy demand. According to the EIA, a typical south atlantic household uses 67.5 million Btu a year or 19782.3 kWh a year.

Our following ideas seek to offer methods for households to decrease their energy demand usage, reduce their carbon footprint and enjoy cost savings. Programmable Thermostats are relatively standard in all modern homes and offer vast cost savings. Geothermal Heating and Cooling uses thermal energy from the ground to heat water as it circulates through a home. While initially costly to install, saving are realized in the long term. Lastly, window attachments prevent overglazing and limit a home's internal temperature by limiting the amount of sunlight let in.

## Idea 1: Programmable Thermostats

In the United States, the first oil crisis in 1973 inspired national attention at energy consumption. The first energy code was written in 1978 for the state of California, requiring clock or "setback" thermostats in new homes. Studies from the 1970s suggested that **a daily 8-hour reduction in temperature during sleeping hours could bring a 1% reduction in natural gas consumption for each Fahrenheit degree**, and in 1995 the EPA started promoting programmable thermostats as a way to save anywhere from 10 to 30% off a home's heating and cooling bill[1].

**What is a programmable thermostat?**

A programmable thermostat is a thermostat which is designed to adjust the temperature according to a series of programmed settings that take effect at different times of the day. Programmable thermostats may also be called setback thermostats or clock thermostats.

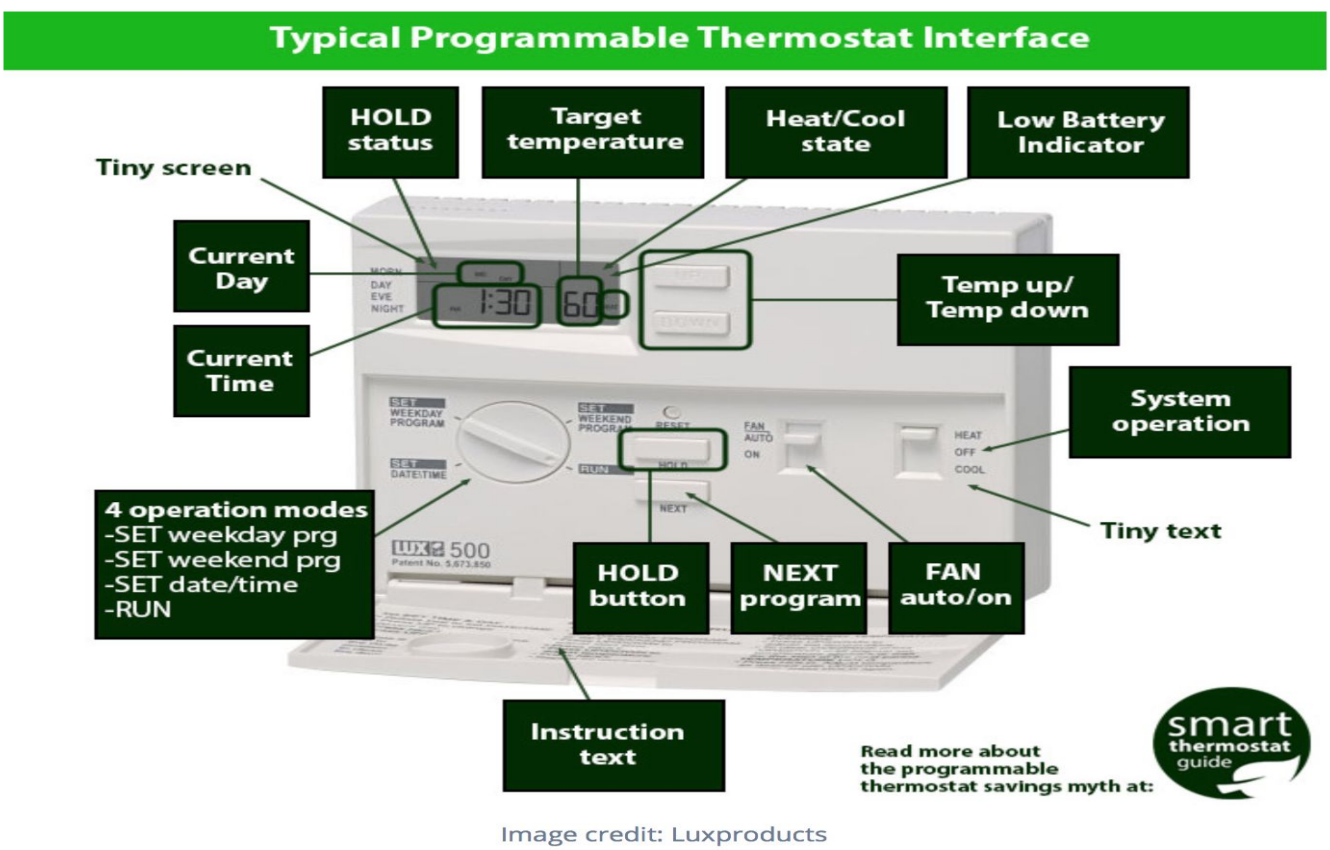



*Fig 1: A Programmable Thermostat*

**Benefits of using a programmable thermostat**

A programmable thermostat provides two main benefits. First, programmable thermostats make it easy to lower the temperature in our home while we are away or sleeping. Second, the more frequent use of lower temperatures will result in measurable and significant energy and cost savings. Generally speaking, if we lower the temperature in our home by one degree Celsius (1°C) over an eight hour period for the entire heating season, we can save approximately two percent a year on the heating portion of our energy bill. Thus the more we lower the temperature, the more money we will save.

For example if a normal household uses 50 gigajoules of energy each year for heating and the owner decided to lower the temperature by 5 degree Celsius at night. This adjustment will save 5 gigajoules of natural gas each year.

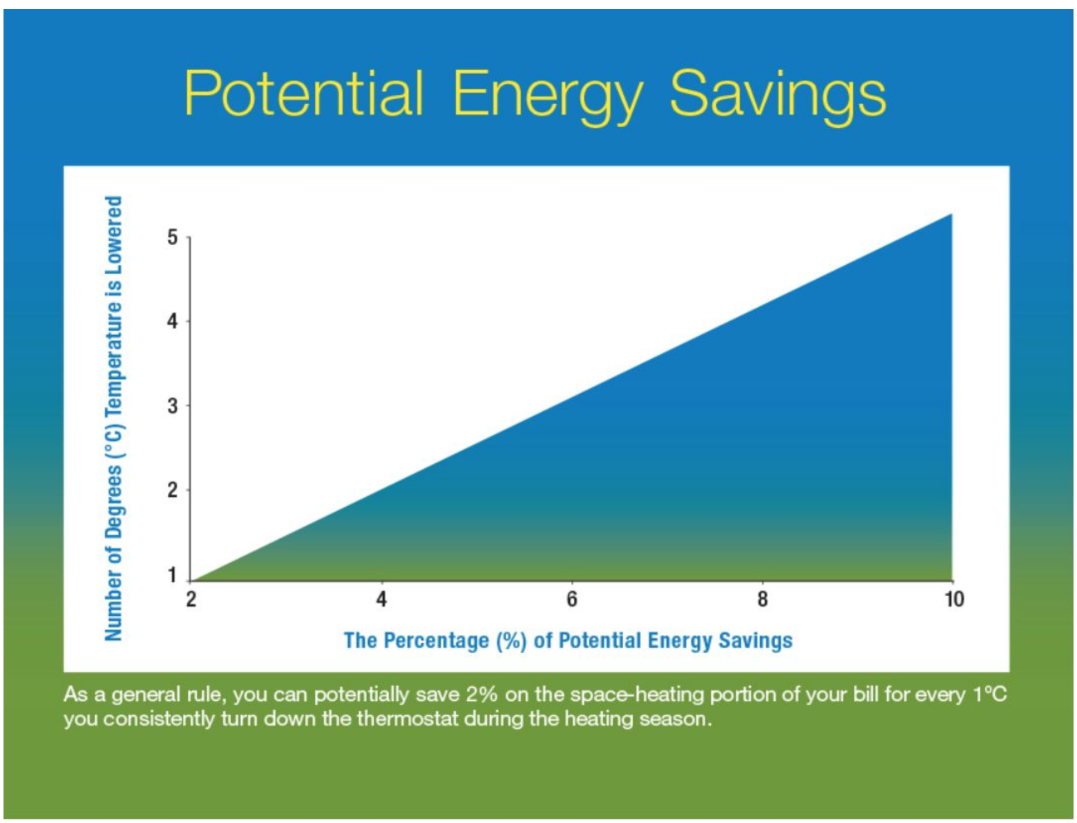



*Fig 2*

The following chart in figure 2 shows the potential energy savings that can be achieved by using a programmable thermostat.

The programmable thermostats provide features like:

1) <u>Multiple setback settings-</u> To maximise energy savings, the programmable thermostats provide multiple setback settings. They automatically adjust the temperature setting by maintaining the highest or lowest required temperatures for four or five hours a day instead of 24 hour.
2) <u>Overriding</u>- Any digital programmable thermostats have a “hold” function. The "hold" function basically allows to override the pre-set temperature and thermostat setting if the person’s schedule changes. For instance, if the person is having a day off in the middle of a workweek and is at home, he can press the “hold” button to lock the current temperature in the house. When he wants the programmed schedule to go back into effect, he can just press the “run” button. This allows the thermostat to operate at the original setting.

**Choosing and Programming a Programmable Thermostat**

Most programmable thermostats are either digital, electromechanical or a mixture of two. Digital thermostats offer the most features in terms of multiple setback settings, overrides, and adjustments for daylight savings time, but may be difficult for some people to program. Electromechanical systems often involve pegs or sliding bars and are relatively simple to program.

The programming of a particular thermostat depends on the sleep and wake cycle of the person. For example if a person prefers to sleep at a cooler temperature during the winter then he should start the temperature setback a bit ahead of the time before going to bed. Similarly, if there is a time during the day when the house is unoccupied for four hours or more, it makes sense to adjust the temperature during those periods.

## Cost Analysis

According to the Energy Information Administration (EIA), energy costs for heating and cooling together comprise about 42% of consumer home energy expenditures, on average.Twenty-five million households currently have a programmable thermostat and approximately 91 million households use thermostats for their home heating, and many of these households offer a market opportunity for programmable thermostats.

| Type | Cost | Pros | Cons |
|---|---|---|---|
| Mechanical/ Manual | $15-$35 | Lowest cost | Non-programmable, contain mercury |
| Non-Programmable Electronic | $20-$50 | Relatively low cost, digital readout | Manually controlled |
| Programmable Electronic | $100-$150 | Easy-to-read display, auto-adjusts | More expensive, limited preset programs |
| Smart | $200-$300+ | Remote management, automatic programs, long-term savings | Most expensive, more difficult to install, requires Wi-Fi |

*Fig 3*

The fig 3 shows the typical values for different types of the thermostats that can be installed in a household. The manual thermostats are the cheapest whereas the smart thermostats are the most expensive ones.

For the  cost analysis of the operation of a manual thermostat versus a programmable thermostat , the group made some assumptions based on the average household energy needs and consumption.

**Some of the assumptions made were:**

**Assumptions for Programmable Thermostats**

| Category | Value | Data Source |
|---|---|---|
| **Heating/Cooling System Efficiencies** | | |
| Gas Furnace | 84.0 | LBNL 2004, Average of ENERGY STAR and Conventional |
| Gas Boiler | 82.5 | LBNL 2004, Average of ENERGY STAR and Conventional |
| Oil Furnace | 84.0 | LBNL 2004, Average of ENERGY STAR and Conventional |
| Oil Boiler | 82.5 | LBNL 2004, Average of ENERGY STAR and Conventional |
| **Baseline Energy Consumption (MBTU)** | | |
| Gas Furnace | 54.1 | DOE 2001 |
| Gas Boiler | 56.1 | DOE 2001 |
| Oil Furnace | 68.7 | DOE 2001 |
| Oil Boiler | 71.2 | DOE 2001 |
| Central Air Conditioner | 9.5 | DOE 2001 |
| **Reference Degree Days (Heating/Cooling)** | | |
| Gas Furnace | 4,255 | DOE 2001 |
| Gas Boiler | 4,255 | DOE 2001 |
| Oil Furnace | 5,339 | DOE 2001 |
| Oil Boiler | 5,339 | DOE 2001 |
| Central Air Conditioner | 1701 | DOE 2001 |
| Typical Indoor Temperature (Heating Season) | 70 | |
| Typical Indoor Temperature (Cooling Season) | 78 | |
| **Energy Prices** | | |
| Residential Gas Price | $1.14 /therm | US Department of Energy, Annual Energy Outlook 2014 (Early Release edition), (converted from 2012 to 2013 dollars) |
| Residential Electricity Price | $0.1232 $/kWh | |
| Residential Fuel Oil Price | $3.59 $/gallon | |
| **Usage** | | |
| Nighttime Hours | 8 | |
| Daytime Hours | 10 | |
| **Carbon Dioxide Emissions Factors** | | |
| Oil Carbon Emission Factor | 161.27 lbs $CO_2$/MBtu | EPA 2009 |
| Gas Carbon Emission Factor | 117 lbs $CO_2$/MMBtu | EPA 2014 |
| Electricity Carbon Emission Factor | 1.54 lbs $CO_2$/kWh | |
| **Thermostat Savings** | | |
| Savings per Degree of Setback (Heating Season) | 3% | Industry Data 2004 |
| Savings per Degree of Setback (Cooling Season) | 6% | Industry Data 2004 |
| **Thermostat Lifetime** | 15 years | LBNL 2007 |
| **Initial Cost** | | |
| ENERGY STAR Programmable Thermostat | $92 | Industry Data 2008 |
| Conventional Thermostat | $73 | Industry Data 2008 |
| **$CO_2$ Equivalents** | | |
| Annual $CO_2$ emissions per average passenger car | 10,471 lbs $CO_2$/yr | EPA Greenhouse Gas Equivalencies Calculator, 2014 |
| **Discount Rate** | | |
| Commercial and Residential Discount Rate (real) | 4% | A real discount rate of 4 percent is assumed, which is roughly equivalent to the nominal discoun rate of 7 percent (4 percent real discount rate + 3 percent inflation rate). |

For our life cycle cost estimate of a programmable thermostat the team used the energy savings calculator provided by the Energy star.

For the analysis, we assumed the number of units installed to be 1 and the initial cost of a programmable thermostat to be $92 and initial cost for a manual thermostat to be $73 which results in an initial cost difference of $19.

**Life Cycle Cost Estimate for**
**1 Programmable Thermostat(s)**

This energy savings calculator was developed by the U.S. EPA and U.S. DOE and is provided for estimating purposes only. Actual energy savings may vary based on use and other factors.

**Enter your own values in the gray boxes or use our default values.**

| | | | | |
|---|---|---|---|---|
| Number of Units* | 1 | **24 Hour Typical Usage Patterns**** | **Weekday** | **Weekend** |
| Initial Cost for one programmable thermostat | $92 | | | |
| Initial Cost for one manual thermostat | $73 | Nighttime Set-Back/Set-Up Hours | 8 | 8 |
| Unit Fuel Cost (Cooling) ($/kWh) | $0.123 | Daytime Set-Back/Set-Up Hours | 10 | 10 |
| Unit Fuel Cost (Heating) ($/Therm) | $1.14 | Hours without Set-Back/Set-Up | 6 | 6 |
| Choose your city from the drop-down menu | City: DC-Washington | | | |
| **Heating Season**** | | **Cooling Season**** | | |
| Typical Indoor Temperature w/o Set-Back | 70 | Typical Indoor Temperature w/o Set-Up | | 78 |
| Nighttime Set-Back Temperature (Average) | 62 | Nighttime Set-Up Temperature (Average) | | 82 |
| Daytime Set-Back Temperature (Average) | 62 | Daytime Set-Up Temperature (Average) | | 85 |
| Heating System Type | Gas Furnac | Cooling System Type | | Central AC |

**This calculator is based on an average sized home. For buildings with more than one heating/cooling zone, you may enter the appropriate number of thermostat units to increase the implementation cost, but the number of thermostats entered does not affect the building size or heating/cooling load.*

***All temperatures are in degrees Fahrenheit. Setpoint is defined as the temperature setting for any given time period. Set-back temperature is defined as the lower setpoint temperature for the energy-savings periods during the heating season, generally nighttime and daytime. Set-up temperature is defined as the higher setpoint temperature for the energy-savings periods during the cooling season, generally nighttime and daytime.*

**Annual and Life Cycle Costs and Savings for 1 Programmable Thermostat(s)**

| | 1 Programmable Thermostat(s) | 1 Manual Thermostat(s) | Savings |
|---|---|---|---|
| **Annual Energy Costs** | | | |
| Heating Energy Cost | $488 | $595 | $107 |
| *Heating Energy Consumption (MBTU)* | *43* | *52* | *9* |
| Cooling Energy Cost | $216 | $289 | $74 |
| *Cooling Energy Consumption (MBTU)* | *5.9* | *8.0* | *2* |
| **Total** | **$704** | **$885** | **$181** |
| **Life Cycle Costs** | | | |
| Energy Costs | $7,825 | $9,837 | $2,012 |
| *Heating Energy Costs* | *$5,428* | *$6,619* | *$1,191* |
| *Heating Energy Consumption (MBTU)* | *645* | *786* | *141* |
| Cooling Energy Costs | $2,397 | $3,218 | $820 |
| *Cooling Energy Consumption (MBTU)* | *89* | *120* | *31* |
| Purchase Price for 1 Unit(s) | *$92* | *$73* | *-$19* |
| **Total** | **$7,917** | **$9,910** | **$1,993** |
| Simple payback of initial cost (years) | | | **0.1** |

**Summary of Benefits for 1 Programmable Thermostat(s)**

| | |
|---|---|
| Initial cost difference | **$19** |
| Life cycle savings | **$2,012** |
| Net life cycle savings (life cycle savings - additional cost) | **$1,993** |
| Life cycle energy saved (MBTU)-includes both Heating and Cooling | **172** |
| Simple payback of additional cost (years) | **0.1** |
| Life cycle air pollution reduction (lbs of $CO_2$) | **25,546** |
| Air pollution reduction equivalence (number of cars removed from the road for a year) | **2** |
| Savings as a percent of retail price | **2166%** |

*Fig 4*

After doing the analysis , a programmable thermostat on an average will result in net life savings(life cycle savings - additional savings) of about $1993 and life cycle energy saved will be around 172 MBTU(including heating and cooling) based on the assumptions made before the analysis. On average a thermostat can last for ten years. So total energy saved per year will be around 5041 kWh/year.

### Government Incentives

The US government currently doesn't provide any incentives for installation of programmable thermostats. But there are other organisations that offers rebates for replacing the manual thermostats with the programmable ones. Environmental Law and Policy Centre a public interest environmental legal advocacy and eco-business innovation organization is one such organisation provides rebates for installation of programmable thermostats. ELPC offers eighteen different thermostats for $100 in rebates for customers with WiFi, central air, and a furnace. Energy star is another organisation that offers rebates for various certified thermostats.

## Idea 2: Geothermal Heating and Cooling(GHC)

In Maryland at a depth of around 10 ft under the surface of the ground, the temperature stays at a constant year round temperature of ~57 $^{0}$F[4]. A geothermal heat pump, in the simplest terms, is a standard heat pump that uses liquid cooled to this ground temperature for heating and cooling. The working fluid in the geothermal system is used in the heat exchanger in the heat pump.

The specific setup that will be considered in the following analysis is a closed loop horizontal heating and cooling system. This system uses a system of pipe laid at the constant temperature depth through which the operating fluid is pumped. The pipe length varies based on location, but it can be estimated at 500-600 ft per ton, or about 1500 ft for a typical household[2].

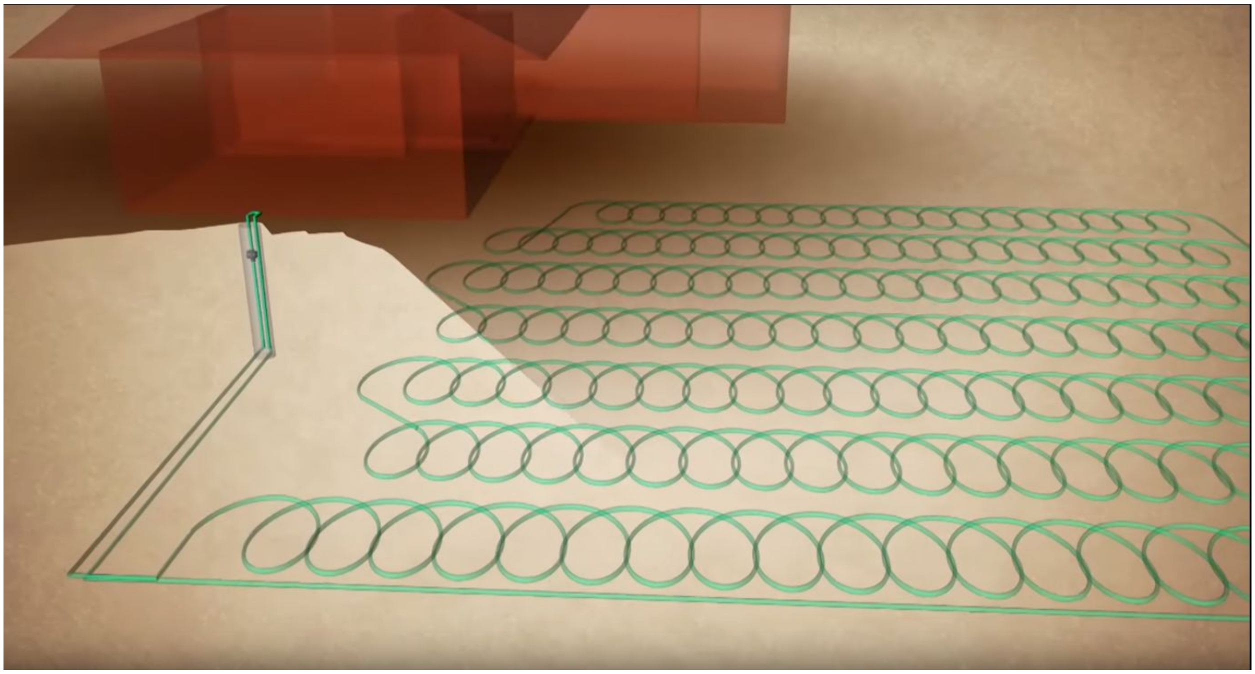


*Fig 5*

Ground conditions, and therefore operational constants, vary greatly depending on location, so analysis may not be universally applicable. Such a system relies on reaching a depth with constant soil temperature. As much information as possible will be sourced for Maryland.

**General Cost Analysis**

According to energy.gov[4], a GHC system can cost up to several times more than a traditional heat pump. However, this is offset by a much lower operational cost. By using the constant temperature earth as a source of heat in the winter and a heat sink in the summer, energy does not need to be expended to maintain those conditions. In general, a geothermal heat pump can result in as much as a 72% energy savings over some traditional systems[4].

The average lifetime of a geothermal system is greater 20 years, so the savings will become money in the pocket of the consumer. Along with the outright lifetime cost savings, The Maryland Energy Administration (MEA) offers Renewable Energy Credits (RECs)[6]. RECs are earned per 1 MWh of electricity produced or offset by a renewable resource. Not only will a consumer with a GHC accrue significant savings over the lifetime of the system, they can sell their RECs. The prices fluctuate dramatically, but they cost nothing to accumulate.

This still leaves the problem of initial cost. Fortunately, MEA has a Residential Clean Energy Grant Program (R-CEGP), which allots money to qualifying residential systems. The incentive for installing a new GHC system is 3000$/Project [7]. This doesn't entirely offset the the cost of installing a new GHC system, but it does reduce the overhead substantially. Along with the R-CEGP, the Maryland Clean Energy Energy Center (MCEC) offers low interest rate loans of up to $20,000 for homeowners interested in improving the energy-efficiency of their homes.[8]

In states where the climate allows, GHC systems provide an excellent opportunity for residential property owners to generate energy savings while reducing their carbon impact. In states like Maryland, where renewable energy advancement and installation is a government priority, incentives and government assistance can make installation costs of GHC systems non-prohibitive and easily competitive with other HVAC solutions.

The EIA states that, in 2015, energy expenditure per household in the Middle Atlantic was 23.2 million Btu for heating and 10.7 million Btu for air conditioning[3]. Assuming an energy savings of 50%:

$$(23.2 \text{ } million \text{ } Btu + 10.7 \text{ } million \text{ } Btu) * \frac{1 \, kWh}{3412.14 \, Btu} * .5 = 4967.6 \text{ } kWh \text{ } savings \text{ /year}$$

The EIA estimates the average energy cost in Maryland to be 12.21 cents per kWh. At this rate, the yearly savings for a residential user would be $606.54/year. The initial cost of the system will be estimated $12,000, with the resident acquiring the $3000 government grant, resulting in a final installation cost of $9,000. The average 3 ton heat pump costs $4500 [22], so the price difference is $4500. At this final cost, the GHC system will pay for itself in ~7.5 years.

After this time, the net energy and cost savings will become net savings for the resident. Assuming a minimum system lifetime of 20 years[22], the net life cycle energy savings will be 12.5 years*4967.6 kWh = 62095 kWh. The life cycle cost saving will be $7581.75.

## <u>Idea 3: Efficient Window Attachments</u>

In a home or building, much of the heating and cooling load depends on the heat transfer properties of materials on the buildings envelope, or external surface. And most of these overall loads come from windows and their surface areas. Given that windows have a very high U-Value, they are poor insulators. This means that the unwanted outside temperature can easily penetrate the surface and make it into the inside space, thus increasing load, increasing cost, and decreasing efficiency. According to the department of energy, an average of "about **30%** of a homes heating energy is lost through windows." There is no way to keep 100% of the heat in during the summer and the 100% of the cold in during the winter, but there are different materials and techniques to help do this as best as possible. Doing so increases overall building efficiency while also keeping residents inside more comfortable and happy.

Over time society has made the switch from single pane windows to more efficient windows such as double pane with gaseous insulation in between paired with special exterior glazing; however, the department of energy states that there is still **76%** of sunlight on windows enters the building as heat during the cooling season with these more efficient double pane windows. We can look further into alternate solutions such as types of window attachments providing cheap and simple benefits to reduce insulation problems.

### Government Incentive

There is a large responsibility for the government to implement policy to encourage and promote energy efficiency in buildings in order to see results in the use of more sustainable alternatives. In 1993, the USGBC (US Green Building Council) was established. Their mission was to promote sustainability in the building industry. Idea's were shared with the American Institute of Architects. These ideas later formed a sustainable rating system that is now not only used by the US government, but internationally. This standard system is known as LEED (Leadership in Energy and Environmental Design) and has been in use as building code since the year 2000. Another standard energy building code that has been implemented into the US is ASHRAE 90.1. Both of these codes are continually being updated and implemented by the US government to require more energy efficient buildings.

More specifically, a market report was made by the DoE regarding window shading and attachments in 2016. In their market overview, it is said that "green products and associated interest by consumers is becoming an important trend in the industry and will continue to drive future energy efficiency reports." Trends predicted in the report are shown here:

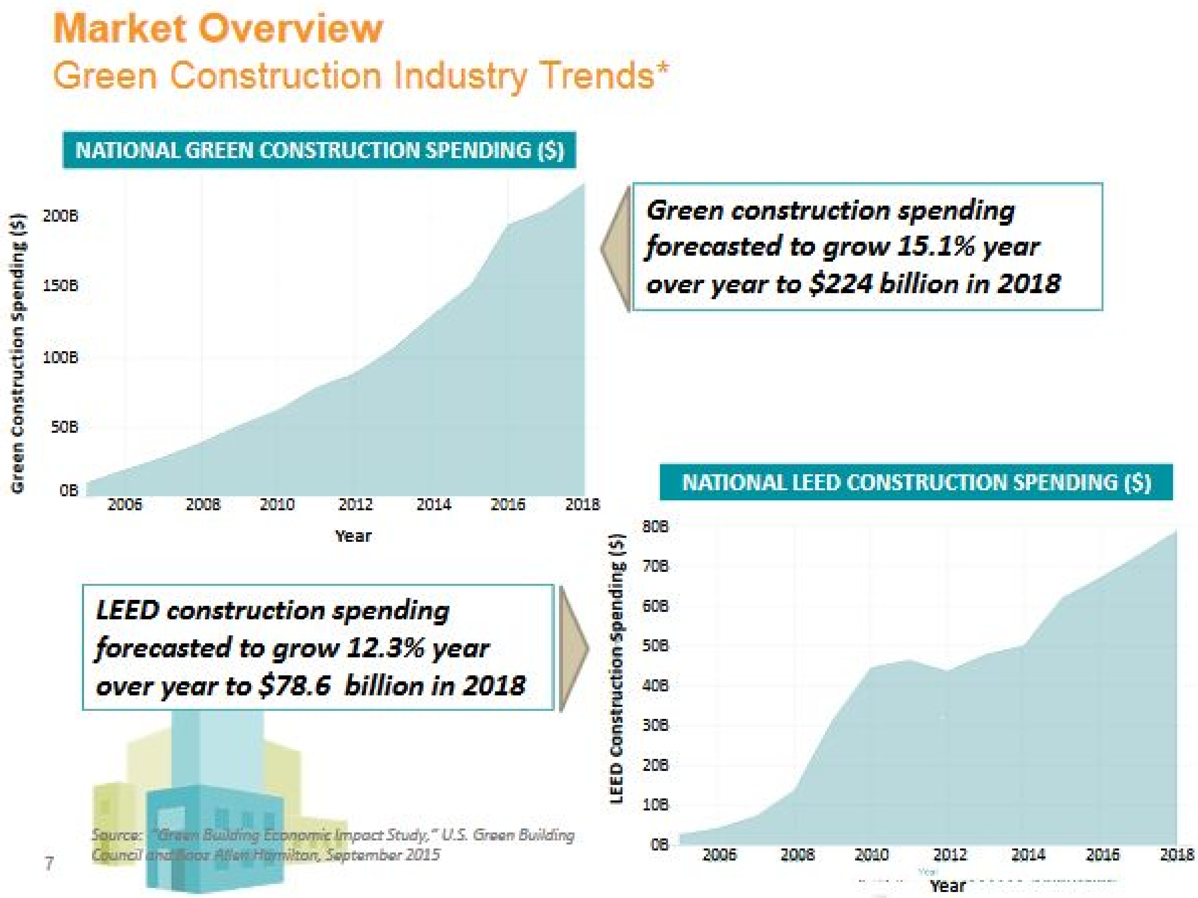



*Fig 6*

This is a fine indicator that the importance of sustainability in buildings is on a steady rise and will continue as time goes on. This report also reviewed incentives for window films in 17 different states. These programs were broken down into two types with different philosophies in each.

- Prescriptive Incentive Programs
    - Rebate amounts were in an amount of money per sq. ft. of window space
    - Tiered rebate dollar amounts based on the improvement of the SHGC (solar heat gain coefficient) post install

- Custom Incentive Programs
    - Rebate amounts based on projected annual saving ($/kWh) through building energy modeling analysis

We can see here an example of the type of rebates from the government depending on energy sustainability of windows specifically.

**Window Overhangs**

While there are many options on improving window sustainability such as film, glazings, blinds, and shades, i'm going to spend time going over one option known as exterior overhangs. Overhangs are placed above south facing windows to prevent direct sunlight heat penetration while also providing natural light into the home to save on interior lighting costs. This is possible due to the different elevations of the sun during different time periods of the year. In the summer months the sun is high while in the winter months the sun is lower to the horizon. This means implementing an overhang at an optimal length would keep heat from entering in the cooling season, while allowing natural heat in during the heating season. The visual below helps represent this more clearly:

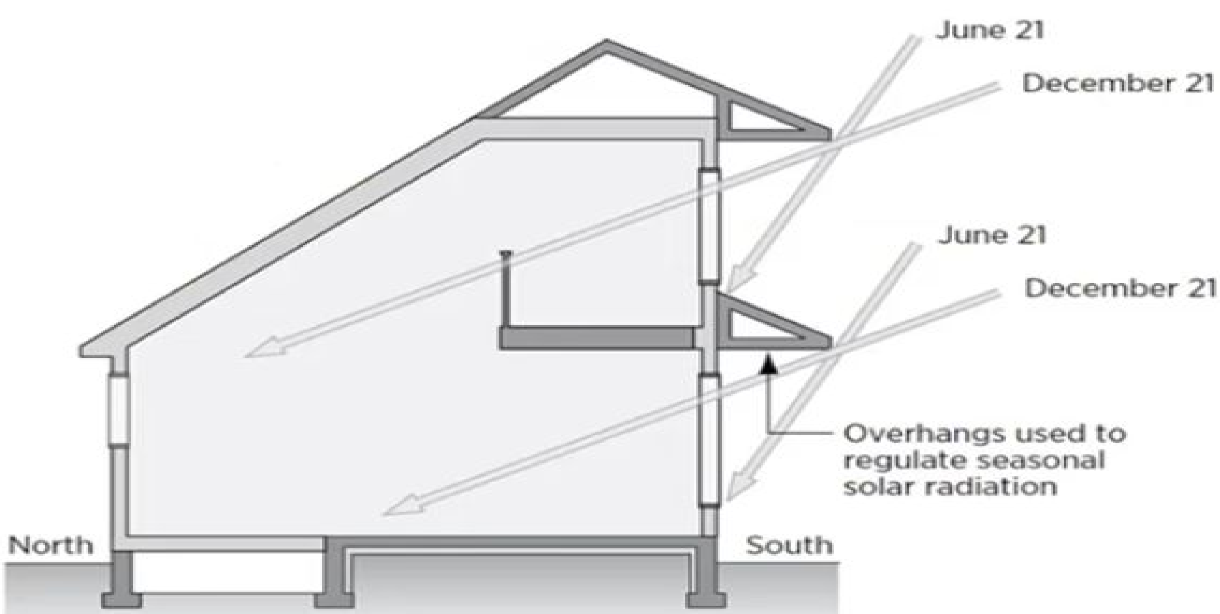



*Fig 7*

As you can see a usual length of overhang used is where that of the angle of the summer and winter solstice intersect. One issue with a static overhang is the “shoulder” months in between heating and cooling seasons. In these corresponding months of the year, the sun is at the same height, however one month the shade is needed and the opposing month the sunlight is needed. This is one con to this approach. Some pros to this approach include low maintenance, one time installation (generally during construction), passive energy design, reduction of building loads, and better building efficiency.

To analyse the difference an overhang makes and its cost effectiveness, i’m going to utilize a tool from Christopher Gronbeck, a sustainability engineer from Seattle Washington. First I will use the tool to calculate solar heat gains from direct sunlight on an unshaded double paned window in Baltimore Maryland as seen below:

## INPUTS

### LOCATION

**city** MD - Baltimore

**latitude** 39.2 degrees North

### CLIMATE

**clearness** 1 (typically 1.0)

**sunshine** [use clear sky]

| Jan 51 % | Feb 55 % | Mar 56 % | Apr 56 % |
|---|---|---|---|
| May 56 % | Jun 62 % | Jul 64 % | Aug 62 % |
| Sep 60 % | Oct 58 % | Nov 51 % | Dec 49 % |

### GROUND

**surface** Custom data

**ground reflectance** 0.2 (0.0 to 1.0)

### WINDOW

**window** double-glazed clear (aluminum)

**SHGC** 0.65 (0.0 to 1.0)

**orientation** SOUTH

### OUTPUT FORMAT

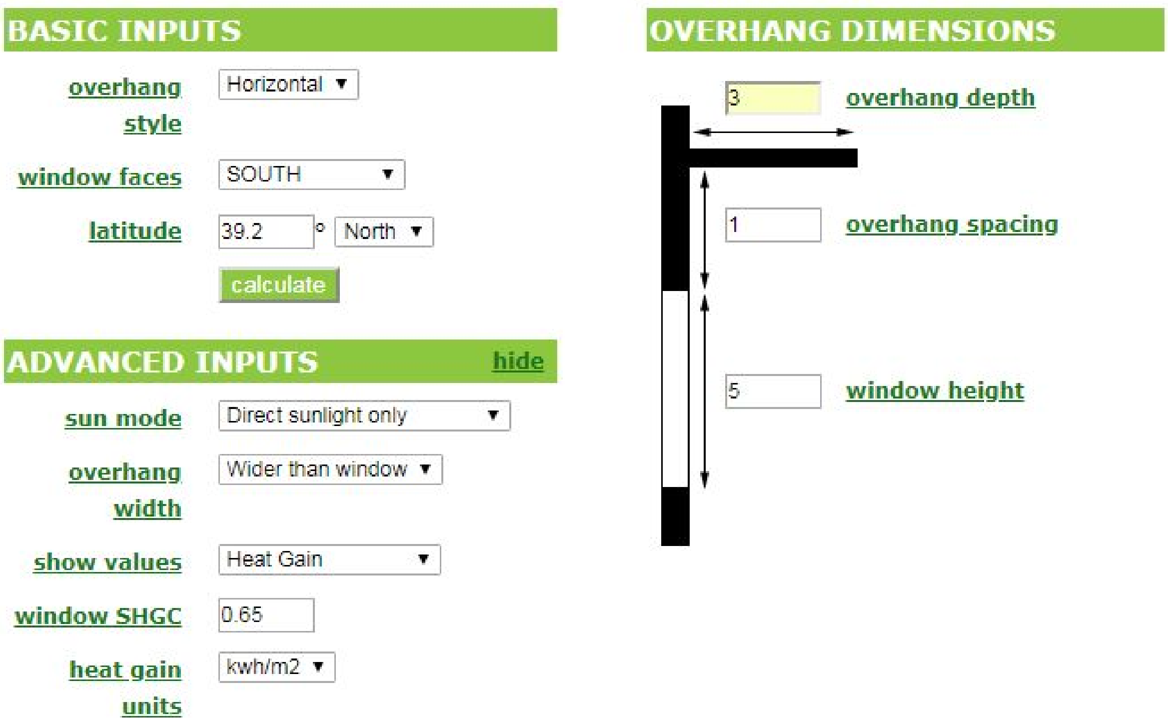
**units** kilowatt-hours / m2

calculate

| | MORNING | | | | | | | | | AFTERNOON | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | MONTHLY | |
| Jan | | | | 0.1 | 2.6 | 5.9 | 7.9 | 9 | 9.4 | 9 | 7.9 | 5.9 | 2.6 | 0.1 | | | | Jan | 60 |
| Feb | | | | 0.6 | 3.3 | 5.7 | 7.4 | 8.4 | 8.8 | 8.4 | 7.4 | 5.7 | 3.3 | 0.6 | | | | Feb | 60 |
| Mar | | | | 1 | 3.2 | 5.5 | 7.2 | 8.3 | 8.6 | 8.3 | 7.2 | 5.5 | 3.2 | 1 | | | | Mar | 59 |
| Apr | | | 0.2 | 0.7 | 1.9 | 3.5 | 5 | 6 | 6.3 | 6 | 5 | 3.5 | 1.9 | 0.7 | 0.2 | | | Apr | 41 |
| May | | | 0.4 | 0.8 | 1.3 | 2.3 | 3.5 | 4.4 | 4.7 | 4.4 | 3.5 | 2.3 | 1.3 | 0.8 | 0.4 | | | May | 30 |
| Jun | | 0.1 | 0.5 | 0.9 | 1.3 | 2 | 3 | 3.8 | 4.1 | 3.8 | 3 | 2 | 1.3 | 0.9 | 0.5 | 0.1 | | Jun | 27 |
| Jul | | 0.1 | 0.5 | 1 | 1.4 | 2.3 | 3.5 | 4.4 | 4.7 | 4.4 | 3.5 | 2.3 | 1.4 | 1 | 0.5 | 0.1 | | Jul | 31 |
| Aug | | | 0.3 | 0.8 | 1.7 | 3.3 | 4.8 | 5.9 | 6.2 | 5.9 | 4.8 | 3.3 | 1.7 | 0.8 | 0.3 | | | Aug | 40 |
| Sep | | | 0.1 | 0.9 | 2.7 | 4.8 | 6.5 | 7.6 | 8 | 7.6 | 6.5 | 4.8 | 2.7 | 0.9 | 0.1 | | | Sep | 53 |
| Oct | | | | 0.8 | 3.7 | 6.2 | 8.1 | 9.3 | 9.7 | 9.3 | 8.1 | 6.2 | 3.7 | 0.8 | | | | Oct | 66 |
| Nov | | | | 0.2 | 2.8 | 5.7 | 7.5 | 8.6 | 9 | 8.6 | 7.5 | 5.7 | 2.8 | 0.2 | | | | Nov | 58 |
| Dec | | | | | 2.1 | 5.5 | 7.5 | 8.7 | 9 | 8.7 | 7.5 | 5.5 | 2.1 | | | | | Dec | 57 |
| | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | ANNUAL | |
| | MORNING | | | | | | | | | AFTERNOON | | | | | | | | 580 | |

We can see that over the course of the year, we have solar heat gain from direct sunlight totaling **580 kWh / square meter** of window. Also noted is that there is slightly more heat gain in the winter months than the summer months due to the angle of the sun being lower to the horizon.

Next I will calculate the same window under the same conditions but now with an overhang that is 1 ft. above the window and protruding 3 ft. from the vertical wall. Different units and measurements can be used and the data will be the same, as long as the ratio is 3:1 (protruding:height above window).




| | MORNING | | | | | | | | AFTERNOON | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | MONTHLY | |
| Jan | | | | | 4.7 | 9.9 | 12.4 | 13.7 | 14.1 | 13.7 | 12.4 | 9.9 | 4.7 | | | | | Jan | 95 |
| Feb | | | | 0.3 | 4.8 | 7.4 | 9 | 9.9 | 10.2 | 9.9 | 8.9 | 7.4 | 4.8 | 0.3 | | | | Feb | 73 |
| Mar | | | | 0.7 | 2.5 | 4.3 | 5.6 | 6.4 | 6.6 | 6.4 | 5.6 | 4.3 | 2.5 | 0.7 | | | | Mar | 45 |
| Apr | | | | 0 | 0 | 0 | 0.5 | 1 | 1.1 | 1 | 0.4 | 0 | 0 | 0 | | | | Apr | 4 |
| May | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | May | 0 |
| Jun | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | Jun | 0 |
| Jul | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | Jul | 0 |
| Aug | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | Aug | 0 |
| Sep | | | | 0 | 0.8 | 2 | 3.1 | 3.7 | 4 | 3.8 | 3.1 | 2 | 0.8 | 0 | | | | Sep | 23 |
| Oct | | | | 0.9 | 4.2 | 6.5 | 8 | 9 | 9.3 | 9 | 8.1 | 6.5 | 4.2 | 0.9 | | | | Oct | 67 |
| Nov | | | | | 4.9 | 9 | 11.1 | 12.3 | 12.7 | 12.3 | 11.1 | 9 | 4.9 | | | | | Nov | 87 |
| Dec | | | | | 3.7 | 10 | 12.8 | 14.2 | 14.6 | 14.2 | 12.8 | 10 | 3.7 | | | | | Dec | 96 |
| | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | ANNUAL | |
| | MORNING | | | | | | | | AFTERNOON | | | | | | | | | 490 | |

What we now see is a reduction in total heat gain down to **490 kWh / square meter**. This is a difference of **90 kWh** from the non shaded window. We are also now seeing a complete reduction of direct sunlight on the windows in the summer months, effectively reducing the use of air conditioning. Contrarily, the winter months are taking in an average of a little over 10 kWh of heat gain, reducing the need for heating. This takes a load off of the conditioning systems of the household. Assuming a household utilized 8 - 12 of these windows and their overhangs, we would see an annual heat gain saving of approximately 1000 kWh of heat energy. At the price of energy around $0.14 / kWh, there would be an annual savings of about $40 - $50. This doesn't seem like a large amount but over the life time of your home, it will save you a few thousand dollars while also creating a much more sustainable home.

On a larger scale, using multiple techniques such as overhangs, glazings/films, and better blinds/shades on each south facing window in the US, we could see a large impact on energy need. To estimate, let's assume 100 million south facing windows, completely optimized for energy. Each of these households could save about $300 annually in space conditioning. This equates to about **$4 billion / year** across the board. This would equate to around 6 gigawatt level energy plants. This is significant when looking at sustainability and eliminating the need for these power plants.

In conclusion, a simple step in the construction phase of a building such as window overhangs could make a small but significant impact when utilized nationally. Although it might be aesthetically less pleasing, it will make for a more cost efficient building while also being conscious of the environment. It is also a static, passive solution, meaning it will not need daily attention and low maintenance. This will minimally affect a residents prior lifestyle which makes it an appealing and optimal choice when looking at future sustainability.

## Total Yearly Energy Savings

Initial Energy Use: 19782.3 kWh/year

Savings from Programmable Thermostat: 172 MBTU per 10 years or 5041 kWh/year

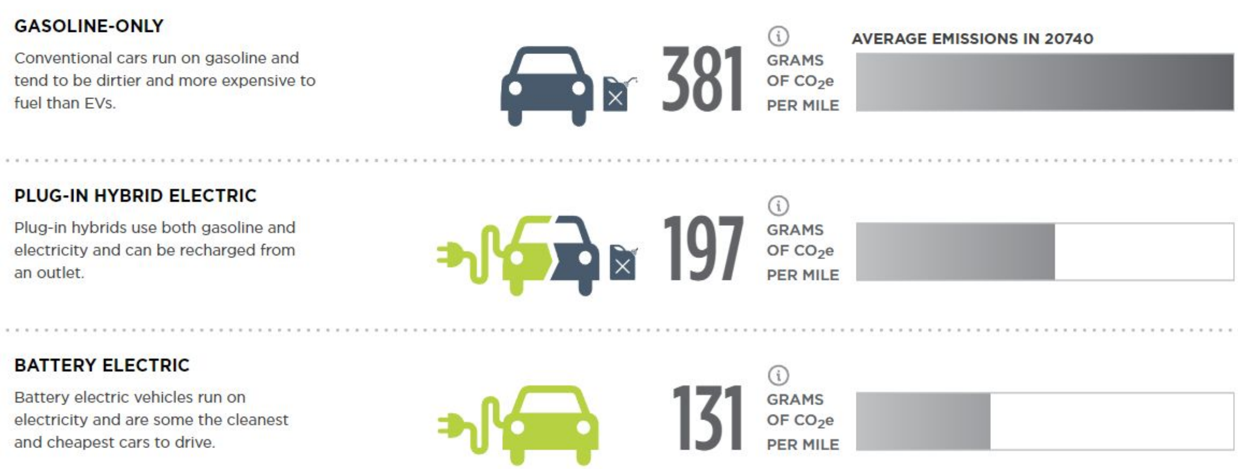
Savings from GHC: 4967.6 kWh/year

Savings from Window Coverings: 1000 kWh/year

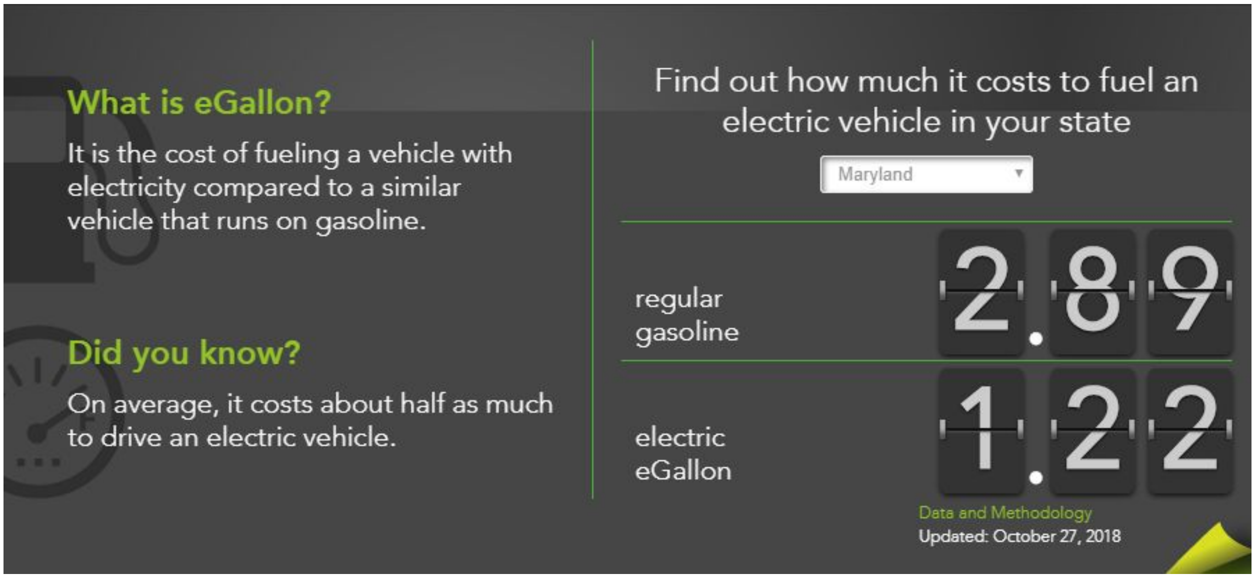
**Total Yearly Savings: 11,009 kWh**

## Part B - Electric Vehicles in the Home

Before factoring in the effect of an Electric Vehicle into the home, it's important to first acknowledge the difference in energy use and cost they have versus internal combustion engine vehicles (ICE.) Even though Electric Vehicles run off of batteries and don't directly burn fuel, they have to get their electricity from power plants and those plants could be generating electricity from burning coal or natural gasses. Also, because their energy is stored in large lithium ion batteries, their initial emissions compared to an ICE vehicle are actually higher. That is made up by the fact that EV's emit only ~35% of an ICE vehicle's grams of $CO_2$ per mile[14].




While EV's may not worry about gas pump type fee's, they do raise the cost of home electricity bills. However, when factoring in the price of electricity generation in maryland and the cost of gasoline, EV's cost half as much per "gallon" relative to ICE vehicles[15]. The price to maintain electric vehicles will only decrease as power plants become more efficient and utilize renewable energy sources more. This will reduce the cost of electricity therefore reducing the cost of charging the battery.




These are important to point out because when it comes to buying an EV, the user is ultimately increasing the amount of energy their household needs. Any energy saved in the home due to the installation of programmable thermostats or geothermal heat pumps will be offset a bit by the energy cost of charging the electric vehicle. Depending on electricity vs. gasoline costs of the area, the addition of an electric car in these already energy conscious homes is still a net gain. Even though the savings won't be entirely reflected from the energy bill of the home, factoring in the savings on fuel costs and the overall smaller emissions of EV's still make them a great option whether a home is using the previously mentioned ideas or not.

According to General Motors, the annual energy use of their Chevy Volt is ~2520 kWh, which is less than what is required to power typical central air conditioning in a home[16]. This means if a homes central air conditioning was replaced with geothermal heating/cooling and this home also had an electric vehicle, it is still saving as much energy as the difference between the vehicles energy usage and the usage of the air conditioning. This savings is only increased when considering the energy savings of the EV vs the ICE as mentioned previously.

Finally, a home using these energy conscious technologies not only reaps the financial incentives and tax credits for their installation and use but will also receive aid and credits for any EV's. In the state of Maryland, financial compensation will be offered for not only energy saved by the electric vehicle but also for the installation of the charging technology used to keep the battery at capacity[17].

| | | |
|---|---|---|
| Maryland | Electric Vehicle Supply Equipment (EVSE) Rebate Program | Offers individuals $700 for the cost of acquiring and installing qualified charging equipment. |
| | Plug-In Electric Vehicle (PEV) Tax Credit | As of July 1, 2017 allows purchasers of qualified vehicles to apply for a tax credit of up to $3,000 calculated as $100 per kWh of battery capacity. |

Considering the results at the end of part A, and assuming the electric vehicle in question was a Tesla Roadster and the annual miles per year driven was 15600.

$$\text{Energy} = (15600 \text{ miles/year}) / (5.6\text{mi/kWh}) = 2785.71 \text{ kWh/year}$$

This means that the GHC's and programmable thermostats will save enough energy to compensate the charging of an electric car. While the window coverings don't save enough energy, the net gain of getting an electric vehicle is still enough of a benefit to justify the extra kWh used annually in your home to charge it.

In conclusion, a homeowner shouldn't be concerned with the energy demand of charging their EV outweighing the savings of their energy conscious technologies. While their energy savings isn't simple to see or notice on an energy bill, it still exists in their reduced $CO_2$ emissions and the savings in mileage vs. that of a ICE vehicle.

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