Ultra-Supercritical Power Plants for Alberta

Group 6a

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Introduction

- Coal has an unjust public image because of the high CO_2 emissions
- Ultra-supercritical (USC) power plants reduce these emissions
- These plants also have greater efficiencies than subcritical power plants
- Coal is an abundant fuel source in Alberta and similar deposits found in Northern USA

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Alberta's Population

- Total population of 3.9 million people
- Population increase of 2.5 %/year
- People moving to Alberta seeking oil & gas jobs (28,000 from other provinces)

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Alberta's Energy Use

- Total energy generation of 70,685 GWh/yr
- Total energy consumption of 52,662 GWh/yr
- 38,859 GWh produced by burning coal as the primary fuel source
- 113,397 kWh per capita (2nd highest)

http://www.energy.alberta.ca/Electricity/682.asp

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Energy Use Per Capita

http://www.canadiangeographic.ca/magazine/jun12/energy_use_canada_map.asp

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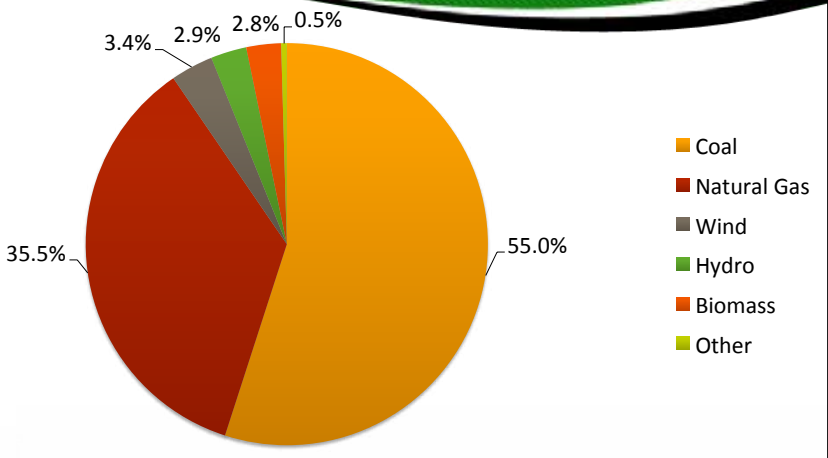
Alberta Energy Use by Fuel Source



http://www.energy.alberta.ca/Electricity/682.asp

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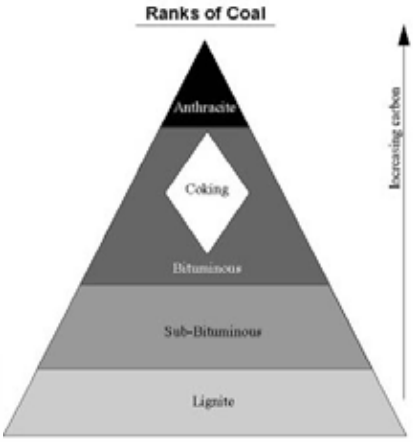
Ranks of Coal



http://www.bato.ca/coalmining.htm

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Coal Availability in Alberta

- All types and grades throughout the province
- Sub-bituminous (sub-bit) typically used for ultra-supercritical
- Lower grade coal but still ideal for USC
  - Lower sulfur content
  - Lower heating value
  - Higher moisture content

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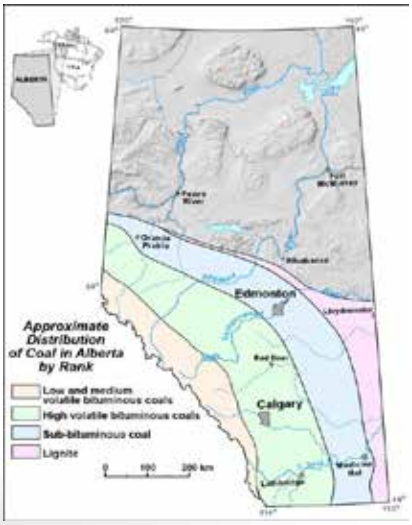
Coal Availability in Alberta

- Sub-bituminous coal found in a belt running from Medicine Hat to Grande Prairie



http://www.ags.gov.ab.ca/energy/cbm/coal_and_cbm_intro2.html

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Proven Concept

- Supercritical furnace already exists in Alberta
- Genesee 3, operational in March 2005
- 450 MWe capacity and 40% net efficiency
- 75 km southwest of Edmonton
- Located on the sub-bituminous coal belt

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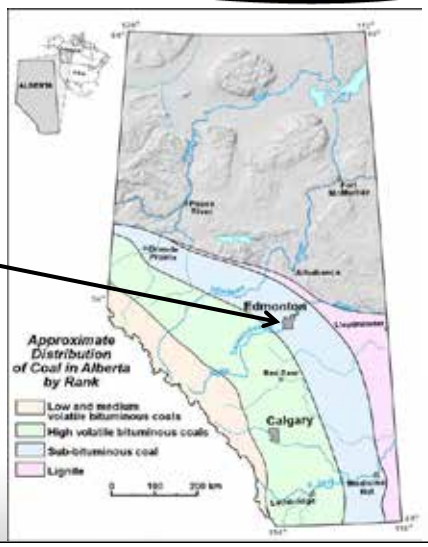
Proven Concept

Genesee 3



http://www.ags.gov.ab.ca/energy/cbm/coal_and_cbm_intro2.html

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Genesee 3

http://www.iea.org/publications/freepublications/publication/name,3752,en.html

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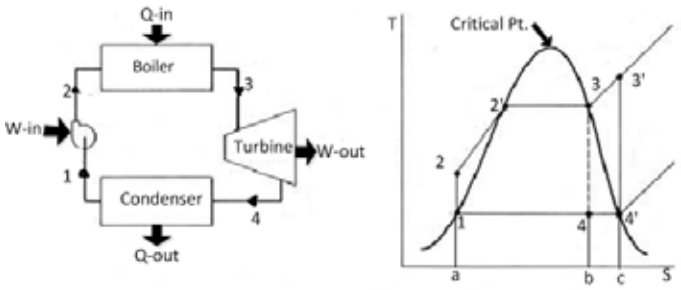
Steam Power Generation



Ideal Rankine Cycle – Subcritical Temperature and Pressure

$efficiency = W\downarrow net / Q\downarrow in = area\ 1-2-2\prime-3-4-1 / area\ a-2-2\prime-3-b-a$

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Let's get Critical

Characteristics of Sub, Super and Ultra-Supercritical Power Plants (Miller, 2011)

Unit Type	Main Steam Pressure (MPa)	Main Steam Temp. (°C)	Reheat Steam Temp. (°C)	Efficiency (% -based on HHV bituminous coal)
Subcritical	<22.1	<565	<565	33-39
Supercritical	22.1-25	540-580	540-580	38-42
Ultra-supercritical	>25	>580	>580	>42

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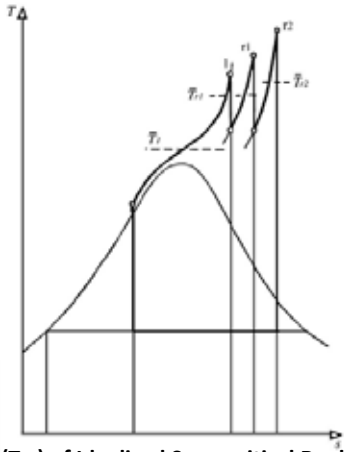
Ultra-Supercritical (USC) Process

- Typically 3 Turbine stages. HP, IP and LP
- Increased efficiency due to reheat stages after HP Turbine and IP Turbine
- Nickel and Chromium super alloys in turbine design are limited by pressure



(T-s) of Idealized Supercritical Rankine cycle with 2 reheats (Beér, 2007)

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Pulverized Coal Fired Furnaces

- Utility sized between 400 MW – 1300 MW
- Preprocessing to fine powder 45-75µm particles
- Mixed with compressed air and injected for Suspension Firing
- Gas Temperatures > 1200 °C

(Miller, 2011)

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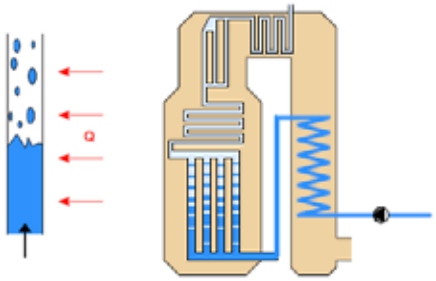
Once Thru Utility (OTU) Boiler

- Only boiler design to work at supercritical pressures
- Requires large compressor to drive steam
- No capacity buffer due to once thru design and lack of steam drum



Simplified OTU boiler principle, and Benzon OTU furnace design (Tier et al., 2002)

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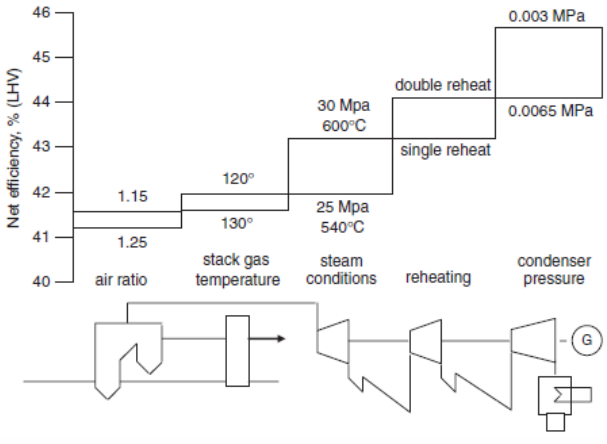
Further Improvement



Effect of various measures for improving the efficiency of pulverized coal-fired power generation (based on LHV of coal) (Beér, 2007)

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Gas Combined Cycle

- Pressurized Fluidized Bed Combustor(PFCB) has potential to each USC parameters
- Temperatures 820°C-980°C reduce NOx emissions
- Requires gas turbine exhaust for Superheat
- CFB boilers require less preprocessing of coal, and can co-fire coke, peat, biomass, low ranking fuels
- In-situ SOx emission control (limestone)
- Gas turbine fueled from coal syngas or natural gas

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Environmental Impacts

- Environmental impact of a coal fired power plant due to two main factors:
  1. Mining – the mining process used to fuel the plant
  2. Emissions – created during the combustion of coal during the power generation process.

www.miningmagazine.com

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Coal Mining

1. Land Disturbance
   - Generally open pit mining in Alberta
   - Typical strip ratios from 4 to 10
2. Water Pollution
   - Acid Mine Drainage (AMD)
3. Dust & Noise Pollution
   - Caused by mining equipment

http://en.wikipedia.org/wiki/Acid_mine_drainage

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Coal Mining

- Benefit of Alberta:
  - Power plant can be built next to mine, cutting down on transportation
    - Transportation via rail car and ocean freighter result in large production of greenhouse gases
  - Current examples in Alberta include Genesee 3 and Keephills 3

http://nodine.photoshelter.com/image/I0000GjrHPGDqyRA

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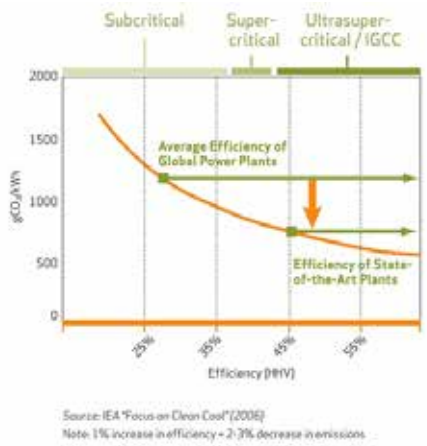
Emissions

- Four Main Types:
  1. Carbon Dioxide
  2. Nitrogen Oxides
  3. Sulfur Dioxides
  4. Particulates

- A 1% increase in efficiency can lead to a 2-3% decrease in emissions



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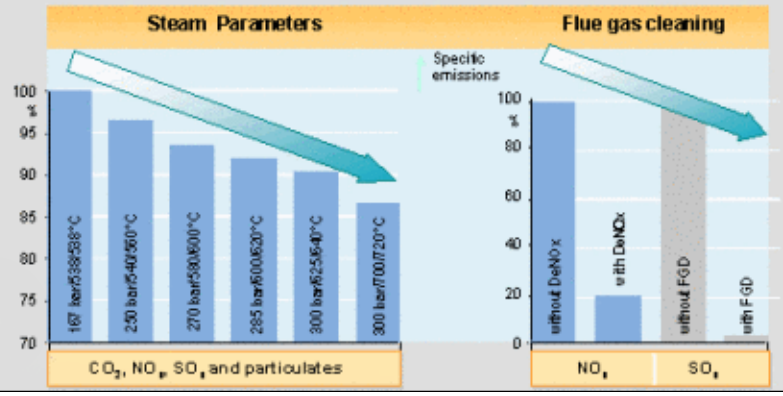
Emissions

http://saferenvironment.wordpress.com/2008

Low Emission Levels - Achieved by High Steam Parameters and Flue Gas Cleaning



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Capital Cost

- $/kW of net output

	Bituminous	Sub Bituminous	Lignite
Ultra Supercritical			
355 MW	$3,878	**$3,580**	$4,083
535 MW	$3,295	**$3,042**	$3,472
830 MW	$2,698	**$2,492**	$2,841
Supercritical			
355 MW	$3,760	$3,475	$3,956
535 MW	$3,194	$2,952	$3,364
830 MW	$2,616	$2,418	$2,756
Subcritical			
355 MW	$3,630	$3,358	$3,817
535 MW	$3,084	$2,852	$3,246
830 MW	$2,560	$2,366	$2,692

Sargent & Lundy. "New Coal-Fired Power Plant Performance and Cost Estimates." (August 2008)

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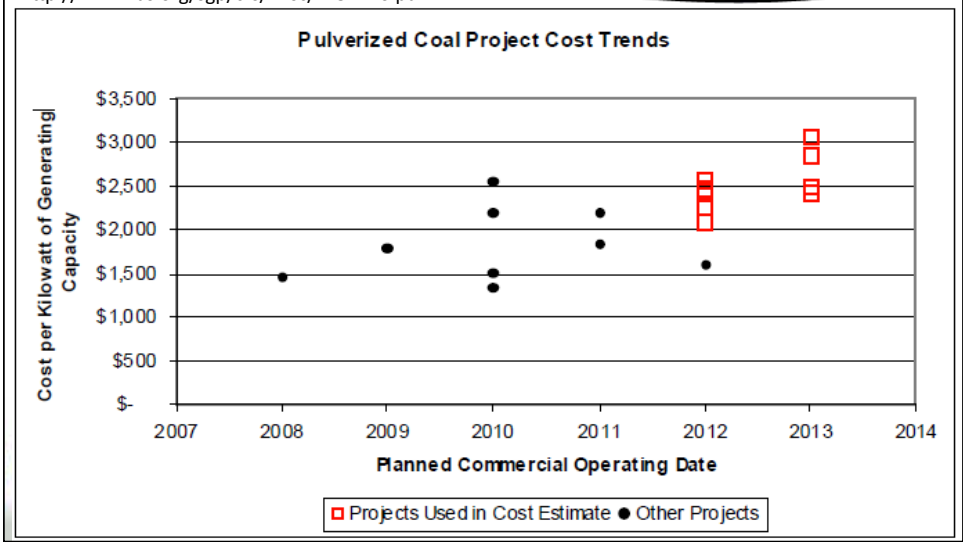
Capital Cost

http://www.fas.org/sgp/crs/misc/RL34746.pdf



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Fuel Cost

- U.S coal - $/short ton

	Central Appalachia 12,500 Btu,	Northern Appalachia 13,000 Btu	Illinois Basin 11,800 Btu	Powder River Basin 8,800 Btu,	Uinta Basin 11,700 Btu,
25-January-13	$68.05	$62.10	$47.90	**$10.15**	$35.85

http://www.eia.gov/coal/news_markets/

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Mine Mouth Operation

Power Plant located at the mouth of a coal mine

- Reduced fuel cost, increased initial cost
- Alberta coal royalty rate: $0.55/tonne

http://www.industcards.com/st-coal-usa-mo.htm

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Electricity Price

- Cost of electricity in Alberta: ≈ $0.085/kWh[1]
- Net 830 MW plant income (at full capacity):

$$830\ MW*(1000\ kW/1\ MW)*(1\ hr/1\ hr)*(\$0.085/kWh)=\$70\ 550/hr$$

- Payback period (at full capacity):

$$(\$2492/kW)*(830\ MW)*(1000\ kW/1\ MW)*(1\ hr/\$70\ 550)=29318\ hr\approx 3.4$$

[1]Residential electricity, from http://www.ucahelps.alberta.ca/price-summary.aspx

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Summary

- Coal is our most abundant and inexpensive fossil fuel source
- USC technologies reduce emissions and have increased efficiencies
- Alberta is the most viable province in Canada to implement USC technologies

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Questions?

www.rottentomatoes.com/**zoolander**