Energy Sustainability & CO₂ Footprint

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Overview

- Energy status – Peaks have passed!
- Energy sustainability
- Pillars of Energy Sustainability
- CO2 emissions & carbon footprint
- You can change!
Why Sustainability?

- Business as usual scenario

![Graph showing the increase in number of Earths required to meet the needs of the present without compromising the ability of future generations to meet their own needs.]

Source: Global Footprint Network and WBCSD Vision 2050, 2010

What is sustainability?

- Development that meets the needs of the present without compromising the ability of future generations to meet their own needs – Brundtland Commission.
- Leave the world better than you found it, take no more than you need, try not to harm life or the environment, make amends if you do. – Paul Hawken, author- Natural Capital and The Ecology of Commerce.
- Sustainability involves a transformation from a wasteful, consumptive linear model of resource use to cyclical model built around reduction, reuse, and recycling.
- Sustainability is based on triple bottom line: planet, people, and prosperity.
Sustainability should address

Biodiversity
Energy
Manufacturing and Industry

Forests and Wood Products
Water Supplies
Climate Change

Agriculture
Justice and Equity
Fisheries

Energy Sustainability

Scientific approach to sustainability

Measure the impact

Understand the global impact of human activities
Take actions to minimize the impact

Measure the post impact and other outcomes

Energy Sustainability
Individual responsibility

- Individuals can make a difference because energy is generated to satisfy the demand placed by individuals. One kWh may not seem much from cost and energy point of view. However, adding millions of individuals' demand may place the need of another coal burning power plant.
- Today, individuals' energy consumption is not visible. As real time energy consumption feedback becomes reality, consumers will have more information related their energy consumption and tools to make wise choices to conserve energy and chose preferred sources of energy.
- **Student activity**: How many times you chose to ride a bicycle to work or school than driving a car? What prevents you from doing that in a regular basis?

Community responsibility

- In this planet, we are living under one roof. Green house gasses (GHG) do not stop at the national boarders. Polluted water reaches to every shore connected to one ocean with different names. Working together, communities can influence national policies that promote the sustainability.
- **Student activities**: List organizations in your town that are committed to sustainability.
Energy Sustainability

- **Energy is the only universal currency:**
  - one of its many forms must be transformed to another in order for stars to shine, planets to rotate, plants to grow, and civilizations to evolve (Smil 1998:10)

- **Definitions**
  - For the purpose of measurement, energy sustainability is defined as ensuring that future generations have energy resources that enable them to achieve a level of well-being at least as good as that of the current generation (Green, D. L.)
  - The Brundtland Commission definition requires that the current generation not diminish the ability of future generations to meet their "needs" rather than requiring that they be ensured the opportunity to achieve at least as good a standard of living (WCED 1987).
Energy Sustainability

- **Energy security**
  - Fossil fuels last for another sixty years
  - Oil supply disruptions are likely to remain relevant in the future
  - Renewable Energy can influence energy security by mitigating concerns with respect to both availability and distribution of resources, as well as to the variability of energy sources.
Marion King Hubbert (1903 – 1989)

"Our ignorance is not so vast as our failure to use what we know."

Dr. M. King Hubbert
(Geophysicist,
Shell Company)

The Hubbert - Curve

CYCLE OF WORLD OIL PRODUCTION is plotted on the basis of two estimates of the amount of oil that will ultimately be produced. The colored curve reflects King's estimate of 2,100 x 10^9 barrels and the black curve represents an estimate of 1,550 x 10^9 barrels.
US Oil Production and Imports

Peak-Oil is NOW!!

OGJ, 9 Feb:2004 (Jan-Nov 2003)
Production of natural gas in Europe

Production of uranium
Energy Sustainability

- **Energy access**
  - Significant parts of the global population today have no or limited access to modern and clean energy services. From a sustainable development perspective, sustainable energy expansion needs to increase the availability of energy services to groups that currently have no or limited access to them: the poor (measured by wealth, income or more integrative indicators), those in rural areas and those without connections to the grid.
Energy Sustainability

- **Creation and expansion of energy resources**
  - Energy resources can be created when technological advances reduce the cost of using renewable resources. Technological advances and learning-by-doing have significantly reduced the costs of solar photovoltaics, biofuels (especially from sugarcane), and wind energy over the past two or three decades (e.g., Goldemberg and Johansson 2004:51)
Energy Sustainability

- **Flows: Measuring Energy Resource Use**
  - Energy flows (i.e., the rates of use of energy resources) are perhaps the best measured component of the sustainability equation. (ENERGY EFFICIENCY)
  - The total quantity of solar energy intercepted by Earth is on the order of 10,000 times the total energy use by human beings (Nakićenović et al. 1998:55). Though far smaller, wind energy resources are also very large relative to global energy use. The question is how much of the enormous quantities of renewable energy resources are economically, technologically, and socially useful? Not only are there questions of economics and the performance of technologies but also issues about site selection and integration with the rest of the energy system.

Sunny Future of Solar

**Veränderung des weltweiten Energiemixes bis 2100**

Prognose des Wissenschaftlichen Beirates der Bundesregierung
Globalen Umwelterminen

<table>
<thead>
<tr>
<th>Jahr</th>
<th>Jährlicher Primärenergieeinsatz [EJ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>200</td>
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<tr>
<td>2020</td>
<td>400</td>
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<tr>
<td>2030</td>
<td>600</td>
</tr>
<tr>
<td>2040</td>
<td>800</td>
</tr>
<tr>
<td>2050</td>
<td>1,000</td>
</tr>
<tr>
<td>2100</td>
<td>1,400</td>
</tr>
</tbody>
</table>

**Quelle:** solarwirtschaft.de
Energy Sustainability

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IEA CO2 Reduction Potentials

*Figure 1: CO₂ reduction potential within the power generation sector by contributing factor*

- **Gt CO₂**
  - Baseline
  - 2003
  - 2050

- **Factors**
  - End-use energy efficiency
  - Generation efficiency
  - Non-hydro renewables
  - Fossil fuel mix
  - Hydropower
  - CCS
  - Nuclear power
  - Tech Plus
Measuring Energy Sustainability

- **Measuring Linkages**
  - Fossil fuel combustion emits the precursors of ozone pollution, particulates, acid rain, and toxic chemicals. Exploration, development, transformation, transport, and storage of fossil fuels have some degree of negative impact on the environment. Nuclear energy creates radioactive wastes that given current technology must be safely stored for tens of thousands of years. Even renewable fuels are not free from unintended environmental consequences and will impose significant demands on water resources and arable land (Fargione et al. 2008). New energy conversion technologies (e.g., fuel cells) will demand significant quantities of mineral resources.
Fossil Fuel & CO2

Energy Sustainability

Atmospheric CO2

Fig. 1-1: Atmospheric CO2 concentration from 1000 to 2008 (Data from National Oceanic and Atmospheric Administration: Dr. Pieter Tans, NOAA/ESRL and D.M. Etheridge et al., 2001, Law Dome Atmospheric CO2 Data, IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2001-083. NOAA/NGDC Paleoclimatology Program, Boulder CO, U.S.)
CO2 Sources

- CO2 emissions from consumption and flaring of fossil fuels

- Asia and Oceania
- North America
- Western Europe
- Eastern Europe and Former Soviet Union
- Middle East
- Latin America

Source: EIA, 2002

CO2 by sector in USA

Carbon Dioxide Emissions by Direct-Fuel Use
Energy Consumption in Sectors

- When the electric power sector is considered by itself, it is the largest sector in terms of energy-related carbon dioxide emissions (41 percent of total emissions)
- Transportation emissions contain very little indirect CO2 from the electric power sector and they are growing at about the same rate, but both declined in 2008
- Direct-fuel use emissions in the residential and commercial sectors have remained relatively flat since 1990
- Direct fuel use industrial emissions have declined by about 8 percent since 1990

Source: Energy Information Administration, preliminary estimate for 2008
World CO2 Emissions

\[ CO_2\text{ emissions} = \frac{Pop \times GDP}{Pop} \times \frac{Energy}{GDP} \times \frac{CO_2}{Energy} \]

where the equation conveys the level of CO2 emissions as a function of four indicators: (i) population (Pop), (ii) Gross Domestic Product (GDP) per capita, (iii) energy intensity (Total Primary Energy Supply [TPES] per unit of GDP) and (iv) carbon intensity (CO2 emissions per unit of energy) (Kaya, 1990).

Figure 1: Global energy use and related economic and environmental intensities. Data source: IEA Data 2009.
Evaluating CO2 contribution (Carbon Foot Print)

- Why carbon footprint?
- What is your carbon footprint?
- How to determine?

CO2 Estimation

- How much CO2 is emitted as a result of my using specific electrical appliances?

- 1kWh = 2.3 lb CO2
- Simply calculate by multiplying kWh/appliance x 2.3 lb/kWh
- Example: 60W light bulb burns for 24h. What is CO2 footprint?
  - 60W x 24h / 100 = 1.4 kWh
  - 1.4kWh x 2.3lb/kWh = 3.3 lb
CO2 Estimation

- How can I calculate CO2 contribution in general?
- Electricity
  - From the EIA, we find the pounds of CO2 emissions per kWh of electricity produced by various fuel sources in 1999:
    - 2.1 Coal
    - 2.0 Petroleum
    - 1.3 Natural Gas
    - 0 Solar, Wind, Hydro, Nuclear
    - 1.3 Average for all forms of generation in US
- Gasoline
  - 20 lbs per gallon

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CO2 Estimation

- Student Activity 1: List all activities you perform in a given day. Identify applicable CO2 emissions associated with each activity. List challenges you phase when developing a carbon-foot print.

<table>
<thead>
<tr>
<th>Daily Activity</th>
<th>Time or distance per day</th>
<th>Fuel used per day</th>
<th>Energy Source</th>
<th>CO2 emissions lbs per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive to work in a 20 miles/gallon car</td>
<td>20 miles</td>
<td>1 gallon</td>
<td>gasoline</td>
<td>(x20) 20</td>
</tr>
<tr>
<td>Cooking with 1.5kW electric stove</td>
<td>3 hrs</td>
<td>(1.5x3) 4.5 kWh</td>
<td>Coal</td>
<td>(x2.1x3) 28.35</td>
</tr>
<tr>
<td>Natural gas heating 6 cubic feet per day</td>
<td>1 day</td>
<td>(6x11.7) 67kWh</td>
<td>Natural gas</td>
<td>(x1.3) 87.126</td>
</tr>
</tbody>
</table>

Total
CO2 Estimation with Energy Bills

- **Electric bill**
  - Energy = Power (Watts) x Time (hours)
  - Consumption in kilo watt-hours (kWh)
  - Monthly consumption is given
  - 1kWh = 3412 BTUs
  - 10 BTUs at Coal burning power plant = 1kWh (3412 BTUs) at home

- **Gas bill**
  - Natural gas consumption (Therm = 100 cubic feet)
  - 1 cubic feet = 1000 BTUs
  - 1 Therm = 100,000 BTUs
How to Cut Emissions

Emission levels from fossil fuel use should be cut by at least half over the next 50 years to avoid a future global warming disaster, Princeton researchers Robert Stavins and Stephen Pacala have described in "emission mitigation" efforts that could create 20 million jobs.

- Emission reductions by 2050 would cut atmospheric CO2 levels to 450 ppm.
- About 200 billion metric tons of CO2 is produced each year in the United States, so a 50 percent reduction could lower emissions 90 percent.

ONE WEDGE AT A TIME

Each strategy listed below, in descending order, could reduce US carbon emissions by 20 percent.

- Conservation
  - Reduce natural gas consumption
  - Increase fuel efficiency

- Energy efficiency
  - Retrofit homes
  - Increase energy efficiency in buildings

- Energy diversity
  - Increase use of wind, solar, and nuclear energy
  - Reduce reliance on coal

- Carbon capture
  - Capture carbon from coal power plants
  - Use carbon capture to enhance oil recovery

- Biofuels
  - Produce 30 billion gallons per year
  - Increase use of ethanol

- Nuclear power
  - Increase nuclear power generation

- Carbon taxes
  - Implement carbon tax on carbon-intensive industries
  - Implement carbon tax on all sectors

- Renewable energy
  - Increase renewable energy generation
  - Use renewable energy to supply 25 percent of US demand

CO2 Estimation with Energy Bills

Gas Usage (Therms/CCF)

<table>
<thead>
<tr>
<th>Therms</th>
<th>Degree Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>1,000</td>
</tr>
<tr>
<td>150</td>
<td>800</td>
</tr>
<tr>
<td>50</td>
<td>400</td>
</tr>
<tr>
<td>0</td>
<td>200</td>
</tr>
</tbody>
</table>

Therms
- Heating Degree Days
- Cooling Degree Days
Discussion

- How will you reduce your carbon footprint?
- How will you reduce your home carbon footprint?
- How will you reduce your school carbon footprint?
How to Cut Emissions

Scientists warn that current CO₂ emissions should be cut by at least half over the next 50 years to avert a future global warming disaster. Princeton researchers Robert Socolow and Stephen Pacala have described 15 “stabilization wedges” (far right) to realize that goal using existing technologies. Each carbon-cutting wedge would reduce emissions by a billion metric ton a year by 2057. Adopting any combination of these strategies that equals 12 wedges could lower emissions 50 percent.

ONE WEDGE AT A TIME

Each strategy listed below would, by 2057, reduce annual carbon emissions by a billion metric tons.

- **EFFICIENCY AND CONSERVATION**
  - Improve fuel economy of the two billion cars expected on the road by 2057 to 60 mpg from 30 mpg.
  - Reduce miles traveled annually per car from 10,000 to 5,000.
  - Increase efficiency in heating, cooling, lighting, and appliances by 25 percent.
  - Improve coal-fired power plant efficiency to 60 percent from 40 percent.

- **CARBON CAPTURE AND STORAGE**
  - Introduce systems to capture CO₂ and store it underground at 600 large coal-fired plants or 1,000 natural-gas-fired plants.
  - Use capture systems at coal-derived hydrogen plants producing fuel for a billion cars.
  - Use capture systems in coal-derived synthetic fuels plants producing 30 million barrels a day.

- **LOW CARBON FUELS**
  - Replace 1,400 large coal-fired power plants with natural-gas-fired plants.
  - Displace coal by increasing production of nuclear power to three times today's capacity.

- **RENEWABLES AND BIOSTORAGE**
  - Increase wind-generated power to 22 times current capacity.
  - Increase solar power to 700 times current capacity.
  - Increase wind power to 50 times current capacity to make hydrogen for fuel-cell cars.
  - Increase ethanol biofuel production to 50 times current capacity. About one-sixth of the world's cropland would be needed.
  - Stop all deforestation.
  - Expand conservation tillage to all cropland (normal plowing releases carbon by speeding decomposition of organic matter).