California Energy Commission
Joint IEPR and Renewables Committee Workshop on Biopower in California

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Workshop Presentation

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Cofiring of Coal Fired Power Plants with Biomass

Introduction

- Co-firing has been introduced for years but so far few incentives have been put in place for co-firing of biomass on a large scale

- New drivers make co-firing an attractive option to consider:
  - Renewable Portfolio Standards
  - Greenhouse Gas trading
  - Fuel Switching
  - Life-extension / repowering options
  - Cheaper (opportunity) fuels
  - RECs
  - Job creation

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Cofiring of Coal Fired Power Plants with Biomass

WECC Coal-fired Capacity by Coal Type (Including California)

*Anthracite Culm, Bituminous Gob, Fine Coal, Lignite Waste, Waste Coal

**Coal-based solid fuel that has been processed by a coal synfuel plant, and coal-based fuels such as briquettes, pellets, or extrusions, which are formed from fresh or recycled coal and binding materials

Source: EIA, "Existing Generating Units in the United States by State, Company and Plant, 2007," January 2009. http://www.eia.doe.gov/cneaf/electricity/epa/epat2p2.html

Assumptions

This analysis only included coal-fired plants located in the United States. Those located in Canada and Mexico were excluded, although these facilities are eligible to meet California's RPS requirements, provided they deliver electricity into California. We also assumed that the entire states of Montana and New Mexico are in WECC, though small portions of these states fall outside WECC; likewise, South Dakota and Texas were fully excluded, though small portions of these states are located within WECC.

We excluded three facilities that are already engaging in co-firing by utilizing wood/wood waste as secondary fuels.

Cofiring Market Potential

The research team analyzed the potential in GW using biomass as a fuel:

KEMA made two estimates of co-firing potential at coal-fired plants in the Western Electric Coordinating Council (WECC) region:

Low-cost co-firing – 1.5% of coal generation

High-cost co-firing – 10% of coal generation (this percentage can be increased to typically 30%)

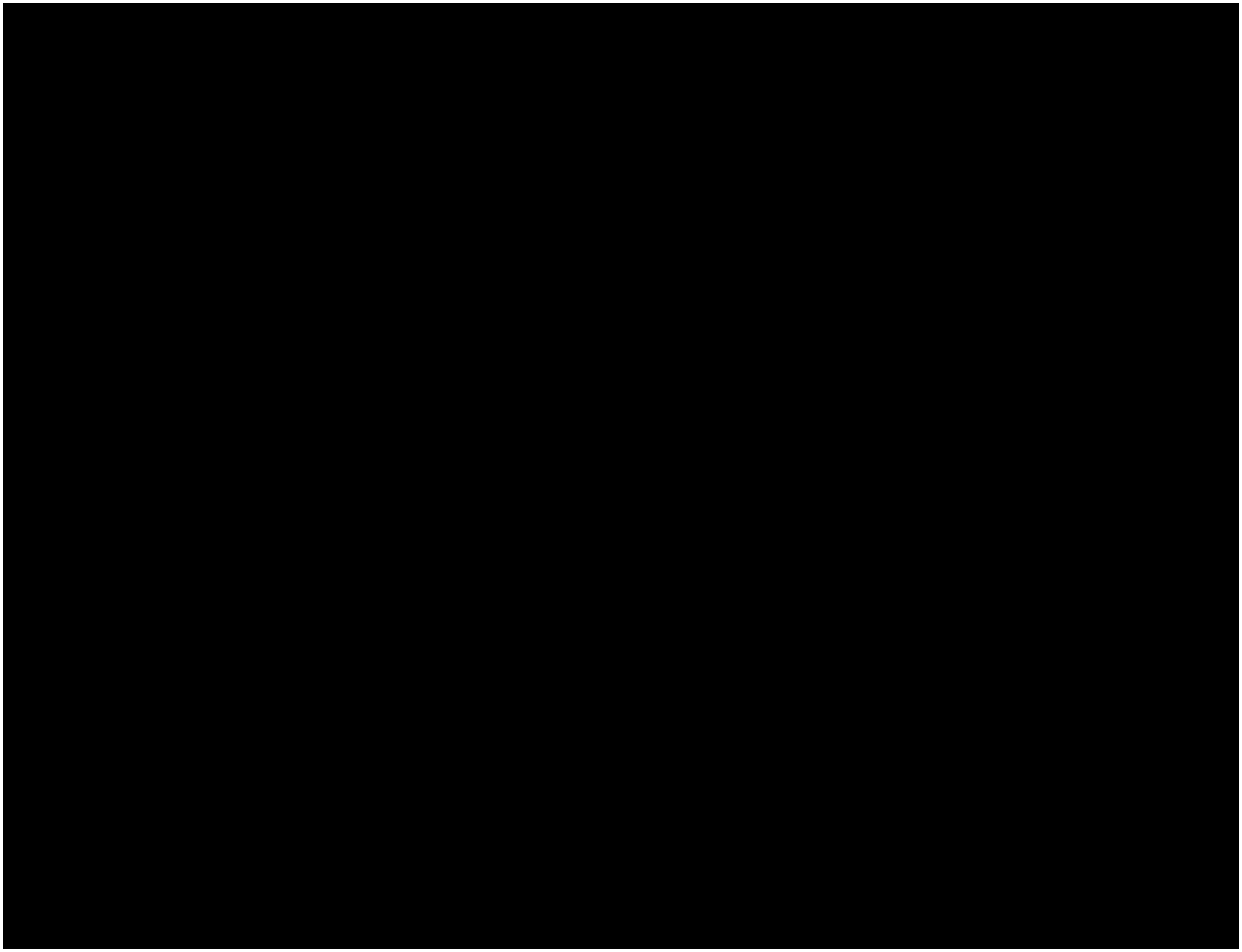
Low-cost co-firing applications are those in which plant operators simply mix biomass feedstocks with coal without modifying the boilers at the facility. The capital costs are simply those required to receive and handle the biomass fuel.

High-cost co-firing applications can require significant modifications and capital upgrades to boiler systems due to upgrades in fuel handling equipment and burners. These allow a far greater level of co-firing.

We have applied the same two coefficients (1.5 percent and 10 percent) to all facilities. If we had data on the specific types of boilers employed at each facility, we could conduct a more in-depth analysis with more specific co-firing coefficients for each boiler type.

[redacted]

WECC Coal Based Generation Capacity (33GW / 225,574GWh)
(Source: EIA)



CA Coal Based Generation Capacity (440MW, 2,895 GWh)

About 9,000 GWh of additional biomass/biogas needed to meet 20 percent of California's 33 percent by 2020 RPS goal

Plant Name	Nameplate Capacity (MW)	Summer Capacity (MW)	Net Generation (Annual GWh)	Capacity Factor	Co-firing (low)	Co-firing (high)	Co-firing (high)
					2%	**10%**	**30%**
ACE Cogeneration Facility	108	101	729	77%	15	73	219
Stockton Cogen	60	54	434	83%	9	43	130
Port of Stockton District Energy Fac	54	44	268	57%	5	27	80
Mt Poso Cogeneration	62	52	417	77%	8	42	125
Rio Bravo Poso	38	33	291	87%	6	29	87
Argus Cogen Plant (Unit 1, bituminous)	28	25	173	72%	3	17	52
Argus Cogen Plant (Unit 2, synfuel)	28	25	173	72%	3	17	52
TXI Riverside Cement Power House (Unit 1)	12	11	70	66%	1	7	21
TXI Riverside Cement Power House (Unit 2)	12	11	70	66%	1	7	21
Rio Bravo Jasmin	38	33	272	81%	5	27	82
Total:	**439**	**389**	**2,895**	**75%**	**58**	**290**	**869**

Sources: US DOE, Energy Information Administration, Form EIA-860. "Annual Electric Generator Report."
(Existing generating units as of December 31, 2007)

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Cofiring of Coal Fired Power Plants with Biomass

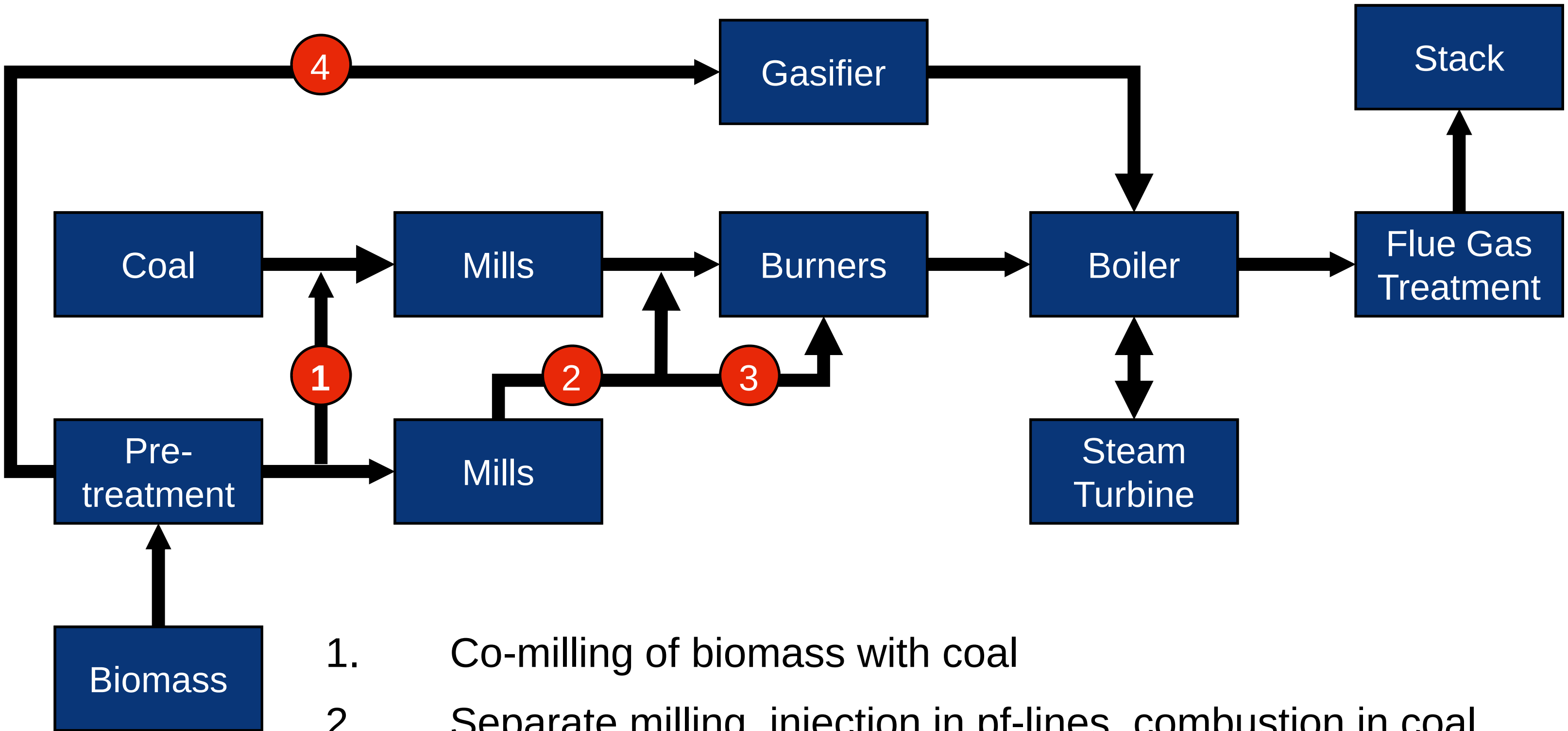
Technology Aspects

- Co-firing up to 30% is technically feasible without significant modification, with following considerations:
  - Enough biomass available
  - Suitable area for feedstock storage
  - Suitable area for pre-processing unit
  - No unit derating
  - No undue degradation of combustion properties

- Based on our modeling the most dominant economic parameters are:
  - The biomass price and current coal price
  - The specific investment costs and
  - The CO_2 price

- Examples of break even biomass prices seen from 1.7 to 2.1 US$/MMBtu without consideration of RPS and Carbon allowance costs

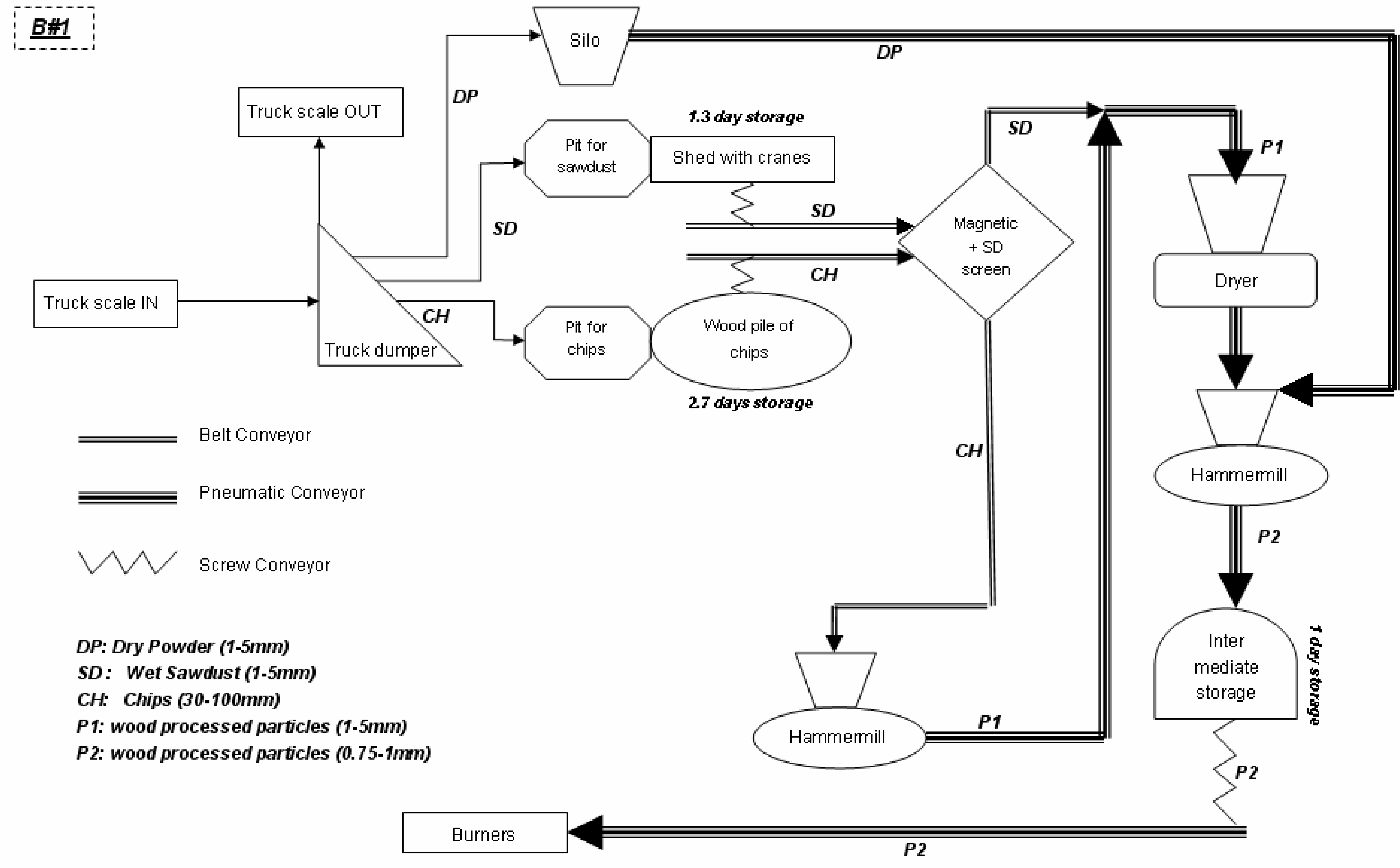
There are four Biomass injection point possibilities



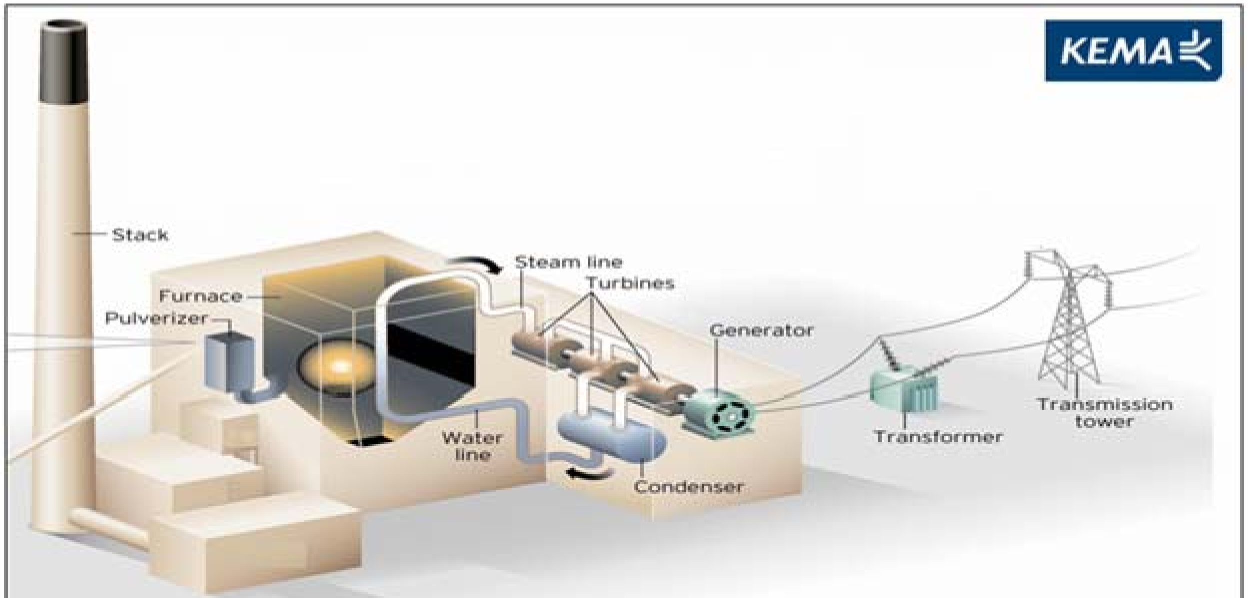
1. Co-milling of biomass with coal
2. Separate milling, injection in pf-lines, combustion in coal burners
3. Separate milling, combustion in dedicated biomass burners
4. Biomass gasification, syngas combusted in furnace boiler

Each co-firing route has its own (unique) operational requirements and constraints and specific demands on fuel quality

Process flow scheme



Other Efficiency and Emissions improvements to consider



Technology Areas to "Clean" Fossil Power Generation

Fuel	Combustion	Gas Emissions	Solid Waste
• Fuel Pre-treatment • Pulverization / Fluidized Beds • Biomass / Co firing • Compression / Pellets • Fuel-mix/Conversion • Fuel conditioning	• Advance Combustion • Dry Low NOx burners • Thermal optimization • IGCC	• Electrostatic precipitators (ESP) • Selective Catalytic Reduction (SCR) • Flue gas Desulphurization (FGDS)	• Fly ash reprocessing • Bottom ash reprocessing • Recycle fly ash – cement, road surfacing
• CO_2 Pre-combustion Gasification or partial Oxydation	• Post Combustion – CO_2 separation • CO_2 Separation	• Oxyfuel- O_2/CO_2 recycle • CO_2 Dehydration & Compression	• CO_2 Storage **Sequestration Under Development**

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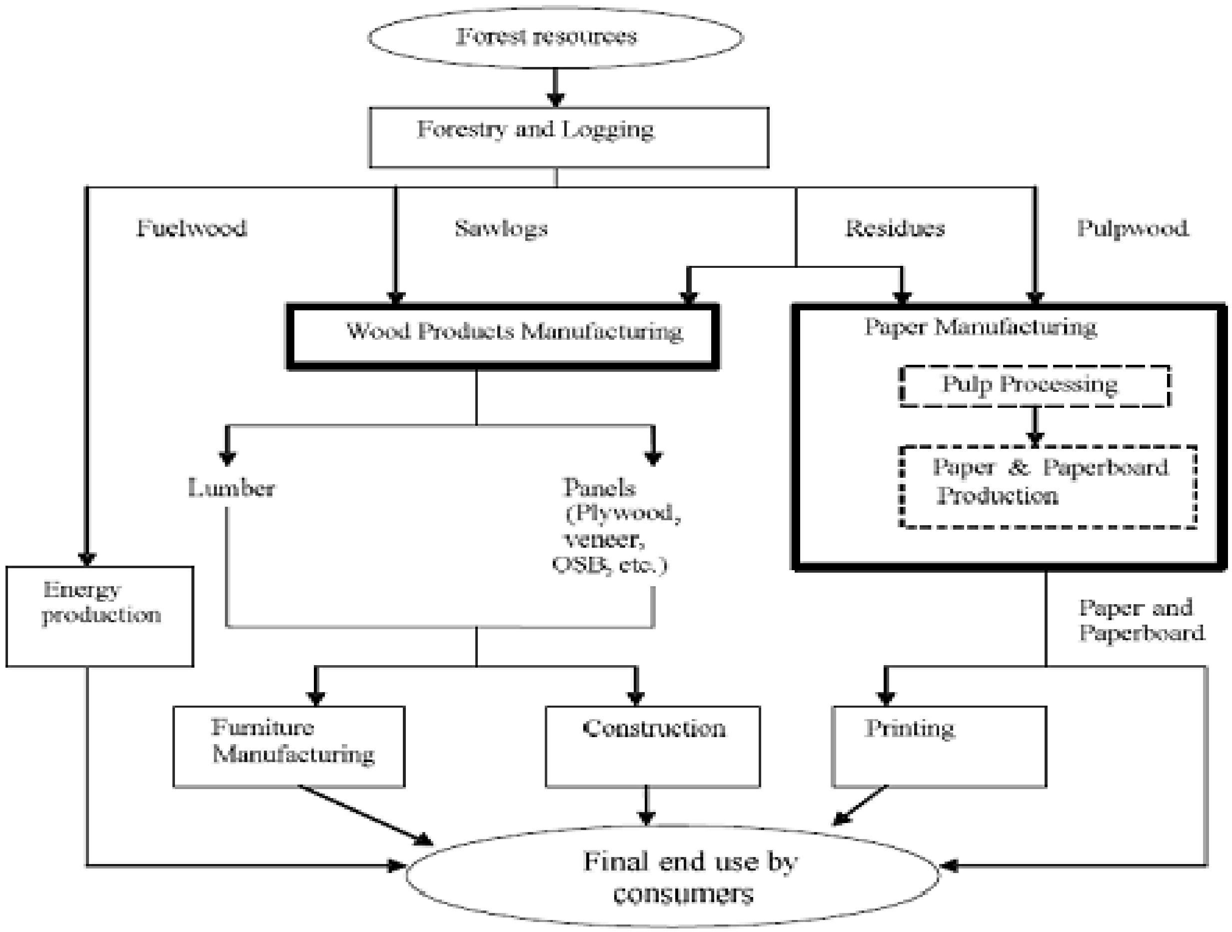
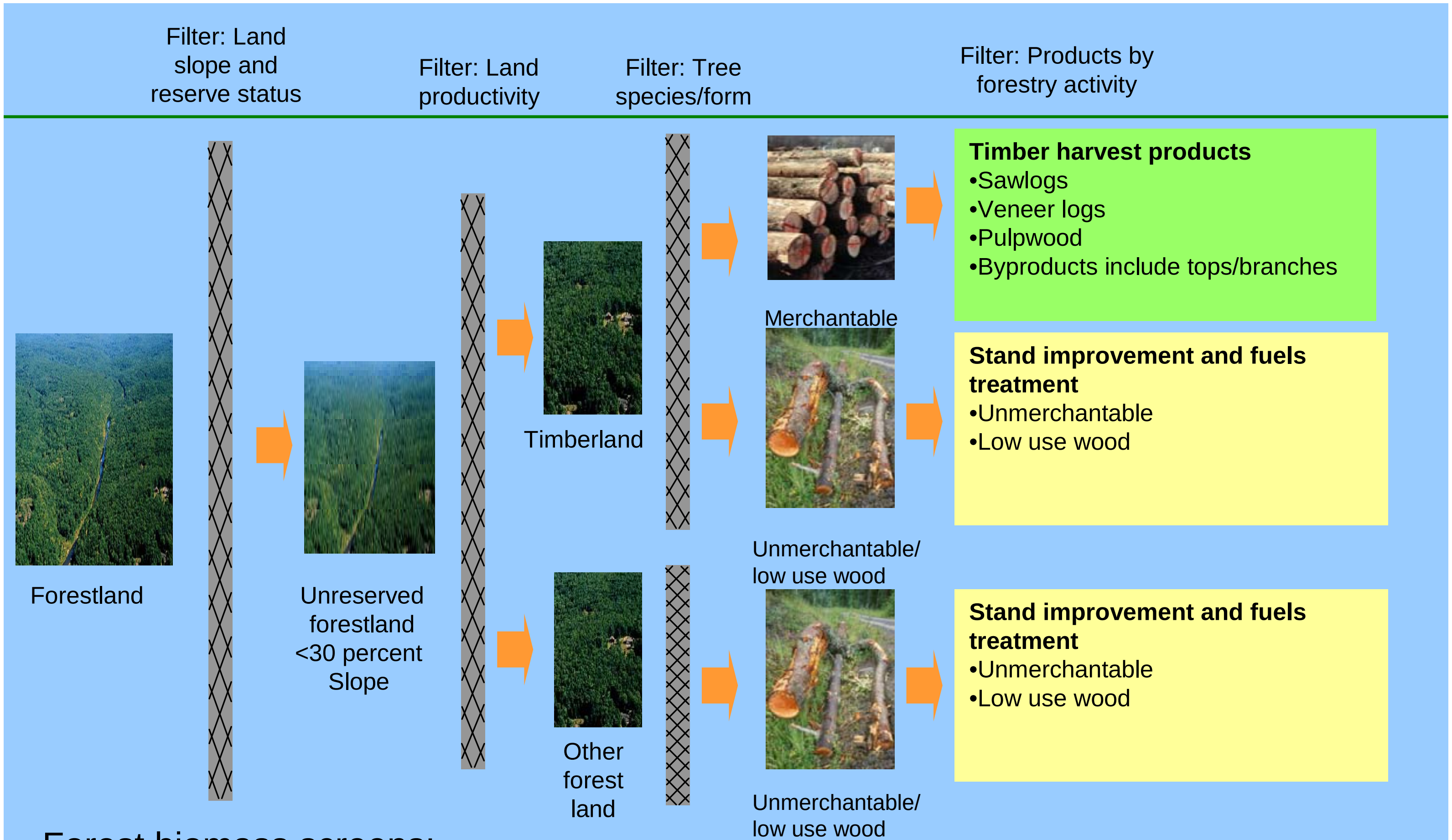
Cofiring of Coal Fired Power Plants with Biomass

Sources and uses of wood

From Forests to Final Products



Forest Resource Data Screening Process

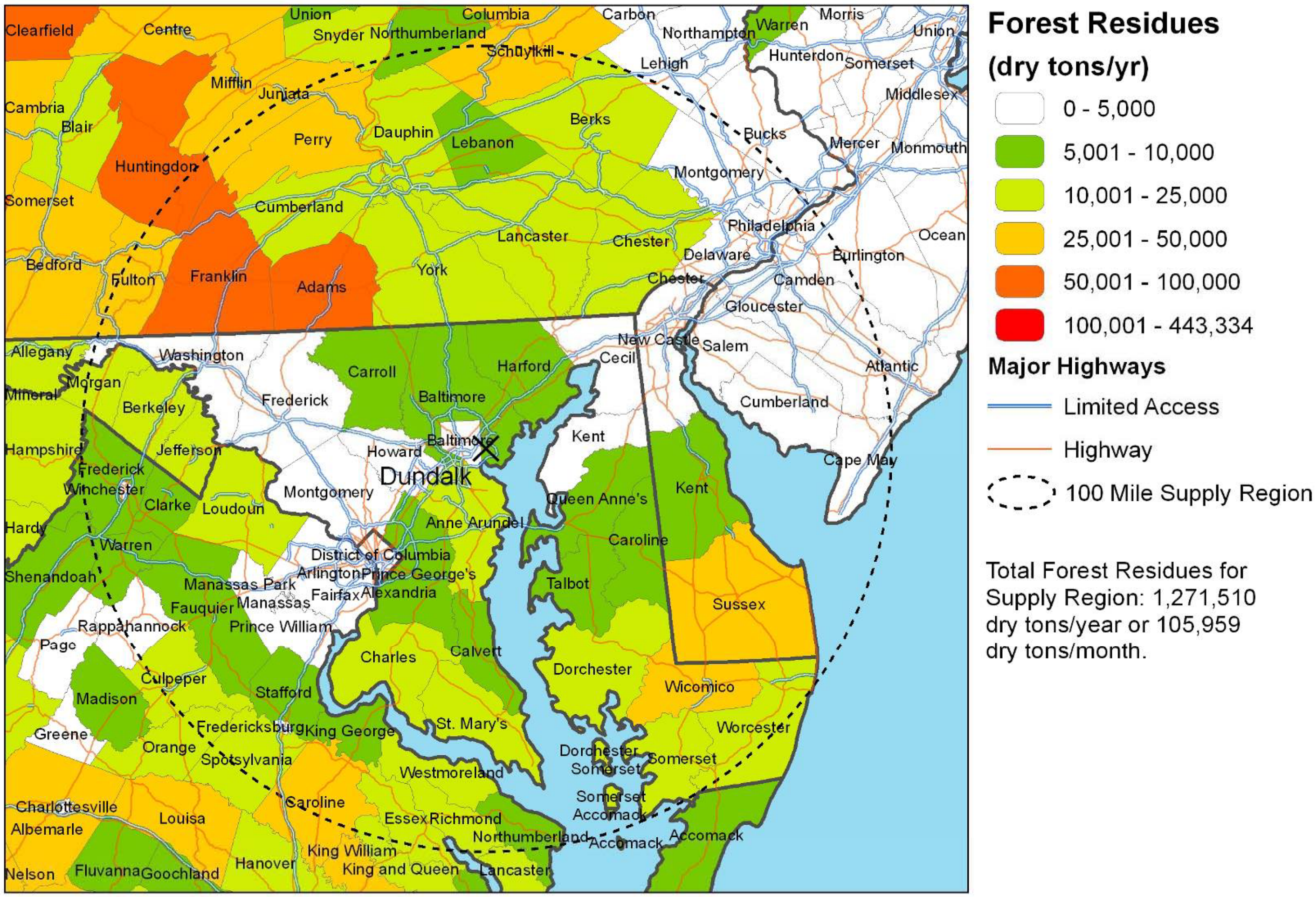


Forest biomass screens:

1. Unreserved land excludes protected land such as parks and monuments.
2. Land productivity and forest density are the key determinants of classification as timberland.
3. Unmerchantable trees include Un-commercial species or trees with poor form or defects.

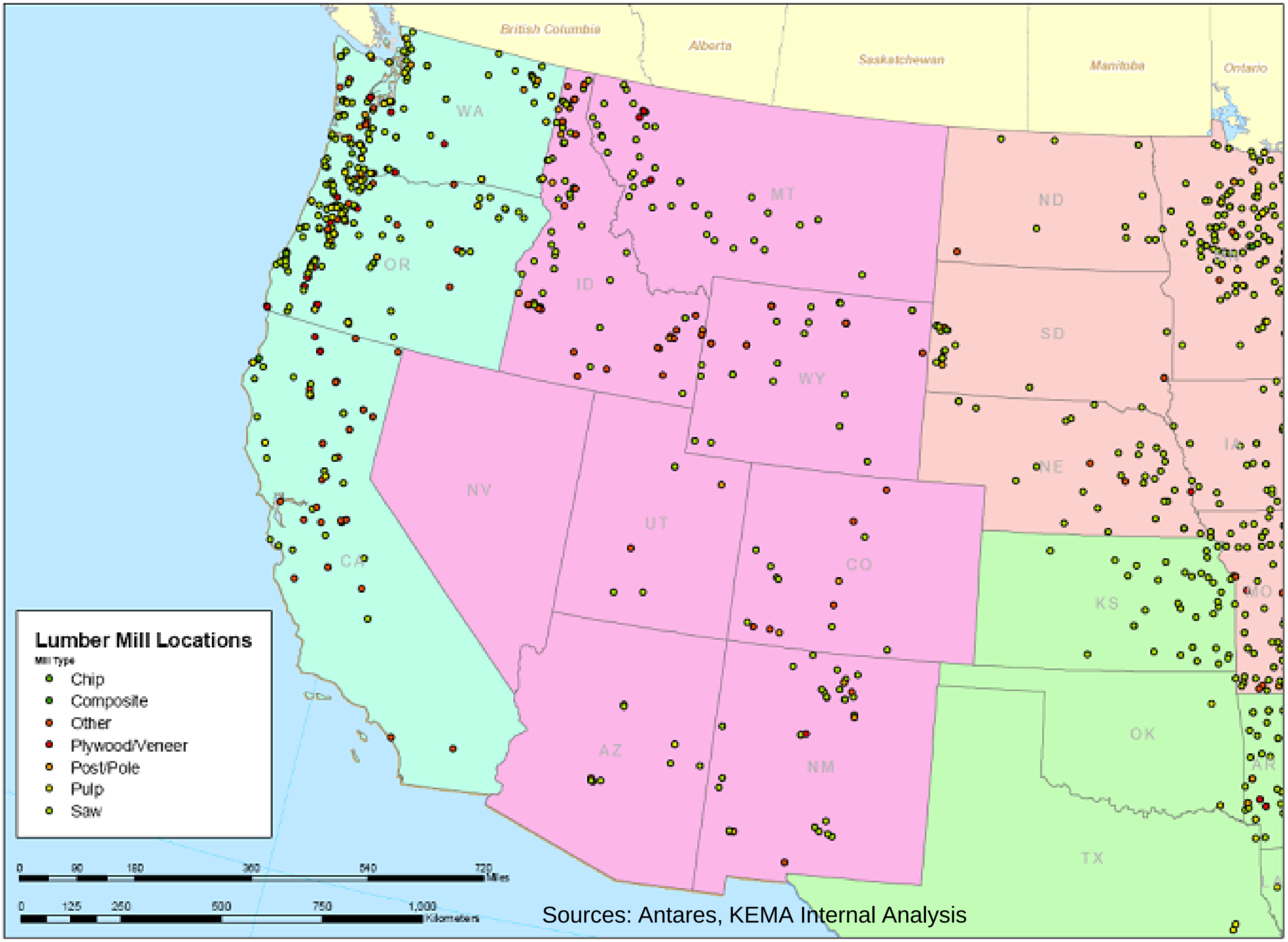
Sample GIS-Based Resource Intensity Map

Resource Intensity Maps can be used to site biomass torrefaction facilities, based on convergence of available biomass resources.



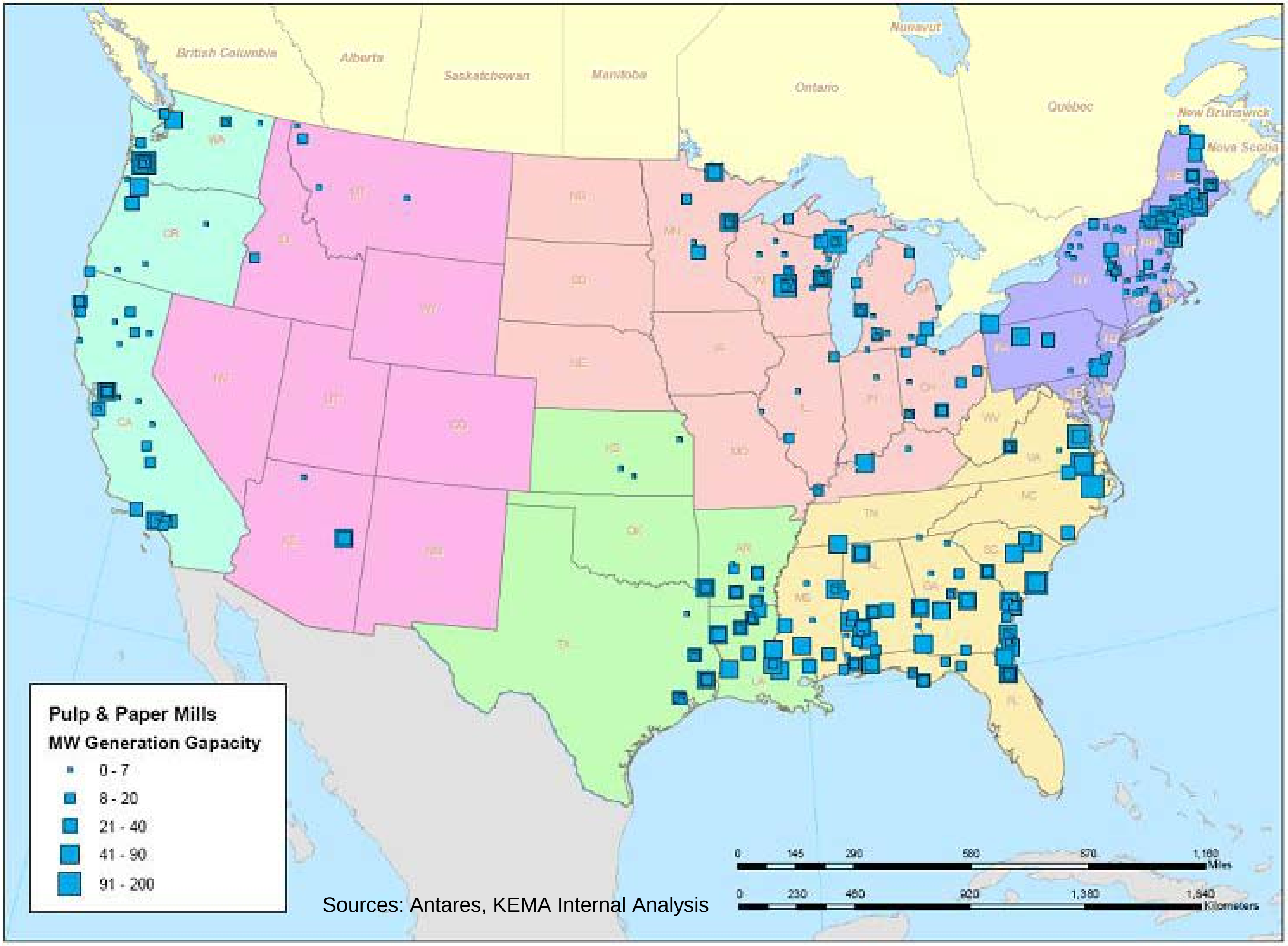
Total Forest Residues for Supply Region: 1,271,510 dry tons/year or 105,959 dry tons/month.

Lumber Mill Locations

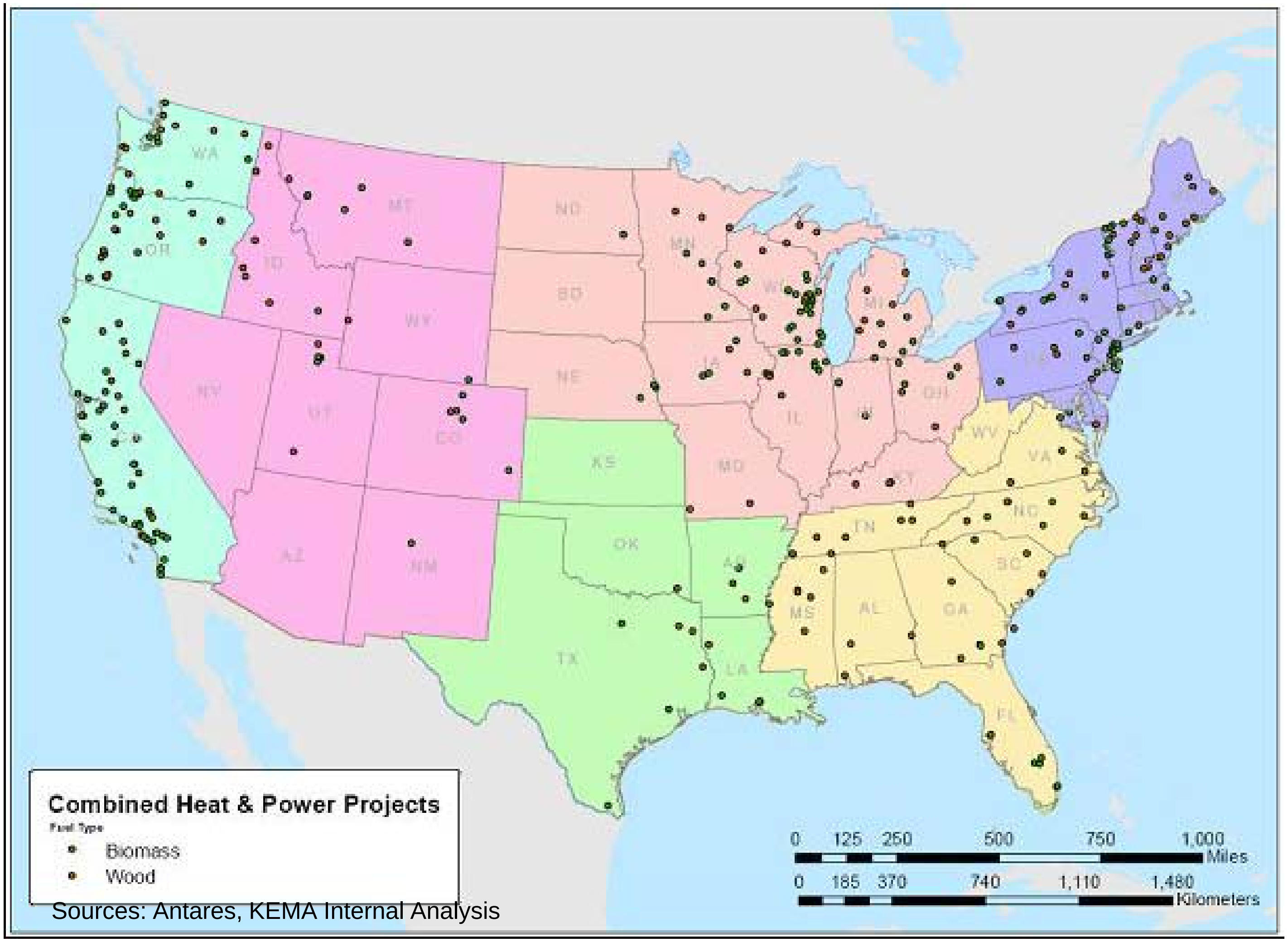


Sources: Antares, KEMA Internal Analysis

Pulp & Paper Mill Generating Capacity



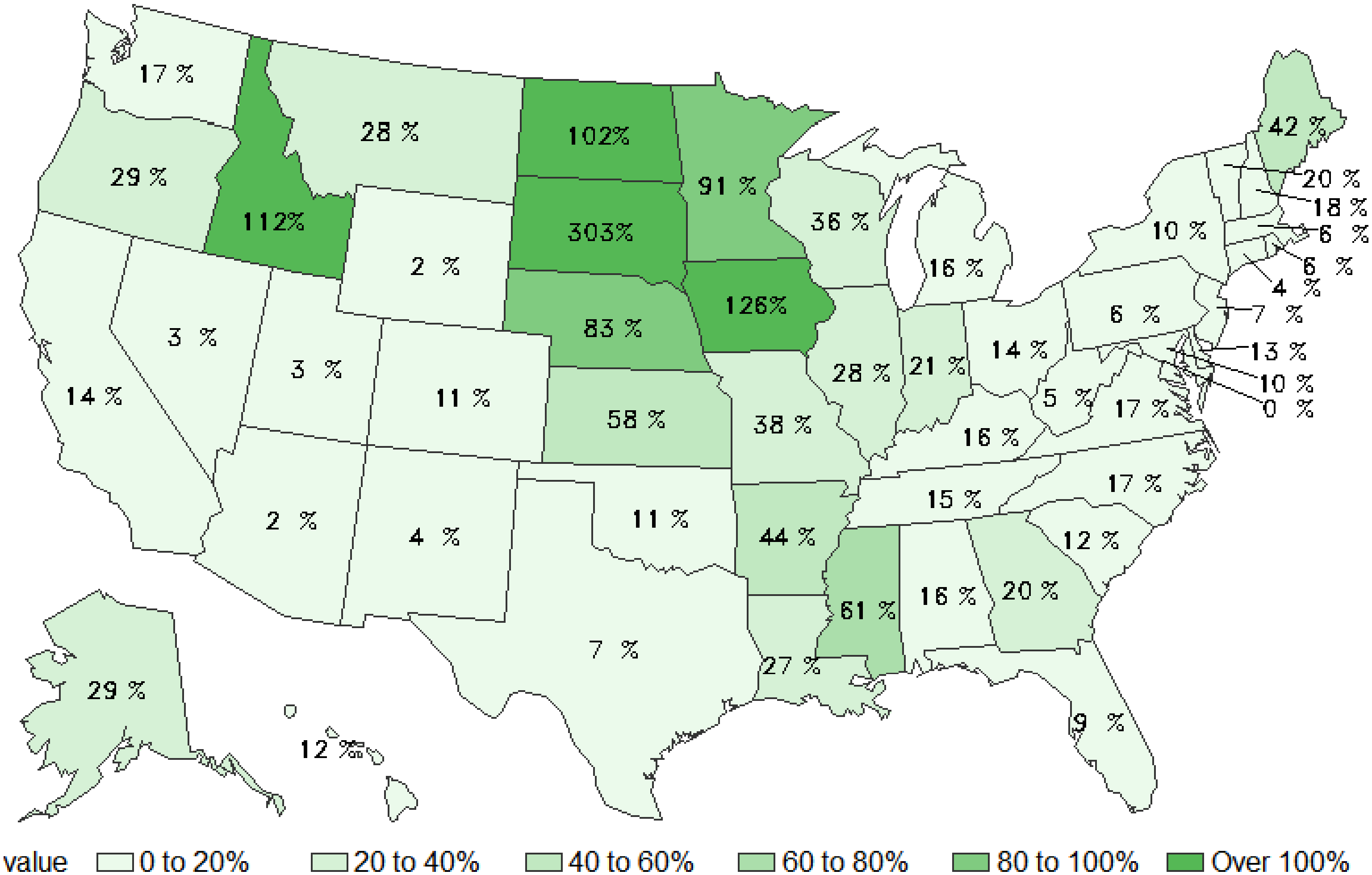
Current CHP Facilities Utilizing Biomass



Sources: Antares, KEMA Internal Analysis

Biomass Potential as a percentage of TWh generated in each state

Biomass Potential as a Percentage of Total Generation



Source: U.S. DOE Energy Information Administration, Jan. 2009

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Cofiring of Coal Fired Power Plants with Biomass

Biomass Pelletizing and Torrefaction

Woody Biomass

Torrefied

Pelletized

Pelletized biomass is an efficient fuel source for heating and energy generation, and is now being utilized in Europe and the eastern US.

Torrefaction

Torrefaction = Roasting

Every morning millions of people drink coffee, made from roasted coffee beans….

Fibrous Biomass can be torrefied in a similar fashion

Thermal Processing of Wood / Biomass/ Agri-Waste

	Drying	Torrefaction (Roasting)	Devolatilization (Pyrolysis)	Gasification	Combustion
Temp. (°C)	80 - 140	~140 - 350	~350 - 650	650 - 900 (1)	800 - 900
Volatiles (2) remaining	100%	75% – 90%	0 – 15%	0%	0%
Fixed Carbon remaining	100% FC	100% FC	90 – 100% FC	0 – 10% FC	0% FC
Process Oxygen	Low	0% O_2	Sub-stoichiometric O_2	Sub-stoichiometric O_2	Excess O_2
Off-Gas	Water Vapour	Some CO, CO_2, Organic Acids	$CO/CO_2/H_2/C_xH_y$	$CO/CO_2/H_2/C_xH_y$	$CO_2 + H_2O$
Solids	Dry Product	• Roasted product (smokeless fuel) • Embrittled & hydrophobic	• Char product • Most volatiles driven off • FC and ash remains	• Ash product • Low residual FC	• Ash product

1. *Depends on Ash Characterization.*
2. *As per Proximate Analysis.*

Source: Torbed, Topell

Torrefaction of Biomass

It takes Nature 60 million years

With Compact Bed Reactors it can take
60 seconds !

- Wood Chips
- Grass
- Straw
- Rice husks

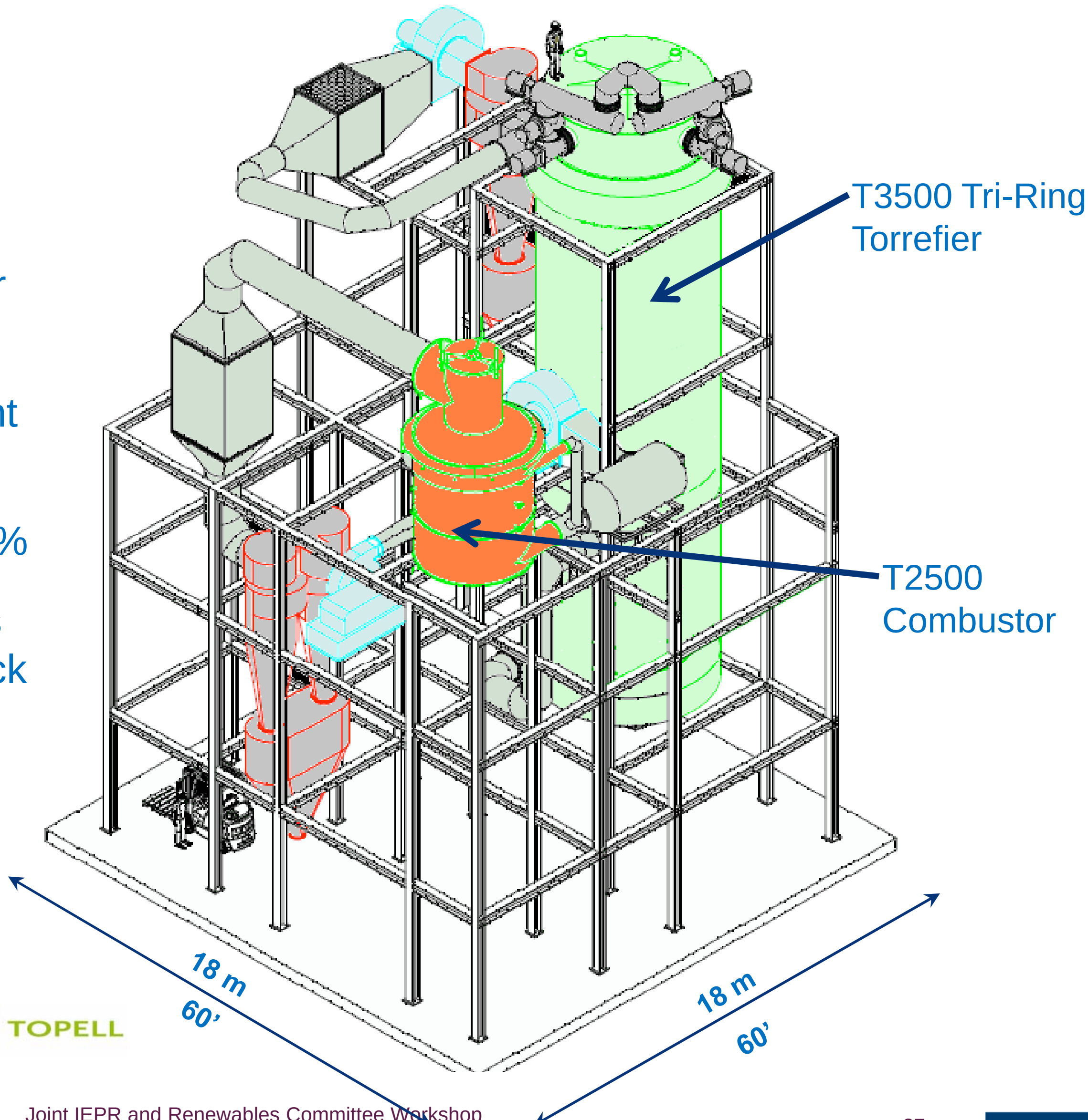
250 – 350°C
Torrefaction
Atmospheric Pressure
Reducing Environment

Pulverized,
Torrefied Wood

Torrefied Wood Pellets
“Bio-Pellets”

Technology for Torrefaction of Wood Chips is available

- Capacity: 60,000 tonnes / year
- Design for Polow Energy Systems in Netherlands
- Construction start scheduled for 2009
- Product destined for power plant in Germany
- Wood Chips Feed Moisture: 40%
- Modular plants sited in biomass rich areas can process feedstock for efficient rail transport



POLOW energy systems TOPELL

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Cofiring of Coal Fired Power Plants with Biomass

Preliminary Estimate of Potential Co-firing in WECC (Co-firing Biomass in Coal Power Plant Units)

- Total biomass potential in WECC is approx 33GW
- Based on existing assets with 100% biomass firing:
  - Approx 10 GW of coal units in WECC areas
  - Approx 0.5GW of coal units generate in CA
- Based on conservative 10% to 30% cofiring of these plants:
  - Between 1GW to 3 GW of Biomass power could be generated (replacing coal)
- Estimates assume biomass feedstock is readily available.

Coal-fired Power Plants in WECC (Out-of-State) Contracting with California Utilities

Plant Name[1]	State	Nameplate Capacity (MW) [2]	Summer Capacity (MW) [2]	2006 Claims (GWh) [1]
Four Corners (Units 4 and 5)	NM	1,636	1,500	5,647
San Juan (Units 3 and 4)	NM	1,110	1,002	2,016
Navajo	AZ	2,409	2,250	3,180
Boardman Plant	OR	601	585	499
Deseret (Hunter)	UT	1,472	1,320	76
Deseret (Bonanza)	UT	500	458	309
Intermountain Power	UT	1,640	1,800	10,503
Total		9,368	8,915	22,230

1. Source: California Energy Commission, SB 1305 Data
2. EIA, “Existing Generating Units in the United States by State, Company and Plant, 2007“

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Cofiring of Coal Fired Power Plants with Biomass

Issues and Challenges

- Maximize the job creation by building a supply chain
  - Infrastructure for biomass transportation
  - Construct torrefaction and pelletizing facilities
- Operators challenge and incentives to implementation
- Torrefaction and air quality issues
  - Extract potential for low NOx and SOx from biomass firing
  - Fouling of SCR with biomass flue gas constituents

End

Questions and Discussion