The role of electricity transmission on sustainable energy technologies

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Electric Energy Systems and Sustainability Workshop
November 29 – December 1, 2000
Georgia Institute of Technology, Atlanta, Georgia

The key questions

- Will we need transmission in 10 years?
  - How about in 20?
    - And how about in 40?
- What are the sustainable technologies?
  - How many of those are “electric”?
    - What are their environmental effects?
- Isn’t distributed generation all about eliminating the need for the grid?
- How does restructuring play into this?
- Policy and implementation issues

10 year criteria

- Fewer by-products
- Economically viable
- Compatible with current systems
- Environmentally benign

40 year criteria

- Minimal by-products
- Economically viable
- “Unlimited” resource
- Diversified suppliers
- Acceptable area use
- Environmentally sustainable

Historical Basis for Transmission

Renewable resources remote from load

- Hydroelectricity

Thermal generation economies of scale

Reduced transportation (“coal by wire”)

Reliability (pooling of resources)

Interregional exchanges (seasonal, daily)

The sustainable technologies

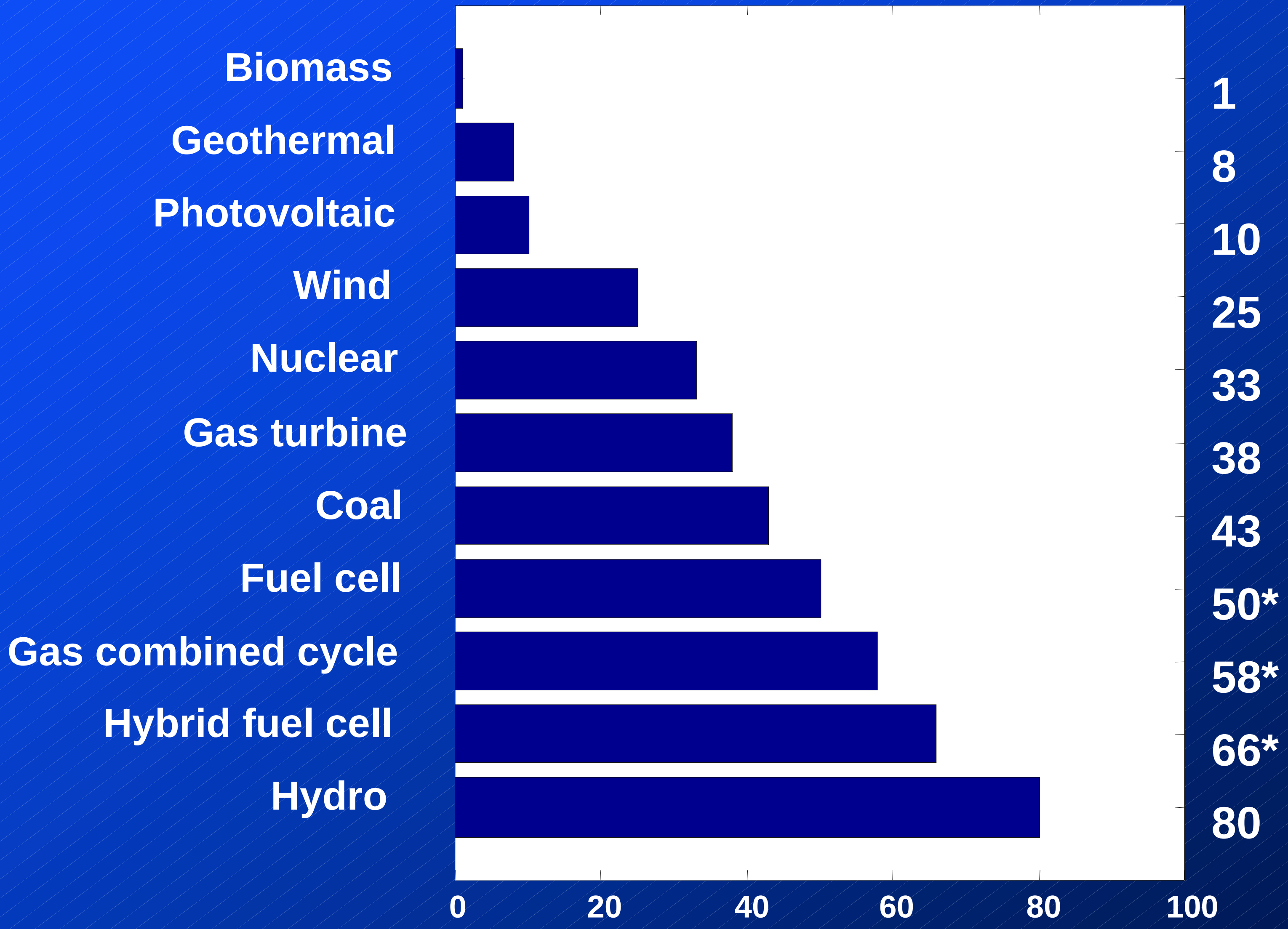
Technology	Issues and concerns
Nuclear	Spent fuel, safety
Coal	Emissions
Hydro	Environmental impact
Photovoltaic	Cost, intermittency
Wind	Low density
Biomass	Very low density
Geothermal	Limited sites
Gas turbines/Fuel cells	Needs hydrogen source

Area requirements by technology

Technology	Requirements for 1000MWe
Nuclear	3.5 sq. miles
Coal*	7-14 sq. miles
Hydro	28 sq. miles
Photovoltaic	40 sq. miles
Wind	100 sq. miles
Biomass	1000 sq. miles
Geothermal	3 sq. miles
Gas turbines/Fuel cells*	It depends

*Sustainability is only in relative terms

Technology efficiencies



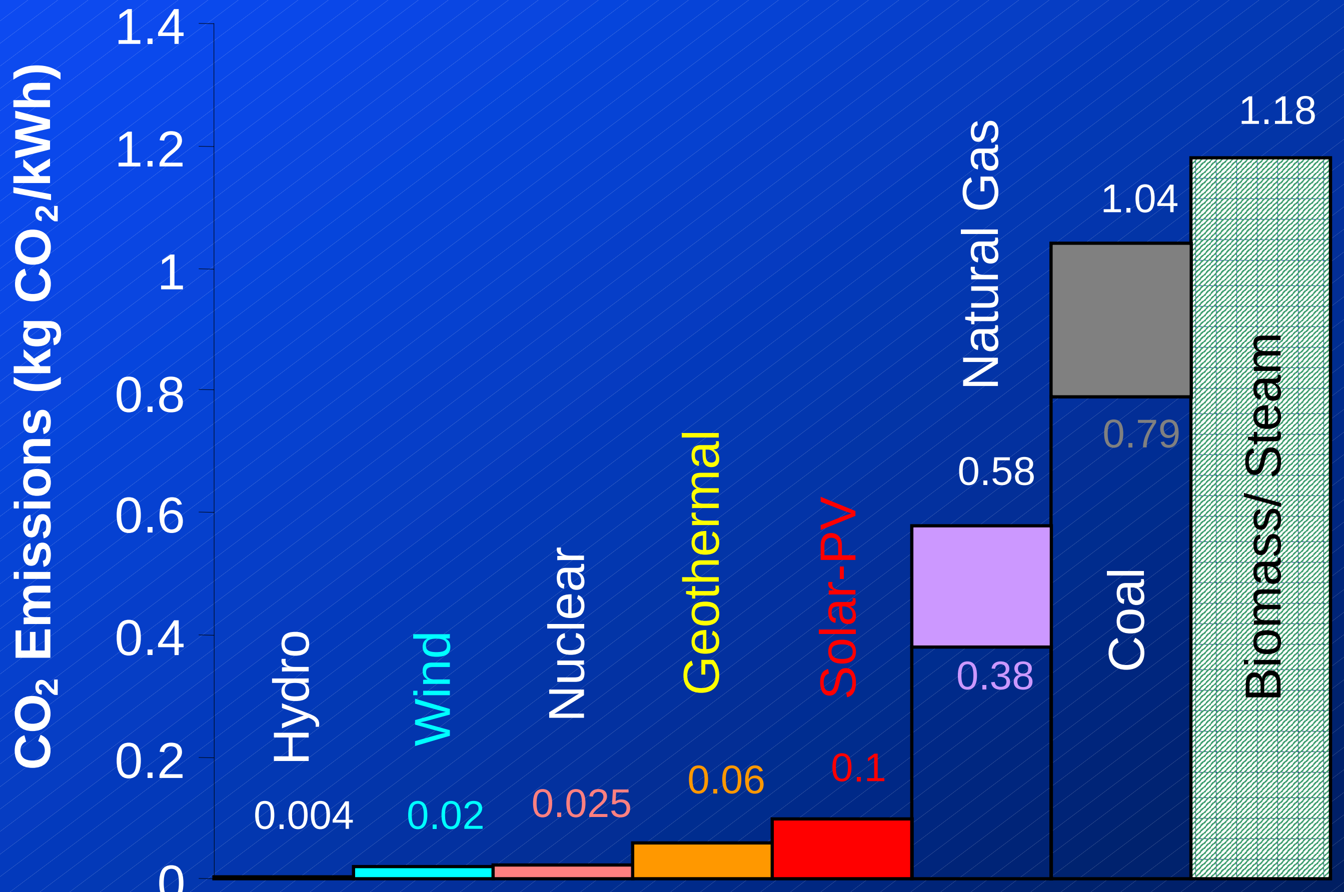
(*) DER efficiencies improve with heat recovery

Mike Corradini, UW

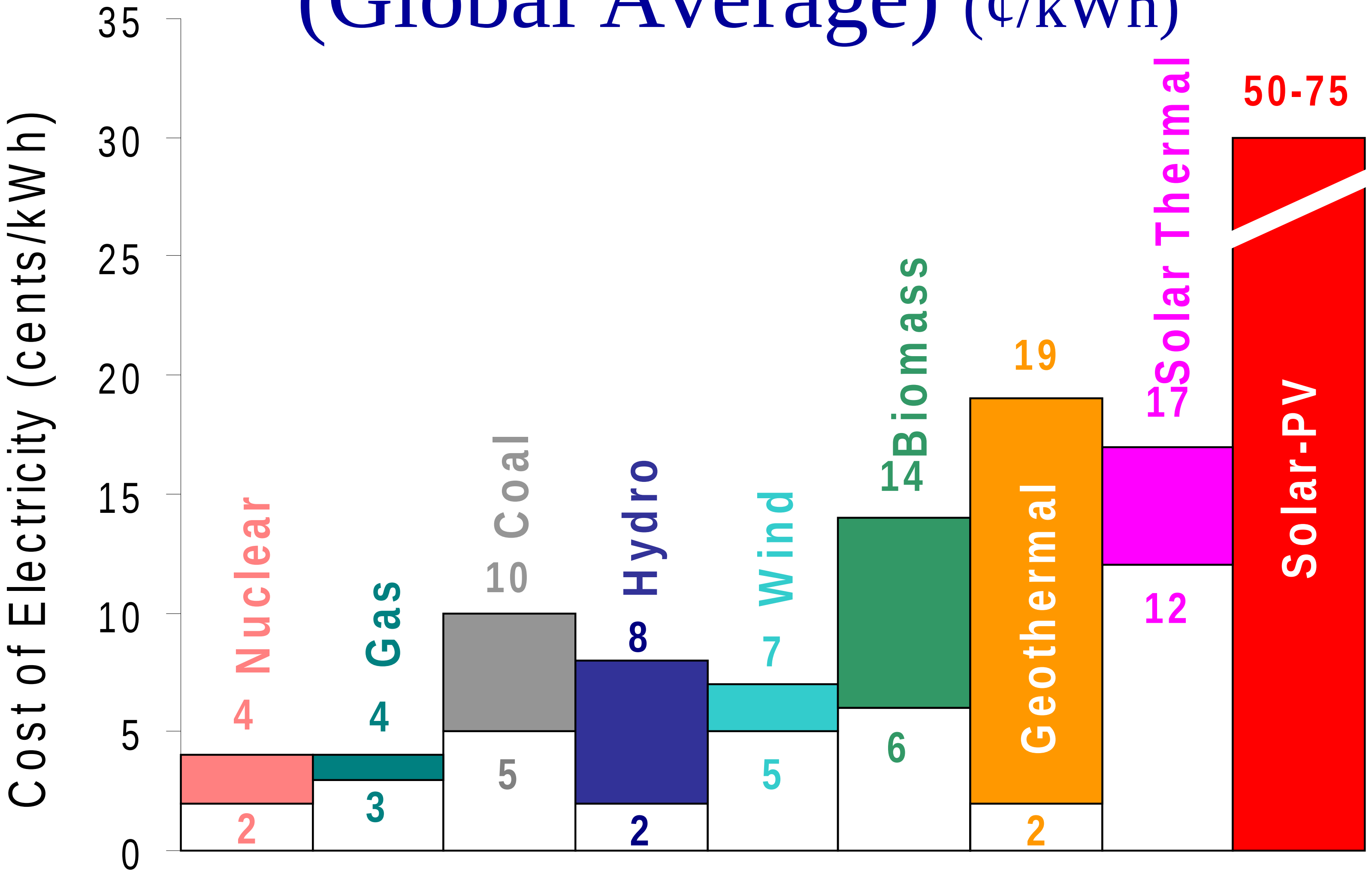
CARBON DIOXIDE EMISSIONS

Construction/Operation/Fuel Preparation

(kg CO_2 / kWh)



Cost of Electricity (Global Average) (¢/kWh)



Transmission needs by technology

Technology	Economies	Remoteness	Fuel transport	Reliability	Inter-region
Nuclear	Scale	Yes	Inexpensive	Maintenance	Yes
Coal	Scale	Yes	Expensive	Maintenance	Yes
Hydro	Custom	Yes	Impossible	Water	Yes
Photovoltaic	Production	It depends	Impossible	Insolation	Yes
Wind	Production	Yes	Impossible	Wind	Yes
Biomass	Custom	Yes	Expensive	Maintenance	Yes
Geothermal	Custom	Yes	Impossible	Maintenance	Yes
Fuel cells	Production	No	Pipelines	Maintenance	No

Distributed Generation (DER) Trends

Smaller generation closer to the load

  Natural gas, renewable

Displaces some T&D

Can be used to mitigate constraints

Provides backup resource to the load

Potential for combined heat and power

Conventional turbines OR fuel cells

What is a fuel cell?

DC Voltage Source with low emissions

High fuel-to-electric efficiency

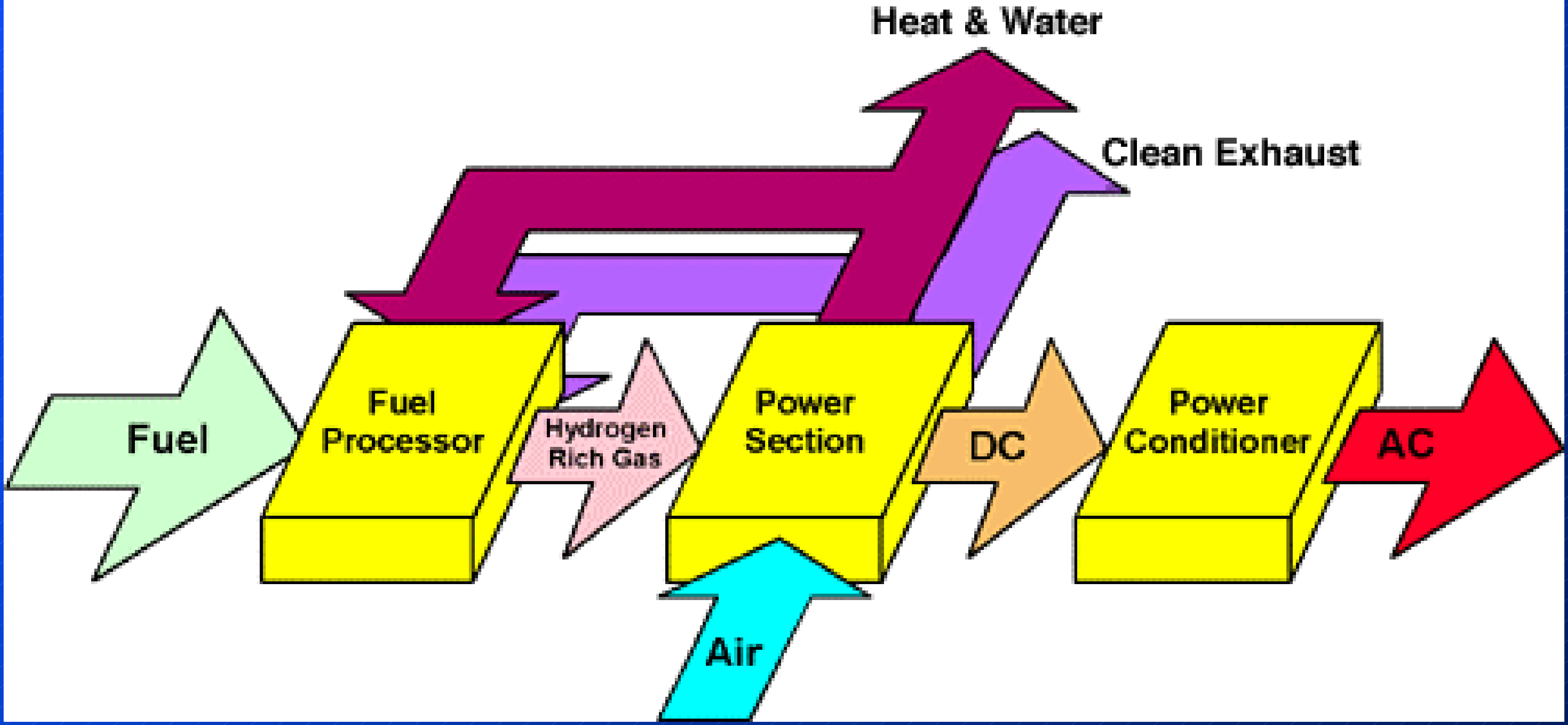
Low noise

No moving parts

One step generation

48 Vdc 7.5 kW Fuel Cell

A fuel cell system

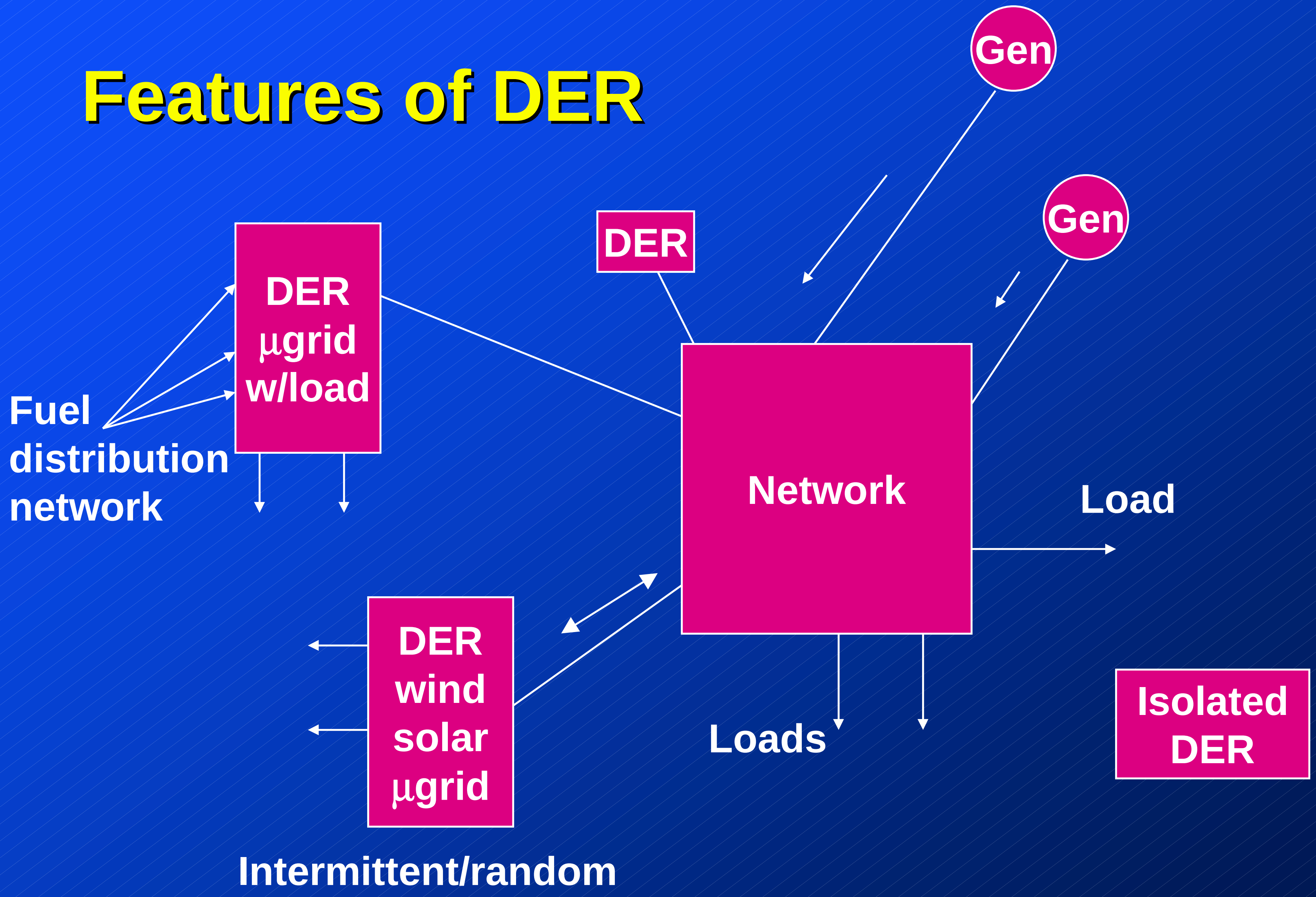


For top efficiency, you must use the heat!
Ultimately, hydrogen is needed!

Need for a Grid with DER

- Historical factors still relevant
  - Economies of scale, resource location, reliability enhancement and resource sharing
- Large central technologies quite viable
  - Hydroelectric, coal, nuclear
- DER will supplement rather than supplant the T&D grid

Features of DER



Grid Implications of DER

- DER can offset local adequacy constraints
- Grid security can be enhanced through proper design and operation of DER
  - Safety considerations properly addressed
  - Localized voltage support, stability enhancement
- Planning takes on a whole new dimension
  - Grid utilization factors *may* decrease

DER siting and sizing

- For stand-alone, size for peak demand
  - Both electrical and thermal demands
  - (Thermal important for heat recovery systems)
- For maximum efficiency, size for average thermal load utilization
  - Either thermal or electric will be undersized
- For reliability, provide redundancy
  - Using grid to provide redundancy decreases the utilization factor of the grid

Nuclear Power Generation

United States

- 104 operating reactors
- 20% nation’s electricity generation
- No new units ordered or under construction

Worldwide

- 433 operating reactors
- Some countries (e.g., France) heavily dependent on nuclear power

Mike Corradini

Evolution of Nuclear Power Systems

Generation I

Early Prototype Reactors

- Shippingport
- Dresden,Fermi-I
- Magnox

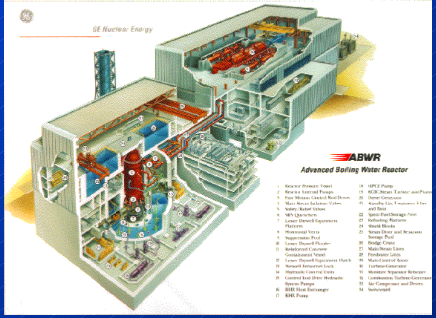
Generation II

Commercial Power Reactors

- LWR: PWR/BWR
- CANDU
- VVER/RBMK

Generation III

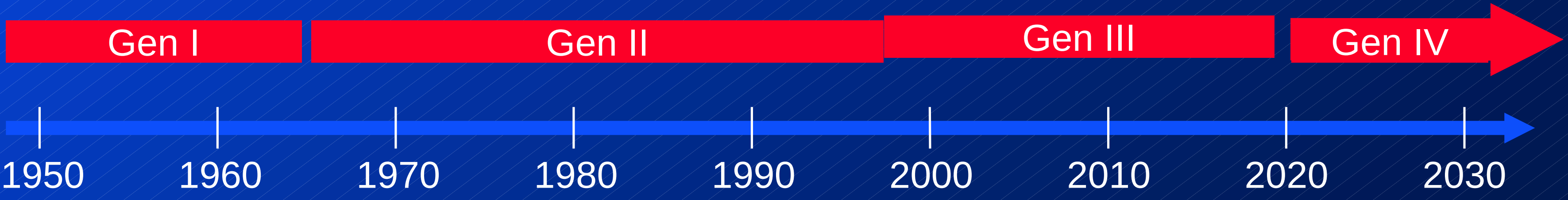
Advanced LWRs



- System 80+
- EPR
- AP600
- ABWR

Generation IV

- Highly economical
- Enhanced safety
- Minimized wastes
- Proliferation resistance



Prospects for Nuclear Power

- New capacity will be primarily in Asia
- Most new capacity will be offset by retiring plants in the US and industrialized nations
- DOE Energy Information Administration projects decline in nuclear generation
  - Yet reputable scientists see eventual expansion

Key Issues for Nuclear Power

- Safety concerns
  - Recent events in Japan, S. Korea, China
- Competition in US electricity sector
  - Ownership consolidation
  - Likely to result in more efficient operations
- Fatigue cracking
  - Recent French issue
- European Union talks
  - At issue is the safety of older Soviet-style reactors
- Political movements
  - Germany, Sweden, etc. (Green Party)
- Long-term nuclear waste depository
  - A big problem in the US and worldwide

Nuclear Power Plant Waste

All nuclear fuel cycle waste (except HLW) safely disposed: milling, enrichment, fabrication

US defines High Level Waste as spent nuclear fuel since no reprocessing has occurred since 1976 (not so in France and Japan)

Spent fuel currently at nuclear power plants (~75,000 mt) to be stored at Yucca Mountain

HLW radiation exposure at disposal site similar to natural background radiation

Nuclear electricity taxed at 1mill/kwhre for a HLW fund (~$500 million/yr, or >$15 billion)

Future of Nuclear Power

- Waste disposal problem must be solved
  - Reprocessing should be encouraged
- Standardized (modular) designs needed
  - Cost efficient
  - Smarter "failsafe" design, reduces need for complex contingency and backup protection schemes
- Fuel cycle issues (breeder reactor program)
- Price-competitive with alternative sources

Impact of deregulation of the grid

- Deregulation changes grid utilization
  - Congestion pricing reduced some peak flows
  - Flow control (PAR, FACTS, DC) increase use
- Inter-regional price differences are the result of grid congestion
  - Nodal pricing makes results unintuitive
    - Nodal pricing is efficient (also flowgate pricing)
- Reliability has become a big concern
  - Initial uses of DER likely to be for reliability
    - Strong reserve markets must develop

Grid utilization in New York

	Central East		Total East	
Year	Flow>75% of the time	% of time within 200MW of limit	Flow>75% of the time	% of time within 200MW of limit
1999	1697MW	26%	3375MW	1%
1998	1549MW	35%	3493MW	3%
1997	2285MW	85%	4800MW	7%
1996	2365MW	90%	4800MW	2%

Transmission use appears to be on the decline

However, not always so in other cases

More “intra-regional” problems surfacing

Policy and implementation issues

“Having the answer is not enough”

“The role of government is the internalization of externalities”

“Having the answer is not enough”

- Engineers think that once the answer is known, the problem is solved
  - Individual interests and greed interfere
  - Political realities must be considered
  - Human behavior must be factored in
- Some think the problem is politicians lack of understanding
  - I maintain that it is engineers lack of understanding of the entire decision-making cycle

“Internalization of externalities”

- It is individually efficient to ignore externalities
  - Emissions
  - Resource depletion (sustainability)
- Role of policy: establish the rules
  - Example: automobile air emissions
  - Example: power plant emission restrictions
    - Industry is realizing that what is good for society is good for industry
    - “We all have to do it”

“When I was younger, I used to think that government was the enemy of industry. I used to think that clean air regulations would kill the automobile and the power industry. Having grown older and wiser, I now recognize the enormous value to society of past clean air policies. I now believe that what is good for society is actually good for corporations” (Mike Gent paraphrased, IEEE EPC, July 2000)

“The role of policymakers is to lineup the interests of society with individual greed and then take a step back and watch” (yours truly, November 2000)

Conclusions: future of the T&D grid

- Traditional reasons for the grid still here
  - Pooling resources, interregional exchanges, etc.
  - Even pessimistic scenarios show nuclear production beyond 2020
  - Central generation and renewable (hydro) key to the nation’s electricity portfolio
  - Intermittency of renewables is an issue
    - Technology hybridization may help (Tatro)
- New economic analysis needed
  - Transmission service is key to competition
- Externalities must be internalized