

## Building, Environment and Our Future

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[www.civil.uwaterloo.ca/beg](http://www.civil.uwaterloo.ca/beg)



"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait 'til oil and coal run out before we tackle that."  
--Thomas Edison 190?

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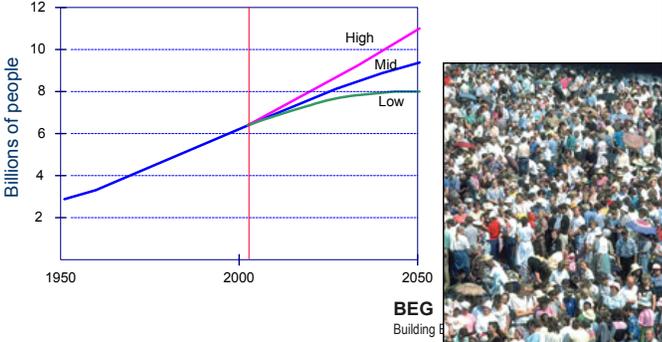
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## Population Growth

- Slowing, only another 50%, 3 billion to go!



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## Consumption Growth

- Increasing "affluence" means increased consumption
  - e.g., Chinese GDP growing by 6-10%/yr
  - bigger houses, more appliances, more cars
  - replace labor with materials/energy
- North American house
  - 1950: 400 sf/person
    - 1600 sf/house (4 people)
  - 2000: 750 sf/person or
    - 2400 sf/house (3.2 people)

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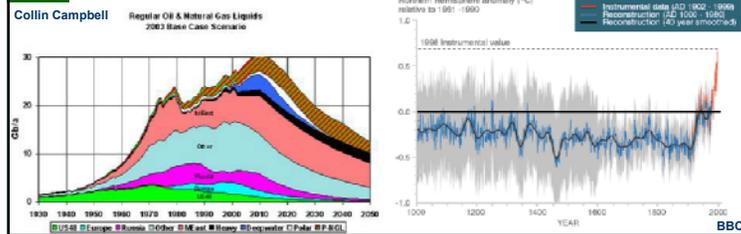
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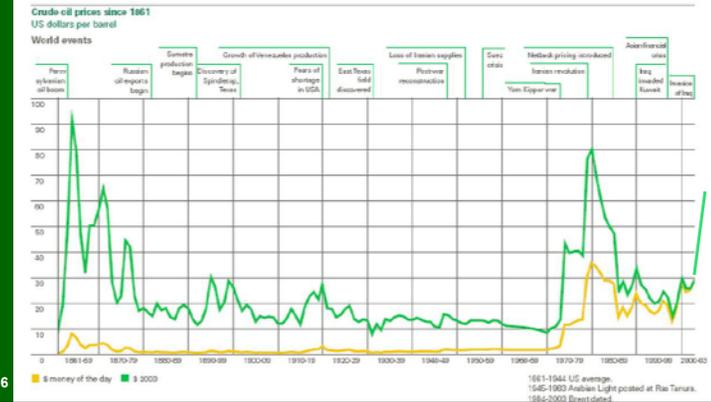


## Depleting Energy

- **Cheap** oil and gas is almost gone
- Huge new energy services required for developing world
- We shouldn't burn more, certainly not tar sands!

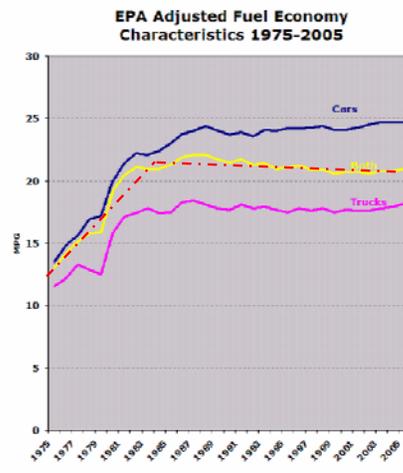


## Oil Prices – BP Survey



## Cars/Trucks

- We have not increased efficiency
- Many more vehicles on road
- Consumption and pollution increases



## This presentation

- **Buildings**
  - Context
  - Importance
- **Role of Technology**
  - Good design
  - Less waste = more efficiency

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## Components of the Built Environment

- Buildings and the parts thereof
- Service infrastructure/utilities, etc.
- Distribution/transportation/traffic handling systems
- Occupants/users/owners
- **Providing and maintaining the built environment is the largest single industry on the planet**



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## Problems with the Built Environment

- Environmental damage
- Buildings don't work well
- Buildings cost too much
- Sometimes they even hurt us
  
- Can technology help?

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## Buildings

- Buildings also part of the **environment**
- They consume resources
  - materials and energy
  - Cost a lot of money
- Pollute, displace, destroy (provide) habitats
- A "durable good"
  - Running shoe (1 yr), car (10 yr), bldg (100yr?)
- Hence - more careful long-term design
  - i.e. societal involvement is justified

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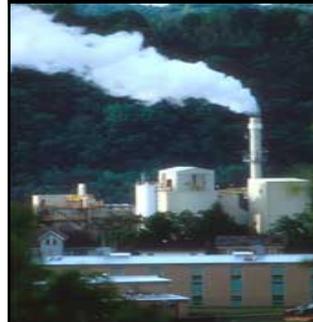
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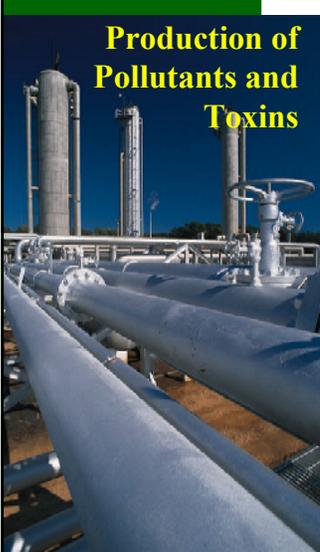
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## Resource Depletion & Pollution

- Buildings consume 35-50% of world energy in production and use
- about 40% in Canada



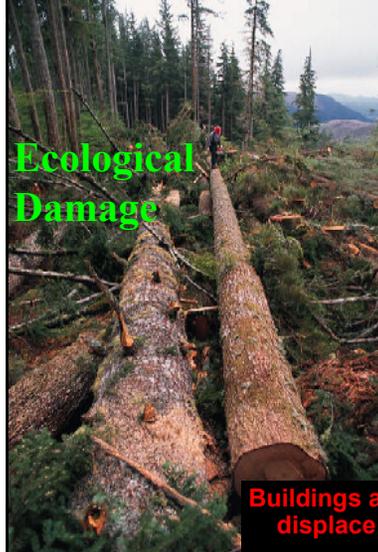


**Production of Pollutants and Toxins**

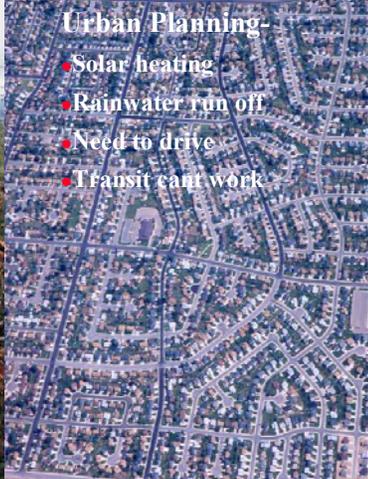
- Landfill waste
- Energy pollution
- Toxic materials



- Buildings consume 40+% of all harvested or mined resources



**Ecological Damage**



**Urban Planning**

- Solar heating
- Rainwater run off
- Need to drive
- Transit can't work

**Buildings and their connections (roads) displace and destroy habitat**

**Buildings, Energy, Pollution**

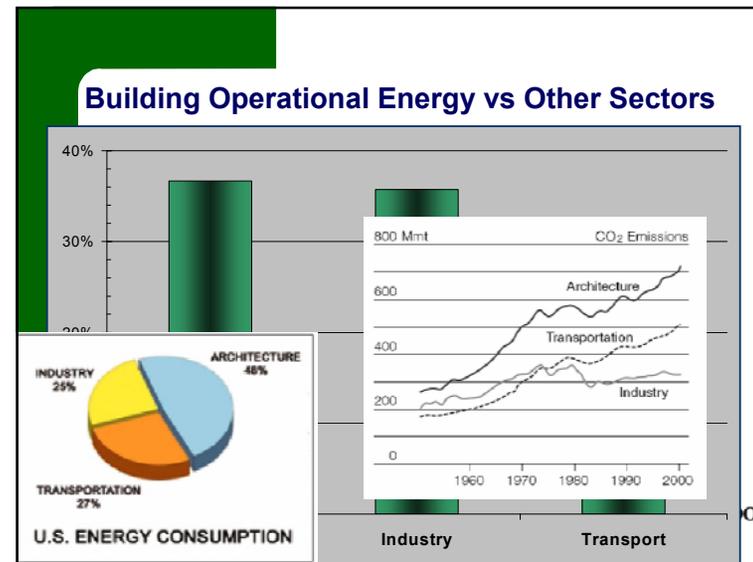
- Buildings consume **68%** of all electricity
- Operation of US buildings
  - Purchased energy costs \$265 Billion in US
  - 560 million tons of CO<sub>2</sub> per year
  - 36% of US total and 9% of global CO<sub>2</sub> production
  - 49% of US total SO<sub>2</sub>

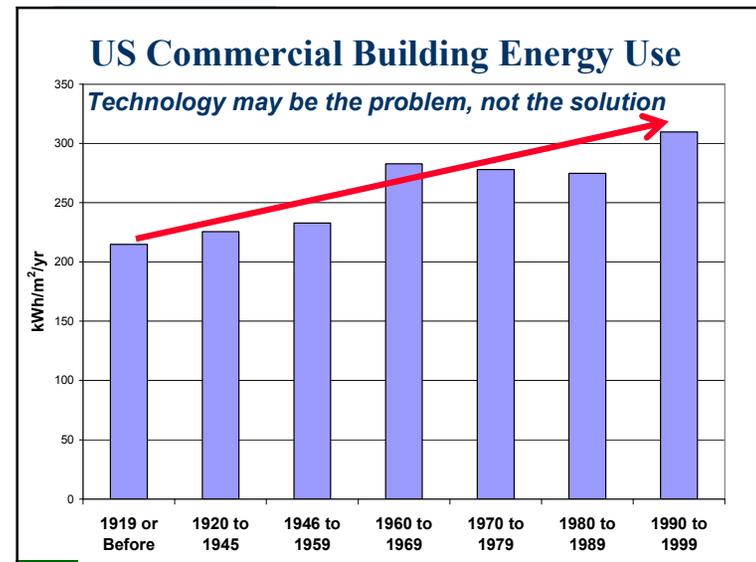
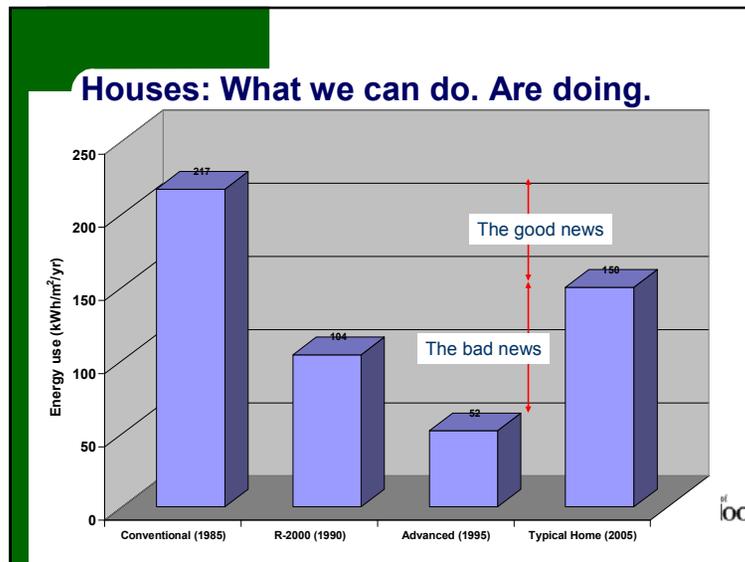
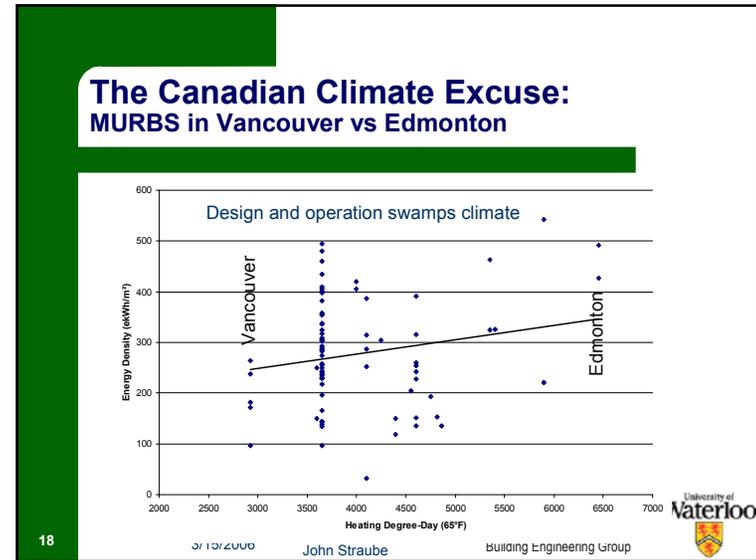
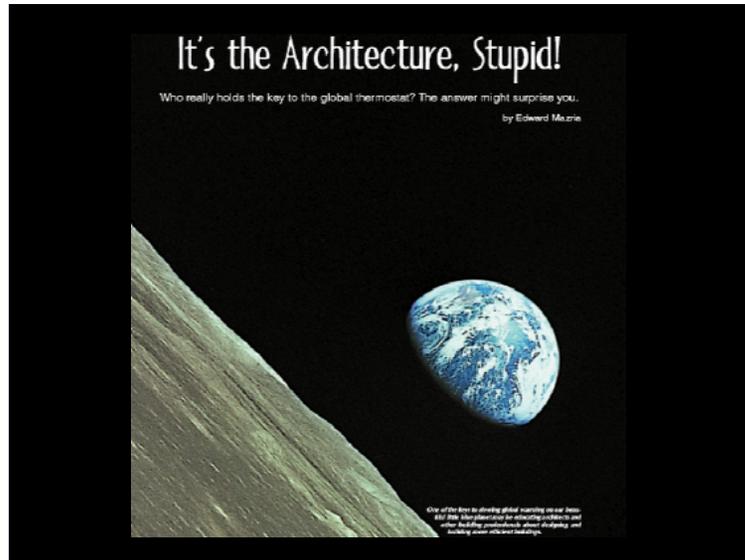


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**Technology is the answer.  
But what is the question?**

Amory Lovins

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**So... what is the answer?**

- Technology is necessary, but not sufficient

**Design**

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**Design & Technology**

- What problem do you wish to solve?



Fridge Energy consumption  
1973 –1800 kWh/yr  
2003 - 500 kWh/yr  
Best available – Sun Frost – uses 200 kWh/yr  
(but costs \$3000! so is not economical)

\$4000  
[www.smarthome.com](http://www.smarthome.com)

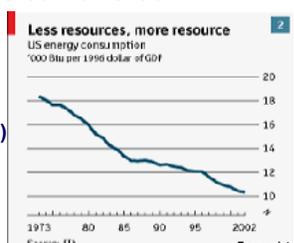
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**Energy & Efficiency**

- People want services not energy
  - Warm house, not gas
  - Light, not electricity
- Hence, efficiency allow us to have our cake and eat it
- Energy reductions after '73 / '79
- California brownouts(2001)
  - 14% cut in 6 months simply by citizen action



**Less resources, more resource**

US energy consumption  
'000 Btu per 1995 dollar of GDP

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Source: EIA Economist

## Goal

- If we must build, build greener buildings
- Eventually,
  - Buildings that use no net energy, enhance ecology, clean air and water
  - sustainable buildings in a sustainable community
- Future
  - Renewable / bio-materials (like cellulose)
  - Building systems that allow reuse/recycling
- ***"Within one generation, nations can achieve a ten-fold increase in the efficiency with which they use energy, resources and other materials"***

1997 Carnoules Statement to Government and Business Leaders



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## Is it Green? Learning to count

- Depends on answers to:
  - Does it use less non renewable energy to operate?
  - Will it last longer? (less life-cycle resources)
  - Does it use fewer non renewable resources to build?
  - Does it pollute less?
- Compared to?:
  - Zero (sustainable)
  - Average (move forward, "green")

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## Technology to reduce energy+pollution

- Reduce heat loss and gain
  - Insulation
  - Avoid thermal bridges
  - Use good windows
  - Airtight
- Avoid energy use
  - Efficient appliances and elevators
  - Collect from sun
  - Use daylighting
- Then, generate renewable energy

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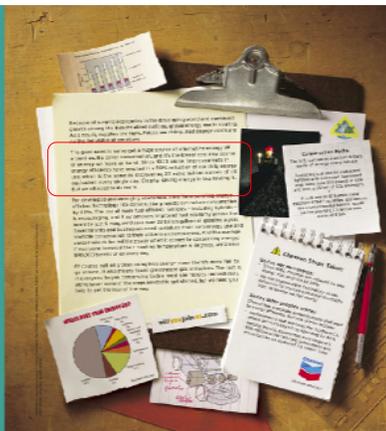


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## Chevron Gets it

You use 25 barrels of oil a year.

So are we ready to do something about it?



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## The Zero-sum Myth

- **Myth:** *"It is not economical to save energy and reduce pollution"*
- **Fact: Median threshold for EE decisions**
  - 1.9 yr payback / 71% after-tax ROI (Dept of Energy)
- **Pollution inspection & control = expensive**
- **Saving energy is not expensive**
  - Can often be **CHEAPER!**
  - e.g. Dupont, Lockheed
  - Building Science Corp ([www.buildingscience.com](http://www.buildingscience.com))

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## How to do it

- **We already know how!**
  - E.g. Compact fluorescents (1/5)
  - E.g. Highly insulating windows (1/3)
  - E.g. Better enclosure insulation / airtightness (1/2)
  - E.g. Efficient HVAC and office equipment (1/2)
- **Future**
  - Superwindows
  - Renewable / bio-materials
  - Building systems that allow recycling

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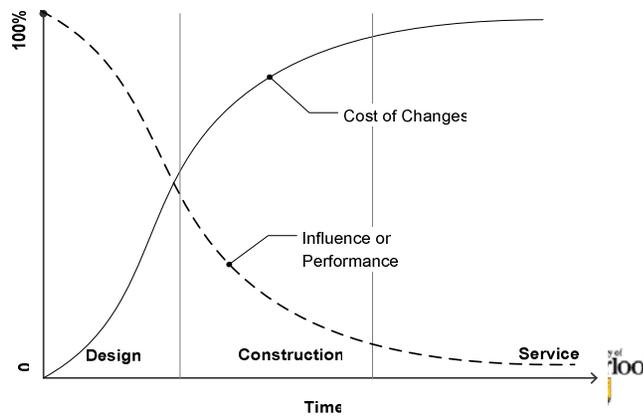
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## Performance vs Cost & Time



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## Fans

- **Most use dampers to control airflow**
  - Close to valve to control flow
- **Modern systems control speed of fan**
- **Controls respond to needs**

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## Lights

- **Compact Fluorescents - duh**
  - Use 1/5 as much energy, last 10 times as long
- **LED Exit Lights**
  - Last 15 yrs, use 2 Watts (\$1/yr operating)
- **Incandescent Exit lights**
  - Last 2 years, use 40 Watts (\$20/yr + replace)
  - Replacement costs \$15-30 each time
- **Turn off lights if you not there**
  - Stairwells, meeting rooms, bathrooms

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## Solutions



- **Design new building systems**
  - Requires simulation
  - Requires teamwork for implementation
- **Energy Efficiency**
  - Cheapest form of energy
  - Reduce active equipment
  - Upgrade building stock, change city planning
- **Improved renewable energy**
  - Integrated power networks to share

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## How to do it

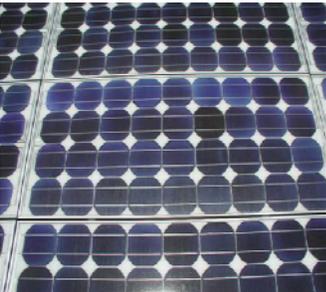
- **System integration**
  - "Professional specialization" disease
  - Sub-system optimization
  - Non-optimal whole system design
- **Real benefits come as a system, not individual**
  - Airtight, shade and solar windows save AC costs, fans, and ducts
  - Better insulation can mean no furnace
  - Reduced power req't = alternative energy economical

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## Renewable Energy Growth

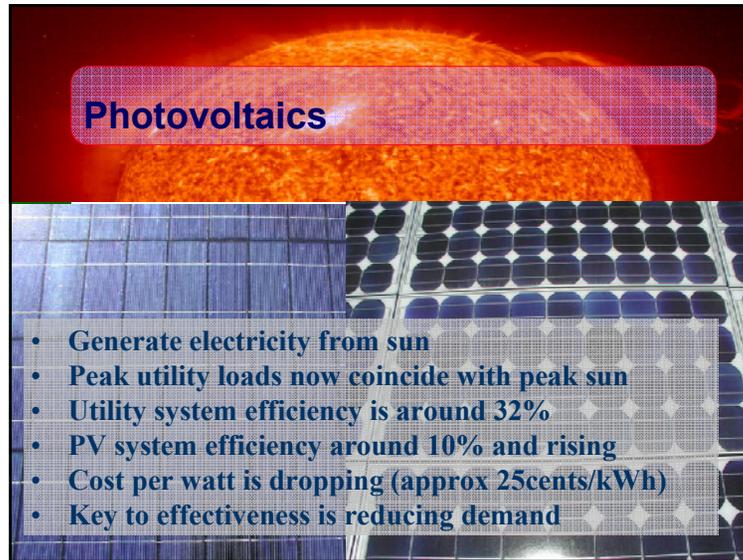


- **PV and Wind growing fast (>20% annual)**
- **Europe aiming for >20% electricity by RE**



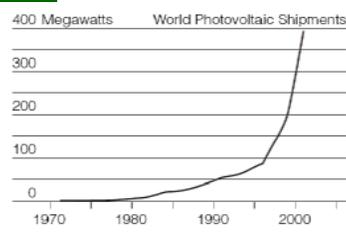
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## Photovoltaics

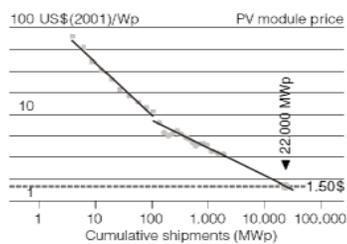


- Generate electricity from sun
- Peak utility loads now coincide with peak sun
- Utility system efficiency is around 32%
- PV system efficiency around 10% and rising
- Cost per watt is dropping (approx 25cents/kWh)
- Key to effectiveness is reducing demand

## PV Growth >35% compound



400 Megawatts World Photovoltaic Shipments



100 US\$(2001)/Wp PV module price

Fig. 15a The dramatic increase in world photovoltaic module shipments. It surpassed 500 MW<sub>p</sub> in 2002. Data source: Paul Maycock.

Fig. 15b: PV experience curves for 1976-2001 and projection to a breakeven price of US\$ 1.50/W<sub>p</sub>, demonstrating the importance of promoting high volume applications. Slide source: Dr. John Byme, data by Paul Maycock (2002)

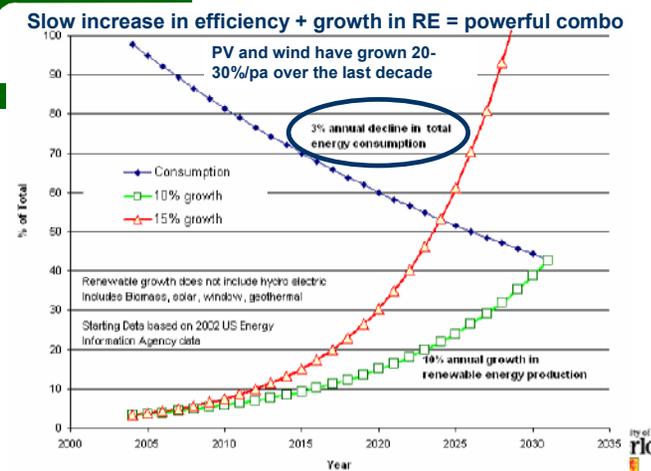
## Wind Energy



- Used for at least a millennium
- Depends on site and climate
- Highly sensitive to scale
  - Large much cheaper
- Highly sensitive to windspeed
  - Energy  $\propto V^3$
- Intermittent, alas
- Europe growing at >20%

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## Slow increase in efficiency + growth in RE = powerful combo



PV and wind have grown 20-30%/pa over the last decade

3% annual decline in total energy consumption

10% annual growth in renewable energy production

15% growth

Renewable growth does not include hydro electric  
Includes Biomass, solar, wind, geothermal

Starting Data based on 2002 US Energy Information Agency data

40 Prediction based on Straube 2004

## The Hydrogen Economy Myth

- Hydrogen is not a source of energy
- Hydrogen is an energy currency
  - like electricity: hard to store, very useful
- Where is it to come from?
  - Natural gas? Nuclear?
  - Electrolysis from renewables?
- Electricity ->hydrogen ->fuel cell-> electricity  
= cycle efficiency = 33% (maybe 50%+ in 25 years)

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## Hydrogen Economy

- Hydrogen is difficult to store and handle
  - It may be worth it eventually
- Biofuels (H carriers) may be better:
  - Gas: Methane?
  - Liquid: Ethanol? BioDiesel?
  - Cellulosic ethanol of course
  - E.g. Waterloo Landfill Power
  - Algae generation of bio-diesel
- Hydrogen useful for clean burning

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## Storage and Generation

- Distributed energy production
  - Power to become like internet
  - User and consumers are the same
  - Utility is an arbiter, deal maker
- Storage will become incredibly important
  - Local storage / central storage
  - Low loss technologies
  - Billion dollar prize
  - Maybe Hydrogen

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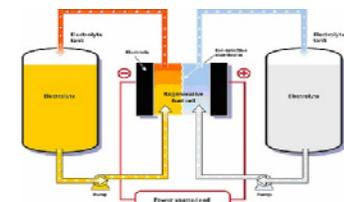
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## Storage

- Utility scale storage being developed
- Eg VRB Power Systems
  - Operation < 0.1 cent/kWh, 70-75% eff.
- Pumped head hydro
  - 70+% efficient, established technology



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## Energy use is changing ..

- Plug-in Hybrid, Natural Gas Co-Gen will compete with homes
- Fuel cells, PV make electricity
- Homes ↔ Cars

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## “Smart Buildings”

- Embedded electronics
  - Dramatically better controls
- Communication between building components
- Communication between building components and the world



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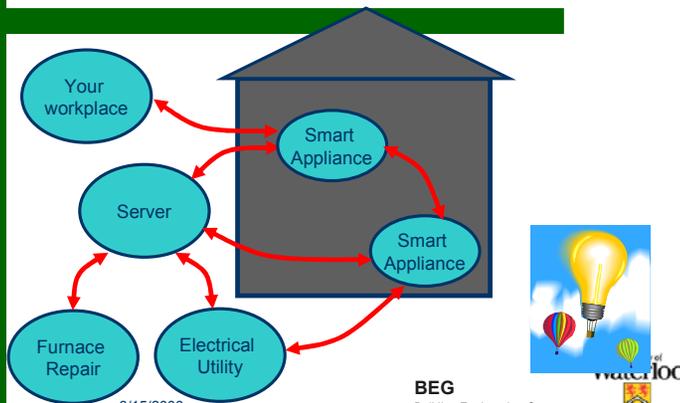
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## “Smart” Building – Demand Management



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## Bio materials

- Plastics from plants
  - Dupont-Pioneer and Dow-Cargill
- Fuel from plants
  - Bio diesel, bio gas
- Renewable materials
- Tunable properties

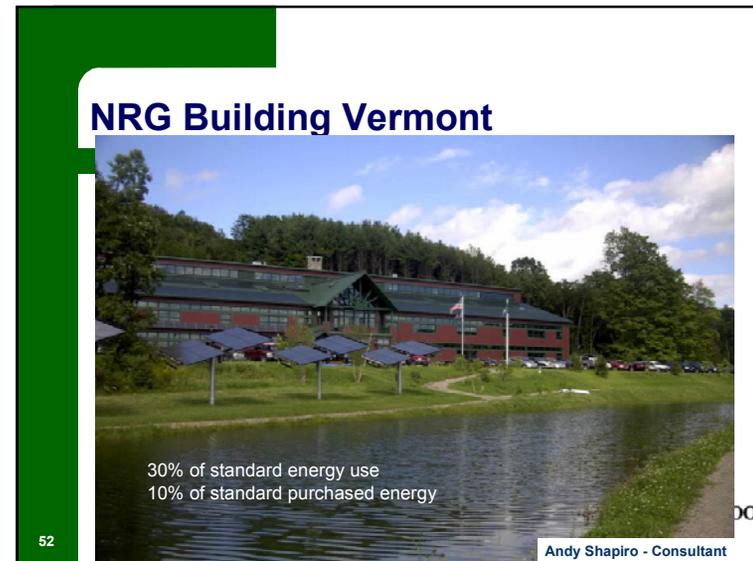
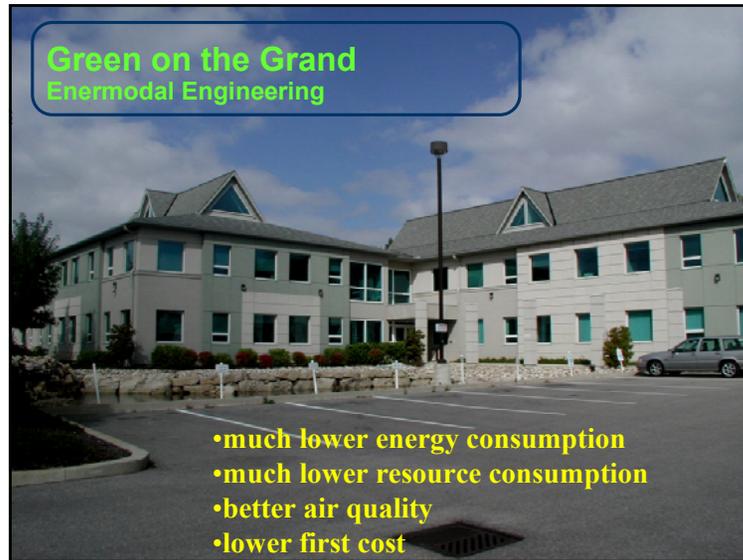
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**Real Goods  
.com**

**Arkin-Tilt  
Architects**



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**Rocky Mountain Institute (RMI.org)**

- Less than median cost
- Purchases 99% less heating
- 90% less electricity



**Ridge Winery**

- Strawbale-earth plaster
- Low-energy



## Future

- Change will occur slowly and gradually
- Pollution is waste - hence expensive
- Fossil fuels will not run out, but our ability to accept pollution will
- Must make efficient energy and resource use a core value, never an add on
- *Good design, rationally based, can save non-renewable resources, without pollution*

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## The Future

- Paradigm shift from “least evil” to “as much good”
- Buildings must eventually
  - Produce energy
  - Clean air and water
  - Enhance local ecology
  - Reuse materials, low-damage recycle,

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## Conclusion

- Buildings
  - Are very important
  - Consume resources & damage the environment
  - can be much better
- We need better design
  - Technology is a tool
  - Must understand, apply and invent technology
  - Remember the big picture
  - Solve problems that are worthwhile

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"Great spirits have always been met with violent opposition from mediocre minds."  
- Albert Einstein

"To achieve results never before accomplished, we must employ methods never before attempted."  
- Sir Francis Bacon

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