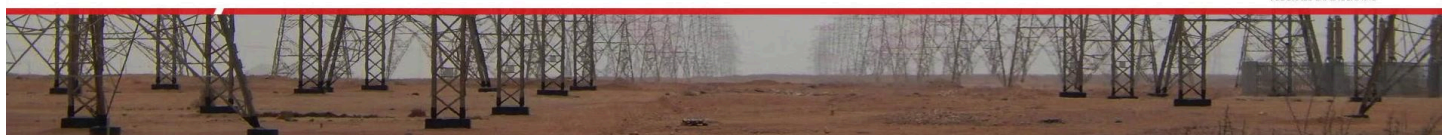




ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE



EPFL



## Cooking Pots & Stoves



Technology innovation for sustainable development



The topic of today's lecture is Energy as an Essential Technology. It is estimated that nearly 1.3B people do not have access to electricity. And this has great consequences. According to statistics from the WHO around 3B people cook and heat their homes using open fires and simply stones. They burn coal and biomass such as wood animal dung and crop waste. And over 4 million people die prematurely from illnesses attributed to household air pollution from cooking with solid fuels. While more than 50% of premature deaths from pneumonia among children under 5 are caused by particular matter such as soot, which is inhaled from household air pollution, and 3.8 million premature deaths annually from non-communicable diseases including stroke, ischemic heart disease, chronic obstructive pulmonary disease and lung cancer are all attributed to exposure to household air pollution. Therefore the lack of access to power is truly a major global concern.

Notes

Summary



0m 05s

# Energy Supply Chain

- Coal, Oil, Gas, Uranium, Hydro, Biomass, Solar, Wind, Geothermal...
- Heat, Electricity, Fuels...
- Storage Tanks, Grids, Dams...

Primary Energy Sources



Energy Carriers



Storage & Distribution



Usage

Technology innovation for sustainable development



Before we continue, let's briefly look at how the global energy supply chain is structured in general. It consists of primary energy sources that include Coal, Oil, Gas, Uranium, Hydro, Biomass, Solar, Wind, Geothermal, Ocean energies, etc. These primary energy sources need to be converted and processed into energy carriers such as Heat, Electricity and Fuels. The energy carriers may be stored and then distributed to the final consumer for usage. For example, fuel stored in specialized tanks as it is combustible. And then distributed via road, rail and the sea. Whereas, electricity requires an extensive great network for distribution. And surplus grid electricity's mainly stored in dams as hydroelectricity.

Notes

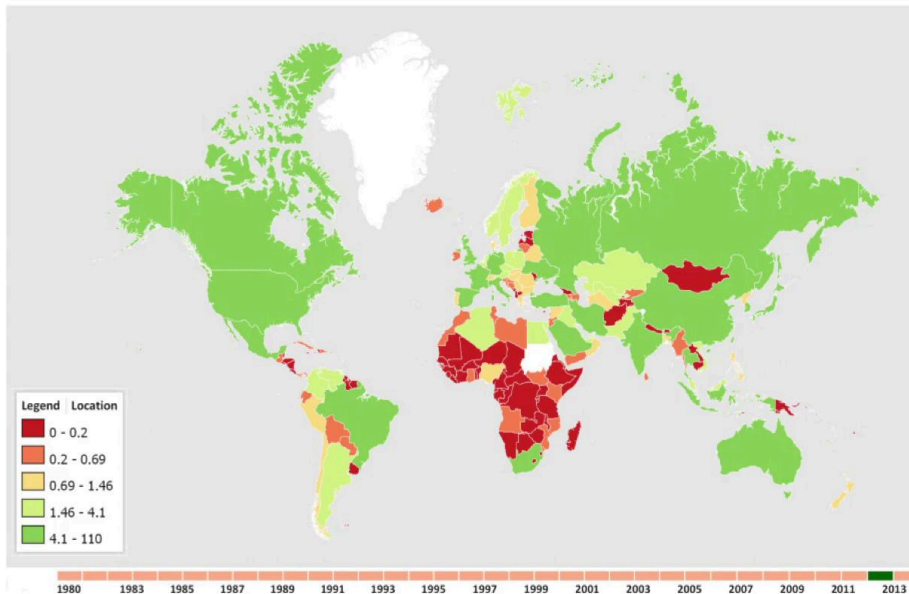
Summary



1m 21s

# Global Energy Consumption

Total Primary Energy Consumption (Quadrillion Btu)



- Total Energy Produced  $\neq$  Total Energy Consumed.

Technology innovation for sustainable development



Surplus electricity may typically arise from energy sources which produce electricity intermittently. Where intermittent energy sources are those sources whose supply can't be controlled by the operator to be continuously available as needed. Which is the case with a variety of renewable energy sources. Such as the wind, solar, tidal waves. Therefore, when they are available, one may wish to generate a maximum of energy, which you can store and retrieve upon need. There are a variety of uses of energy in all phases of our daily lives, which include: transport, construction, industry, domestic use, agriculture communications, etc. Let us now look at who produces energy around the world. As can be seen on the map, North America and most of Asia dominate energy production capacity. Let us now look at who consumes energy around the world. With respect to terminology, we know that global energy produced actually differs from the world final energy consumption because much of the energy that is acquired by humans is lost as other forms of energy during the process of its refinement into usable forms of energy, And it's transport from its initial place of supply to consumers.

Notes

Summary

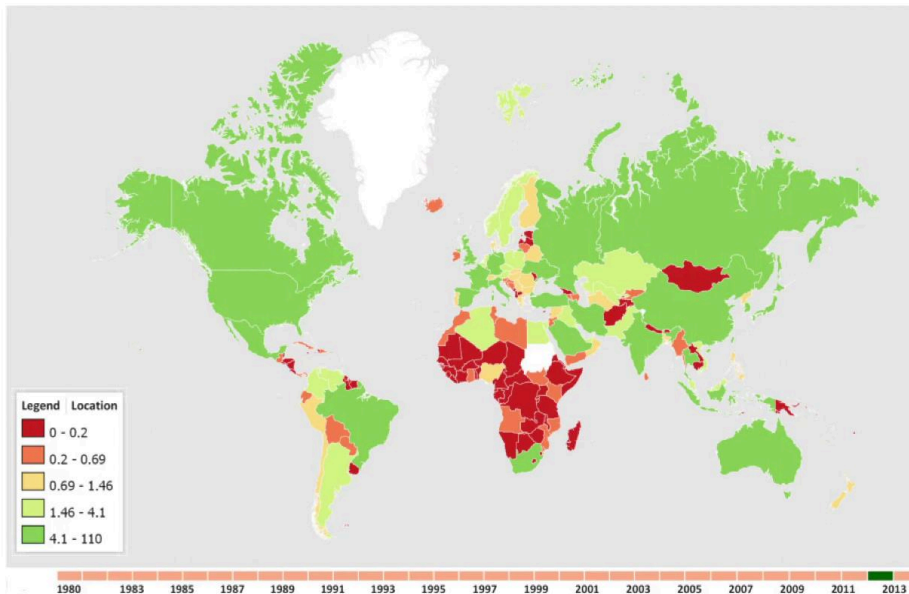


2m 15s



# Global Energy Consumption

Total Primary Energy Consumption (Quadrillion Btu)



- Total Energy Produced  $\neq$  Total Energy Consumed.
- **Link:** Access to Energy & Poverty.

Technology innovation for sustainable development



For instance, when oil is extracted from the ground it must be refined into gasoline so that it can be used in a car, and then transported over the long distances to gas stations where it can be accessible to consumers. So, global energy consumption refers to the fraction of the world's primary energy that is used in its final form by humanity. We see that the global distribution of energy consumption is almost a carbon copy of the energy production distribution maps. In particular, we note that some of the poorest countries, notably in Africa and South Asia, score the lowest in both production and consumption levels.

Notes

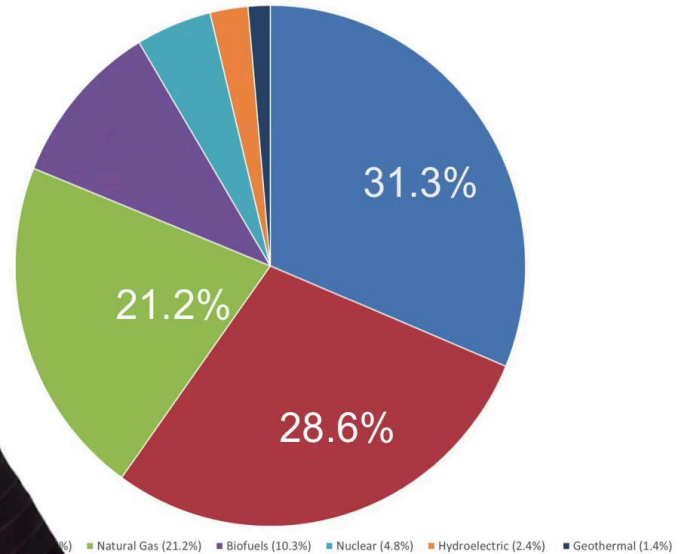
Summary



3m 41s



## Primary Sources of Energy



## Technology innovation for sustainable development



According to the 2016 report from the International Energy Agency fossil fuels account for a share of about 81% in the total of primary sources of energy. Which can be broken down into 31.3% Petroleum 28.6% coal, and 21.2% natural gas. Amounting to a total of 81.1% share for fossil fuels in the primary energy consumption in the world. Well, non-fossil sources include 10.3% from biofuels and waste, 4.8 % from nuclear, 2.4 % from hydroelectricity. Now, although fossil fuels are continuously being formed via natural processes, they are considered to be non-renewable resources because they take millions of years to form. And the known reserves available today are being depleted much faster than any new ones are being made. However, the use of fossil fuels has been linked to serious environmental concerns, as the combustion of fossil fuels is set to produce a net increase of 10.65 billion tons of atmospheric carbon dioxide per year. And carbon dioxide is one of the main greenhouse gases that is set to contribute to global warming. And hence, there has been a global movement towards advocating the use of renewable energy sources to produce energy. And where the favoured renewable energy sources include solar, wind and geothermal sources. And most of these sources happen to be in abundant supply, in fact, in some of or all the poorest countries that still lack energy supply today.

- Notes

## Summary





Technology innovation for sustainable development



The majority of energy today is derived from fossil sources. The generation and use of energy has been accompanied by collateral damage to the environment, however. The burning of coal, natural gas, and oil for electricity and heat is the largest single source of global greenhouse gas emission. Greenhouse gas emission from the transportation sector account for about 40 % and primarily involve fossil fuels burnt for road rail and marine transportation. Almost all of the world's transportation energy comes from Petroleum based fuels. Largely gasoline and diesel. Thus, there's an urgent need for technology innovations that are environmentally clean.

Notes

Summary



6m 08s

## The Unfulfilled Promise of Renewable Energy

- Cost of generating 1kW of electricity still lowest with Coal.
- Level Cost of Electricity:  
$$\text{LCOE} = \frac{\text{Cost over Lifespan}}{\text{Sum of Energy Prod. over Lifespan.}}$$



Technology innovation for sustainable development



Renewable energy sources such as solar, wind and geothermal look to be the ideal candidates to fill this global energy gap, as well as address the concerns we have with greenhouse emissions. However, in reality, progress has been alarmingly slow, especially in developing countries which have abundance of these energy sources. One major issue relates to economics, in fact. While the cost of the infrastructure itself has been going down dramatically recently, it's still very difficult to match the overall cost of generating each kilowatt when compared to using fossil fuels such as coal. For example, a solar energy project in Rwanda that cost about 24 million US dollars to build generates electricity at a rate of 24 cents per kilowatt hour. While industry experts claim that if natural gases is used instead, it would generate electricity at half of that cost. Now how do you determine solar energy generation cost? A common metric is the levelized cost of electricity, LCOE. which is simply the sum of all cost over the lifetime of the facility. divided by the sum of all energy produced over lifetime by that facility.

Notes

Summary



6m 57s



## The Unfulfilled Promise of Renewable Energy

- Cost of generating 1kW of electricity still lowest with Coal.
- Level Cost of Electricity:  
$$\text{LCOE} = \frac{\text{Cost over Lifespan}}{\text{Sum of Energy Prod. over Lifespan.}}$$



Technology innovation for sustainable development



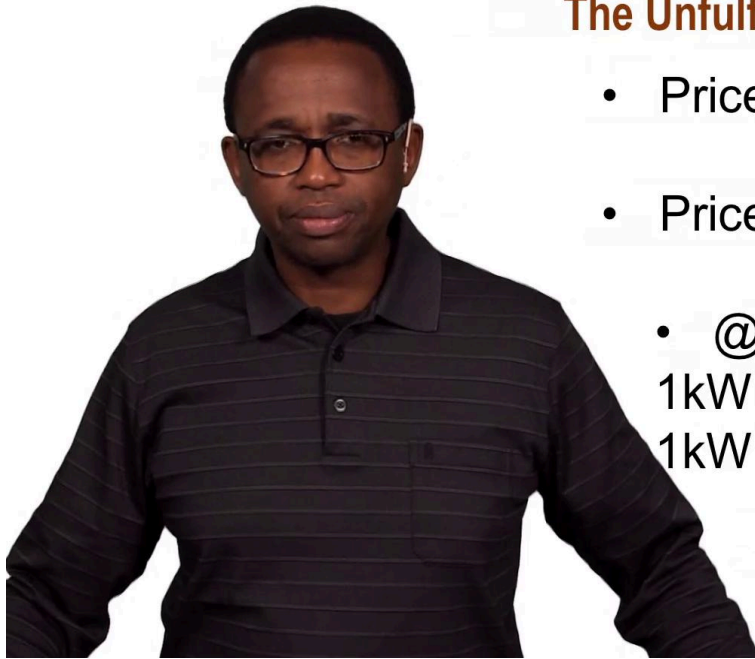
Now, since the costs after installation, are minimal for solar electricity, then the relevant costs are the equipment purchase price, installation cost and the cost of land, that is capital cost. Equipment components of a typical solar system comprise solar modules and other equipment such as an inverter, connection devices and storage devices.

Notes

Summary



8m 18s



## The Unfulfilled Promise of Renewable Energy

- Price of PV Module @2006: **\$3.25**
- Price of PV Module @2006: **\$0.72**
- **@2017 Coal Parity:**  
1kW PV Solar-generated electricity =  
1kW Coal-generated electricity.

Technology innovation for sustainable development



Notes

One of the main cost factors has been the price of solar cells, which are used to make the solar modules. But from 2006 to 2014 the worldwide average prices for solar modules have dropped by about 78 % to the extent that it is anticipated that PV (photovoltaic) solar cost will reach conventional Coal Parity by 2017, which simply means that the cost of generating one watt of electrical power will be similar for coal and solar energy. This factor is expected to encourage a shift to more solar energy electricity plants being built in the future. And less nuclear plants being built. And the continued advancement in technologies for distributed electrical systems and energy storage will also have a major impact on the adoption and integration of renewable energies into power utilities.

Summary



8m 40s

# Renewable Energy & Transportation

- **Transportation:**
  - 50% global oil cons.
  - 25% total emissions.
- **Biofuels:** Lower gas emissions, but affect food prices.



Technology innovation for sustainable development



Transportation currently accounts for about half of global oil consumption in over 1/4 of global greenhouse gas emissions from fossil fuels. Of even more concern though is that carbon dioxide emission derived from transportation have increased more rapidly than the total global emissions in the past 2 decades, according to a report from International Council of Clean Transportation. This report also states that world's motor vehicle population will double over the next 2 decades. And the transportation sector is a hole, which also includes commercial trucks, rail, marine, and aviation. It is also expected to continue to grow at a similar pace over the same period. This forecast that does underscore the importance of current and future strategies that target reductions in oil consumption and greenhouse gases from the transportation sector. Now, from a technology viewpoint various alternative initiatives are ongoing towards reducing and replacing fossil fuels in transportation. These include biofuels, electric and hydrogen powered vehicles all of which still have their pros and cons today. For example, biofuels have low emissions in general, however, they are typically made from vegetables and food crops such as rapeseed for biodiesel.

Notes

Summary



9m 39s

# Renewable Energy & Transportation

- **Transportation:**
  - 50% global oil cons.
  - 25% total emissions.
- **Biofuels:** Lower gas emissions, but affect food prices.
- **Hydrogen Fuel:** Zero gas emissions, but costly infrastructure.



Technology innovation for sustainable development



And thus can adversely affect the food prices. Unfortunately, the most farm equipment involved in crop production typically runs on Petroleum, thus reducing the net benefits. While cars running on hydrogen fuels may give out zero greenhouse emissions, besides water vapor, unfortunately hydrogen is very expensive to transport. And also, currently hydrogen fuel is primarily made from natural gas, which is non-renewable, and also uses processes that create significant CO<sub>2</sub> emissions.

Notes

Summary



11m 04s





## M-KOPA IV Solar Home System



<http://www.m-kopa.com>

Technology innovation for sustainable development



As we said earlier, there are still over 1 billion people without electricity today. In sub-saharan Africa the overall average urban electrification rate is 60 % compared with only 14 % in rural areas. So, one of the biggest challenges is how to reach and provide electricity to the rural and poorer communities that are typically off the electricity grid. There are various promising initiatives in East Africa worth mentioning, that have intelligently benefited from mobile telephony for their success. One such example, is the social enterprise M-Kopa which operates in 3 countries currently, namely Kenya, Uganda and Tanzania. M-Kopa offers a package of useful appliances, such as LED lights, mobile phone charger, and a radio. All powered by a solar panel and a storage battery. Payments are made via the mobile phone and instead of paying up for the package upfront, the client pays monthly installments. Where the amounts are typically less than the monthly cost of Kerosine for lamps. And once the full amount is paid, the package then belongs to the client and they can go back later for bigger and more sophisticated appliances, such as a flat screen television.

Notes

Summary



11m 43s



## M-KOPA IV Solar Home System



<http://www.m-kopa.com>

Technology innovation for sustainable development



So, the main trick and secret for success is that they have managed to convince the customers that are buying the appliances that they are buying the appliances rather than paying for electricity. M-Kopa intends to offer a low energy refrigerators that could also help the customers start up a small restaurant or grocery stores and other forms of businesses. There are various other inspiring and innovative initiatives taking on the challenge of rural electrification in developing countries, which have been provided in the reference section at the end of this lecture. And you're highly encouraged to consult them especially if taking this course for credit. This now brings us to the end of this lecture today. Goodbye.

Notes

Summary



13m 06s