Stan Rhodes, Scientific Certification Systems

Assessing Environmental Performance in the Electricity Sector

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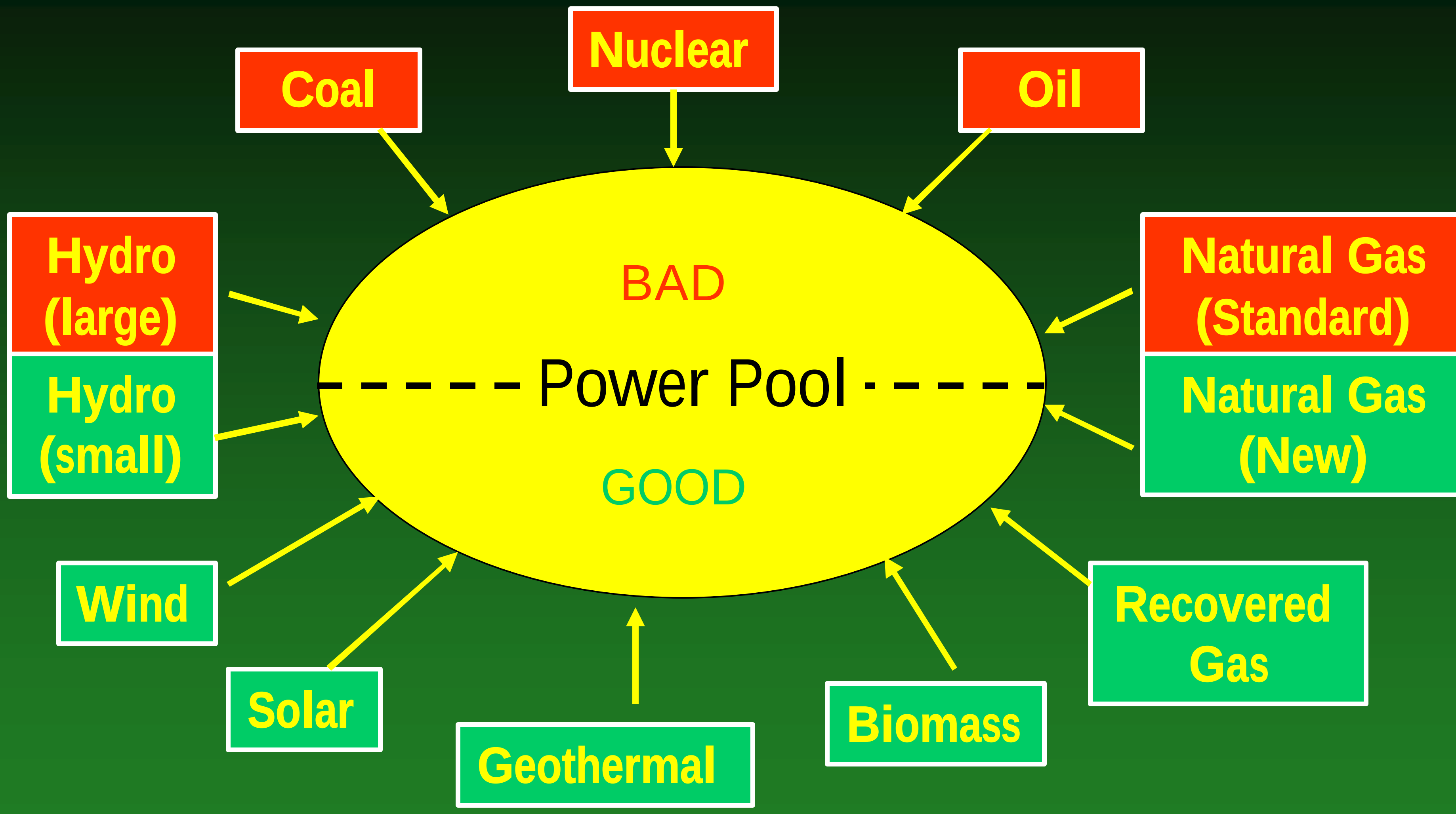
Presented April 28, 2004

IAIA'04 —Vancouver, British Columbia
"Impact Assessment for Industrial Development: Whose Business Is It?"

Traditional View of "Green" Power



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Assumptions Underlying Traditional View

Key Assumptions	True or False?
• Environmental impacts of all generation systems within a given technology sector are roughly the same.	Not always true
• Environmental impacts of "green" technologies is smaller than that of the traditional technologies.	Not always true

Taking a Scientific Approach

If the blanket acceptance of a selected group power technologies is not necessarily an accurate determinant of "greenness", what is?

Actual environmental performance based upon the overall impacts to human health and the environment:

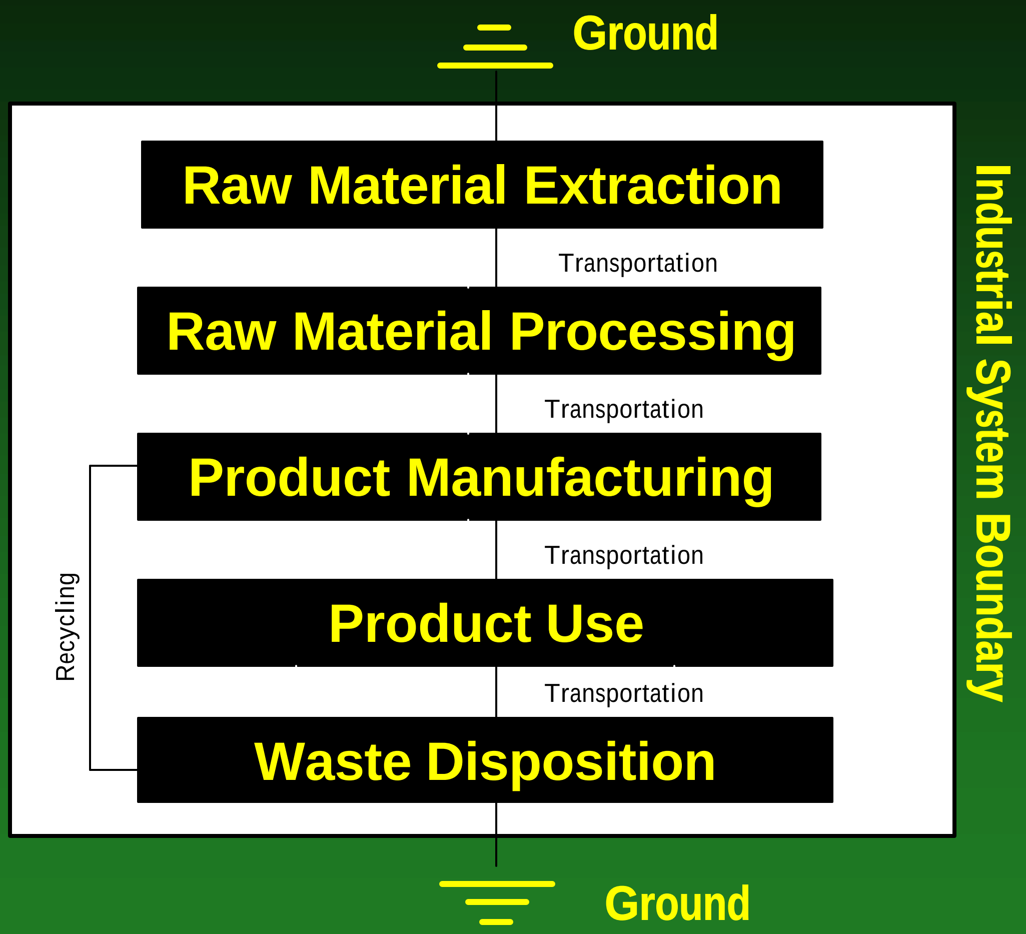
- **by technology**
- **by site**
- **by regional power grid**

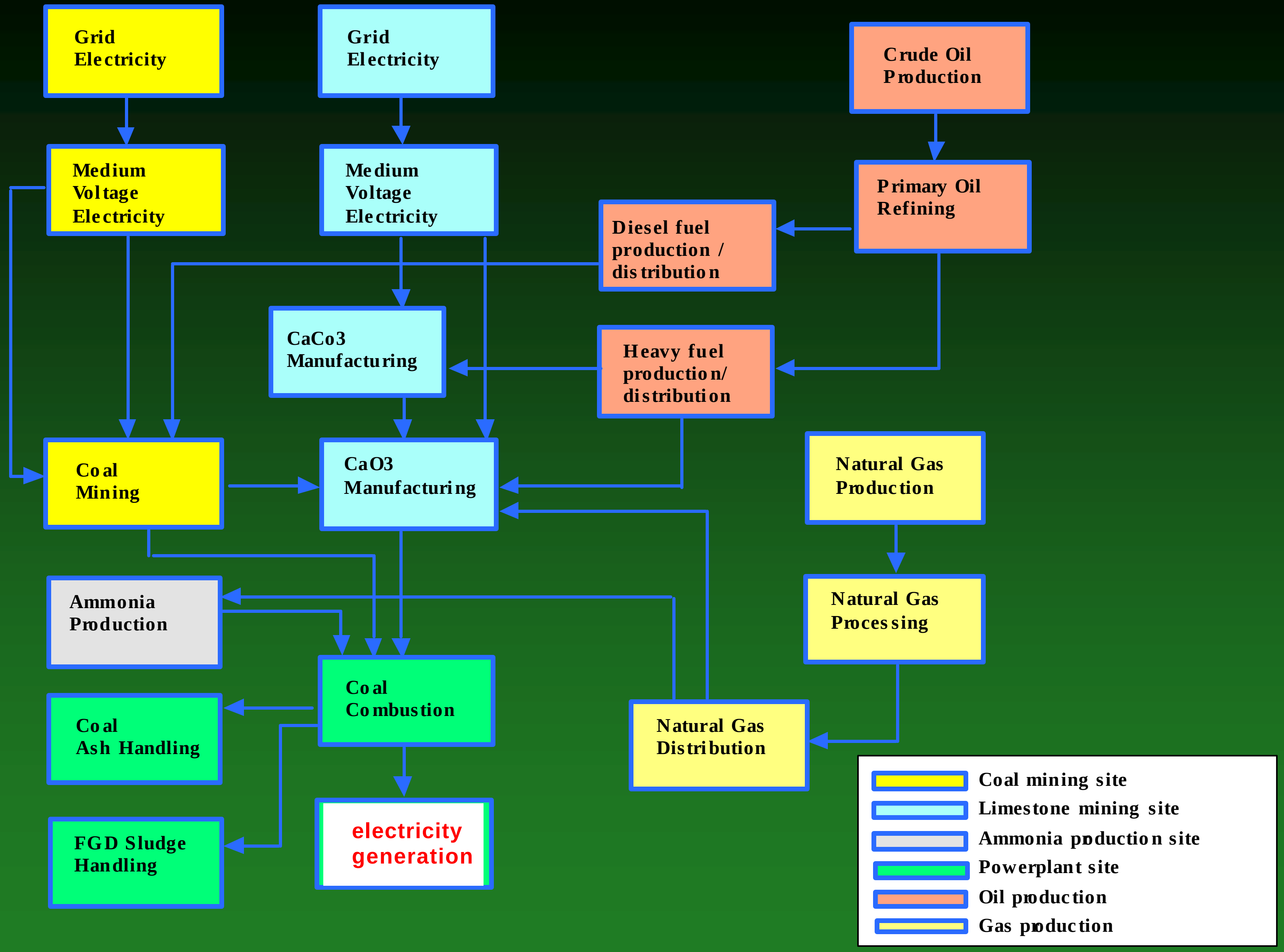
LCIA

Life-Cycle Impact Assessment

Comprehensive tool for assessing the levels of impacts in all areas of environmental and human health concern.

A "Cradle-to-Grave" Scope of Assessment





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The Three Mandatory Stages of Life Cycle Assessment

ISO 14040 — Goal Definition and Scoping

Establishes standards for scoping, boundary conditions, and peer review protocols.

ISO 14041 — Life Cycle Inventory Analysis

Collects data pertaining to all input and outputs within the scope of the study.

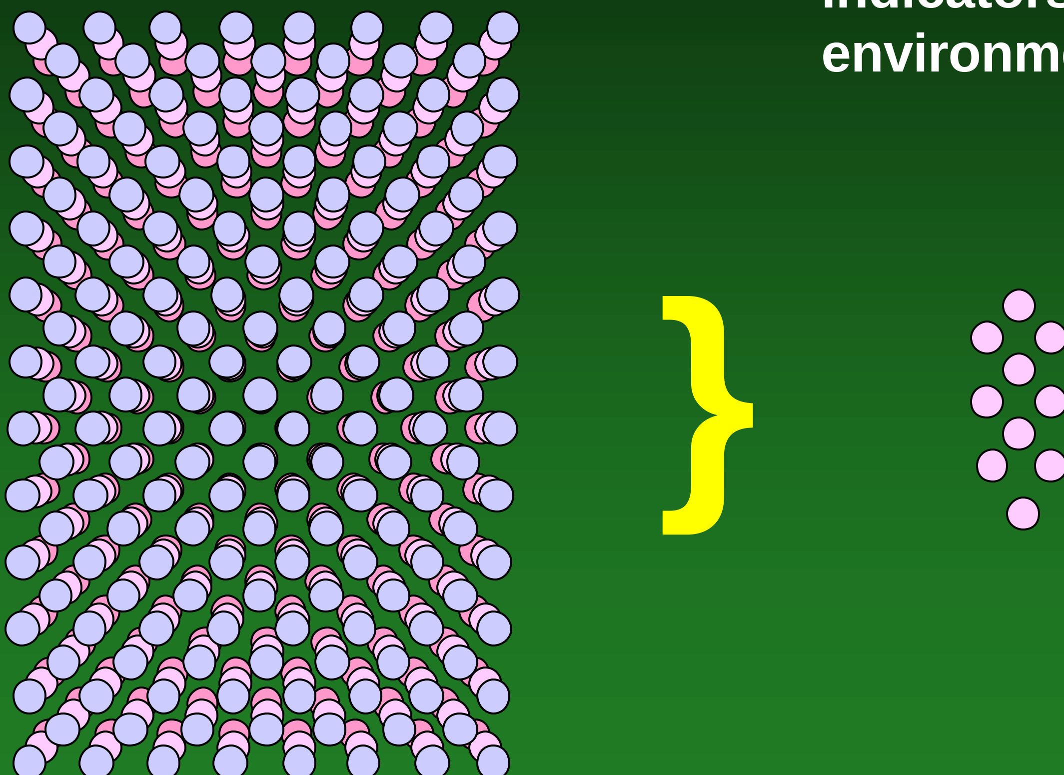
ISO 14042 — Life Cycle Impact Assessment

Establishes the groundrules for converting and aggregating LCI data into set of impact indicators.

Converting LCI Data into LCIA Impact Indicators

Life-Cycle Inventory
> 5000 data points

Life-Cycle Impact Assessment
converts LCI data into 12-20 “impact indicators” that address all relevant environmental issues



The Evolution of LCIA

- Initial LCIA models were limited to establishing gross potential impacts (e.g. acidification potential) and used only LCI data.

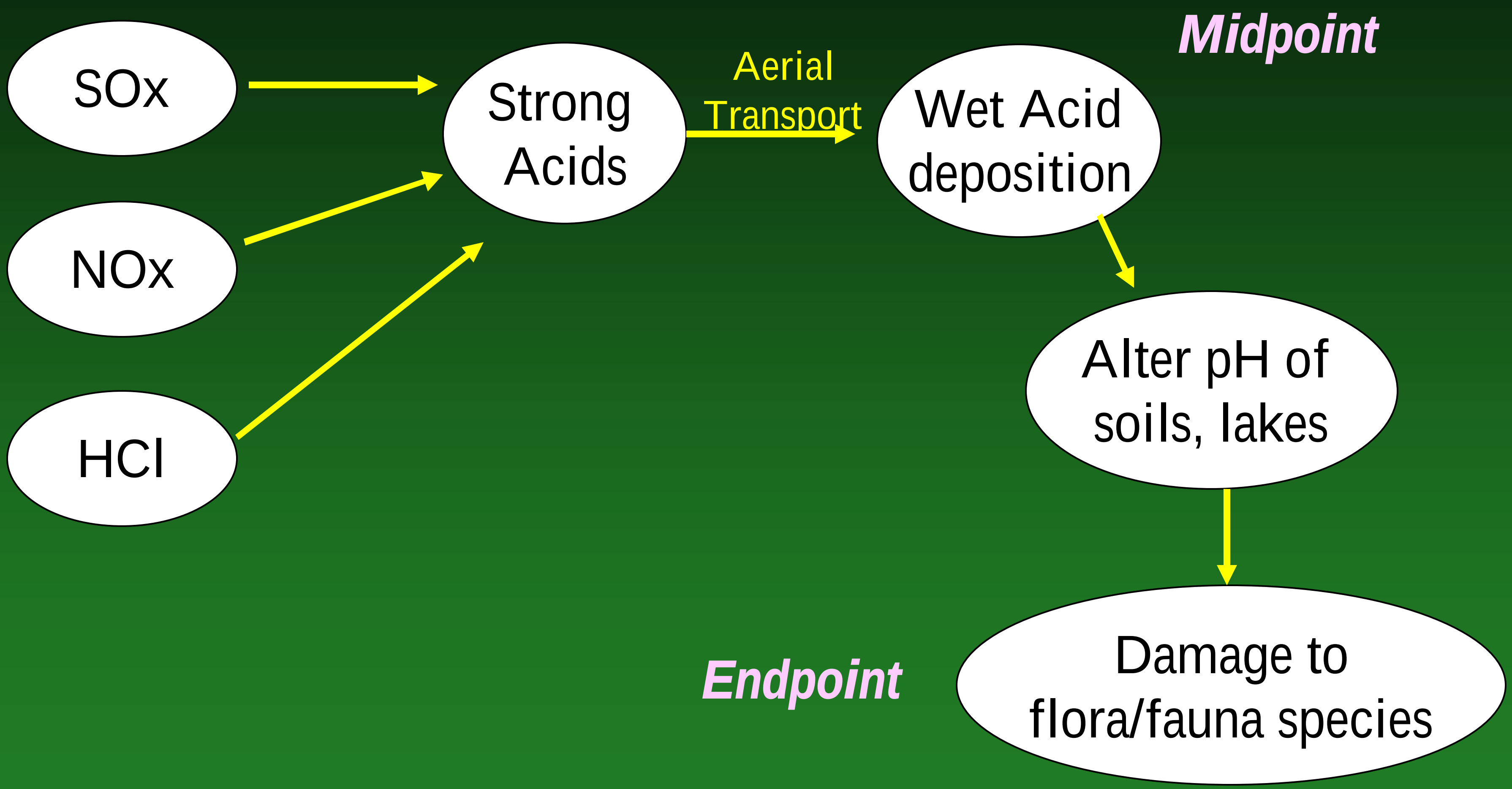
- Initial LCIA models did not address all impacts (e.g., leaving out impacts on habitats resulting from direct physical disruption).

- Newer LCIA Models are based upon modeling environmental mechanisms. As a result these models include:

  - Spatial and temporal characterization
  - Intensity and the potential for reversibility of relevant impacts
  - Formal inclusion of environmental data

Modeling an Environmental Mechanism

Acidification



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Types of Environmental Data Collected

- Air dispersion modeling data (integrated annual data)
- Mapping areas where exceedances of threshold occur
- GIS-based mapping of large area habitats (IR, visual, etc.)
- Reserves of energy resources

Impact Indicators for the Power Sector

1. Sustainability of Natural Resources	Net depletion of energy resources Net depletion of other resources
2. Direct Physical Disturbance	General Habitats Riparian Habitats Wetland Habitats Critical Habitats Increased mortality of key species
3. Emission Loadings	Greenhouse Gases Acidifying Gases Ground Level Ozone Particulates Stratospheric Ozone Depletion Neurotoxins Oncogens/Reproductive Toxins
4. Untreated Hazardous Waste Loadings	Radioactive wastes Other wastes

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1. Sustainability of Natural Resources	**Net depletion of energy resources** **Net depletion of other resources**
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4. Untreated Hazardous Waste Loadings	**Radioactive wastes** **Other wastes**

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Sustainability of Natural Resources

Takes into account:

- the size of the technically & economically available resource reserve base
- the rate of use of the resource
- the rate of natural replenishment (for renewables)

Calculating the Sustainability of Energy Resources

$$\text{Resource Depletion Factor (RDF)} = \frac{\text{(Use - Natural Replenishment)}}{\text{Proven Reserves}_{?T}}$$

?T = 50 years

By this formula: RDF < 1 represents a relatively slow rate of depletion
RDF > 1 represents a relatively fast rate of depletion

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The RDF of Energy Resources

Coal: **RDF = 0.13**

This resource reserve base is abundant, and technically and economically available, and therefore has the lowest (most sustainable) RDF value.

Uranium: **RDF = 0.2**

Proven reserves of uranium ore: 250 years

Theoretically, there is enough U_{235} in the ocean to provide 80,000 years of energy. However, it would require more energy to collect/process this energy than the total energy derived.

Oil: **RDF = 1.35**

Technically/economically available world oil reserves are estimated at approximately 40 years (subject to change pending new discoveries).

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Quantifying Impacts from Direct Physical Disturbance

Calculations are based upon the degree of impacts between pre-disturbance and post-disturbance periods.

Data requirements include:

- Pre and post-disturbance mapping, aerial photographs and GIS/Landsat, digitized vegetative types (GIS), and site assessment by appropriate experts.
- Assessment of quality changes to disturbed habitat.
- Utilization of existing databases (e.g., government, industry, non-profit).

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Habitat Issues Associated with the Electricity Generation, Transmission and Delivery System

Examples

- Water impoundment (hydro)
- Mining and transport (coal)
- Logging/tree-farming (biomass)
- Transmission ROWs (varies by power type and region)

Impacts to habitats are accounted for under four impact indicators:

General Habitat
Critical Habitat
Wetland Habitat
Riparian Habitat

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Data Requirements

Example: Hydro

- Boundary area for project
- Acres of impoundment
- Vegetation types in project area
- Habitat types in project area
- Linear distance of downstream effects from water regulation
- Width of riparian zone in downstream affected area
- Fish species
- Fish Habitat (type and area) by species
- Avifauna (species and habitats)
- Mammal (species and habitats)
- Invertebrates (terrestrial and aquatic)
- Listed and protected species and the associated habitats
- Transmission line ROWs (habitat types and distances)

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Calculating an Emission Loading

Example: Acidifying Gas Loading

1. Establish the areas of exceedance of threshold (characterization of the acidified regions in North America)

2. Normalize all acid releases to equivalent tons of sulfuric acid

3. Model the dispersion of strong acids (e.g., RAINS model).

4. Determine the percent of strong acids (in tons of SO_4) that deposit within the areas of exceedance of threshold from all significant point sources.

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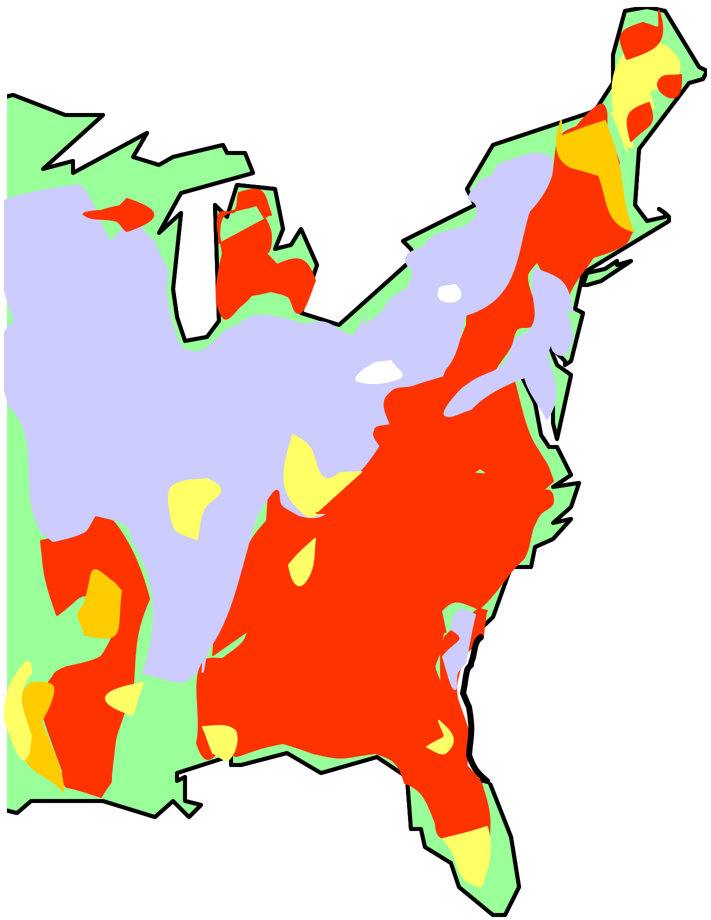
Calculating the Acidification Loading

2. Characterizing the areas of exceedance



Acid deposition (S+N) / critical load (meq)

- 0-10
- 10-15
- 15-21
- Over 20
- Agriculture
- Ice, water, no data

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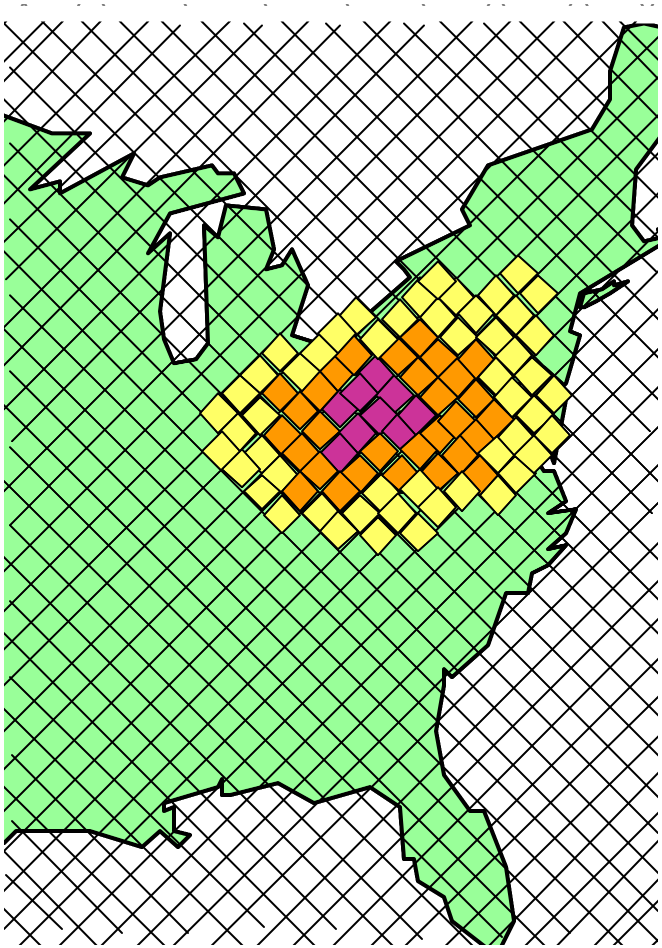
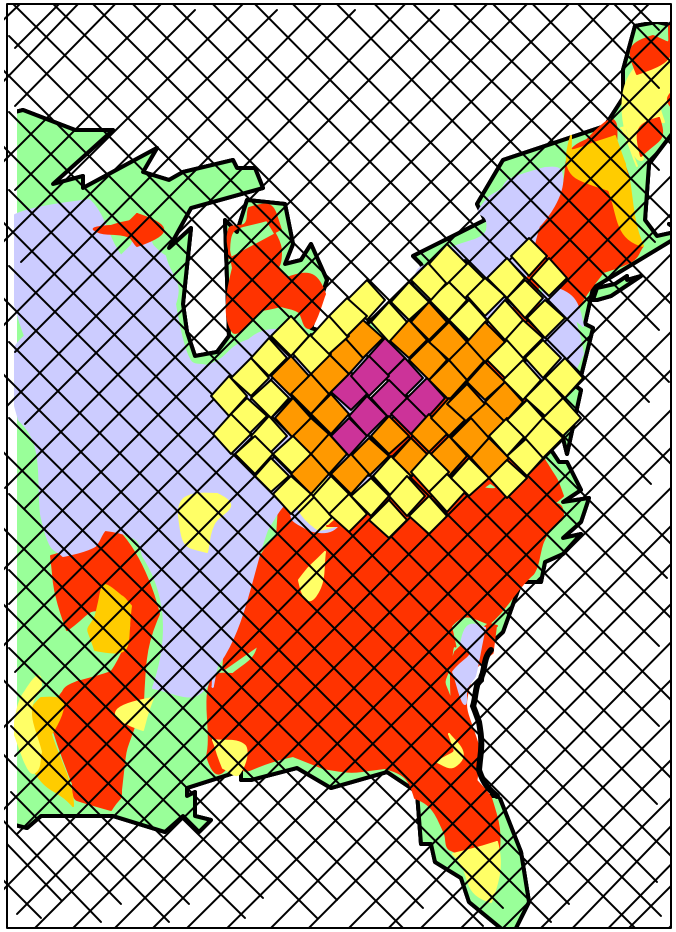
Calculating the Acidification Loading

3. modeling dispersion of strong acids



Calculating the Acidification Loading

4. Data Integration: Calculating the percentage of strong acids deposited in areas of exceedance



Unit Oper.	Inventory Emission	LCI Value (ton/30a)	Relative Potency	LCSEA LCIA Result (ton/30a)	Environ. Charact. Fact.	Emission Loading (ton/30a)
Coal mining / transport	SOx	31620	1.00	31620	0.5	15810
	NOx	9660	0.70	6762	0.3	2029
	HCl	270	0.88	238	0.5	119
CaO product/ transport	SOx	240	1.00	240	0.15	36
	NOx	1260	0.70	882	0.075	66
Coal use	SOx	50190	1.00	50190	0.15	7529
	NOx	36480	0.70	25536	0.075	1915
	HCl	15210	0.88	13385	0.15	2008
				128,853 t		29,512 t

Case Studies in the US and Canada

Case Studies

Safe Harbor Water Power Co.	Hydro
Exelon	Wind, Hydro, Coal, Nuclear
PSE&G	Natural Gas
PG&E	Hydro
Chelan Co. PUD	Hydro
Canadian Electricity Assn. /NRCan	
-Manitoba Power	Hydro
-Saskatchewan Power	Wind
-Nova Scotia Power	Oil to Gas Conversion
-Ontario Power	Nuclear
-EPCOR	Coal
Western Area Power Admin.	Wind, Hydro, Coal, Nuclear, Gas Renewable Portfolio Establish WECC Baseline

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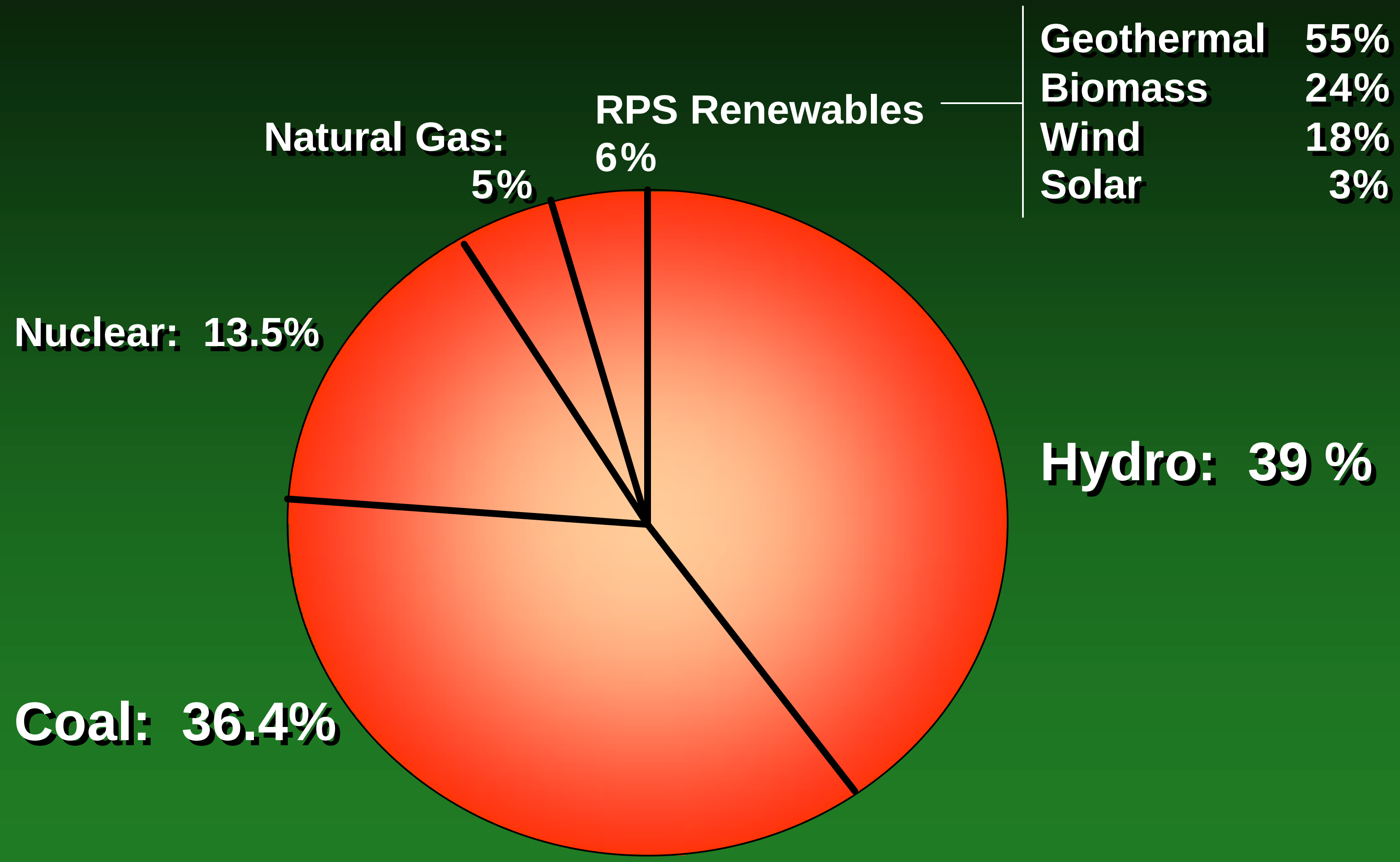
Establish a Regional Power Pool Baseline

The Production Mix Constituting the WECC



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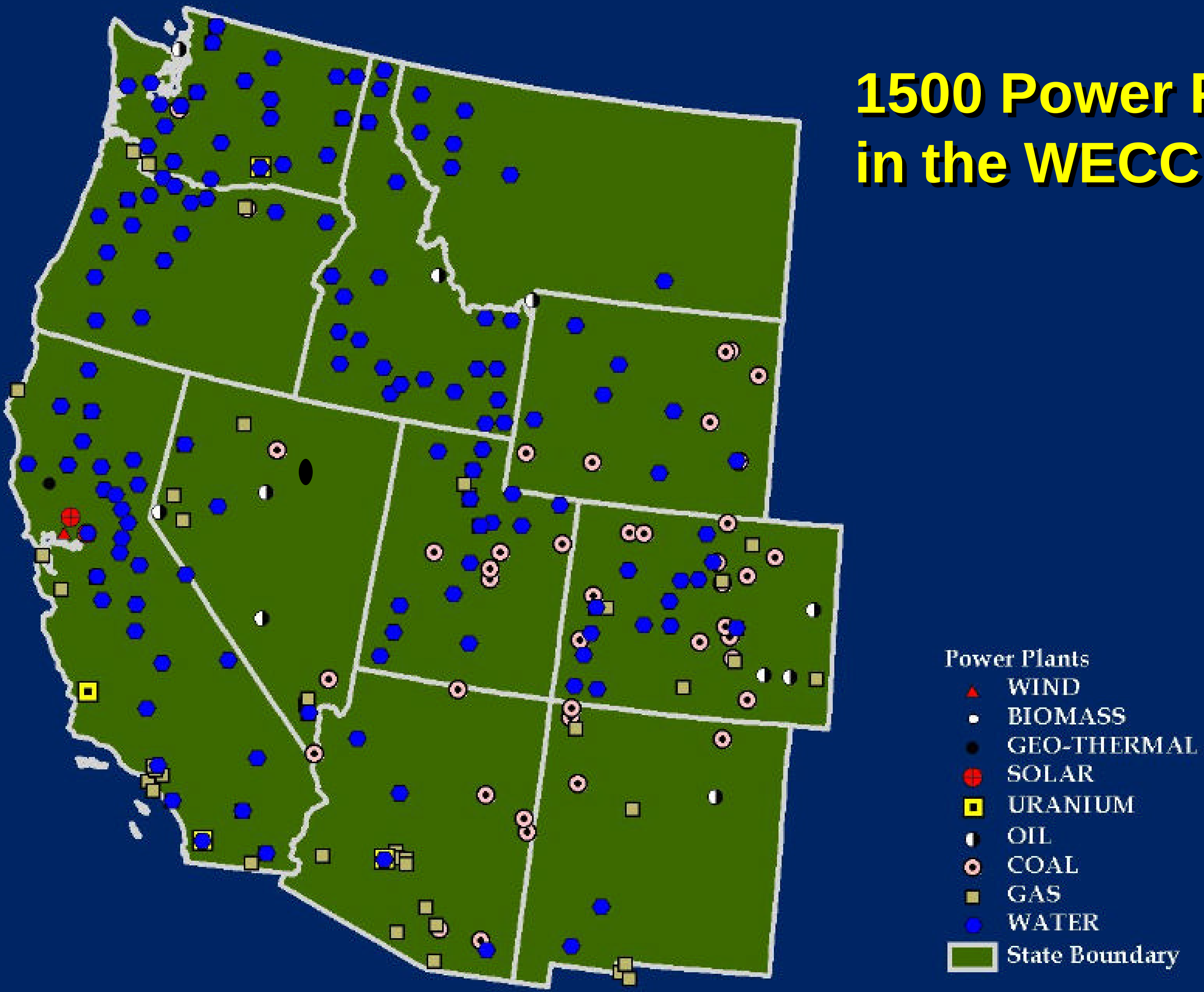
1500 Power Plants in the WECC



WECC Baseline

Environmental Impact Profile

Sustainability of Energy Resources	Amt. per 1000 GWh
Net Resource Depletion..........................	85,700 toe
Ecosystem Disruption	
Terrestrial/Aquatic Habitat......................	11,480 acres
Key Species (by species)........................	TBD
Emission and Waste Loadings	
Greenhouse Gas....................................	527,000 ton CO2 eq.
Acidifying Gases	1 ton SOx eq.
Ground level Ozone	34 tons O3 eq.
Particulates	24 tons
Stratospheric Ozone Depl......................	0.04 tons CFC-11 eq.
Hazardous Air Pollutants	0.0013 tons Hg eq.
Nuclear Wastes	97,000 IBHP U ore eq.

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Renewable Energy Generation in the WECC

Type	MWe Capacity	Capacity Factor	Delivered MWe Capacity	% of RPS Baseline	GWh
Geothermal	2,000	99%	1,980	55%	17,345
Biomass	1,002	85%	852	24%	7,464
Wind	2,215	30%	665	18%	5,825
Solar	350	30%	105	3%	920
			3,602	100%	31,554

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Sustainability of Geothermal Resources

California Geothermal

Facility	MWe Output*	# Units	Type
The Geysers	1,137	23	Dry steam plants
Coso	260	9	Flash plants
Salton Sea	267	10	Flash plants
East Mesa	105	71	Binary plants
Heber	80	14	Flash and Binary
Mammoth Lakes	43	4	Binary plants
Amadee Hot Springs	2	2	Binary plants
Susanville	1	2	Binary plants

** Actual for The Geysers only, Rated output for all others*

Sustainability of Geothermal Resources

Mammoth Lakes

- Finger reservoir
- Cold groundwater seeping into reservoir
- Estimated remaining lifetime: 15 years

Heber

- Geologically collapsing — once porous rock has become compacted
- As such, cannot maintain current capacity of 80 MW
- Estimated remaining lifetime: 15 years

East Mesa

- The 35 MW flash plant is not producing at all, and the 70 MW binary plant is only producing 47 MWe
- Reservoir is cooling rapidly.
- Estimated remaining lifetime: 15-20 years

(sources NREL, DOE, DOE consultants)

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Sustainability of Geothermal Resources

The Geysers: Largest geothermal producer in US

- Efficient dry steam system
- Power output has dropped 40%, from 1,875 MW (1990) to 1,137 (2001)
- Wet cooling towers lose 30% of the water through steam evaporation. 50% of the water has been depleted to date, and 5% of the thermal heat.
- Recent efforts to reinject gray water from nearby community have the capacity to replace enough water to build back about 50 MW
- Dry cooling towers are cost prohibitive.
- These fields are projected to continue to decline over the next 20 years due to limitations in availability of water resources.

(sources NREL, DOE, DOE consultants)

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Sustainability of Geothermal Resources

Plans to raise production from 2002 MW to 3500 MW over the next 10 years with a proven reserve base of 30-35 years. Recharging of reservoirs will take hundreds to thousands of years (NREL).

Assuming production is raised to 3000 MW, and a 40-year lifetime:
RDF = 1.25

Looking at the *actual sustainability* of energy resources, rather than the *theoretical renewability*:

- **Geothermal as an energy resource is no more sustainable than oil**
- **Coal as an energy resource is 10 times more sustainable than geothermal**

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Habitat Disruption By Energy Type in the WECC

Based on Preliminary Data Review

Energy Type	Average Estimated Acres Disturbed per 1,000 GWh
Coal	5,460
Nuclear	90
Natural Gas	570
Oil	200
Hydro	13,740
Wind	710
Geothermal	200
Biomass	138,000
Solar	7,880

→ **Mining, coal transport, and transmission ROWs** (Coal)

→ **WECC is worst-case: large impoundments, not run-of-river, evaporation.** (Hydro)

→ **Land use required for production of fuel.** (Biomass)

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Renewable Portfolio in the WECC

Environmental Impact Profile

Sustainability of Energy Resources	Amt. per 1000 GWh
Net Resource Depletion..........................	161,000 toe
Ecosystem Disruption	
Terrestrial/Aquatic Habitat.......................	57,900 acres
Key Species (by species)........................	TBD
Emission and Waste Loadings	
Greenhouse Gas....................................	600,000 ton CO_2 eq.
Acidifying Gases	2.5 ton SO_x eq.
Ground level Ozone	160 tons O_3 eq.
Particulates	42 tons
Stratospheric Ozone Depl......................	negligible
Hazardous Air Pollutants	TBD
Nuclear Wastes	negligible

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Comparing the Environmental Performance of Renewable Energy To the WECC Baseline

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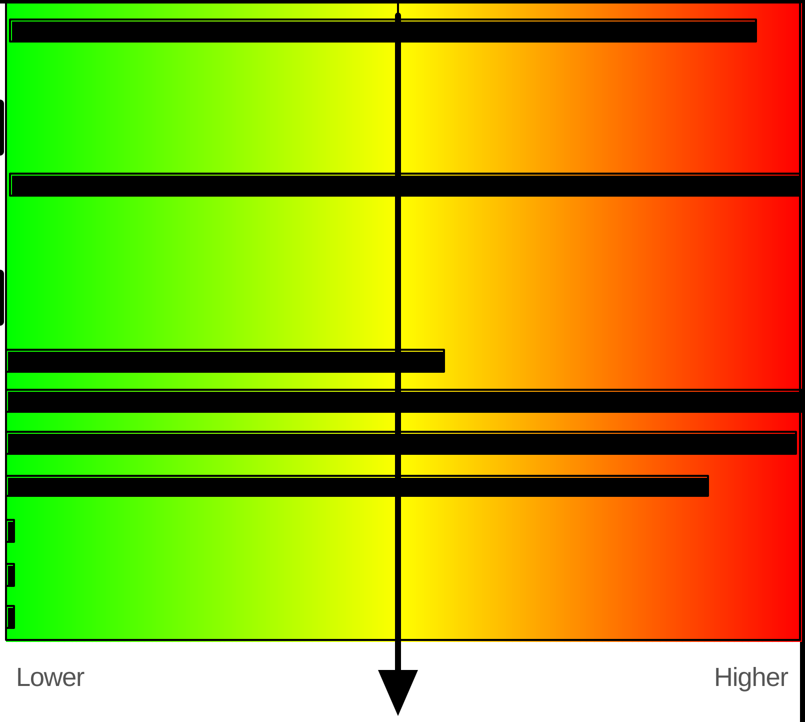
WSCC Non-Hydro Renewable Portfolio Environmental Performance Rating

Preliminary

Sustainability of Energy Resources	Amt. *
Net Depletion - energy resources (equiv. tons of oil)	161,000
Net Depletion - water resources (acre-ft.)	--
Ecosystem Disruption	
Terrestrial and Aquatic Habitats (equiv. acres)	57,900
Key Species (% increased mortality)	TBD
Emission Loadings and Wastes	
Greenhouse Gases (equiv. tons CO_2)	600,000
Acidifying Chemicals (equiv. tons SO_2)	2.5
Ground Level Ozone (equiv. tons O_3)	160
Particulates (equiv. tons PM-10)	42
Stratospheric Ozone Depletion (equiv. tons CFC-113)	negl.
Hazardous Air Pollutants (equiv. tons Hg)	TBD
Nuclear Waste (REM Yr.)	negl.

Scale of Impacts



equiv. = equivalent
-- is used to denote negligible results

* Per 1,000 GWh

WSCC Average Impacts (2001)

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Additional Comparisons under Study

- Coal (Lower Impact) vs. Standard Coal Operations
- Coal Operations (Lower Impact) vs. Natural Gas
- Large Hydro vs. Small Hydro
- Certified Low Impact Hydro* vs. Std. Hydro
- Wind vs Hydro
- CANDU nuclear (heavy water) vs. Light Water Reactor

* Certified by the Low Impact Hydro Institute

ASTM Standardization

- New Work Item approved 2/21/04
- Performance-based standard as opposed to technology-based
- Requires the use of an LCIA-type model

END