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The image is a screenshot of a presentation slide. At the top left is the UWI logo with the text 'UWI MONA CAMPUS JAMAICA WEST INDIES'. At the top center is the title 'Sources of Energy' in blue. At the top right is the Caribbean Examinations Council logo with the text 'CARIBBEAN EXAMINATIONS COUNCIL'. The main content area is a large, solid teal rectangle. At the bottom left is the URL 'WWW.CXC.ORG'. At the bottom center are several accreditation logos: CPEA™, CCSLC®, CVQ\*, CSEC®, CAPE®, and CXC®-AD. At the bottom right is a small number '2'. Below the accreditation logos is a small footnote: '\*CVQ is the trademark of the Caribbean Association of National Training Authorities'.

<https://www.youtube.com/watch?v=KEeH4EniM3E>

Our lives are built around fossil fuels:

Centralised electricity supply

Centralised fuel supply for transportation

Industrial and agricultural equipment are fuelled by fossil fuels

It is wasteful, polluting, and dominated by a few powerful players

Significant embedded infrastructure and cost barriers prevent new entrants and alternative solutions reaching scale

Established 'proven' solutions are preferred over innovative alternatives

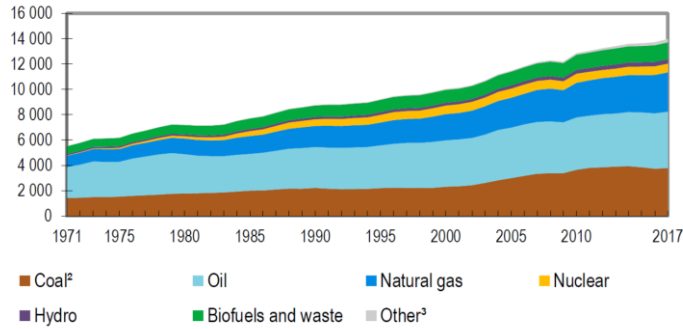
Centralised delivery model; electricity flows from 1 large power station to thousands of customers.

This places a physical and psychological distance between communities and where their energy comes from.

Access to energy and the benefits it can bring is inequitable and regressive

Profits flow out of the communities that use the energy

World<sup>1</sup> TPES from 1971 to 2017 by source (Mtoe)



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*Increase in consumption of fossil fuels. Most recent times, greater increase in the use of natural gas*

*Very minimal increase in the use of renewables*

*1. World includes international aviation and international marine bunkers.*

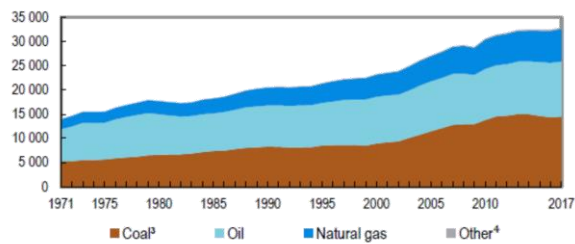
*2. In these graphs, peat and oil shale are aggregated with coal.*

*3. Includes geothermal, solar, wind, tide/wave/ocean, heat and other sources.*

*Source: IEA, World Energy Balances, 2019.*

## CO<sub>2</sub> emissions by fuel

World<sup>1</sup> CO<sub>2</sub> emissions from fuel combustion<sup>2</sup> from 1971 to 2017 by fuel (Mt of CO<sub>2</sub>)



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Emissions raised from 14,000Mt of CO<sub>2</sub> in 1971 to 32,000Mt of CO<sub>2</sub> in 2017

1. World includes international aviation and international marine bunkers.
  2. CO<sub>2</sub> emissions from fuel combustion are based on the IEA World Energy Balances and on the 2006 IPCC Guidelines, and exclude emissions from non-energy.
  3. In these graphs, peat and oil shale are aggregated with coal.
  4. Includes industrial waste and non-renewable municipal waste.
- Source: IEA, CO<sub>2</sub> Emissions from Fuel Combustion, 2019.

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Why Do CO<sub>2</sub> Emissions Matter?

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<https://youtu.be/n4e5UPu1co0>

CO<sub>2</sub> is a green house gas which contribute to global warming which has lead to changes in our climate.



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## Which Climate Impacts have you observed?



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<https://www.youtube.com/watch?v=ioWuEJZ77Mk>

Increase in the number of warm days and nights  
Decrease in the number of cool days and nights  
More intense hurricanes  
Greater number of heavy rainfall events in a short time  
Increased Flooding  
Increased incidents of drought  
Coral Bleaching

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**PEOPLE**  
Social variables dealing with community, education, equity, social resources, health, well-being, and quality of life

**BEARABLE**

**EQUITABLE**

**PLANET**  
Environmental variables relating to natural resources, water & air quality, energy conservation & land use

**VIABLE**

**PROFIT**  
Economic variables dealing with the bottom line & cash flow

**SUSTAINABLE**

**Sustainable Development**

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Our Common Future (Brundtland Commission 1987)

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Green Engineering is built on the principle of sustainability.

Designs and development are conducted with consideration being given to all 3-tiers of sustainability

That is, sustainable development.

We will, therefore, design in such a way that we meet our needs without hampering the ability of our children and our children’s children to provide for their own needs.



The use of Renewable Energy is one way to help us accomplish this. The sun is the ultimate source of energy for most renewable energy technologies.

Solar Thermal driven by the heat energy from the sun

[https://commons.wikimedia.org/wiki/File:Zaragoza\\_DIY\\_SHW\\_system.jpg](https://commons.wikimedia.org/wiki/File:Zaragoza_DIY_SHW_system.jpg)

Solar PV extracts energy from the light (photons) provided by the sun

<https://pxhere.com/en/photo/708107>

Wind energy driven by uneven heating of the earth's surface which as it blows over the ocean/sea leads to wave energy <https://pxhere.com/en/photo/30068>

The sun drives the water cycle which gives rise to rivers and hydropower

The heating of the ocean's surface gives rise to the temperature difference that fuels

Ocean Thermal Energy Conversion (OTEC) We also may extract energy in the form of

kinetic energy from waves and tides. <https://pxhere.com/en/photos?q=ocean>

Photosynthesis, which derives energy from the sun gives rise to biomass

<https://pxhere.com/en/photos?q=photosynthesis>

Geothermal energy, energy from the earth's core

<https://pxhere.com/en/photo/1347318>



OTEC is still in the research phase within the region, though it theoretically has promise.

Geothermal, Wind Hydro Power are more likely to be implemented at utility scale. However, you may find residential, commercial and industrial installations of solar PV and thermal and bioenergy.



## Solar Thermal Installations



$75 \text{ rooms} \times 2750 \text{ Watts} \times 3 \text{ hours} = 618,750 \text{ Wh/day}$

$= 618,750 \text{ Wh} / 1,000 = 618.75 \text{ kWh/day}$

$= 618.75 \text{ kWh} \times 365 \text{ days} = 225,843.75 \text{ kWh/yr}$

$= 225,843.75 \text{ kWh} / 1699.4 \text{ kWh/boe} = 133 \text{ boe/yr}$

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Image credit: <http://www.solarthermalmagazine.com> Image of a solar water heater installation in Barbados completed by Solar Dynamics

In the Caribbean, Solar Thermal technology is applied for heating purposes and not for electricity generation since our weather does not allow for electricity generation from solar thermal to be possible. Solar Thermal for electricity production will more likely be found in desert like climates where they receive significant amounts of direct radiation, without the interference of cloud cover.

The International Energy Agency (IEA) has announced that Barbados is the number one country in the world in British Thermal Unit per thousand penetration in 2017. Barbados achieved this position in 2015.

To measure the efficacy of various energy saving measures, they are often expressed as Barrel of Oil Equivalent. That is, the energy consumed or saved is compared to the energy in one barrel of oil, 1699.4 kWh.

Let's look at the example of a small boutique hotel with 75 rooms.



## Solar PV Installations



$$1.6\text{MW} = 1.6 \text{ MW} * 1,000 = 1,600 \text{ kW}$$

$$= 1,600 * 6\text{h} = 8,000 \text{ kWh per day}$$

$$= 8,000 \text{ kWh} * 365 = 2,920,000 \text{ kWh/yr}$$

$$= 2,920,000 \text{ kWh/yr} / 1699.4\text{kWh/boe} = 1,718.3 \text{ boe/yr}$$

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<http://www.jamaicaobserver.com/business/grand-palladium-resort-unveils-largest-solar-pv-plant-in-Jamaica>


Picture: Grand Palladium Resort and Spa, a 1,000 room hotel was projected to save over US\$600,000 in energy cost per year from the installation of a 1.6MW solar Photo Voltaic (PV) power plant.

Throughout the region, because of our year round consistent sunny weather, this lends it self to widespread applications of solar PV installations given a consistent solar insolation for approximately 12 hours per day.




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## Bioenergy



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232MWh\*1,000 / 1699.4kWh/boe  
= 136.5 boe

328MWh\*1,000 / 1699.4kWh/boe  
= 193 boe

192MWh\*1,000 / 1699.4kWh/boe  
= 113 boe

270MWh\*1,000 / 1699.4kWh/boe  
= 159 boe

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Image credit: <https://jaspasjourney.files.wordpress.com/2018/04/st-lucia-2014-2.jpg>

Biological energy (bioenergy) is derived from non-fossil organic (living or recently living) matter and its metabolic by products.

Typically starchy and cereal crops are used to produce ethanol by fermentation. Biodiesel is extracted from oily plants and seeds, animal fats and waste vegetable oils. Biogas, which is mostly composed of methane, is generated during the anaerobic decomposition of organic matter, usually municipal solid waste (MSW) and sewage. Other organic by-products of industrial and manufacturing processes could also be considered biofuels when used for energy or electricity, e.g. bagasse produced from sugar production.

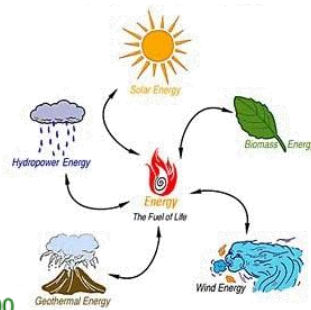
In the region, bioenergy is primarily used in transportation (ethanol blends), by industries which produce biological waste sugar (bagasse) , agriculture (biogas from plant and animal waste)

Due to available amounts, banana and sewer waste were selected to describe a best-practice bio-gas system in Belize.

A 2017 report estimates 232 MWh of power, 328 MWh of heat and 3,766 ton of hot water will be produced yearly by establishing a central digester using banana waste, and 192 MWh of power, 270 MWh of heat and 3,106 ton of hot water will be produced yearly by establishing a biogas plant using sewer waste in Belmopan.

(Source: <https://renewableenergycaribbean.com/2017/02/27/study-on-biomass-and-waste-in-belize/>)

- relatively expensive to use
- relatively high area needs
- solar, wind and wave power are intermittent in nature
- high share of renewables needs high share of storage in the electricity system
- available for another five billion years (on this planet)
- no additional GHG emissions (if done well)
- environmentally friendly in most other aspects
- the annual solar energy income is about 10,000 times the present world energy consumption





## Energy Conservation and Efficiency



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<https://www.youtube.com/watch?v=-IBz3DdVgU>

Energy Conservation – using less energy

Energy Efficiency – Doing more with the same amount of energy

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What observations of renewable energy, energy and other conservation and efficiency measures have you made in your case studies?  
 Did the company have an energy manager?  
 What would be the benefit of having an energy manager?  
 Were there any standards being used as guidelines for the energy measures like ASHRAE, Green Globe, LEED?  
 Have you implemented any energy conservation or energy efficiency measures in your home?

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What Observations of renewable energy, energy and other conservation and efficiency measures have you made in your case studies?

- Making use of Daylight
- Inverter A/C Units
- Central HVAC Systems rather than Split units
- Water recycling
- Water Harvesting
- Occupancy sensors

How were these energy measures maintained?

Did the company have an energy manager?

What would be the benefit of having an energy manager?

Were there any standards being used as guidelines for the energy measures like ASHRAE, Green Globe, LEED?

Have you implemented any energy conservation or energy efficiency measures in your home?





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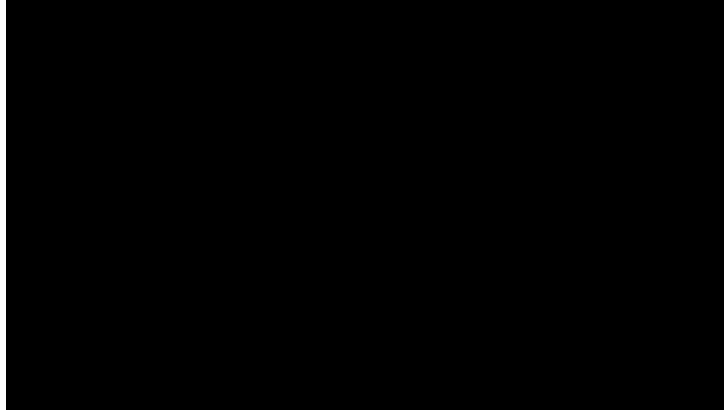
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<https://www.youtube.com/watch?v=5VMXL3IEYTI&list=PLACD8E92715335CB2&index=8>



## An example of a Green Energy System



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