“If you gave me only one wish for the next 50 years,
• I can pick who is president,
• I can pick a vaccine… or
• I can pick that [an energy technology] at half the cost with no CO₂ emissions gets invented,
this is the wish I would pick. This is the one with the greatest impact.”

Bill Gates
100 W → 10 W
Human Energy Intake

\[
\frac{2500 \text{ kcal}}{\text{day}} \times \frac{\text{day}}{24 \text{ hr}} \times \frac{1.163 \text{ W} \cdot \text{hr}}{1 \text{ kcal}} \approx 121 \text{ W}
\]
Human Work Capacity

200 - 300 W/day

\[
\frac{240 \text{ W}}{\text{day}} \times \frac{\text{day}}{24 \text{ hr}} \approx 10 \text{ W}
\]
WORLD ENERGY USAGE

15 TW-YR TOTAL

5.6 - OIL
3.8 - COAL
3.5 - NATURAL GAS
0.9 - NUCLEAR
0.9 - HYDRO
0.1 - OTHER

12.9 TW-YR (86%)
WORLD ELECTRICITY USAGE

2 TW-YR TOTAL

0.1 - OIL
0.8 - COAL
0.4 - NATURAL GAS
0.3 - NUCLEAR
0.3 - HYDRO
0.1 - OTHER

1.3 TW-YR (65%)
U.S. ELECTRICITY USAGE

0.5 TW-YR TOTAL

1.9% - OIL
49.5% - COAL
19.5% - NATURAL GAS
19.0% - NUCLEAR
7.4% - HYDRO
2.7% - OTHER (0.14 TW-YR)

1.3 TW-YR (65%)
Today  15 TW

2050  22 TW --- no change

2050  66 TW --- all @ 1/2 current level

2050  100+ TW --all @ American level
Energy Issues

Supply
Impact
Lifestyle
Supply

Do we have enough?

Is it in the right form?

Is the cost acceptable?
Net Energy
<table>
<thead>
<tr>
<th>Energy Carrier</th>
<th>$/1000 MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>1.87</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>6.72</td>
</tr>
<tr>
<td>Petroleum</td>
<td>13.10</td>
</tr>
<tr>
<td>Electricity</td>
<td>22.80</td>
</tr>
</tbody>
</table>
Supply

Do we have enough?
Is it in the right form?
Is the cost acceptable?
Change from 1900 to 2000

- Industrial output = 40x
- Marine fish catch = 35x
- Emissions = 17x
- Energy use = 16x
- Coal production = 7x
- World population = 4x
If growth stays the same --- in 2100

24 Billion people

240 TW-yr of energy use each year

20 Billion people living in poverty
240 TW-yr of energy use each year
The Earth

178 PW

40 TW

177.96 PW
In

Solar = 178 PW

Out

Reflected = 62 PW
Radiated = 115.96 PW

Total = 177.96 PW

Available

Photosynthesis = 0.04 PW
In

Solar = 178 PW

Out

Reflected = 62 PW
Radiated = 115.96 PW

Available

Photosynthesis = 0.04 PW

Total = 177.96 PW
## Recoverable Resources

<table>
<thead>
<tr>
<th>Resource</th>
<th>Recoverable Energy (TW-yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Oil/Gas</td>
<td>1,000</td>
</tr>
<tr>
<td>Unconventional Oil</td>
<td>2,000</td>
</tr>
<tr>
<td>Coal</td>
<td>5,000</td>
</tr>
<tr>
<td>Methane Clathrates</td>
<td>20,000</td>
</tr>
<tr>
<td>Oil Shale</td>
<td>30,000</td>
</tr>
<tr>
<td>Uranium Ore</td>
<td>2,000</td>
</tr>
<tr>
<td>Geothermal Steam</td>
<td>4,000</td>
</tr>
</tbody>
</table>
**“Sustainable” Resources**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Capacity (TW-yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeder Reactor</td>
<td>2,000,000</td>
</tr>
<tr>
<td>Hot Dry Rock</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Ocean thermal energy conversion</td>
<td>9,000,000</td>
</tr>
<tr>
<td>Wind Energy</td>
<td>200,000</td>
</tr>
<tr>
<td>Gulf Stream</td>
<td>140,000</td>
</tr>
<tr>
<td>Global Biomass</td>
<td>10,000</td>
</tr>
</tbody>
</table>
240 TW

270,000 coal fired plants
40,000 dams
50 million wind farms
10 million km² of solar panels
Everyone needs to be included
conclusion ...

we can’t make it
Sustainability, renewable portfolios, carbon credits and host of other current concerns, while a step in the right direction, are dead and powerless to change the course of society ...

... unless we find appropriate technologies, paths, and patterns for ourselves, our communities, and our society.
we can’t make it
we can’t make it
we can’t make it
!!!
Other options

dead, disease, and famine

... or
10-12 billion people
10-12 billion people x 5 kW per person
10-12 billion people x 5 kW per person

= 50 TW
so what do we need to do?
accept limits
define life as more than consumption
develop new technologies
allow for diversity
respect individual preference
Promotes values such as health, beauty and permanence

A technology that can be easily purchased and used by poor people and can lead to greater productivity while minimizing social dislocation.

Appropriate Technology
Promotes values such as health, beauty and permanence

A technology that can be easily purchased and used by poor people and can lead to greater productivity while minimizing social dislocation.

Appropriate Technology
Energy Issues

Supply
Impact
Lifestyle