Over a barrel: A worldwide energy crisis …

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A worldwide energy crisis... towards a sustainable energy future

An emerging worldwide energy crisis... demands a new approach for a sustainable energy future. How we adapt will determine our future on the planet.

Outline
- Worldwide energy problems
- Causes of problems
- Energy supply options: renewable energy sources
- Example: transportation
Over a barrel...trapped by our dependence...

Over a barrel (idiom): to be in a situation of helplessness; to be in a very awkward position from which extrication is difficult.

...trapped by our dependence on imported oil...and the threat of global climate change...
High price of gasoline and oil: Wrecking America’s financial security

America is going broke

Cost: $700 billion for imported oil in 2007

$2000 per man, woman, and child in America is being sent abroad, to many countries which are not our friends.

http://tonto.eia.doe.gov/dnav/pet/hist/mg_rt_usw.htm Feb2009
Our energy security is threatened:
War over oil; exhausting the supply

Fighting over scarce resources

Running out of oil…

War in Iraq: $150 billion/year and thousands of lives…cost to date $1000 billion

The world’s readily-available oil supply will be exhausted within a century…
Our planet is threatened...  

We all live on the same planet  

Possible global climate change:  
many of the choices we make affect everyone on Earth...and their choices affect us....
Our present energy sources* are not sustainable and cause global climate change

*except for renewable sources

What does make sense?
Natural gas? Wind? Solar?

Some renewable sources might be useful

Turning food into fuel makes no sense
Our energy problem(s)

- Global climate change
  Our planet is threatened

- Geopolitical strife/war
  Our national security is threatened

- High energy prices; price instability
  Our economy is threatened

- Energy supplies
  Our energy supplies are threatened
There are only four sources of energy on earth

Primary sources of energy:

• sun
  
  active stored

• nucleus
  
  \[E=mc^2\]

• geothermal (heat in earth)

• gravity/moon (tide)
Where we get our energy

Worldwide energy sources

- Fossil fuel 88% -> global climate change.
- Only renewable source is hydroelectric.
Why we have an energy problem

(1) The world’s population is increasing.

World’s population:
Today: 6 billion
Year 2050: 9 billion

Source: U.S. Census Bureau population projections, October 1987.
(2) Some countries use too much energy

United States:
5% of the world’s population
25% of the world’s energy use.
Why we have an energy problem
People in rich countries use more energy than in poor countries.

Nearly 2 billion people live without electricity.

These people have plenty of energy.
Why we have an energy problem
(3) The oil is not where most of the people are -> war

United States: Needs oil
OPEC: Produces oil
Why we have an energy problem

(4) We will use up all the readily available petroleum.

The world's readily-available oil production will peak between 2010 and 2060. It will be gone in about 100 years.

Worldwide oil production from existing fields is decreasing by 8% per year, while demand has been rising by 1.5% per year.*

* Demand will flatten or decrease slightly in 2009.

Petroleum supply curve
There are increasingly expensive and carbon-intensive alternatives to readily available petroleum.

We will have used in only a few centuries all the readily-available oil made millions of years ago.
Oil prices are high and volatile: both are threats to economy and stability

Oil price

Price of a barrel of petroleum $ 

Volatility is evidence for market speculation and manipulation

Worldwide consumption is relatively flat.

Fluctuations in price of oil are not due to change in oil consumption, which is decreasing slightly worldwide*.

The price of oil is NOT following classic supply/demand

Demand from China, India, and Middle East is projected to increase (IEA-2008)

*Update (February 2009). EIA *Global oil consumption is estimated to have been largely unchanged in 2008 and is projected to fall by 800K barrels (1%) in 2009 http://www.eia.doe.gov/steo#Overview.

Figure updated from US EIA February 2009

Worldwide consumption is relatively flat.
**Oil prices: supply and demand**

**Supply and demand** (demand is slowly increasing)
- increasing demand, especially from Asia, as population and income grow
- geopolitical unrest and disruptions (Iran, Iraq...)

**Major factors in volatility: speculation and fear**
- market speculation...“oil is the new gold...”
- fear of running out of oil
- manipulation of futures prices by hedge funds

**Worldwide economic downturn** (new uncertainties)

**OPEC control of market** (41% in 2006)

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*World energy demand expected to grow (IEA-2008)*

*Weekly All Countries Spot Price FOB Weighted by Estimated Export Volume*

*World Oil Consumption*
Classic “bubble” economics: tulipmania

Dutch tulip bubble 1634-1637: “tulipmania”

In 1634 the rage among the Dutch to possess tulip bulbs was so great... the population embarked in the tulip trade... so that by early 1637 one bulb was reportedly sold for a price forty times greater than the average income and equivalent to the price of a house... [Historians] attributed the economic and political decline of the Netherlands to tulipmania.

The South Sea bubble”: England 1720

Through incompetence or corruption the South Sea Company’s directors talked up the price of their shares, fueling a speculative bubble that featured claims about the discovery of new technologies (including perpetual motion machines), and forecasts that prices would continue to climb.

The collapse came in September 1720, an event that ruined many speculators and financial institutions.

Sir Isaac Newton lost £20,000 and lamenting “I can calculate the motions of the heavenly bodies but not the madness of people.”
Classic “bubble” economics

NASDAQ Composite Index

Oil price

Home Price Index

Inflation-adjusted National Home Price Index Since 1980

Weekly All Countries Spot Price FOB Weighted by Estimated Export Volume

Source: U.S. Energy Information Administration
America’s addiction to oil

Contrary to popular wisdom, if America is addicted to oil, then the last thing we want to do is to reduce the price.

A way to treat addiction is to raise the price of the substance.

America has gone from importing almost no oil in 1950 to importing 65% of our oil at present.

The cost is enormous ($700 billion last year) and our energy security is at risk.
Potential sources of energy

**Renewable**: we can get more
- Solar
- Wind
- Waves
- Biomass
- Hydroelectric

**Non-Renewable**: use it up and its gone
- Oil, coal, natural gas
- Nuclear
Solar energy

We can use the sun’s energy in three ways:

• Making electricity directly (photovoltaic)

• Using the sun’s heat (thermal)

• Storing the sun’s energy in chemical bonds (photosynthesis)

More energy from sunlight hits the earth in an **hour** than all the energy consumed on the planet in a **year**.
Utilization of solar energy

Small scale: local/village

Medium scale: house

Large scale: industrial

Nevada Solar One: 64MW (Boulder City, Nevada)
The issues:
- Capture the energy
- Convert the energy to a useful form
- Store the energy for later use

Solar energy:
- Sunlight is free
- All these methods are too expensive
- We cannot efficiently store energy
- Scientists are working on improvements

Solar energy is our most likely energy source of the future….but it is not yet economical.
Utilization of solar energy: industrial scale

GRAND PLAN:

**Generation:** Solar thermal and photovoltaic arrays over 100,000 km² (60,000 square miles) in the desert generate 70% of electricity needs of U.S.

**Storage:** Energy is stored by compressed air stored underground.

**Cost:** $500B (half the cost of the Iraq War to date; less than the cost of one year’s oil imports).

No one knows if this is sensible.
Wind, waves, ocean currents: caused by the sun.

**Wind** is caused by uneven heating of the earth’s surface by the sun.

**Waves** are caused by wind.

**Tide** is not caused by the sun. It is caused by the gravitational pull of the moon.
Wind energy

The sun is the source of energy for wind.

Wind energy: wind is free

Issues:

- Expensive
- Very large
- Kills birds
- Wind blows mainly at night: (cannot efficiently store energy)

There is lots of energy in wind; wind energy deserves more attention.

Blade for a wind turbine is 60 meters long. The tower will be 120 meters feet high.
Tide energy

The gravitational pull of the moon and sun are responsible for the tides.

Tidal energy:
- Works in very few sites around the world
- Expensive
- Irregular

There is lots of energy in tides; but there is no easy way to get it.
Wave energy

The sun is the source of energy for waves.

Converting wave energy to electricity.

- May be a good idea
- Seawater is corrosive
- Very expensive
- Need cables to land
- Not regular

To date: not practical
Maybe in the future…

There is lots of energy in waves; but there is no easy way to get it.
The inside of the earth has been hot since the earth was formed.

Geothermal energy:
- Corrosive/expensive
- Not cost effective at present.
- Some methods can cause earthquakes.

There is lots of heat inside the earth; but there is no easy way to get it.

A geothermal energy plant in Iceland.

Geothermal energy is considered renewable because the supply is huge. It cannot be renewed.
Nuclear energy: fission

Lots of energy is stored inside atoms...nucleus ($E=mc^2$).
Energy is released when the nucleus splits (fission).

Advantages:
• we have lots of uranium
• no greenhouse-gas emissions

France: 80% of its electricity is from nuclear power.

Potential problems:
• storage of radioactive waste
• threat of terrorist attack/accident
• nuclear proliferation (bad guys making bombs)
• limited supply eventually
• public acceptance and high cost
Nuclear energy: fusion

Lots of energy is stored inside atoms...nucleus ($E=mc^2$).

Energy is released when two nuclei stick together and join.

**Advantages:**
- runs on hydrogen
- releases huge amounts of energy
- no radioactive wastes
- no fissile material to make bombs.
- no greenhouse-gas emissions

**Disadvantage:**
- There *are* no fusion reactors.
- This is a research project.
Biofuels: ethanol from corn…a truly bad idea.

The sun is the source of energy for biofuels.

Ethanol from corn:
- a net loss of energy,
- more greenhouse gases emission.
Corn is important for food.

Food is too valuable to convert to fuel when there are a billion starving people on the planet.
Electricity? Not a fuel

Electricity is not a primary source of energy: we make electricity in a power plant.

Electricity is a means of getting energy from one place to another.

Most electricity is made from fossil fuels. Very little is made from renewable sources other than hydroelectric.

- sun: active and stored
- nucleus
- geothermal (heat in earth)
- tide (gravity of moon...)
Hydrogen?

Hydrogen is not a primary source of energy: we make hydrogen in a factory.

Hydrogen is a means of getting energy from one place to another.

Hydrogen is always found in nature as a molecule (like $H_2O$).

There is no inexpensive or efficient way to make hydrogen, nor to transport it, nor to store it.

A hydrogen fuel-cell vehicle:
not yet technologically feasible.

- sun: *active and stored*
- nucleus
- geothermal (heat in earth)
- tide (gravity of moon...)
Hydrogen fuel-cell vehicles

The platinum problem:
Catalyst in PEM fuel cell: 60 grams of platinum.
USA sales: 10 million cars per year.
Platinum required for 10 million cars: 600,000 kg.
Worldwide annual production: 200,000 kg.

The on-board hydrogen storage problem:

There is no inexpensive or efficient way to make hydrogen, nor to transport it, nor to store it.
Transportation: three major issues

Vehicles
Technology: easiest problem

Fuels
New fuels: related to technology plus infrastructure
difficult problem
- Primary source
- Transfer media

Mobility
Markets, sociology, urban planning, human behavior:
very difficult problem
Cars have poor fuel efficiency

Most of the energy in gasoline goes into heat, not into moving the car.

Fuel economy of U.S. cars (miles per gallon) has not improved since 1985.
What can we do about cars?

What can we do?
- Drive fewer miles: carpools, public transit, land-use planning
- Make cars lighter and smaller
- Make cars more efficient...like a Prius or other hybrid
- Develop new means of powering cars....

Vehicles miles traveled began to decrease in 2007.

Fewer miles
Vehicle miles traveled as reported by the Federal Highway Administration. Note the decrease in 2008.

In billions of miles

2006 2007 2008

Miles driven 12-month total, monthly

Sales of SUVs and gas guzzlers are decreasing.

Plunging SUV Sales

Light truck as a share of Total Vehicle Sales

% 92 94 96 98 99 00 02 04 06 08 10 12

Source: Autodata Corporation, GfK CWM

Update: February 24, 2009 (USDOT, FHA)
*Cumulative travel for 2008 changed by -3.6%
Cars need portable fuel: gasoline

Cars need to carry their energy with them. Today this means oil/gasoline/diesel.

Most of our oil is imported... from undemocratic countries

Pollution is bad for people... and bad for our planet

How will we find a portable fuel to run cars and trucks that we do not import and which does not directly cause pollution and global climate change?

Thomas Alva Edison: around 1900. One third of the 4200 cars produced in the U.S. were powered by....
Using electricity to power cars
electric motors are highly efficient

Electric motors are four times as efficient as an internal combustion engine. (about twice as efficient in use of primary energy).

- **Hybrid cars** (Toyota Prius) capture energy lost to heat in braking. Use gasoline engine and electric motor.
  
  All the energy comes from gasoline.

- **Plug-in hybrid vehicles** (PHEV) are on the horizon. Energy will come from gasoline plus electric grid. Awaiting better batteries.

  A PHEV stores energy from the electric grid, and uses gasoline to extend the range of the vehicle.

The advent of practical batteries for plug-in electric vehicles will transform the transportation sector by eventually reducing oil consumption and greenhouse gas emissions to zero.
“Drill, baby, drill…”
Drilling for new sources of oil.

**Issue:** what effect can drilling for oil have on the current energy crisis in the US?

**Time:** generally cited as 10 years for delivery of oil.

*Too late to help the present.*

**Quantity:** AMWR (Arctic National Wildlife Reserve) holds about 8-10B barrels *(DOE, USGS): adding three months to the world’s oil supply.*

US imports 13.5M barrels per day.

World consumes 80M barrels per day.

*Thus all the oil in ANWR would account for three months of world consumption or two years of US imports. Too little to make a difference*

**Greenhouse gas production:** no improvement. *Still bad for global climate change.*

Drilling for oil offshore and in ANWR could provide only temporary benefit, in the future rather than at present.
Plan: produce electricity with wind energy, run cars with the natural gas which is saved.

US natural-gas consumption greater than US production
- US Consumption 21.6 TCF/year
- US production 18.5 TCF/year

**US imports:** 16% of natural gas
- 4.2 TCF/year ...mainly from Canada, Trinidad/Tobago, Egypt, Algeria

**US proven reserves:** 14-year supply 280 TCF (per EIA)*

**World reserves:** 6300 TCF countries not friendly to US

* Number disputed by Pickens

**Issues (natural gas): potential problems**
- Supply: U.S. supply is limited (14 years at current rates).
- Dependence: Largest supplies are in Middle East, Russia, and Africa...not necessarily friendly countries.
- Poor efficiency (car 15%, power plant 60%)

**Issues (wind): might be useful**
- Capital cost
- Fluctuates in time
- Need improvements to grid.

There IS no surplus natural gas. The US is an importer of natural gas.
Mobility? Changing the American way of life…

Newt Gingrich: “Our culture favors driving long distances in powerful vehicles and the car is a social expression.”
Effective use of motor transport...

America

Asia
Better batteries are needed for hybrid electric cars….

- Improvements in efficiency of 2.5% will let us reach 35 mpg* by 2020 (mandated by Energy Act of 2007).
- Increasing use of hybrid electric vehicles will allow us to reach or exceed 50 mpg by 2030…as will use of strong light-weight materials.**
- Advent of plug-in hybrid vehicles with a 40-mile electric range will allow us to decrease fuel use by 63%, for an effective 135 mpg.

* Fuel economy per EPA is inflated 25% relative to actual driving tests.
**Lighter-weight cars can be made more safe by careful design.

The advent of practical batteries for plug-in electric vehicles will transform the transportation sector by eventually reducing oil consumption and greenhouse gas emissions to zero.

No battery existing today has the right combination of characteristics to power a plug-in hybrid vehicles with a 40-mile electric range.
Electric cars: battery swapping

“Better Place”: Shai Agassi

**Concept:**
Put battery charging and swapping stations all over the United States.

**Potential issues:**
- There are no useful batteries nor electric cars.
- Electric range small (20-40 miles)
- All electric cars would need to be standardized.
- A very large number of swapping stations would be needed.*
- Batteries will likely be very expensive and have a short service life -> huge capital cost

* There are 150,000 gas stations in the United States. More CNG stations would be needed as range is smaller.
Two billion cars…

Two billion vehicles projected by 2030.
Note large increase in developing countries…

The Tata Nano will sell for about US$2500.

Imagine each bicycle, rickshaw, and motorbike replaced by a car…..
Traffic jams...

Traffic jams: fundamental instabilities inherent in multiparticle interactions...

Houston: Rita evacuation


Metering lights on Bay Bridge to limit traffic flow
The problem of energy storage

**Small scale**: cell phones, laptop computers
Lithium-ion batteries are expensive but effective.

**Medium scale**: electric cars
There are no batteries which are suitable for mass-market plug-in electric vehicles.

**Large scale**: electric grid
Pumped water (25% loss) and compressed air are used. (Other options: thermal storage, ice storage, flywheel, superconducting magnet, hydrogen…)

There is no effective way to store lots of energy.
A path to a brighter *sustainable* energy future

- We must be ready for change.
- We need sensible government policies.
- We need a decision to end petroleum use.
- We need adequate funding for research on science and energy technologies.
- We need *renewable* energy sources.

*America* cannot remain over a barrel… with our energy security at risk.

* And the world…

**Efficient use of energy is our best option…**

Biofuels and synthetic photosynthesis

Science and materials

Batteries, hydrogen storage, and fuel-cells.
Energy efficiency: doing more with less

Conservation: doing less with less.

Efficiency: doing more with less.
Improving energy efficiency is a relatively easy and inexpensive way to significantly reduce the nation’s demand for imported oil and its greenhouse gas emissions.

Numerous technologies exist today to increase energy efficiency that could save individual consumers money. Need federal policies ...

Increases in energy efficiency will require a larger and better-focused federal research and development program than exists today.

President Obama at DOE: February 5, 2009

“...this plan will end the tyranny of oil in our time.”

“We’ll also lead a revolution in energy efficiency....”

New York Times
February 26, 2009

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Earth: we live here.

Conclusion.......

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Thank you......

Our future and the future of our planet are in our hands.

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Energy: the ability to do work

Energy is the ability to do work......

Energy can take many forms......

Potential energy

Kinetic energy
Transportation: summary

We must replace the use of fossil fuels with electricity from a green grid.

• Drive fewer miles: carpools, public transit, land-use planning
• Make cars lighter and smaller
• Make cars more efficient…like a Prius or other hybrids

Future generations will likely view running internal combustion engines in a city like smoking tobacco: a truly bad idea.
Science research for energy: many examples

Photovoltaics

A multilayer photovoltaic cell with bandgaps tuned to absorb different parts of the solar spectrum (LBNL 2008)

Batteries

Silicon nanowires on anode of lithium-ion battery (Nature Nanotechnology December 2007)

Nanoscience

Carbon nanotubes for hydrogen storage for fuel cells.

There are similar challenges in engineering.
What can we do? Support science and energy research

Examples of research areas to support:

- Nanomaterials for better batteries and for hydrogen storage
- Synthetic photosynthesis for new biofuels
- New photovoltaic materials for efficient solar cells
- Ultracapacitors, new battery chemistries, large-scale energy storage
- Ultra-strong light-weight materials, fabrication of carbon-fiber….
PBS “Planet Forward”
Electric cars: Tesla, Volt, Toyota PHEV….

A battery-electric car—Tesla—is available now.  
*Price very high, runs on 6800 laptop batteries*

The Chevrolet Volt—advertised as a PHEV40—is scheduled for release in late 2010.  
*Price not announced, battery not in production*

A plug-in Prius is advertised for release next year.  
*NiMH battery range 7 miles, Li-ion range perhaps 15 miles*

A Honda FCX Clarity hydrogen vehicle is available now.  
*Lease only, cost several hundred thousand $*

*These cars are not ready for market.*  
*as a replacement for the American family car*