Energy Overview From NREL

This document has no connection to cold fusion, but it is valuable public domain information, it is no longer in print, and it does not appear to be available elsewhere on the Internet.

Pages 2 – 16 are from the U.S. DoE Office of Conservation and Renewable Energy (NREL), *Hydrogen Program Plan--FY 1993--FY 1997*, June 1992, Appendixes A and C.

Page 17 shows a graph published by the Lawrence Livermore National Laboratory in 2001. The graph shows that most energy is lost as "rejected energy" (waste heat), especially in Electricity generation (70% waste) and Transportation (80% waste). Better technology would greatly reduce this waste. Most generators convert only 33% of the heat from burning coal or gas into electricity; advanced generators convert 40%. Most automobiles convert only 15% of the heat from gasoline into useful vehicle propulsion; hybrid and electric automobiles convert 30% or more. This graph is based on the DoE Energy Information Administration *Annual Energy Review*. This review is an excellent, comprehensive source of online information. See:

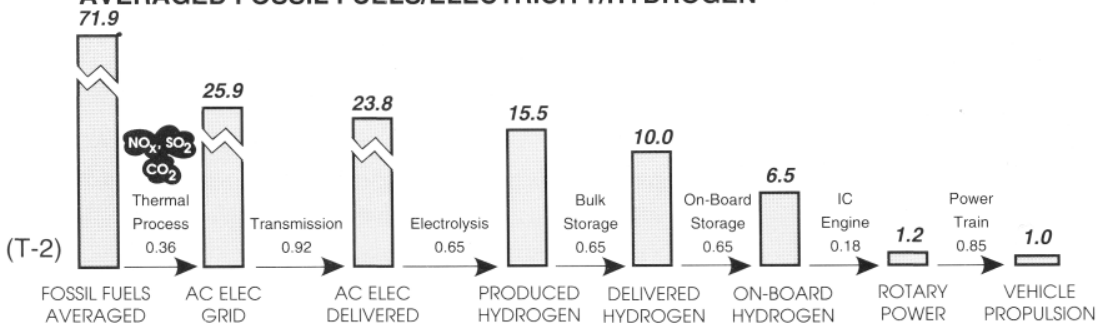
http://www.eia.doe.gov/emeu/aer/contents.html

Exhibit A.2
Transportation Current Technologies

CRUDE OIL/GASOLINE

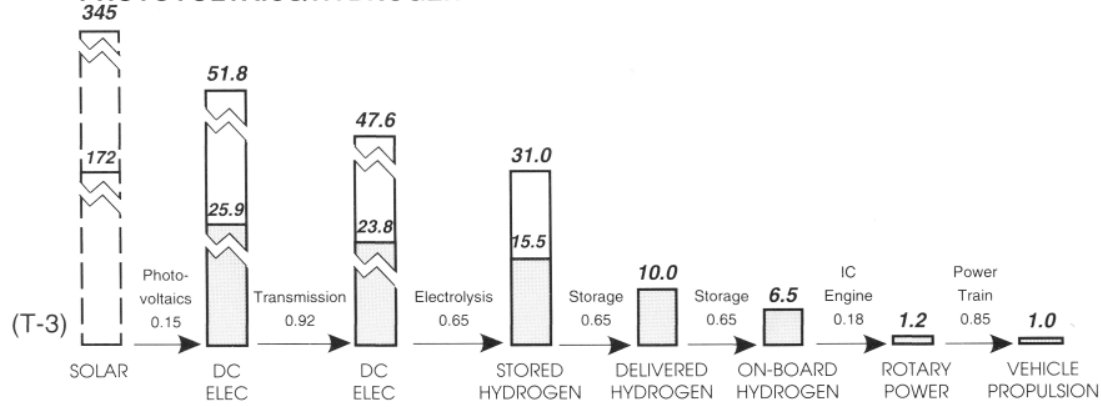
Unit Cost ($/kW):
1000 50*
Total Cost ($/kW delivered): 8,505
Total Emissions (g/kWh delivered): CO_2: 2,400, NO_x: 4.2, SO_2: (trace)

AVERAGED FOSSIL FUELS/ELECTRICITY/HYDROGEN



Unit Cost ($/kW):
1500 300* 1000* 100
Total Cost ($/kW delivered): 71,420
Total Emissions (g/kWh delivered): CO_2: 22,637, NO_x: 62.9, SO_2: 169.6

PHOTOVOLTAICS/HYDROGEN

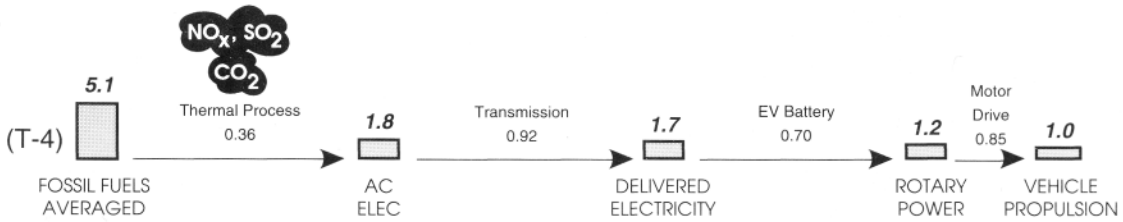


Unit Cost ($/kW):
5000 300* 1000* 100
Total Cost ($/kW delivered): 323,140
Total Emissions (g/kWh delivered): 0

* *These devices are rated on input power; all others are sized on output power levels.*

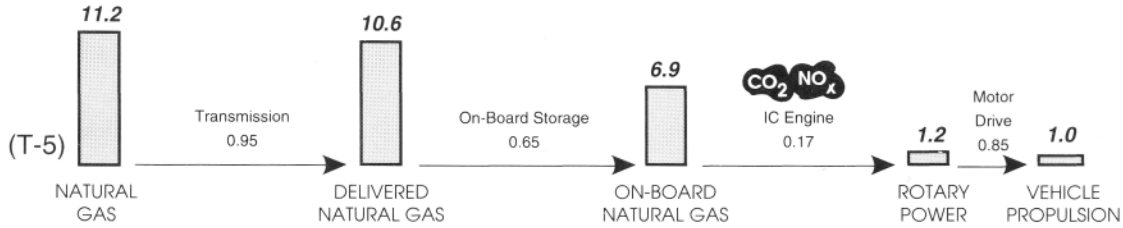
Exhibit A.2
Transportation Current Technologies (Continued)

AVERAGED FOSSIL FUELS/ELECTRICITY/BATTERY



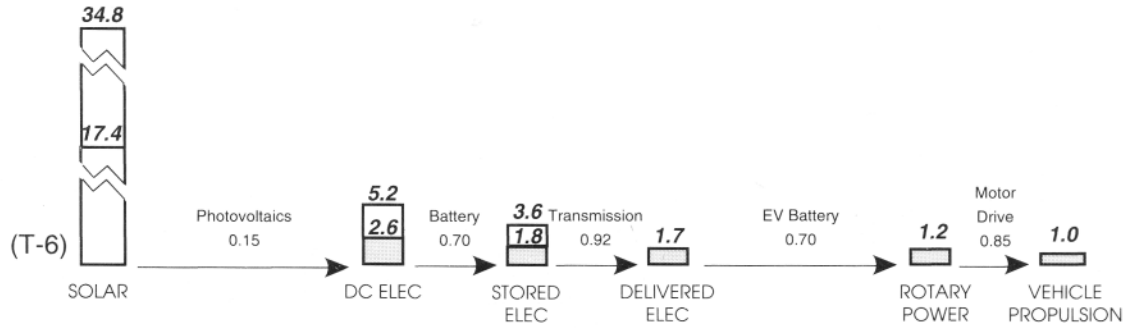
Unit Cost ($/kW):
1500 300*
Total Cost ($/kW delivered): 3,240
Total Emissions (g/kWh delivered): CO_2: 1,505, NO_x: 4.2 SO_2: 11.3

NATURAL GAS/ICE



Unit Cost ($/kW):
50
Total Cost ($/kW delivered): 530
Total Emissions (g/kWh delivered): CO_2: 1300, NO_x: 4.0

PHOTOVOLTAICS/BATTERY/ELECTRICITY

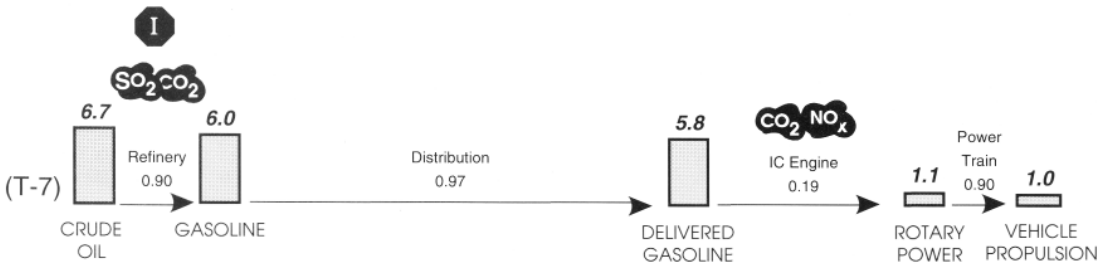


Unit Cost ($/kW):
5000 120 300*
Total Cost ($/kW delivered): 27,512
Total Emissions (g/kWh delivered): 0

* *These devices are rated on input power; all others are sized on output power levels.*

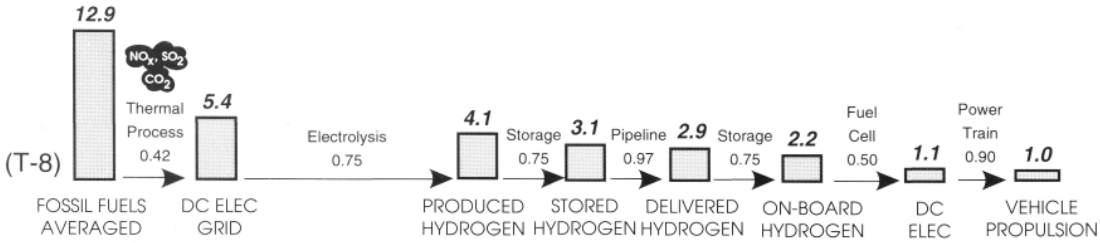
Exhibit A.3
Transportation Advanced Technologies

CRUDE OIL/GASOLINE



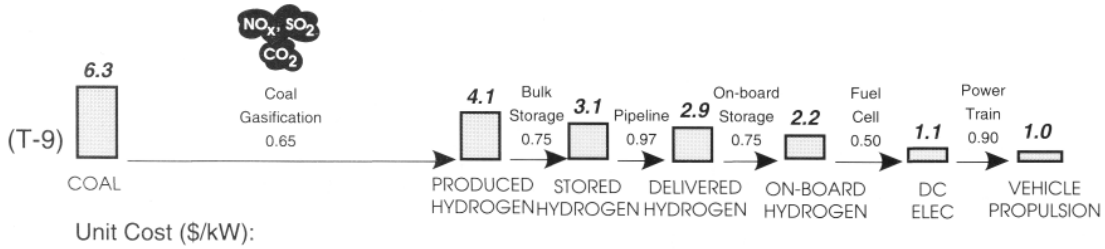
Unit Cost ($/kW):
1000 50*
Total Cost ($/kW delivered): 6,300
Total Emissions (g/kWh delivered): CO_2: 1,384, NO_x: 3.1, SO_2: (trace)

AVERAGED FOSSIL FUELS/ELECTRICITY/HYDROGEN



Unit Cost ($/kW):
1200 250* 50 50*
Total Cost ($/kW delivered): 8,140
Total Emissions (g/kWh delivered): CO_2: 3,445, NO_x: 2.8, SO_2: 1.2

COAL GASIFICATION/HYDROGEN



Unit Cost ($/kW):
900 50 50*
Total Cost ($/kW delivered): 4,000
Total Emissions (g/kWh delivered): CO_2: 1,845 NO_x: 1.4, SO_2: 1.0

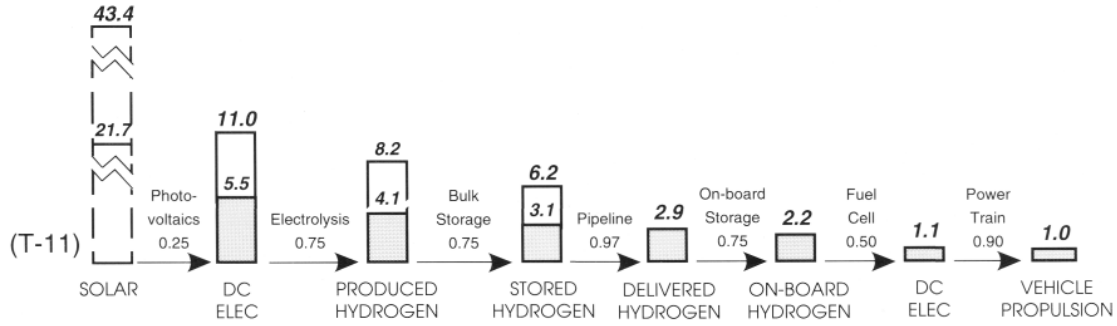
** These devices are rated on input power; all others are sized on output power levels.*

Exhibit A.3
Transportation Advanced Technologies (Continued)

NATURAL GAS/HYDROGEN

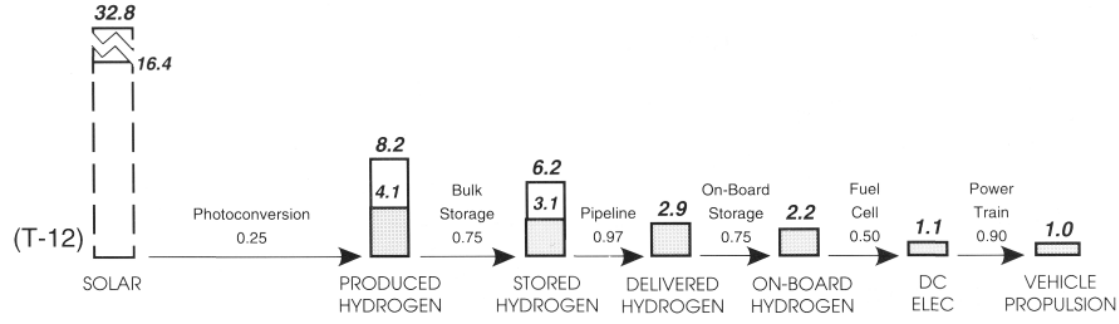
Unit Cost ($/kW):
50*
Total Cost ($/kW delivered): 175
Total Emissions (g/kWh delivered): CO_2: 358

PHOTOVOLTAICS/HYDROGEN



Unit Cost ($/kW):
2500 250* 50 50*
Total Cost ($/kW delivered): 30,870
Total Emissions (g/kWh delivered): 0

DIRECT SOLAR/HYDROGEN

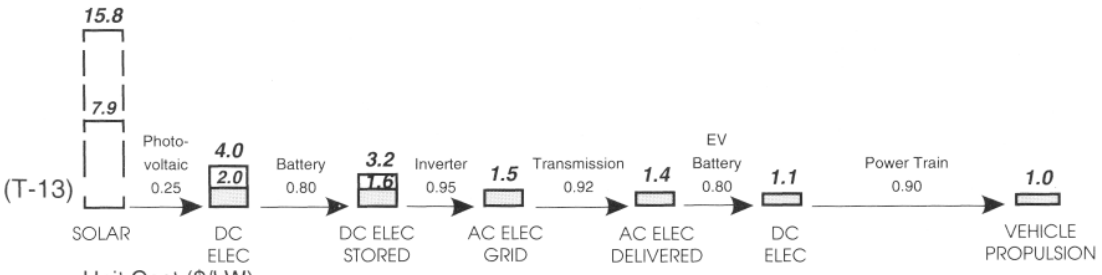


Unit Cost ($/kW):
2500 50 50*
Total Cost ($/kW delivered): 21,120
Total Emissions (g/kWh delivered): 0

** These devices are rated on input power; all others are sized on output power levels.*

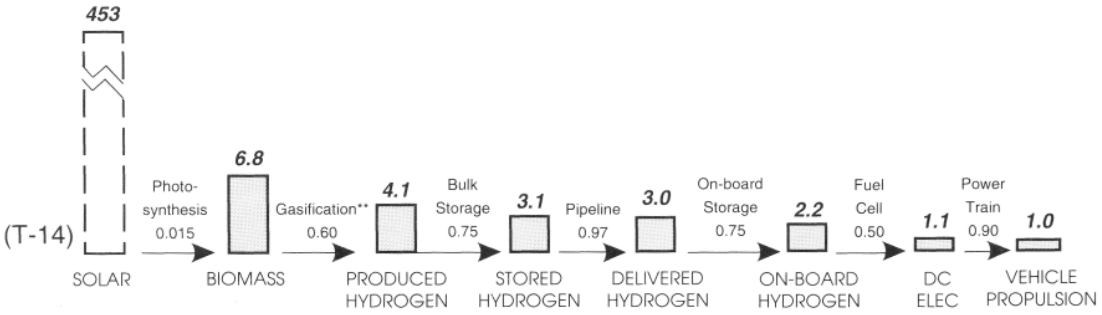
Exhibit A.3
Transportation Advanced Technologies (Continued)

PHOTOVOLTAICS/BATTERY



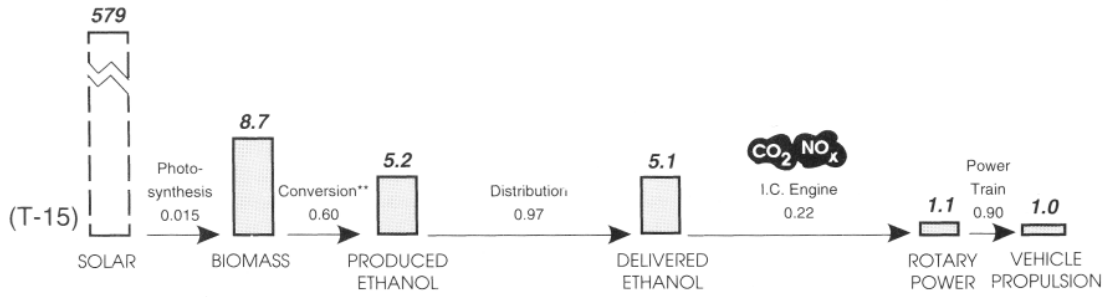
Unit Cost ($/kW):
2500 80 (included) 300*
Total Cost ($/kW delivered): 10,706
Total Emissions (g/kWh delivered): 0

BIOMASS/HYDROGEN



Unit Cost ($/kW):
1000 50 50*
Total Cost ($/kW delivered): 4,410
Total Emissions (g/kWh delivered): CO_2: 0

BIOMASS/ETHANOL



Unit Cost ($/kW):
1000 50*
Total Cost ($/kW delivered): 5,460
Total Emissions (g/kWh delivered): CO_2: 639, NO_x: 1.8

* *These devices are rated on input power; all others are sized on output power levels.*

** *CO_2 produced during H_2 and ethanol production is reabsorbed by subsequent biomass crops.*

Exhibit A.3
Transportation Advanced Technologies (Continued)

AVERAGED FOSSIL FUELS/ELECTRICITY/BATTERY

Unit Cost ($/kW):
1200 300*

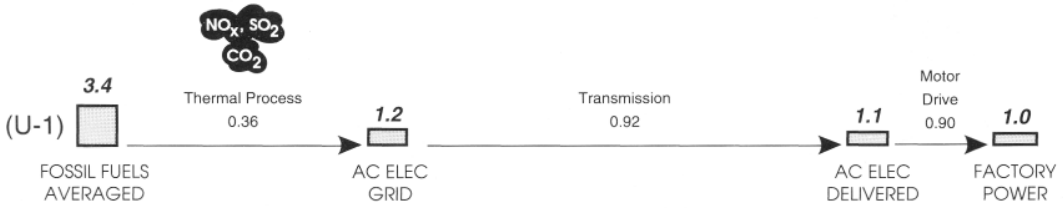
Total Cost ($/kW delivered): 2,250

Total Emissions (g/kWh delivered): CO_2: 957 NO_x: 0.77 SO_2: 0.33

** These devices are rated on input power; all others are sized on output power levels.*

Exhibit A.4
Utility Current Technologies

AVERAGED FOSSIL FUELS/ELECTRICITY

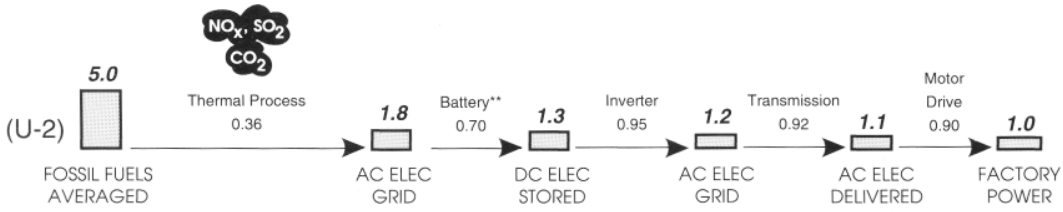


Unit Cost ($/kW):
1500 300*

Total Cost ($/kW delivered): 2,160

Total Emissions (g/kWh delivered): CO_2: 1,003, NO_x: 2.8, SO_2: 7.5

AVERAGED FOSSIL FUELS/BATTERY/ELECTRICITY



Unit Cost ($/kW):
1500 120 (included) 300*

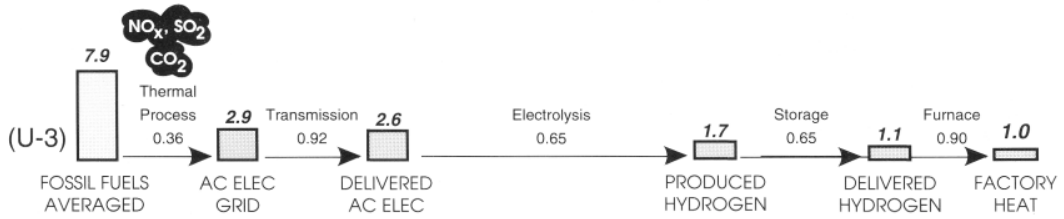
Total Cost ($/kW delivered): 3,216

Total Emissions (g/kWh delivered): CO_2: 1,505, NO_x: 4.2, SO_2: 11.3

** These devices are rated on input power; all others are sized on output power levels.*
*** Other forms of electric storage (i.e., pumped storage) operate at similar efficiencies.*

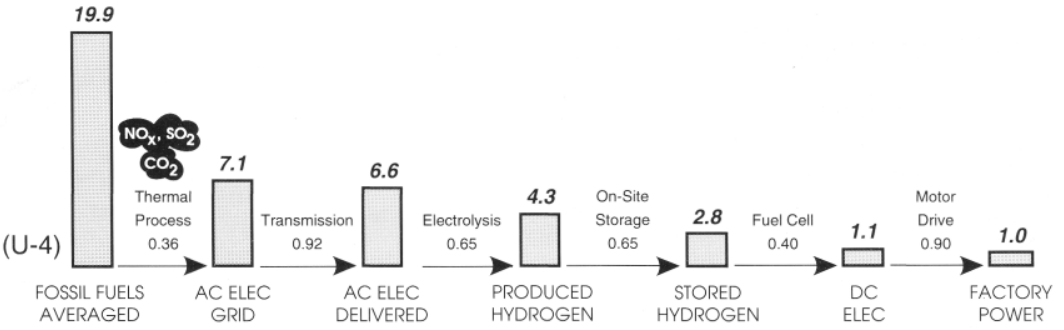
Exhibit A.4
Utility Current Technologies (Continued)

AVERAGED FOSSIL FUELS/ELECTRICITY/HYDROGEN



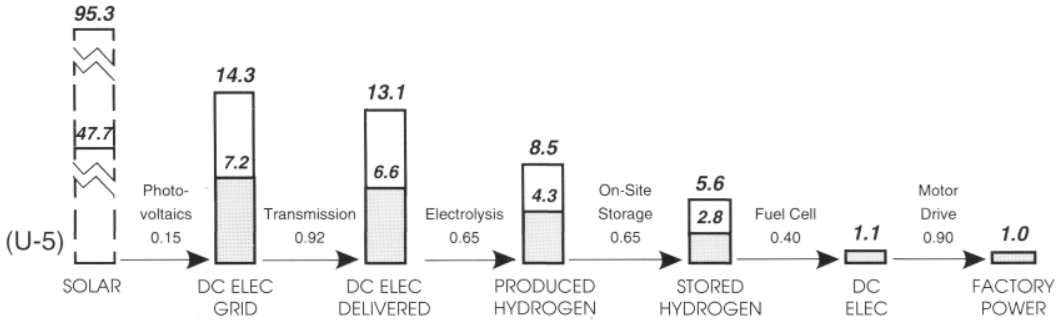
Unit Cost ($/kW):
1500 300* 1000* 100
Total Cost ($/kW delivered): 7,930
Total Emissions (g/kWh delivered): CO_2: 2,424 NO_x: 6.7 SO_2: 18.2

AVERAGED FOSSIL FUELS/HYDROGEN/ELECTRICITY



Unit Cost ($/kW):
1500 300* 1000*
Total Cost ($/kW delivered): 19,380
Total Emissions (g/kWh delivered): CO_2: 5,936, NO_x: 16.5, SO_2: 44.4

PHOTOVOLTAICS/HYDROGEN/ELECTRICITY

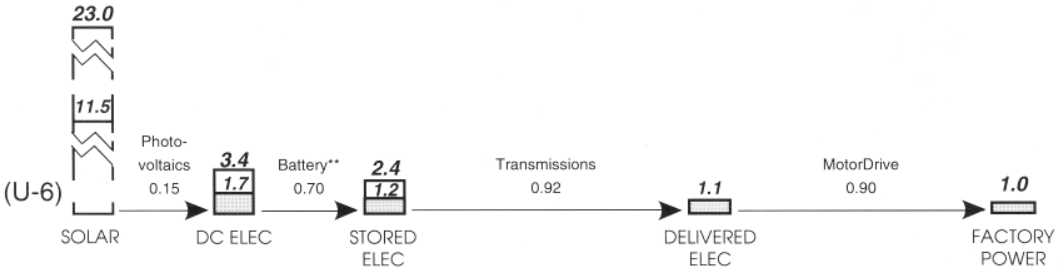


Unit Cost ($/kW):
5000 1000* 100 2500
Total Cost ($/kW delivered): 92,200
Total Emissions (g/kWh delivered): CO_2: 0, NO_x: 0, SO_2: 0

** These devices are rated on input power; all others are sized on output power levels.*

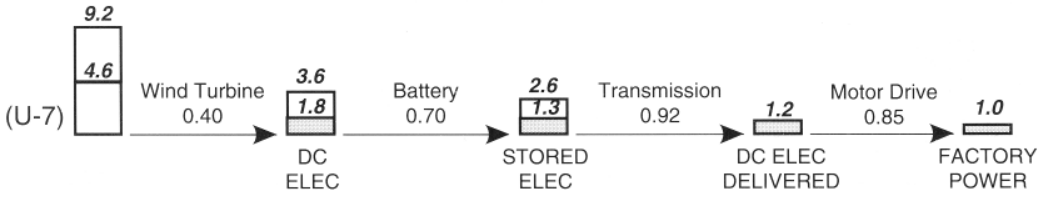
Exhibit A.4
Utility Current Technologies (Continued)

PHOTOVOLTAICS/BATTERY/ELECTRICITY



Unit Cost ($/kW):
2500 120 300*
Total Cost ($/kW delivered): 9,508
Total Emissions (g/kWh delivered): 0

WIND/DC ELECTRICITY



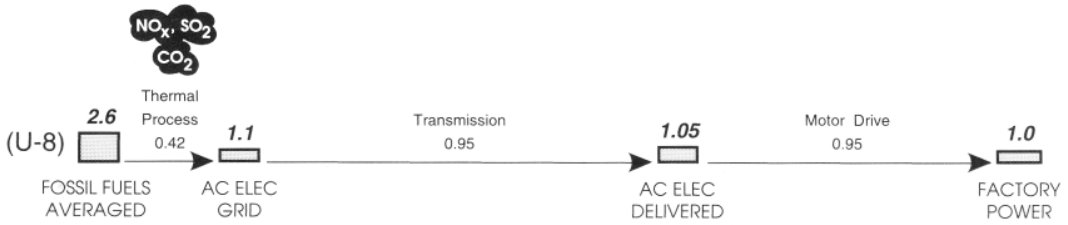
Unit Cost ($/kW):
1100 120 300*
Total Cost ($/kW delivered): 5,052
Total Emissions (g/kWh delivered): 0

** These devices are rated on input power; all others are sized on output power levels.*

*** Other forms of electric storage (i.e. pumped storage) operate at similar efficiencies.*

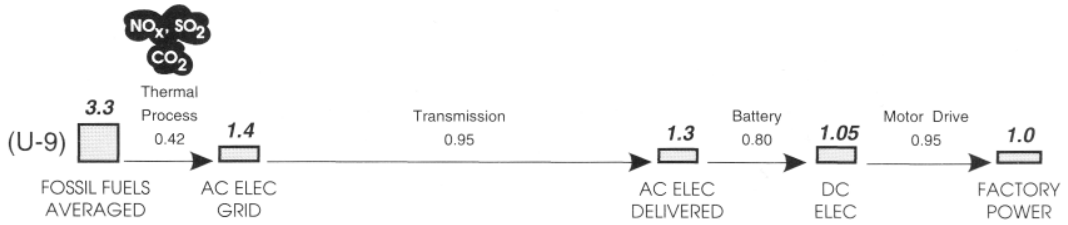
Exhibit A.5
Utility Advanced Technologies

AVERAGED FOSSIL FUELS/ELECTRICITY



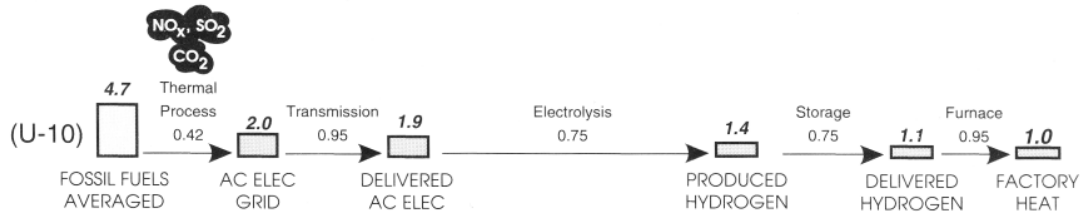
Unit Cost ($/kW):
1200 300*
Total Cost ($/kW delivered): 1,650
Total Emissions (g/kWh delivered): CO_2: 702, NO_x: 0.56, SO_2: 0.24

AVERAGED FOSSIL FUELS/BATTERY/DC ELECTRICITY



Unit Cost ($/kW):
1200 300* 80
Total Cost ($/kW delivered): 2,184
Total Emissions (g/kWh delivered): CO_2: 893, NO_x: 0.71, SO_2: 0.31

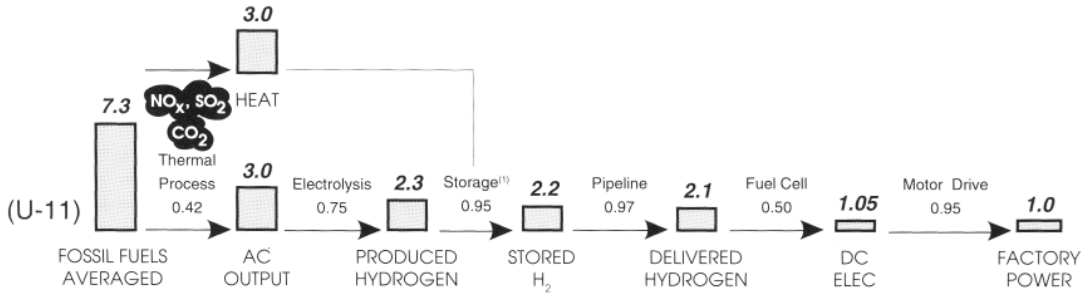
AVERAGED FOSSIL FUELS/ELECTRICITY/HYDROGEN



Unit Cost ($/kW):
1200 300* 250* 50
Total Cost ($/kW delivered): 3,530
Total Emissions (g/kWh delivered): CO_2: 1,276 NO_x: 1.02 SO_2: 0.44

Exhibit A.5
Utility Advanced Technologies (Continued)

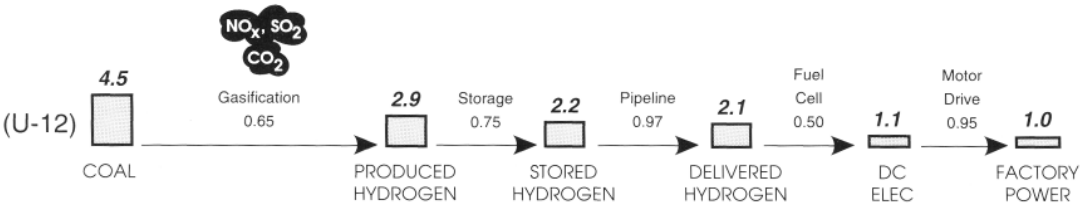
AVERAGED FOSSIL FUELS/HYDROGEN/DC ELECTRICITY
Using Utility Waste Heat



Unit Cost ($/kW):
1200 250* 50 50*
Total Cost ($/kW delivered): 4,642
Total Emissions (g/kWh delivered): CO_2: 1,914, NO_x: 1.53, SO_2: 0.66

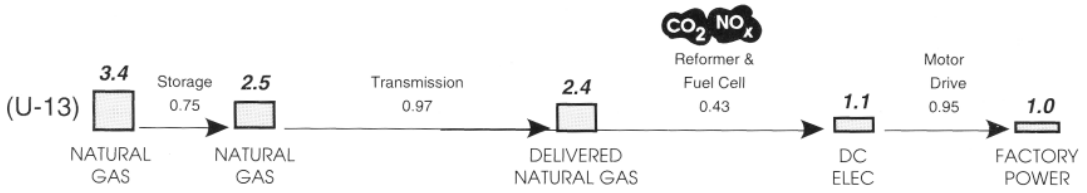
(1) Storage efficiency increased from 0.75 to 0.95 due to utilization of power plant waste heat for hydride discharge.

COAL GASIFICATION/HYDROGEN/DC ELECTRICITY



Unit Cost ($/kW):
900 50 50*
Total Cost ($/kW delivered): 2,830
Total Emissions (g/kWh delivered): CO_2: 1,305, NO_x: 0.96, SO_2: 0.73

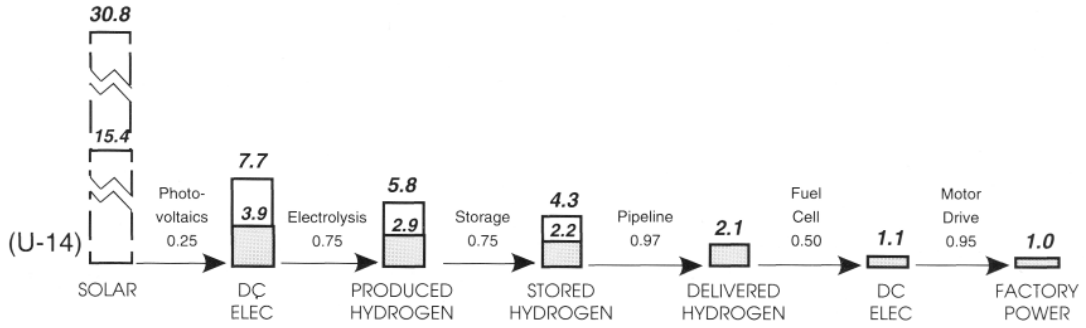
NATURAL GAS/HYDROGEN/DC ELECTRICITY



Unit Cost ($/kW):
50 50*
Total Cost ($/kW delivered): 250
Total Emissions (g/kWh delivered): CO_2: 358, NO_x: 0.13

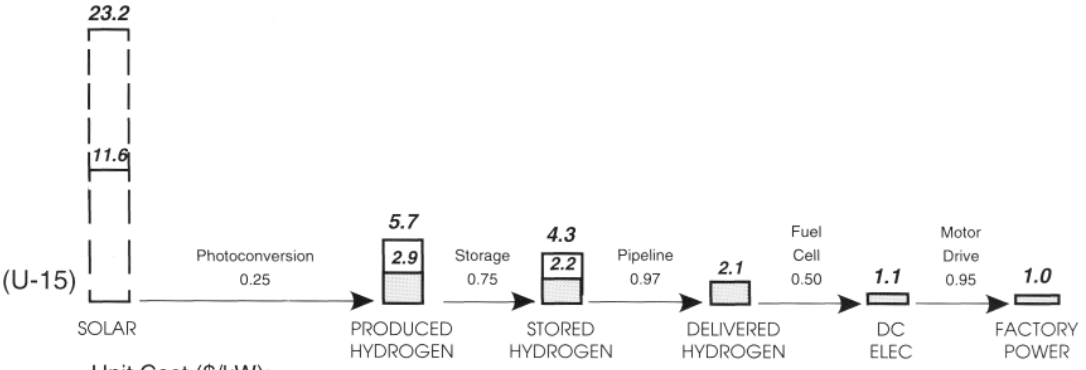
Exhibit A.5
Utility Advanced Technologies (Continued)

PHOTOVOLTAICS/HYDROGEN/DC ELECTRICITY



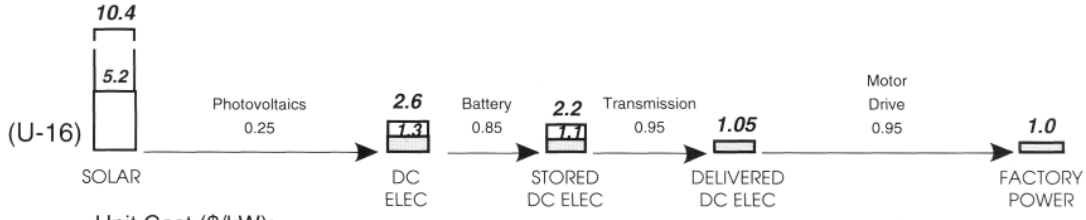
Unit Cost ($/kW):
2500 250* 50 50*
Total Cost ($/kW delivered): 21,605
Total Emissions (g/kWh delivered): 0

DIRECT SOLAR/HYDROGEN/DC ELECTRICITY



Unit Cost ($/kW):
2500 50 50*
Total Cost ($/kW delivered): 14,680
Total Emissions (g/kWh delivered): 0

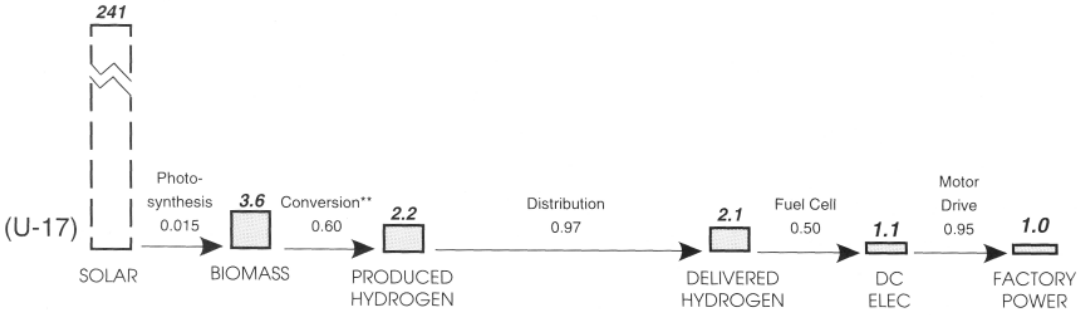
PHOTOVOLTAICS/BATTERY/DC ELECTRICITY



Unit Cost ($/kW):
2500 80* 300*
Total Cost ($/kW delivered): 7,336
Total Emissions (g/kWh delivered): 0

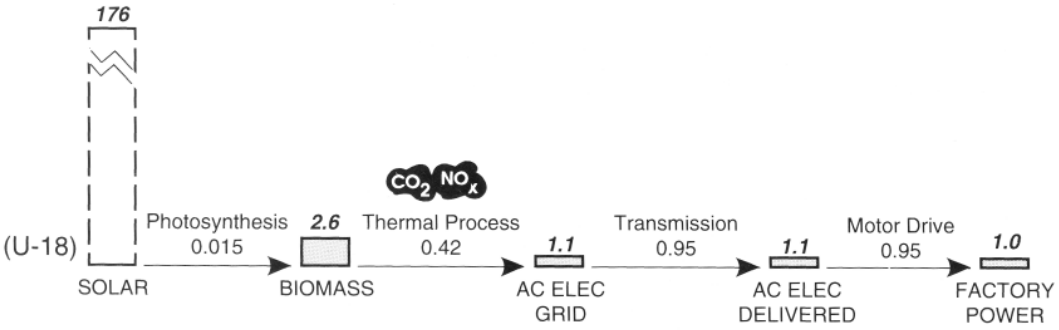
Exhibit A.5
Utility Advanced Technologies (Continued)

BIOMASS/HYDROGEN/DC ELECTRICITY



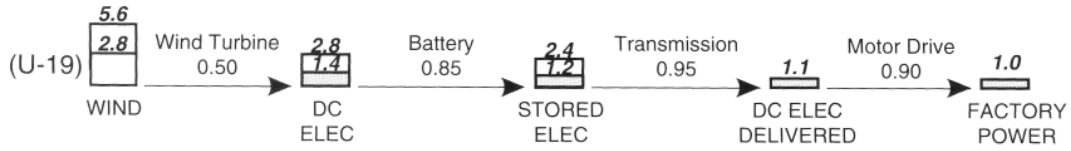
Unit Cost ($/kW): 1000 50*
Total Cost ($/kW delivered): 2,310
Total Emissions (g/kWh delivered): 0

BIOMASS/ELECTRICITY



Unit Cost ($/kW):
900 300*
Total Cost ($/kW delivered): 1,320
Total Emissions (g/kWh delivered): CO_2: 0** NO_x: 0.73

WIND/DC ELECTRICITY



Unit Cost ($/kW):
850 80 300*
Total Cost ($/kW delivered): 3,292
Total Emissions (g/kWh delivered): 0

** CO_2 produced during H_2 and ethanol production is reabsorbed by subsequent biomass crops.

APPENDIX C: TECHNOLOGY ASSUMPTIONS

TABLE C-1

Ref. No.	Technology	Current (1990)		Advanced (2020)	
		Efficiency (%)	Cap. Cost ($/kW)	Efficiency (%)	Cap. Cost ($/kW)
1	Central Baseload Fossil Plant	36	1,500	42	1,200
2	Electricity Transmission (500 miles)	92	300	95	300
3	Electric Motor Drive	90	100	95	100
4	Electrolysis	65	1,000	75	250
5	Hydrogen Storage (5 hours)	65	100	75	50
6	Natural Gas Pipeline (500 miles)	95	50	97	50
7	Hydrogen Pipeline (500 miles)	95	50	97	50
8	Fuel Cell	40	2,500	50	300
9	Battery Storage (5 hours)	70	120	80	80
10	Photovoltaics	15	5,000	25	2,500
11	Photoconversion	—	—	25	2,500
12	I.C. Engine (Fed. Urban Dr. Cycle)	15	50	19	40
13	Vehicle Power Train	85	10	90	10
14	Refinery	85	1000	90	1000
15	Gas Furnace	90	—	—	—
16	Industrial Boiler	70		—	—
17	Combined Cycle- Baseload Coal Plant	39	—	—	—
18	Combustion Turbine	25	—	—	—
19	Steam Reforming (natural gas)	68			
20	Biomass Conversion (ethanol)	—	—	60	1000
21	Biomass Conversion (hydrogen)	—	—	60	1000
22	Coal Gasification	55	1,200	65	900

1. Central Baseload Fossil Plant

"Electricity Supply: Supporting Analysis for the *National Energy Strategy" SR/NES/90-03*, DOE/EIA, 1991 EPRI, *Technical Assessment Guide (TAG)*, Vol. 1,1986

2. Transmission

Pacific Gas and Electric Co., "Hydrogen and Electricity as Carriersof Solar and Wind Energy for the 1990s and Beyond,"G.W. Braun, A. Suchard, J. Martin, 1990

3. Motor Drive

Lawrence Berkeley Laboratory, "Technology Assessment: Adjustable-Speed Motors and Motor Drives," U.S. DOE, 1988
EPRI, Technical Brief, "Efficient Electric Motors and Drives," 1987

4. Electrolysis
PG&E, 1990 (Ibid.)
"The Hydrogen Technology Assessment, Opportunities for Industry and Research, Phase I," National Hydrogen Association
"Economic Assessment of Advanced Electrolytic Hydrogen Production,"S. Dutta, D. Block, R. *PortJnternationalJournalof Hydrogen Energy*, Vol. 15, No. 6, pp. 387-395,1990
"Modern and Prospective Technologies for Hydrogen Production from Fossil Fuels," M. Steinberg, H. Cheng, *InternationalJournal of Hydrogen Energy*, Vol. 14, No. 11, pp. 797-820, 1989

5. Hydrogen Storage
National Hydrogen Association, 1991 (Ibid.)
PG&E, 1990 (Ibid.)
(See references in Appendix B)

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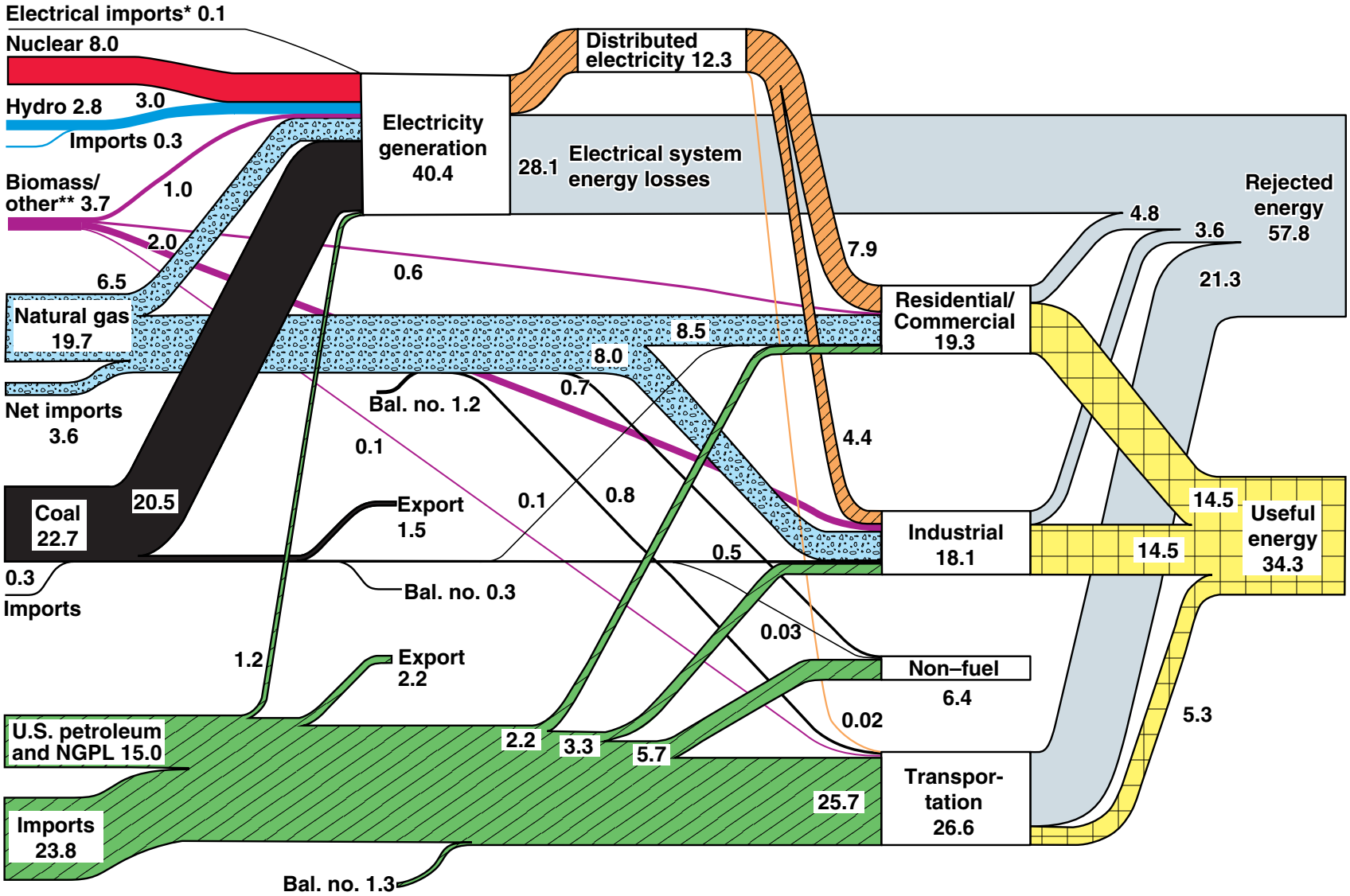
U.S. Energy Flow Trends – 2000
Net Primary Resource Consumption 98.5 Quads



Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 2000*
*Net fossil-fuel electrical imports
**Biomass/other includes wood and waste, geothermal, solar, and wind.

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