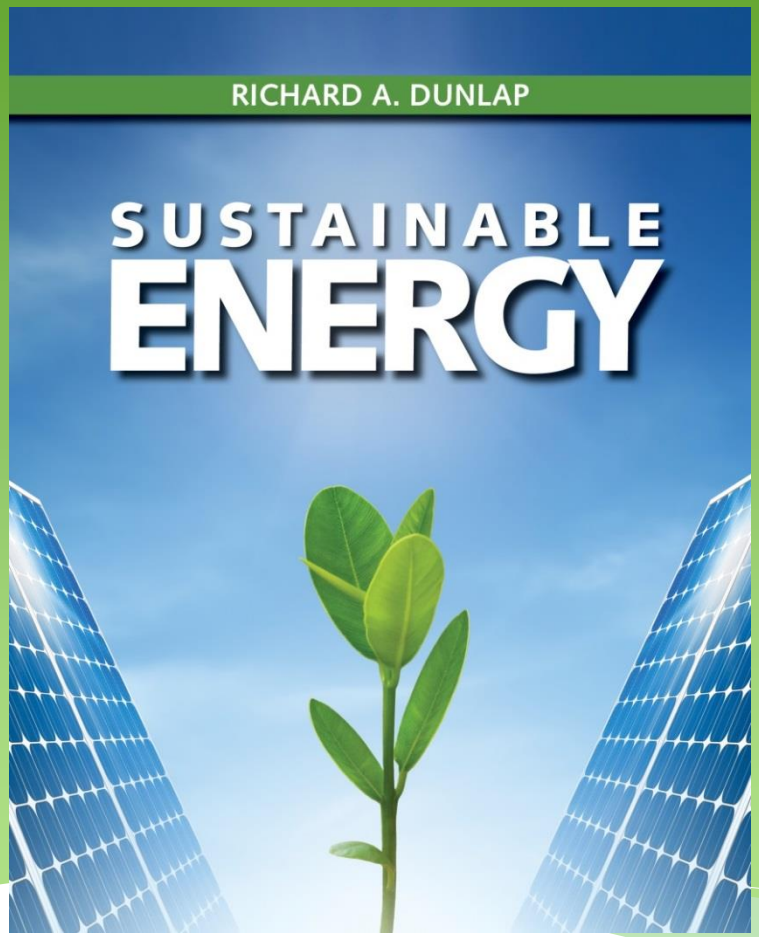
Sustainable Energy



Chapter 21

* Future Prospects
* and
* Research and Design Projects

CENGAGE Learning

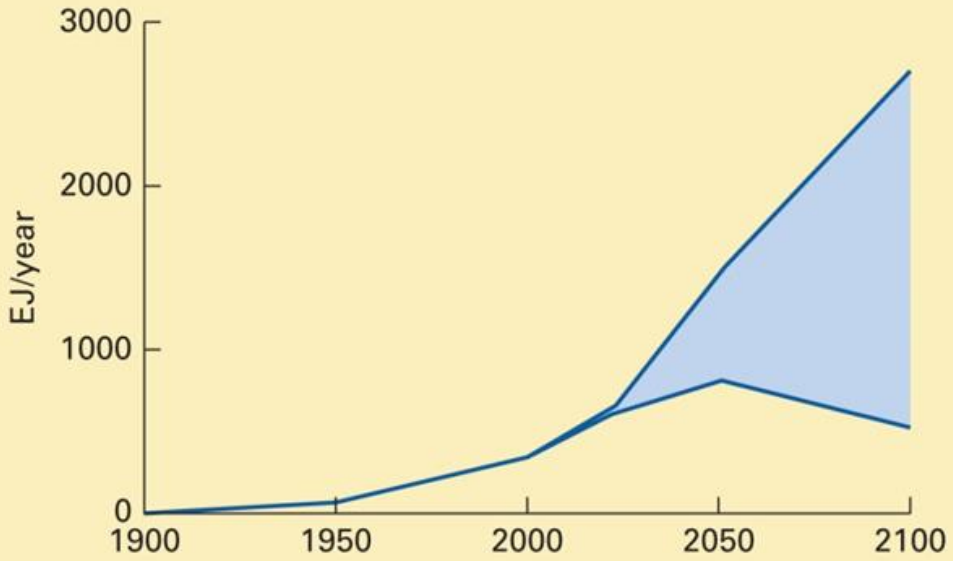
Predicted energy requirements and sources for the future

It is difficult to extrapolate very far into the future.

There are great variations in predicted energy needs by the end of the century.

It is even more difficult to predict mix of energy sources very far into the future.

Range of predicted energy needs by 2100



Based on V. Smil from SRES

Figure 21.1: An example of maximum and minimum predicted world energy requirements.

Current energy mix (U.S.)

To predict energy appropriate energy sources for the future we need to start with the current situation

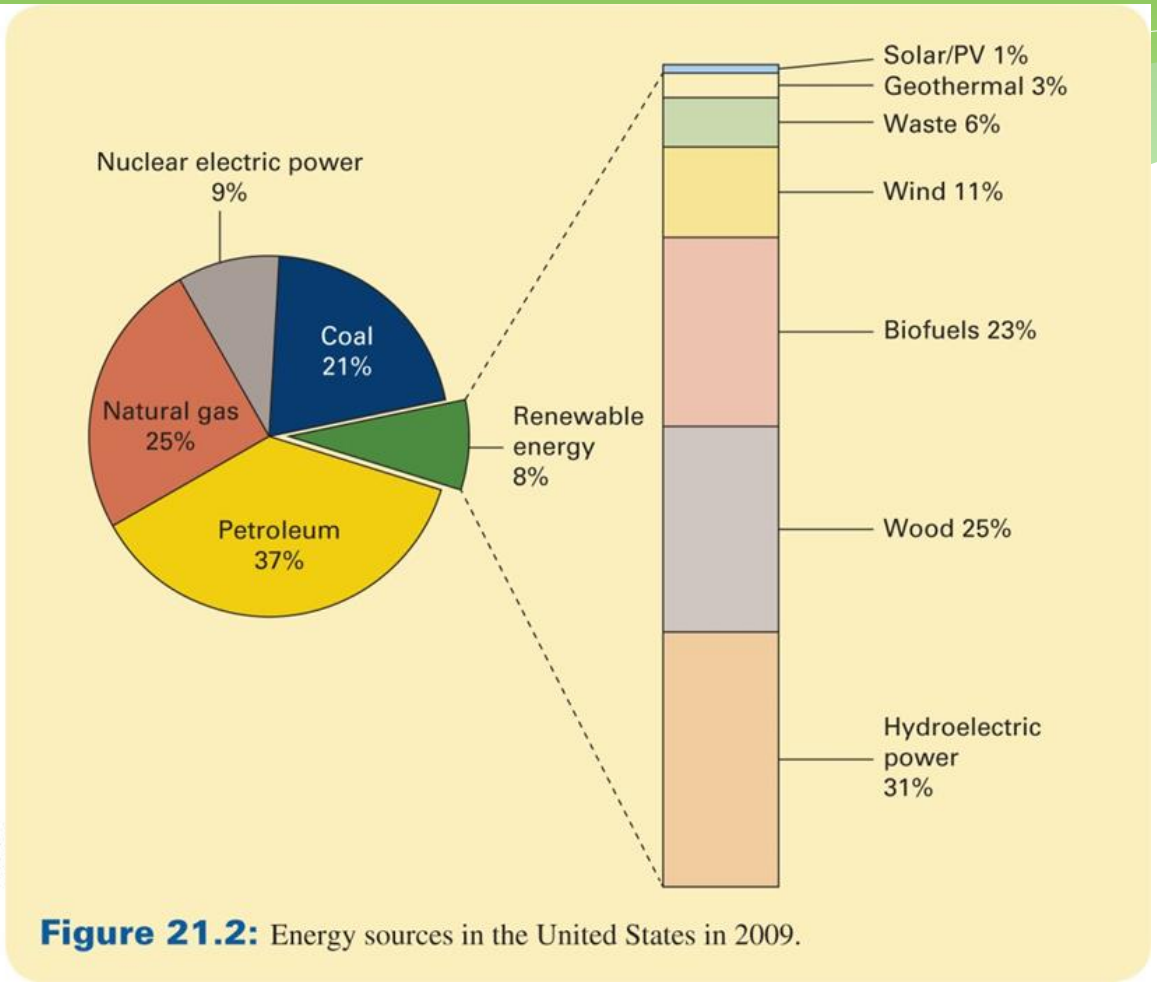


Figure 21.2: Energy sources in the United States in 2009.

One predicted energy future

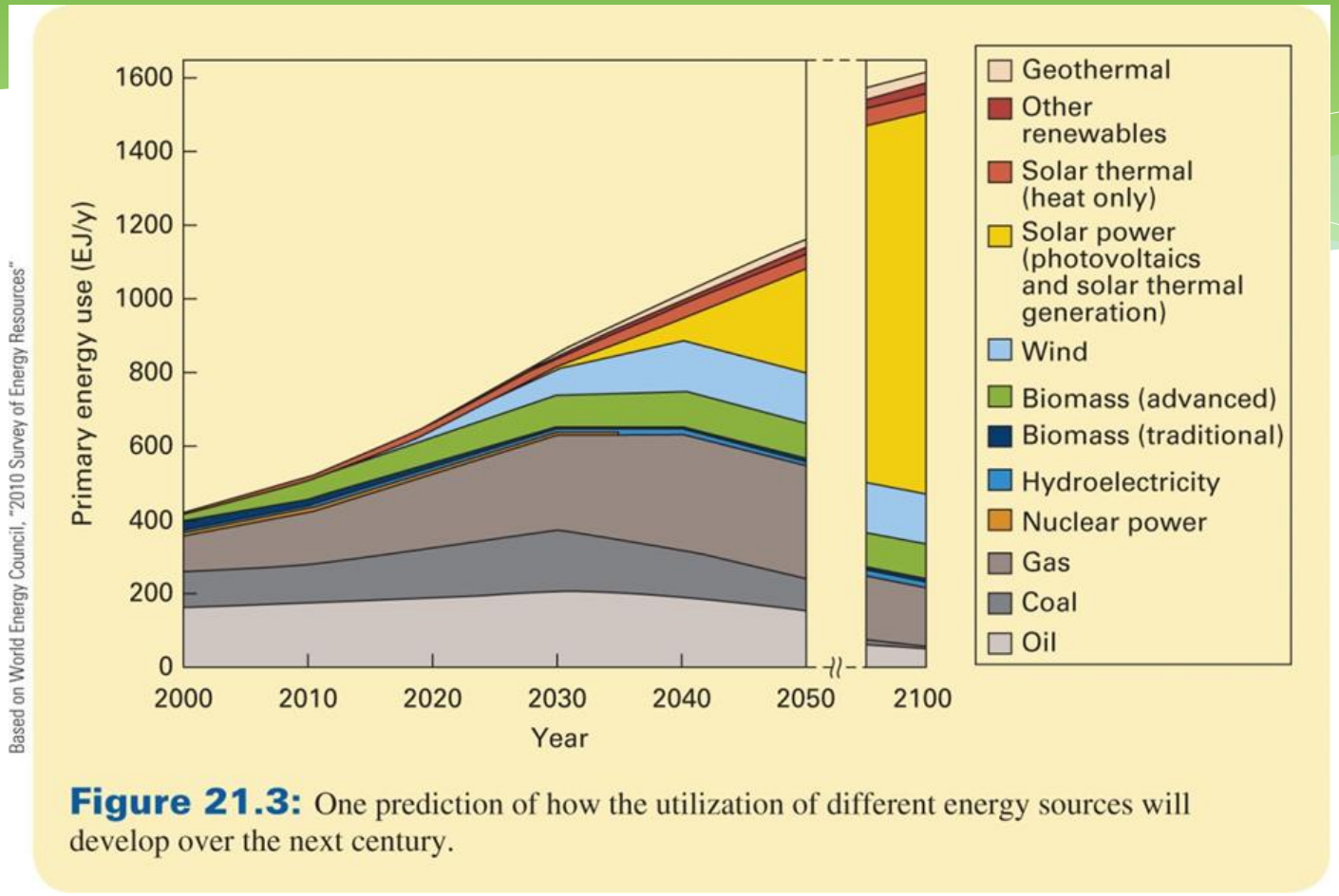


Figure 21.3: One prediction of how the utilization of different energy sources will develop over the next century.

Solar is predicted to the major component of energy by 2100

Considerations for energy sources

- Clean
- Unlimited
- Renewable
- Versatile
- Economical

Clean

An evaluation of the environmental impact of alternative energy sources sometimes shows that they can be worse than traditional fossil fuels (Chapter 16 - Biofuels).

The low energy density of many energy sources needs to be a serious consideration.

Unlimited

The total power that is available (or at least viable) from many sources is much less than our needs.

Any prediction of a future energy mix must consider the availability of each source.

Only the availability of solar energy surpasses estimates of our total power requirements.

Viable power available from alternative sources

Table 21.1: Power available from different renewable energy sources. Power listed is that which is technologically feasible and economically viable on the basis of technical and scientific capabilities at present or in the foreseeable future.

energy source	power available (TW)
solar	>1000
biomass	~6
wind	~4
tidal/waves/currents	~2
hydroelectric	~1
geothermal	<1
OTEC/salinity gradients	<1

Compare with predicted total power requirements for 2100 of 30 - 60 TW

Renewable

Some alternative energy sources may not be renewable indefinitely

Some hydroelectric capacity may decrease due to sedimentation

Geothermal deposits may become depleted as thermal energy is extracted

Our ability to harvest energy from certain sources may decrease due to availability of materials

- Indium to produce photovoltaic devices
- Li for rechargeable batteries for transportation or to breed tritium for fusion energy

Versatile

Energy requirements for transportation are the most demanding

Battery electric vehicles require viable battery technologies and the availability of the necessary materials

Fuel cell vehicles require a careful consideration of the energy efficiencies, economic viability and availability of materials

Biofuels require a consideration of their net environmental impact

Economical

The cost per MJ of useable energy is a factor in the viability of developing certain technologies and maintaining their long term competitiveness.

Solar photovoltaics has one of the highest costs (at present) per unit energy.

Cost per MJ electricity for different generating technologies

Table 21.2: Current cost of electricity from various sources.

energy resource	cost (US$/MJ)	cost (US$/kWh)
solar (photovoltaic)	0.084	0.30
tidal/wave	0.028	0.10
geothermal	0.022	0.08
nuclear (fission)	0.018	0.065
wind	0.017	0.06
oil	0.017	0.06
hydroelectric	0.014	0.05
natural gas	0.011	0.04
coal	0.007	0.025

Possible (non-fossil fuel) future energy technologies

- Nuclear energy (fission)
- Solar energy (photovoltaics)
- Wind energy
- Hydroelectric energy
- Tidal and wave energy
- OTEC and salinity gradient energy
- Geothermal energy
- Biomass energy

Nuclear energy (fission)

The available power and longevity greatly improved by using fast breeder reactors, fuel reprocessing and Th-based reactors.

Concerns for future development:

- reactor safety
- waste disposal
- security of fissile material

Solar energy (photovoltaics)

Virtually unlimited and indefinitely renewable

Concerns for future development:

- low energy density means environmental impact is greater than usually perceived
- land utilization
- future availability of necessary materials
- economics

Wind energy

Indefinitely renewable
Minimal environmental impact
Economical

Concerns for future development:

- land use
- local safety and noise concerns
- probably not sufficient power for all our needs

Hydroelectric energy

Well established technology
Economical

Concerns for future development:

- Not always indefinitely renewable
- Not sufficient availability for all our needs
- Minimal additional resources available
- High head has more environmental impact than many other alternative energy sources

Tidal and wave energy

Indefinitely renewable
Minimal environmental impact
Reasonably economical

Concerns for future development:

- limited availability
- only applicable in certain locations

OTEC and salinity gradient energy

Indefinitely renewable

Concerns for future development:

- limited availability
- low efficiency leads to unattractive economics
- technologically challenging

Geothermal energy

More consistent than other alternative sources
Economical
Effective use of land area

Concerns for future development:

- may not be indefinitely renewable
- limited availability
- only available in certain areas
- effects on geological stability

Biomass energy

Convenient portable replacement for liquid fossil fuels

Indefinitely renewable

Concerns for future development:

- possible adverse environmental consequences
- long term economic viability questionable in most locations
- competition of land area with food production

Energy storage

Need to consider:

- initial and final form of energy
- size and/or weight requirements
- total energy storage capacity
- maximum power available

Storage of electrical energy is most common requirement

- for electric grid storage
- for electric vehicles

Best available options for storage

Large scale grid storage:
- Pumped hydroelectric

Smaller scale grid storage:
- Rechargeable batteries or hydrogen

Transportation:
- Batteries - Li-ion (current)
  or Na-ion (possible future)
- Hydrogen

Factors to consider for future energy

- Scientific considerations
- Technological considerations
- Environmental impact
- Economics
- Political factors