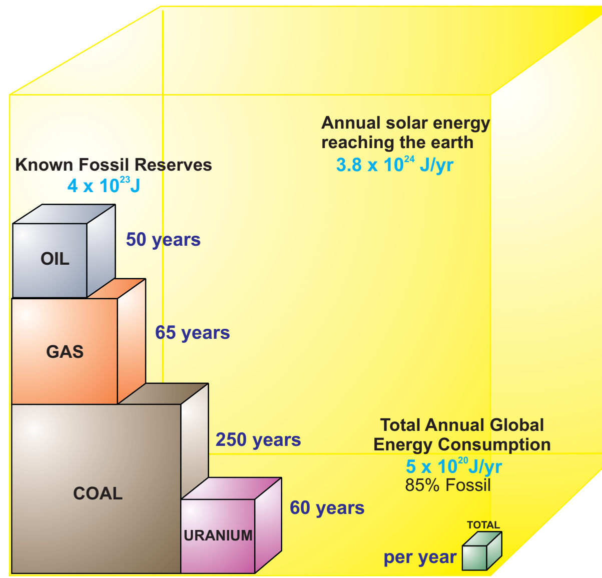
ENERGY

WHY IS SOLAR ENERGY IMPORTANT?

Throughout history, humans have learned to supplement their meagre strength by utilizing external energy sources. Fire released heat for warmth. Oxen were well suited to pull a plough to raise more crops. Horses became a preferred method for long distance transportation. Ships carrying men for warfare or trade goods were powered by the wind. In the 18th century, James Watt perfected the use of coal fired steam to produce mechanical motion ushering in the industrial revolution. But it wasn't until the mid 1800s that the energy source which would lead to the productivity explosion of the 20th century was discovered - oil!

With the exception of nuclear power, all the energy we use comes from the sun. Plants convert sunlight energy and store it chemically through a process called photosynthesis. Fossil fuels were formed over millions of years when decaying plants under pressure changed into oil, coal and natural gas. Mass production of the internal combustion engine (ICE) with the refining methods used to convert oil into useful forms like gasoline has been the driving force for the huge standard of living improvement in the 20th century. Fossil fuels are a large but finite resource. Experts predict that we have already depleted more than half the total available in the last 100 years. No new oil is being created. Without access to abundant energy in a usable form, our current lifestyle cannot continue. The challenge for the 21st century is to develop practical sources of renewable energy that can be used to power our civilization indefinitely.

Each day the energy from the sun reaching the earth is more than we consume in one year.

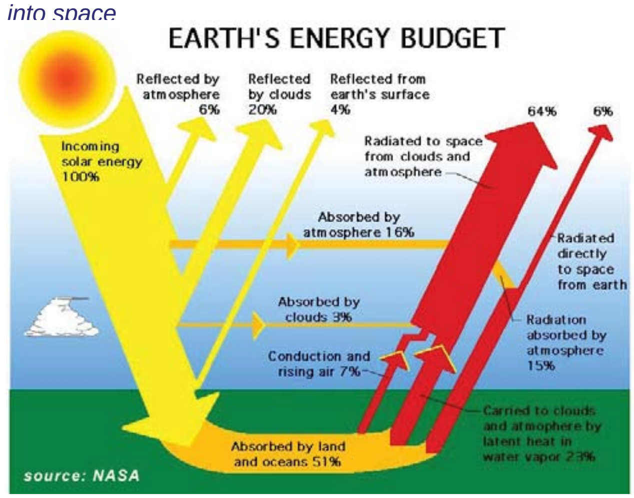


UTILITY DEMAND PROFILE

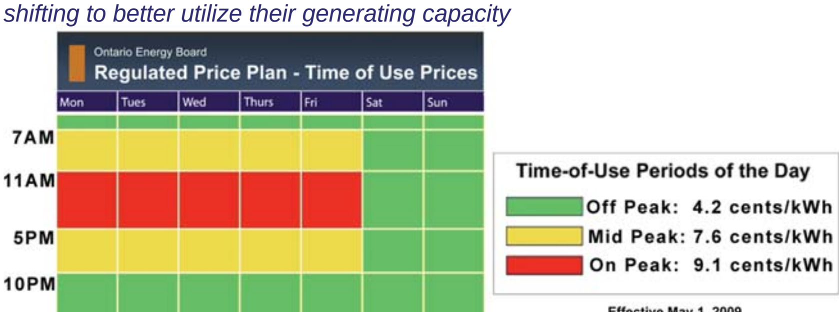
Electric utilities must build enough generation and distribution to meet the peak demand of all customers. In North America this typically occurs in the afternoon on hot sunny days caused by air conditioning and industrial consumption. 10% of the standby generation is only used 1% of the time or 4 days per year. Solar PV generation can provide additional energy during these peak periods eliminating the need for additional power plants and power lines.

Smart grid technology is being developed to intelligently manage demand by monitoring individual usage with smart meters and temporarily shutting down some loads during peak periods. To encourage conservation during peak periods TOU (time of use) billing is being introduced by many utilities. The savings can be more than 2:1 depending on when electricity is used. This financial incentive will cause millions of users to shift discretionary electricity use such as for washing machines and air conditioning to level out the total demand.

Most of the solar energy reaching earth is reflected back into space



Utilities are introducing time of use (TOU) pricing which encourages demand shifting to better utilize their generating capacity



Smart Grid devices like time of use meters allow more efficient use of utility generation and transmission equipment

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ENERGY SOURCES

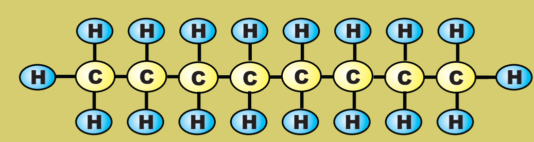
In the late 1800s, the first electrical generators were built to power Edison's new electric lights. Water and fossil fuel powered ICE engines were the 2 main sources of power to turn the generators. Over the next century, the global electrical system evolved by building large central plants to generate power with a transmission infrastructure to deliver the power to remotely located consumers. Nuclear power, which was introduced in the 1950s, despite its early promise, has been slowed by technical, cost and environmental issues. World demand for energy to support the growing economies of countries like China and India is increasing. Traditional sources to power new plants include coal, natural gas, water and nuclear. Many scientists agree that the increasing quantities of CO2 emitted by burning fossil fuels is causing global warming which will have undesirable climatic effects on the earth. Supply of fossil fuels is finite and becoming more expensive. Many countries are concerned with security of supply. Even in the few countries lucky enough to have abundant water resources like Canada, environmental issues slow development. Nuclear has an uncertain future due to the huge cost of construction, safety worries and waste disposal difficulties. In the coming decades, most cars will be electric powered to reduce pollution and fossil fuel dependency. Where will the new energy come from to support our current standard of living?

Each generation faces its own unique challenges to solve. In the 21st century, the current centralized electric power generation model will be supplemented by distributed local generation from renewable sources like solar PV (photovoltaic) and wind. Biomass conversion to a synthetic liquid fuel like ethanol and fusion are long term possibilities requiring much more research. Large scale local solar PV generation today is practical. However, to purchase and finance the necessary equipment costs at least 5 times the amount per kWh that electricity can be bought from conventional grid supply. It takes many years of innovation and volume production to drive the costs of a new technology down to affordable levels for mass adoption. Building codes and standards are established though years of practical experience in local conditions. Utilities that supply power to consumers (called LDCs - local distribution companies) have rules, practices and infrastructure that were never designed to accommodate buying power from thousands of micro generators on their system. Recognizing these issues, progressive governments realized that subsidies are required if large scale deployment of solar PV is to begin before a crisis of energy supply or climatic catastrophe is reached.

FIT IS DRIVING SOLAR PV

In 1990, Germany established a federal energy policy to encourage solar PV installations though the use of a subsidy program called FIT (Feed In Tariff). Due to its success, it was closely copied by other countries like Spain and Italy. Recently, Ontario Canada and some US states have introduced their own versions. To enable investors to justify the high expense of installing solar PV, upon signing an agreement, the LDC (local distribution company) is obligated to buy all the power generated from the customer's PV system at a much higher rate than what they pay for power. In Ontario, the current sell rate for <10kW systems is $0.80/kWh where power is bought at $0.10/kWh. This rate is guarenteed for 20 years to match the expected life of the equipment. A separate utility meter is provided to calculate the total solar energy and payment required at the higher rate. Even though most generators consume all their solar power at the site, local generation reduces the total power the utility must supply and lessens the need for additional distribution lines. The LDC recovers the cost of the subsidy by including it in the base rate paid by all electricity consumers which is typically less than 1%.

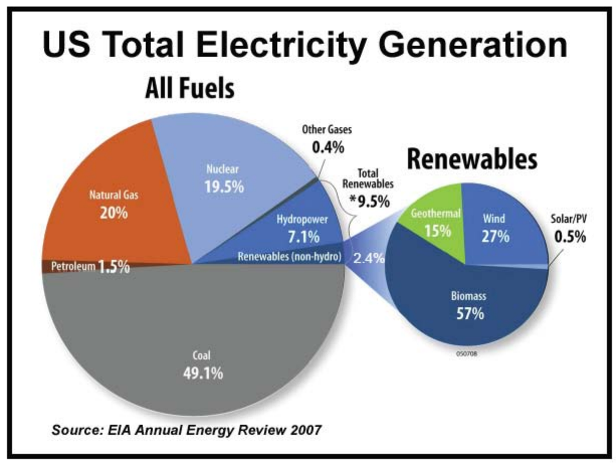
Our Carbon Economy is driven by fossil fuels which produce carbon dioxide during combustion causing global warming



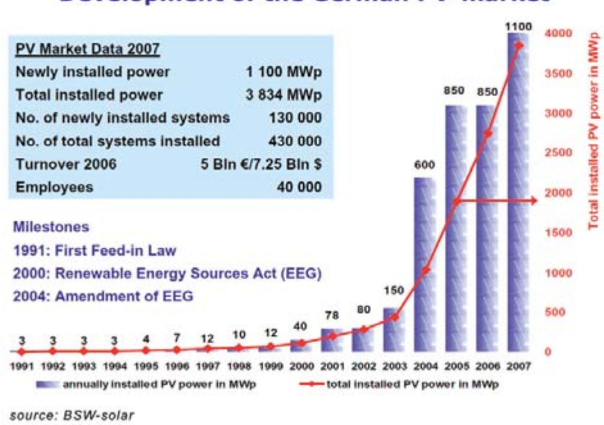
$$C_8H_{18} + 12.5O2 \text{ ---> } 8CO_2 + 9H_20 + Energy$$

gasoline | oxygen | carbon dioxide | water | energy

Solar PV generation will increase from its current small amount as its cost approaches grid parity



Germany developed the first successful FIT (feed in tariff) program to drive solar PV installations



If the solar power is not metered separately, to be sold at a higher rate, but simply used to reduce total power purchased, called net metering, the consumer is only getting the buy rate savings of $0.10/kWh for their solar energy. Until the cost of solar power drops below the cost of purchasing power, a point called grid parity, there is not sufficient financial incentive to install solar PV. Locations with this policy have met with limited success.

Currently it costs about $9/W to install solar PV. It is estimated that by 2015, technology advances and manufacturing economies of scale will drive the cost of solar PV to grid parity. Until that point is reached, FIT incentives will be needed for investors to put in systems today.

CARBON FOOTPRINT

Our modern economies are driven by an abundant supply of energy from fossil fuels. Gasoline, coal and natural gas are compounds that contain hydrogen and carbon which when burned release energy, carbon dioxide and water. Hence the term “Carbon Economy” . To encourage conservation, some governments are introducing carbon taxes and carbon credits. These are complex financial calculations that determine the amount of carbon a business is using based on its fuel bills. In these jurisdictions, businesses that generate energy from clean sources (wind, solar, hydro) can get a credit based on the amount of carbon an equivalent amount of fossil fuel would generate. This does nothing to actually produce more real energy.

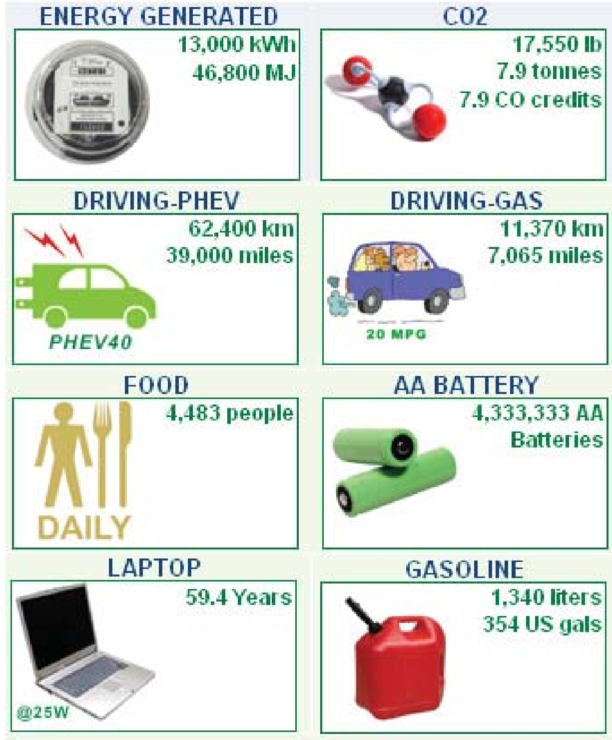
Gases such as CO2, which is produced when fossil fuels are burned, trap heat causing the earth’s surface to warm. These are refered to as GHG (green house gases) because the effect is similar to a greenhouse trapping warm air under glass. Others GHGs include water vapour, methane, ozone and nitrous oxide.

Conservation is the cheapest way to reduce fossil fuel consumption through simple actions like turning off lights and air conditioning. The weight of CO2 that is produced by fossil fuels to produce any amount of energy can be calculated. This can be determined for any energy use such as an airplane trip or running a computer and is called the Carbon Footprint. It can also be expressed in other more familiar energy equivalents than tons of CO2. For example, a litre of gasoline has 9.8kWh of energy capacity and produces 2.3kg of CO2 when burned. For a car that gets 12km/l a 12km trip has a carbon footprint of 2.3kg of CO2. An adult human uses about 250W of power while running run up stairs. Considering that 1 liter of gasoline has the energy equivalent of running up stairs continuously for 39 hours, its no wonder that we need to have abundant energy sources to power our carbon economy.

A 10kW solar PV system, charging a 4km/kWh electric vehicle, can replace 15 liters of gasoline daily with no CO2 emissions

FUEL ENERGY DENSITY COMPARISON		
Gasoline	9,000	W / liter
Liquid natural gas	7,200	W / liter
Ethanol	6,100	W / liter
Liquid natural gas	7,200	W / liter
Lead acid battery	40	W / liter
Compressed air	17	W / liter
10kW solar PV system	35,000-75,000	Wh/day

Typical carbon offset energy savings from a 10kW - 50 panel roof top system in 1 year



Selected energy sources/uses compared to a 10kW solar array

ENERGY VALUES	
SOURCE / USE	**ENERGY(J)**
Yearly solar energy - all directions	10^{35}
Yearly solar energy - reaching earth	10^{25}
Fossil fuels known reserves	10^{23}
US energy consumption - annual	10^{20}
Fission - 1 ton of uranium	10^{17}
Burn 1 million tons of coal	10^{16}
1000MW power station - annual output	10^{16}
Jetliner crossing Atlantic	10^{12}
10kW Solar PV (50 panels) annual	**6×10^{10}**
Human - daily food consumption	10^{7}
Woman running for 1 hour	10^{6}
Candy bar	10^{6}
AA Battery	10^{4}

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