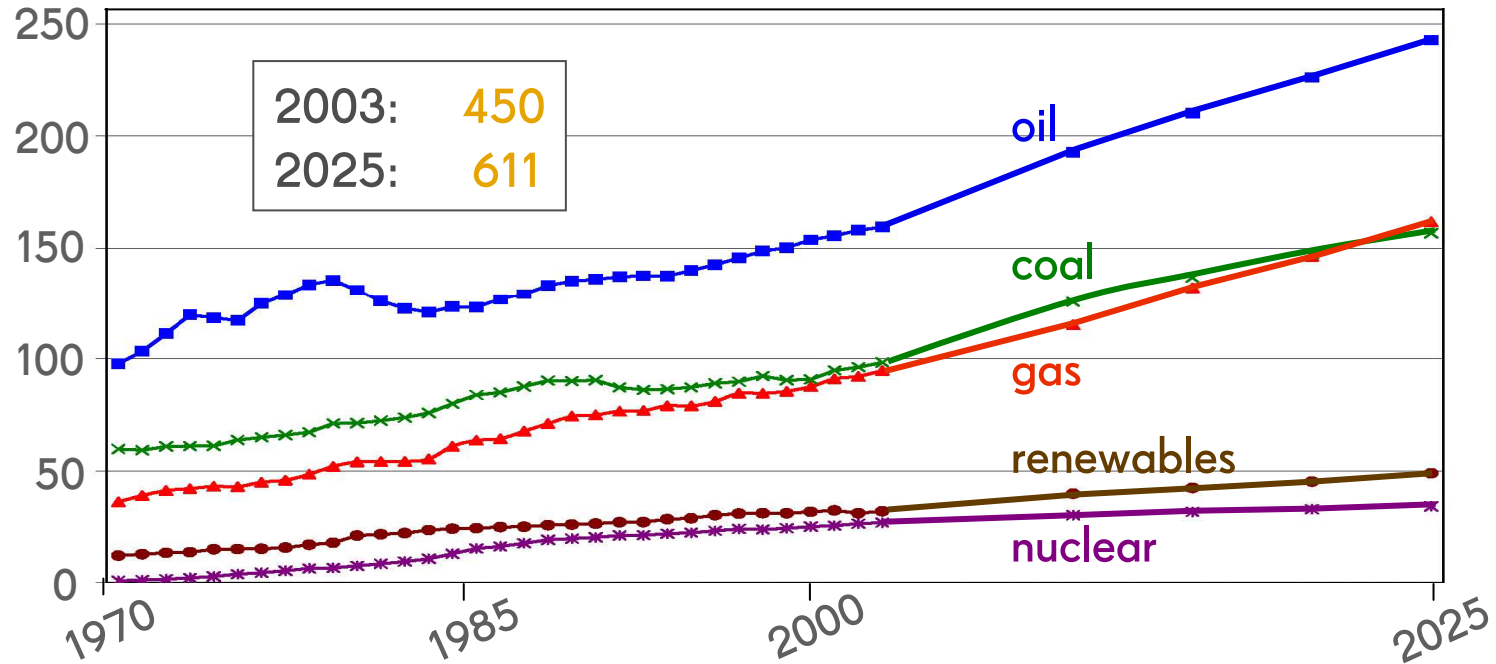


Banking on Alternative Energy ?

Margot Gerritsen (& colleagues)

School of Earth Sciences, Stanford

Historic and predicted world consumption (in EJ=10¹⁸ J)



World consumption	US consumption	1,000,000 barrels oil (Mbbbl)	1 person/year
450 EJ	100 EJ	6×10^{-3}	4×10^{-9} EJ

Key questions in next 20 minutes

Can alternatives help create a sustainable energy future?

I: What's our starting point?

Current usage, resources, history

II: What is potential of most promising alternatives?

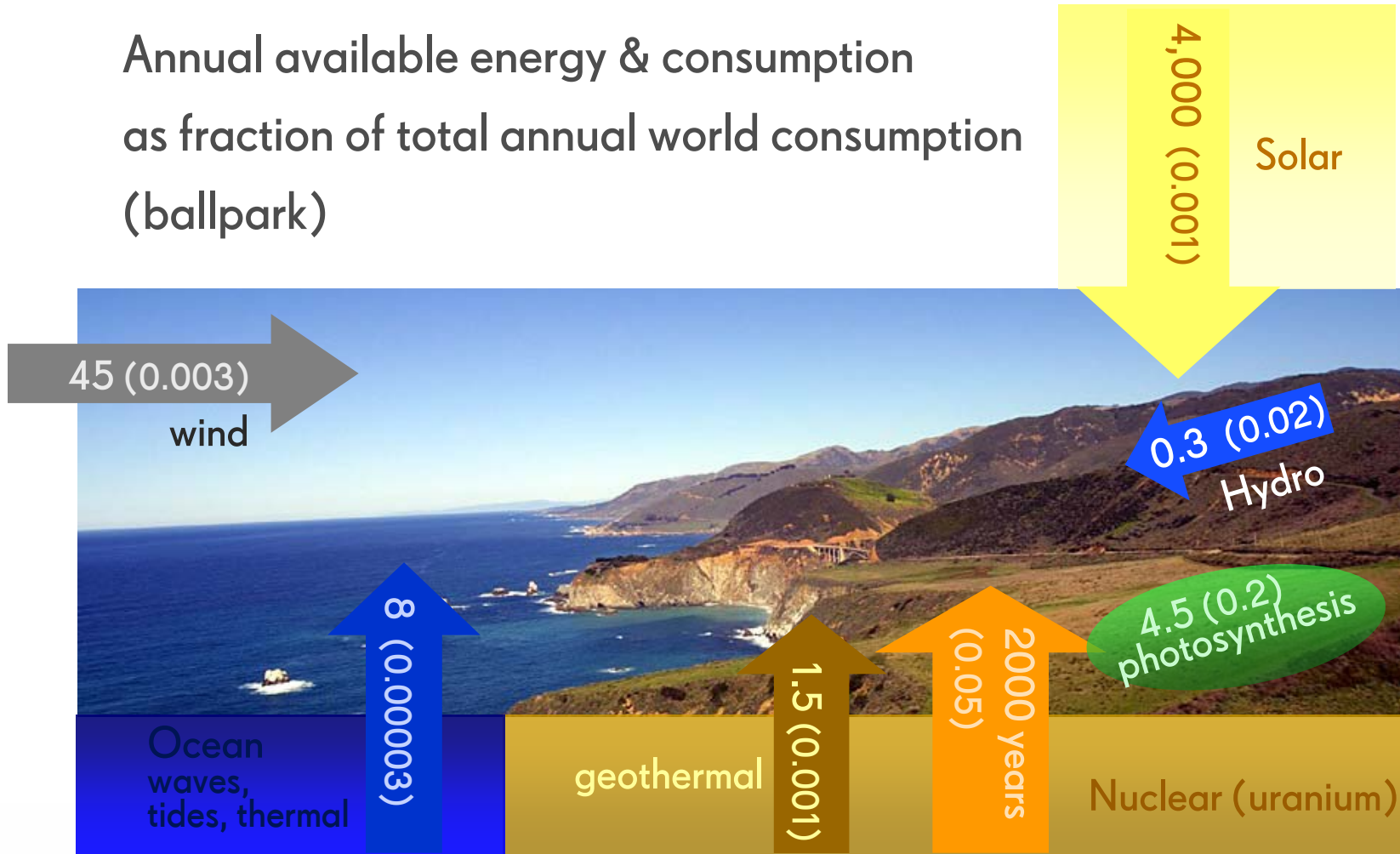
Technology and main challenges

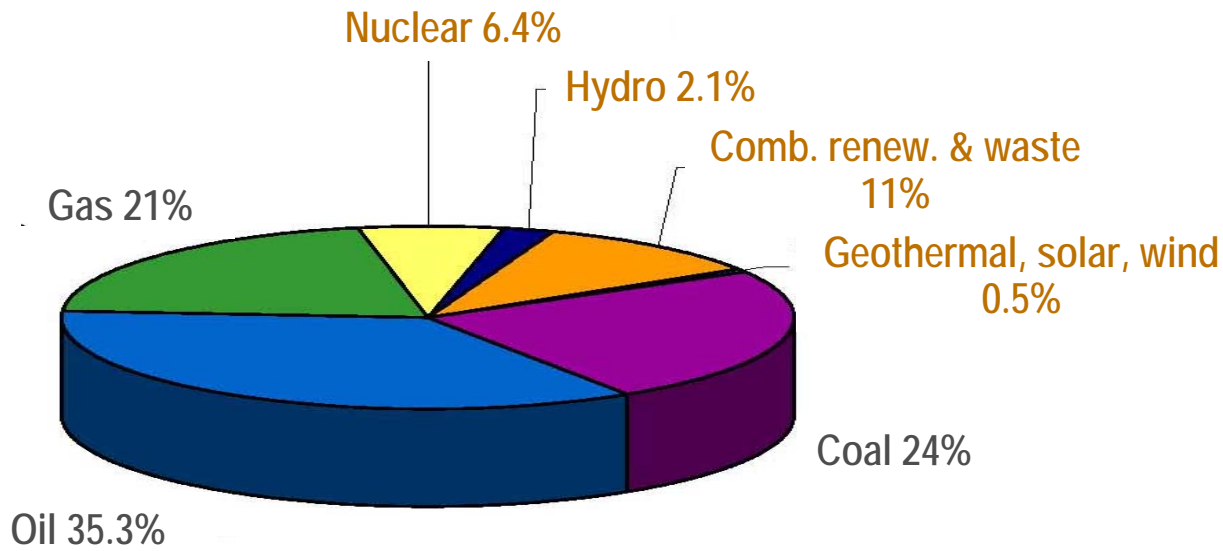
What does it take to competitively produce 5EJ/year?

(5% of current US energy consumption)

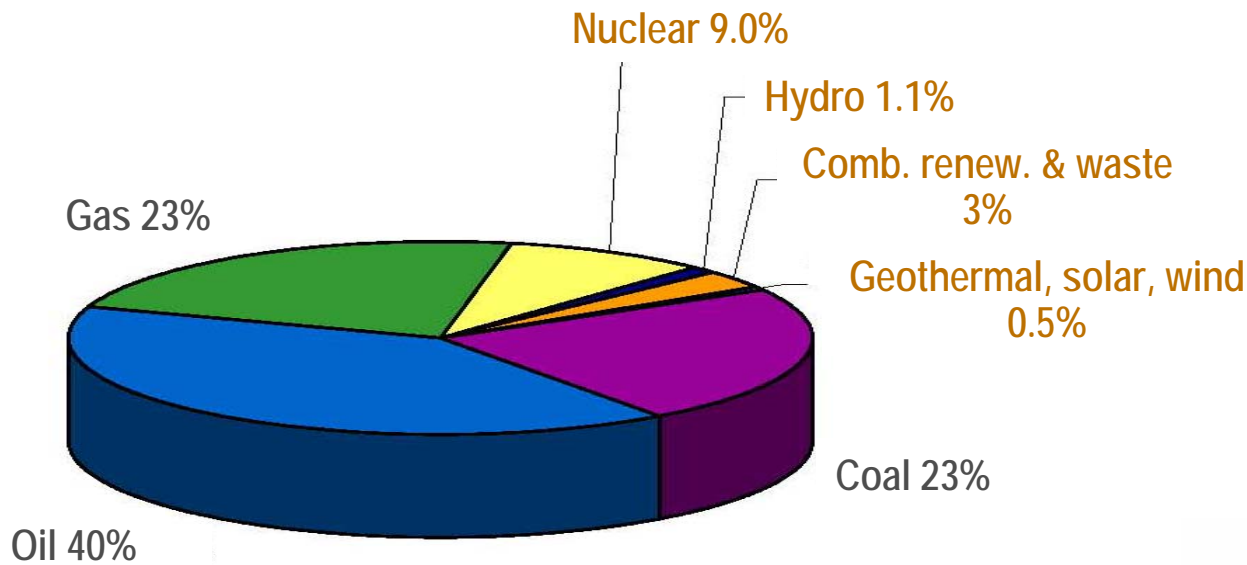
What sources are available?

Annual available energy & consumption
as fraction of total annual world consumption
(ballpark)





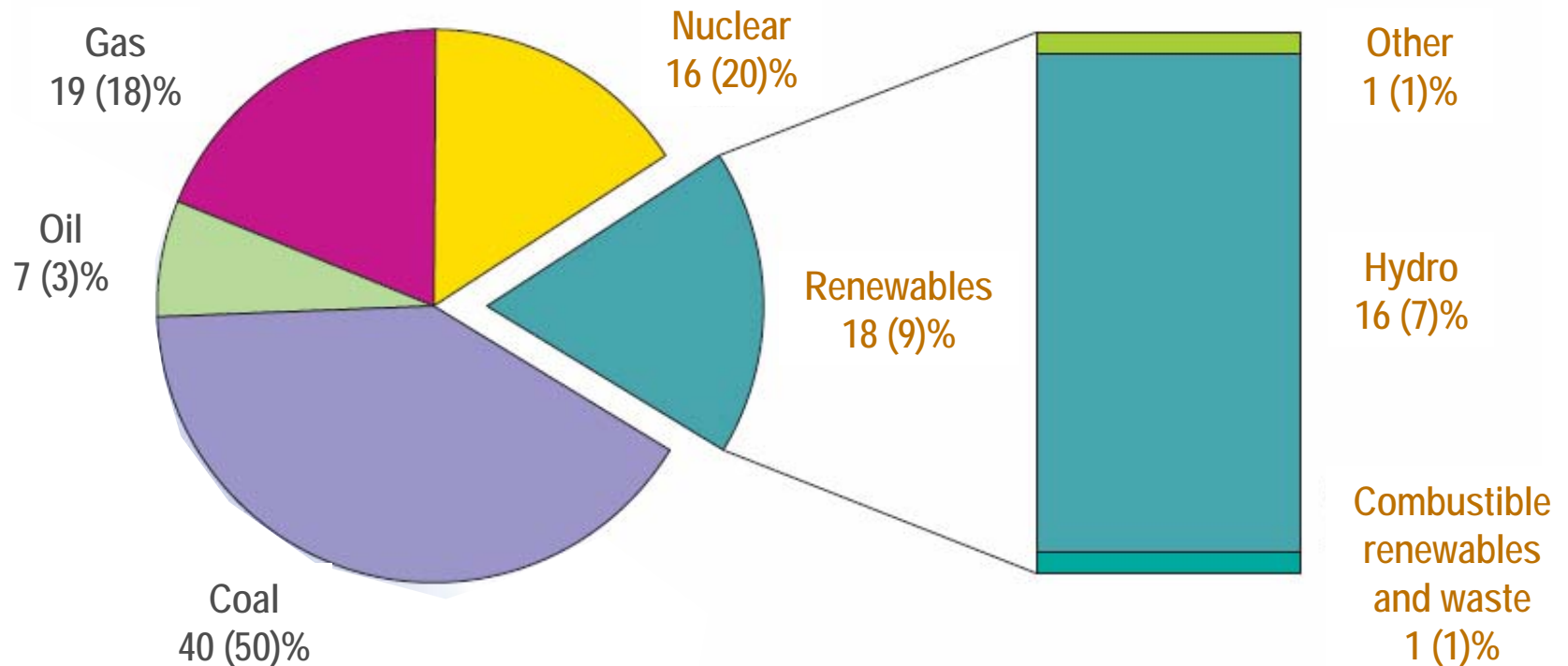
World energy
breakdown
(450EJ total)



US energy
breakdown
(100 EJ total)

Share in world electricity production

US numbers in (brackets)

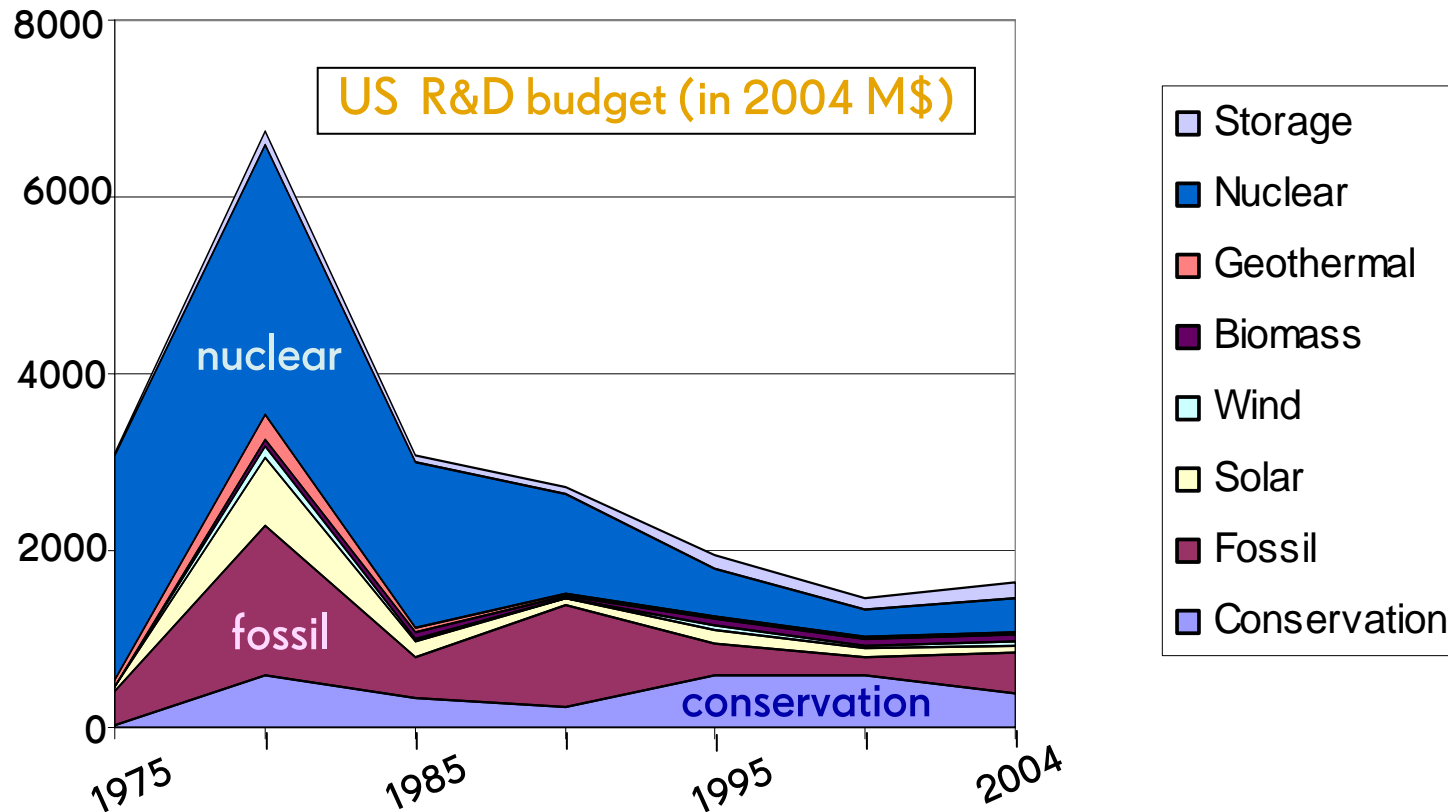


OECD growth, production and R&D

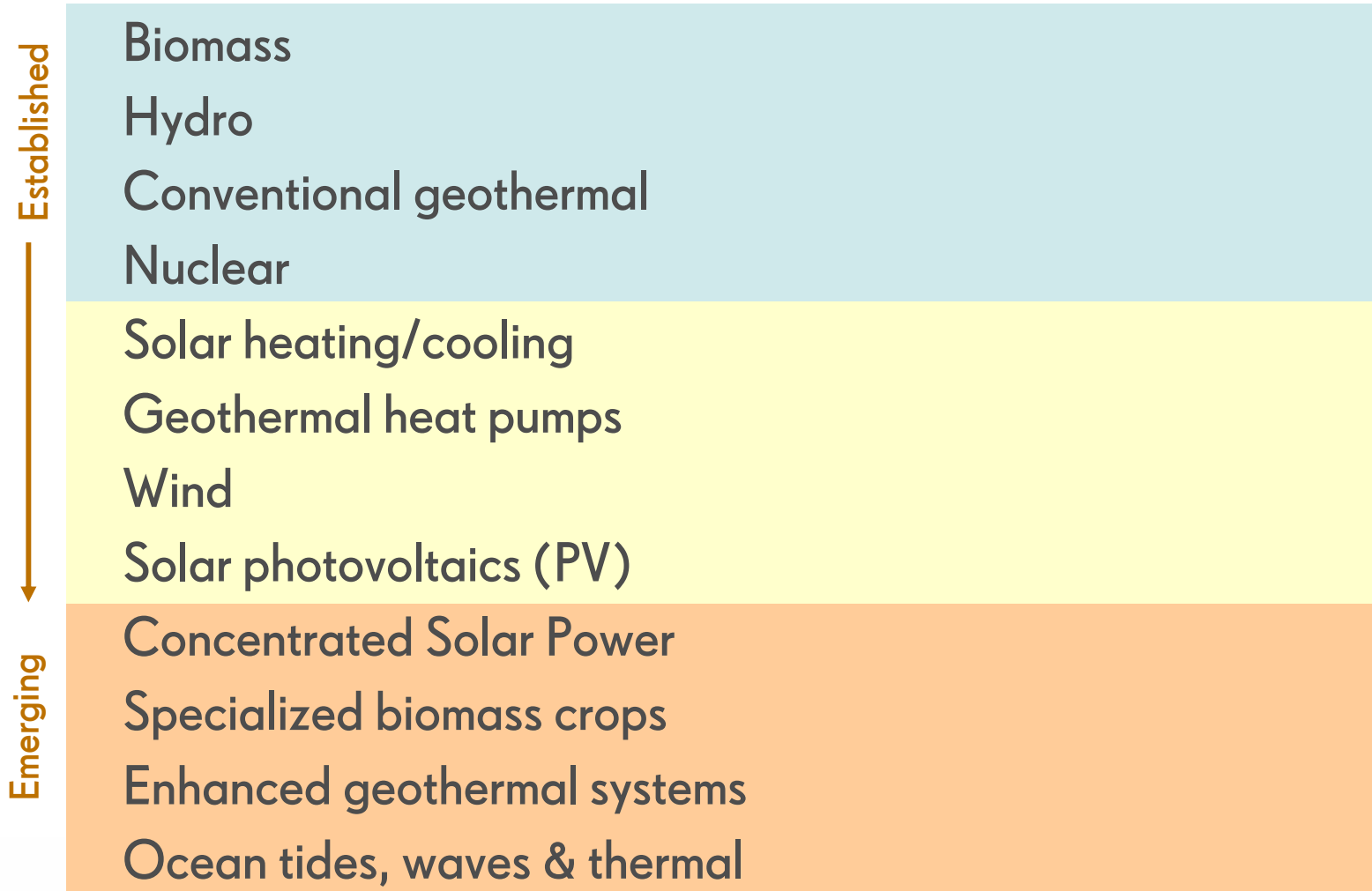
	Geoth.	Biomass + mun. waste	Solar PV	Wind	Nuclear
Annual growth 1990 - 2004	1.7	3.8	14 recent 30%	18 recent 22%	2.3
% electricity 2004	0.4	1	0.007	0.8	16
% energy R&D 2004	0.5	2.8	5.3	1.3	41

Compare to **2%** annual growth in energy consumption

Historic R&D compared to fossil, conservation












Alternative energy sources

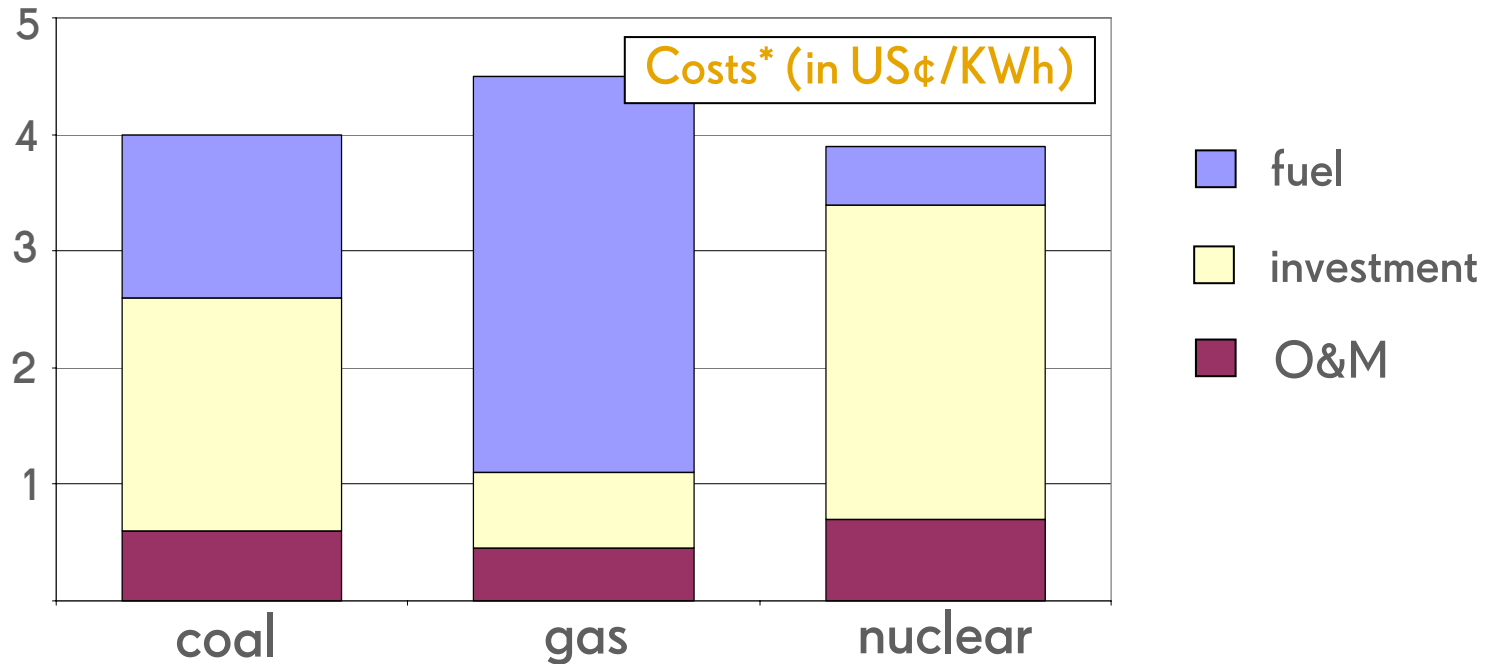


Discussion guide

- Short overview technology
- Main challenges to overcome
- What is likelihood of achieving 5EJ target in 20 years?
- Comparative data
 - Energy production and costs
 - Dependency on R&D support
 - Dependency on exploratory R&D (scientific breakthroughs)
 - Likely or not likely to reach target

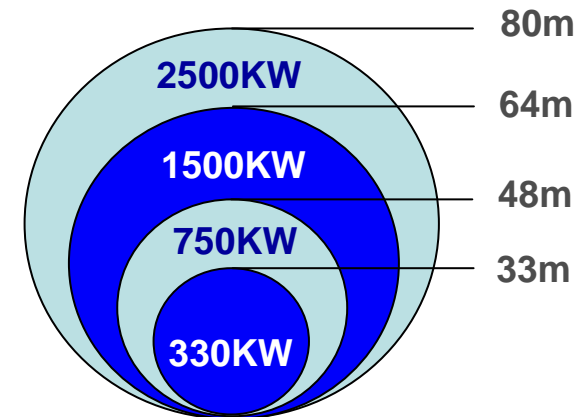
World energy	%
US energy	%
Costs	in US¢/KWh
R&D support	  
Exploratory R&D	  
Target	  

Costs for competitive energy sources



* Environmental costs not included

The answer is blowing in the wind?



Top wind energy producing countries (mid 2005)*

Germany	18,000 MW
Spain	8,000 MW
US	7,000 MW
Total world	48,000 MW




(compare to 20 big power plants)

In last 20 years production costs reduced by factor of 4

In good wind cost competitive

Good potential

5EJ requires build of approximately
200,000 turbines* of 2.5MW
(Annual growth of 17% for 20 years)

World electricity	0.7 %
US electricity	0.1 %
Costs	4-10 ¢/KWh
R&D support	
Exploratory R&D	
Target	

Main challenges:

- Larger, more effective turbines (design, materials, off-shore)
- Transmission availability and pricing
- Intermittency
- Policy consistency to build mature wind industry

R&D support is required, but **close to large scale commercialization**

Specialized biomass crops

Future crops envisioned are perennial grasses and woody crops
Most promising in terms of potential, GHG reduction, net production

Current yield switch grass 5 ton/acre/year
5 EJ would require 1 billion tons or
200 million acres (8% US land)

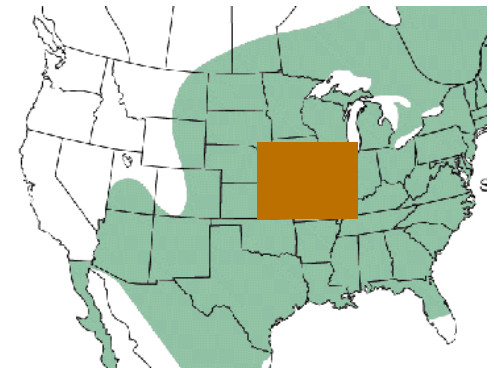
switchgrass



poplar



willow

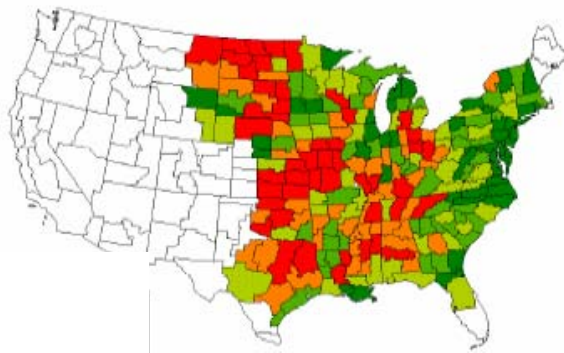


The “Billion Ton” (5EJ) biomass vision

Extensive study ORNL and USDA

Portfolio of

- ($\pm 30\%$) Agricultural waste (wheat & rice straw, corn stover)
- ($\pm 35\%$) Forest: growth, residues, fuel wood
- ($\pm 5\%$) Grain to biofuels
- ($\pm 30\%$) Specialized crops (protein and cellulose)



Potential yield intensity 2030

■ low; ■ high

Many challenges

- **Crop productivity**

Increase energy yield per acre

Conversion – requires new technologies

Conversion – must be efficient for multiple sources

- **Supply logistics**

Harvesting, transportation, storage and processing

- **Environmental/social**

Land use changes

Land use competition

N-fertilizers

US electricity	< 0.1 %
US power	2 %
US fuel	0.5 %
Costs	> 10 ¢/KWh
R&D support	●
Exploratory R&D	●
Target	○

Solar energy

The **main target** because of abundance of solar energy



Photovoltaics



Concentrated Solar Power

CSP is an emerging technology

Great potential

5EJ requires build of approximately
300,000 acres with 150*W/m² PV

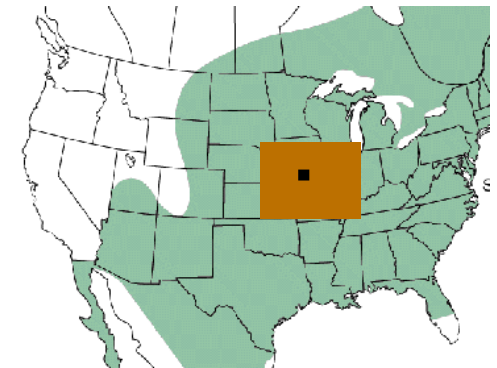
World energy	<0.01%
US energy	<0.01%
Costs	20-30 ¢/KWh

R&D support	●
Exploratory R&D	●
Target	● or ●

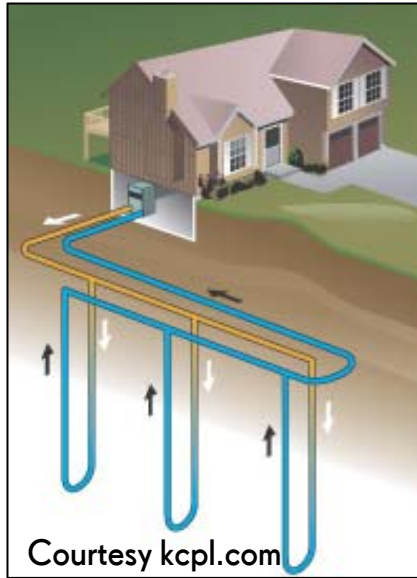
Main challenges

- Lower costs (materials, design, scale-up (CSP))
- Intermittency
- Capital intensive, investment risks

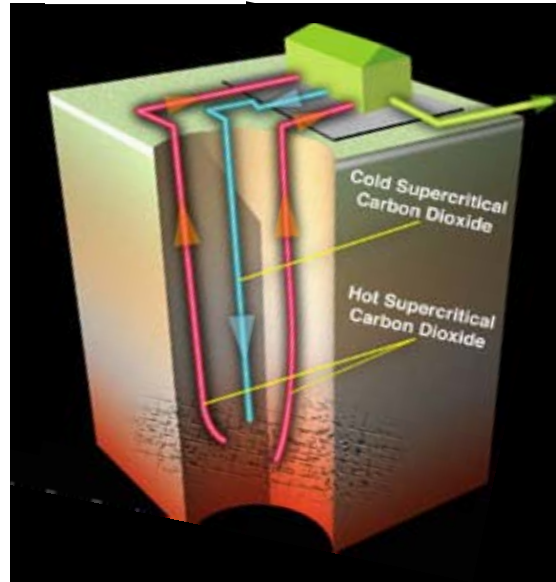
Strong continued R&D support is required



Geothermal



Heat pumps



Enhanced Geothermal Systems

World electricity	0.4 %
Costs	2 ¢/KWh (H) > 10 ¢ (E)

	H	E
R&D support	●	●
Exploratory R&D	●	●
Target	●	●

600,000 pumps in US, annual growth 10%

EGS uses mostly existing technologies from petroleum industry

Recoverable geothermal energy not abundant but optimistic outlook gives **2.5 EJ** in West US in 20-30 years

Should we revisit nuclear?




5EJ would require 100 extra reactors
(doubling US capacity)

There are advantages:

- Abundant source
- clean production
- cost competitive (not including waste storage)

And significant disadvantages:

- Environmental risk long term nuclear waste storage

World energy	6 %
US energy	9 %
Costs	4 ¢/KWh
R&D support	
Exploratory R&D	
Target	

We need a diverse energy portfolio

- Strong push for demand reduction, improved efficiency
- Strong push for alternative transport solutions
- Strong push for cleaner fossil electricity generation

And for alternative energy

- Continued hydro, geothermal and biomass
- Continued R&D funding to explore biomass crops
- Continued R&D funding to develop nuclear waste solutions
- Strong push for large scale wind energy production
- Substantial R&D funding to explore solar energy