Thermal Treatment of Solid Waste

Technical Primer

For Southern Alberta Waste Management Alliance

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Gartner Lee Limited

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Overview

- The role of thermal treatment and how it works
- Types of thermal systems and main components
- Air emissions
- Issues and costs
- Current use of the technology
  - Canada
  - USA
  - Europe
  - Japan
- Future of thermal treatment

Terminology

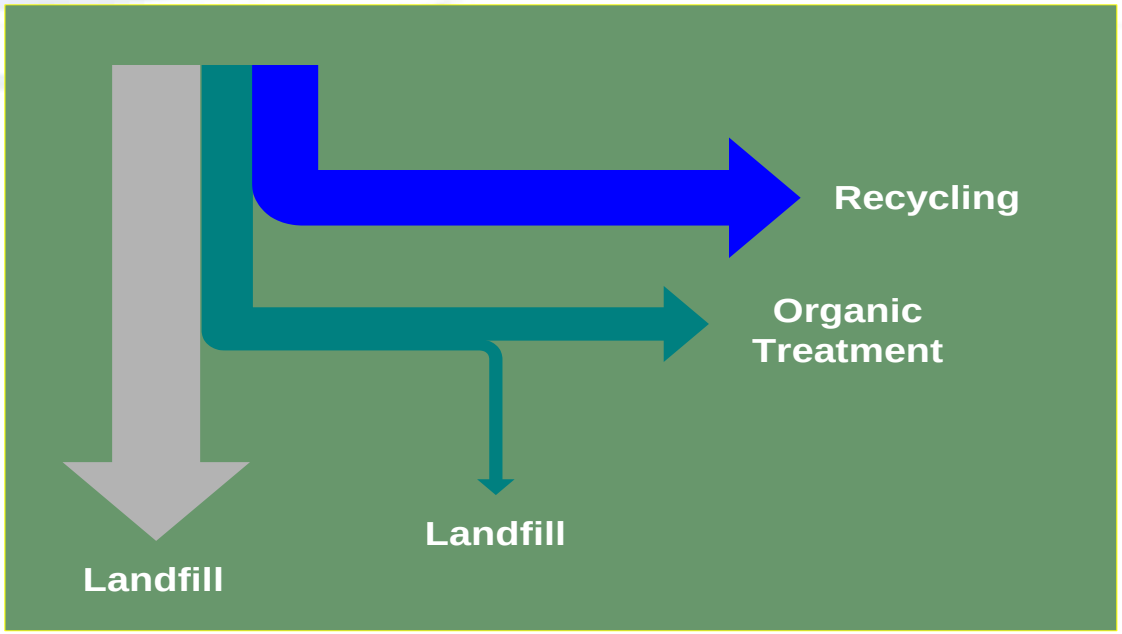
- **Thermal treatment (or incineration):** a range of processes where temperature is used to reduce the volume of waste and to render it harmless.
- **Waste to Energy (WTE):** as above, with the recovery of heat energy to produce steam and/or generate electricity.
- **Conventional WTE**: mass burn, fluidized bed, modular, rotary kiln, (refuse derived fuel)
- **Advanced WTE**: gasification, pyrolysis, plasma

The role of thermal treatment

- Waste volume reduction, preservation of landfill space
  - Does NOT replace the need for a landfill
- Energy recovery from the solid waste stream
- Destruction of contaminants
- Reducing waste transportation requirements
- Dealing with waste here and now

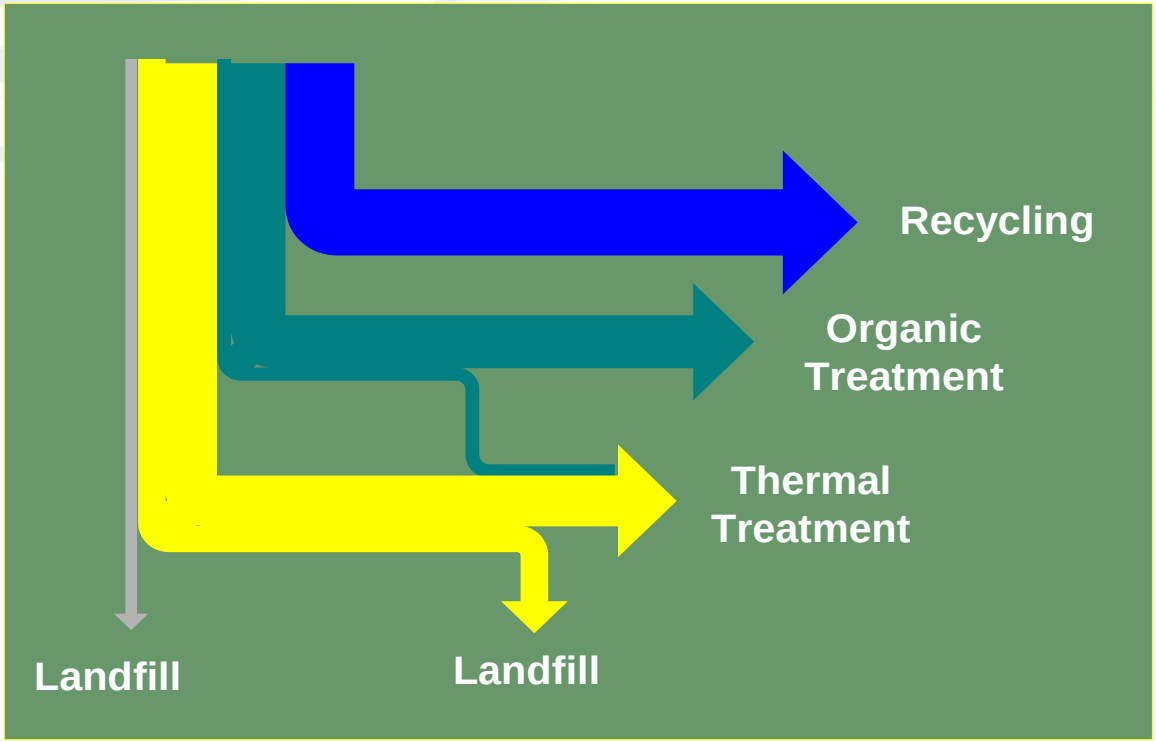
The role of thermal treatment (2)

- Recycling and organics treatment only:



The role of thermal treatment (3)

- With recycling and organics treatment:



The role of thermal treatment (4)

- Last treatment of waste before land disposal
- Applied after recycling, organics management
- If recycling goal is 60%, then WTE can treat balance of waste
- Recovers remaining energy
- Converts energy into heat
- Electricity can be sold to the grid
- Offsets fossil fuel use for power generation

The role of thermal treatment (5)

- One tonne of waste can deliver 400 to 700 kWh of electricity to the grid
- One tonne of waste has the same energy as one barrel of oil, or a quarter tonne of coal
- 24 tonnes of waste can provide all the electricity for a Canadian home for a year

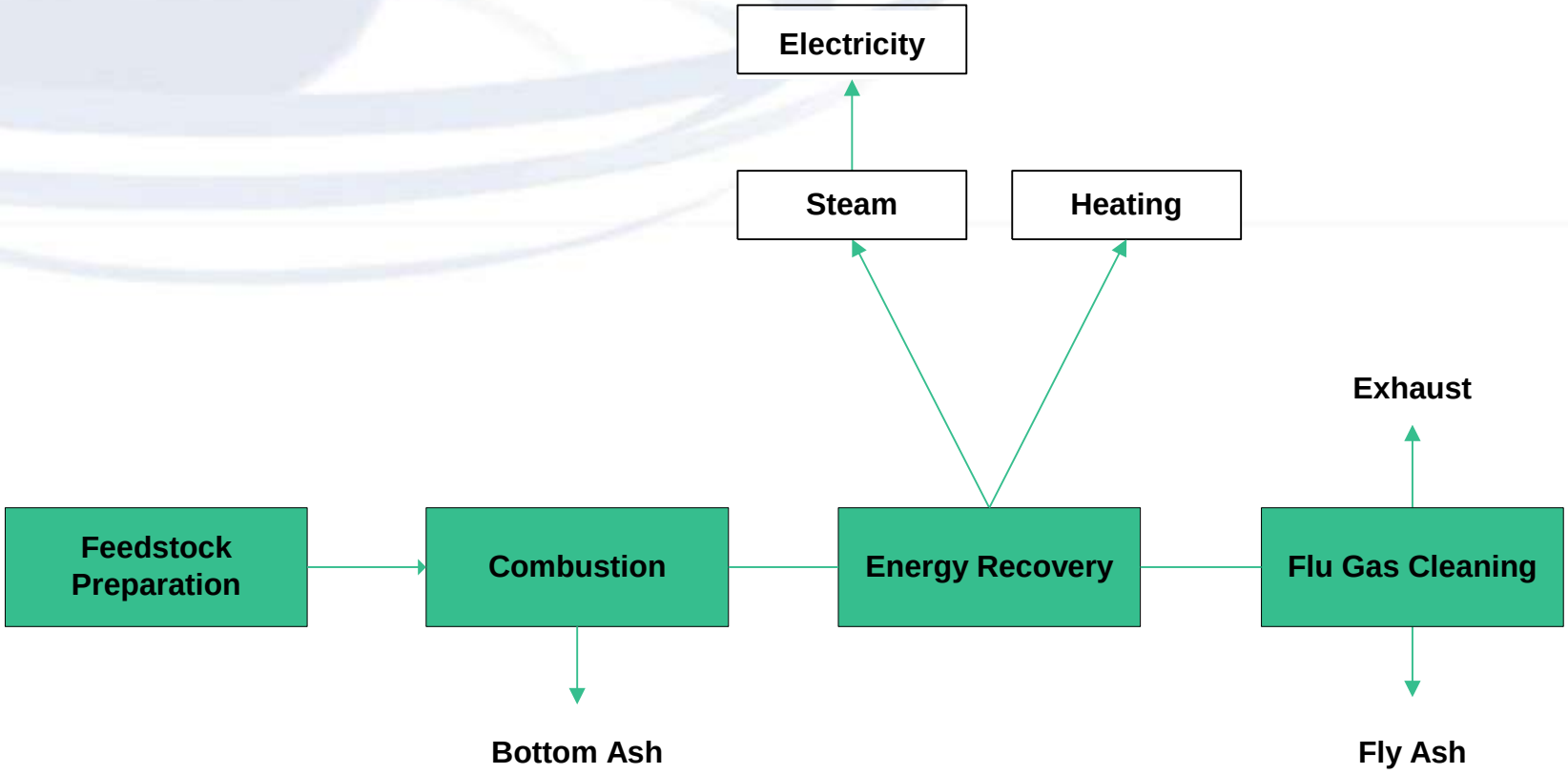
How thermal treatment works

- Technologies offer different ways of releasing the energy in the waste
  - Conventional combustion/WTE
  - Advanced thermal treatment (Gasification/pyrolysis, plasma systems)
- WTE systems are essentially power plants using waste as fuel instead of coal, natural gas or uranium

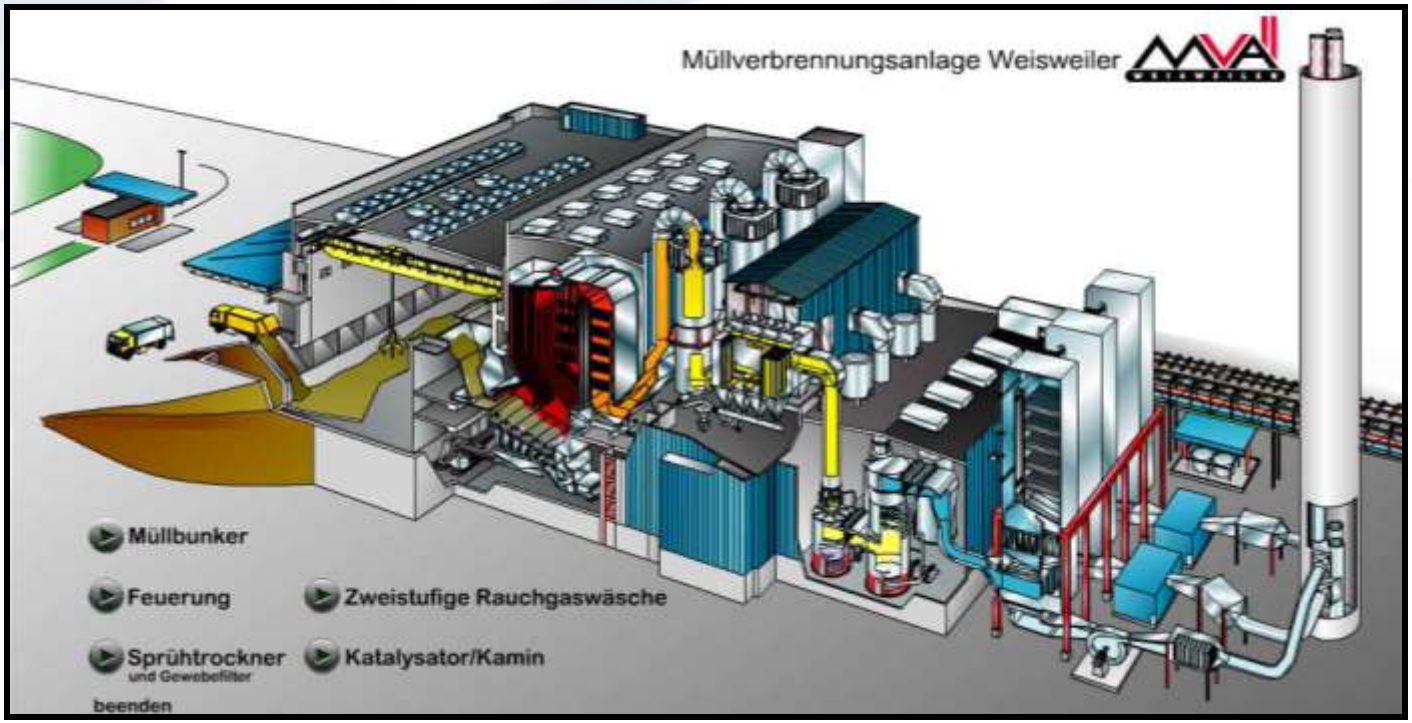
Conventional combustion technologies

- Mass burn – most common (Burnaby)
- Fluidized bed – mid sized and specialty applications (wood, coal)
- Modular – smaller systems
- Rotary kiln – hazardous and medical waste - rarely used for MSW
- Refuse Derived Fuel (RDF)

Conventional waste to energy (WTE)



Mass burn:
Facility overview



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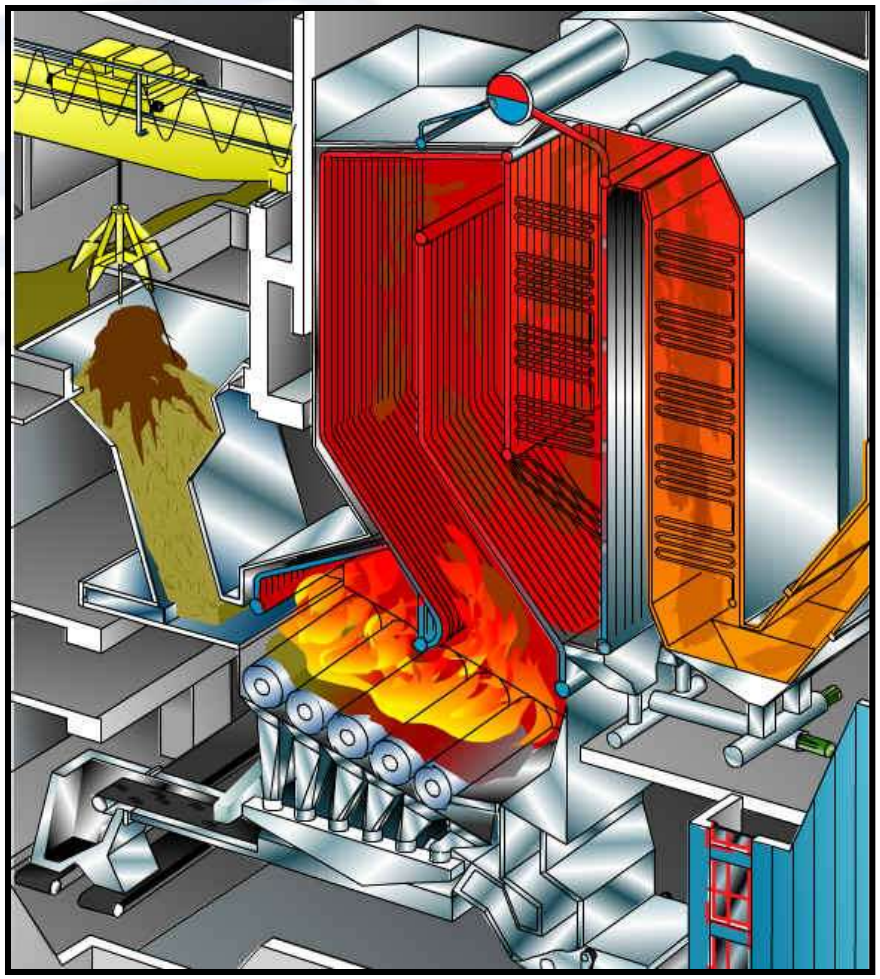
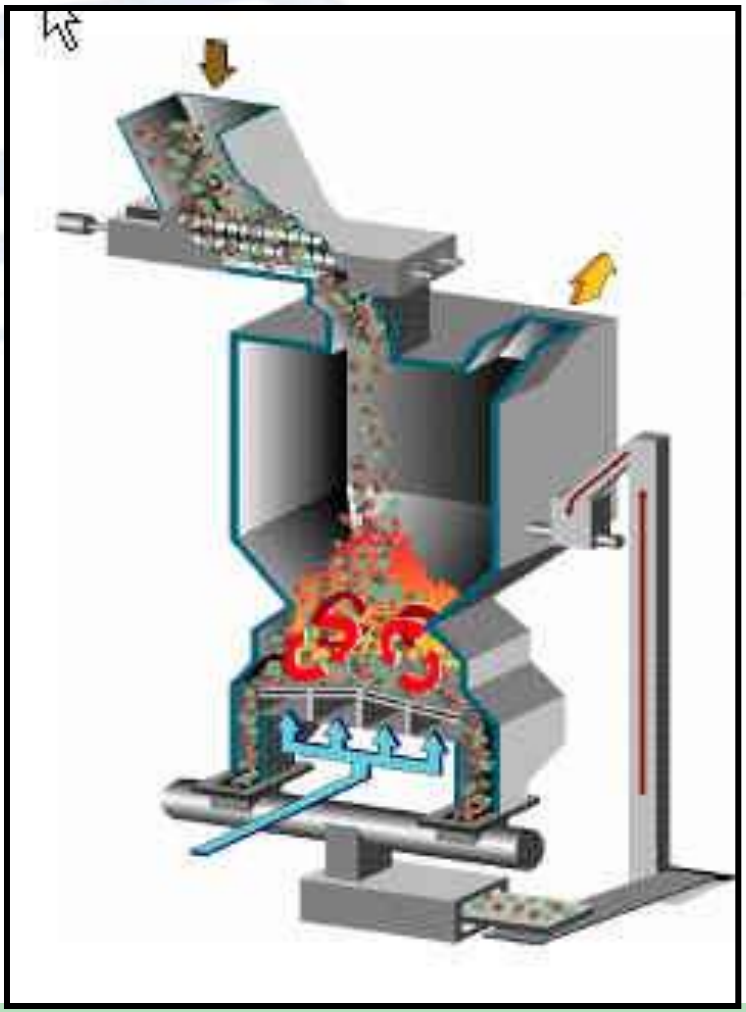
Mass burn: Furnace section

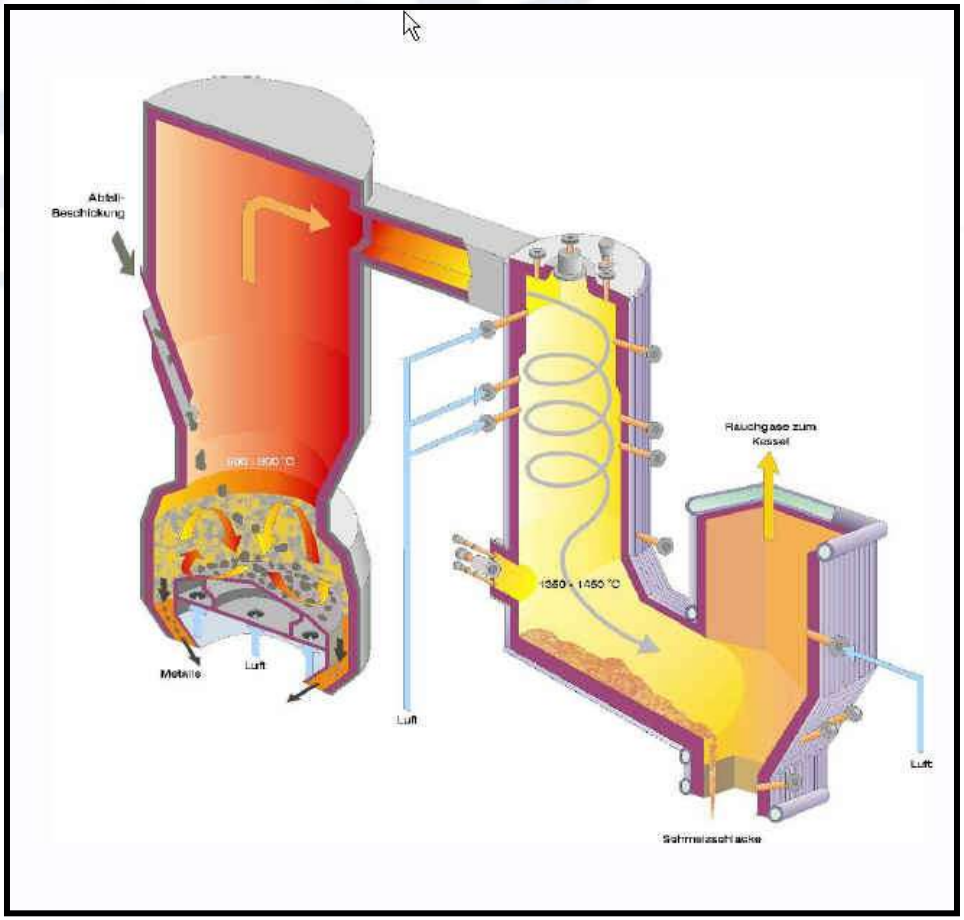


Fluidized bed furnace



Source: Ebara

Fluidized bed with ash melting



Source: Ebara

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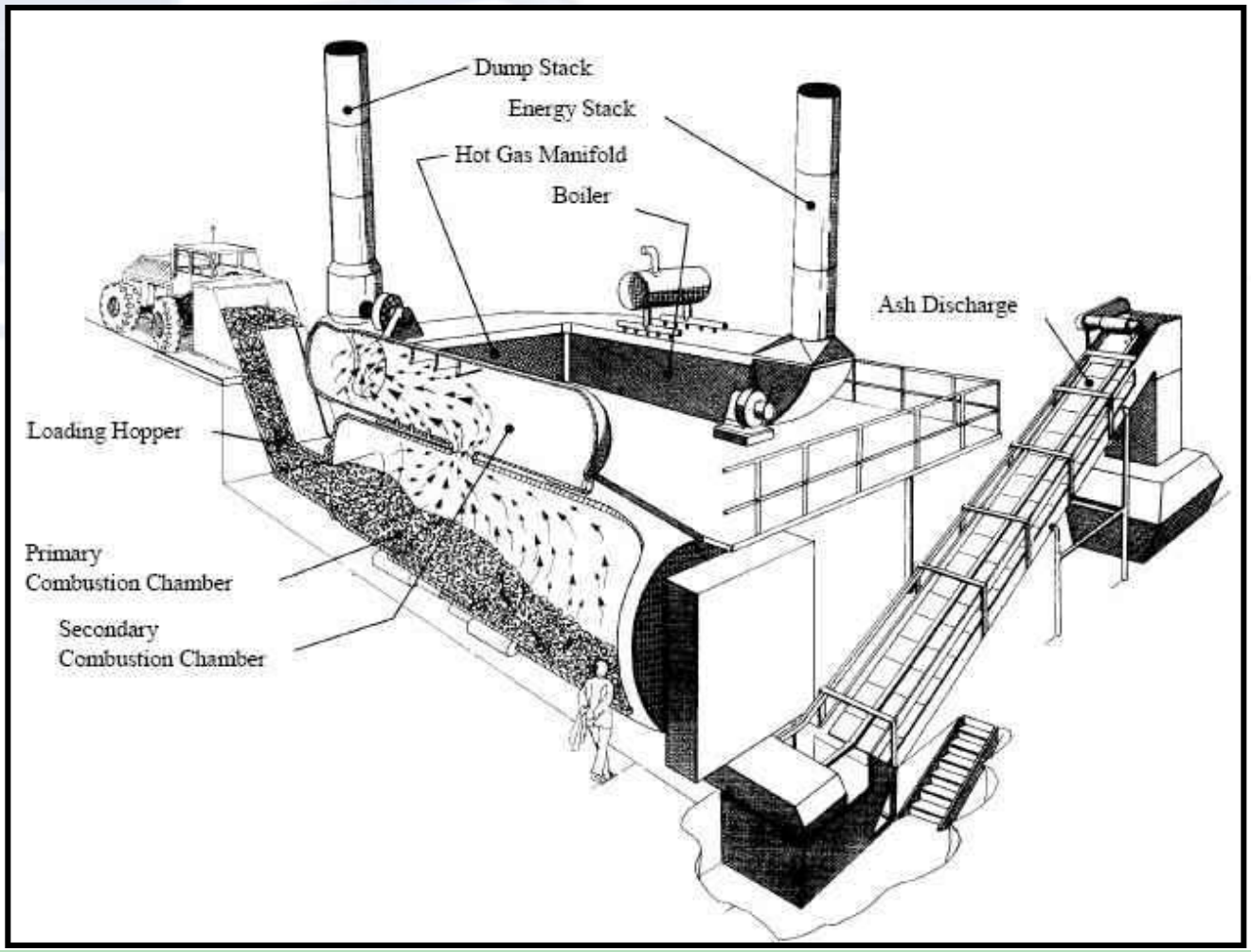
Modular controlled air combustion



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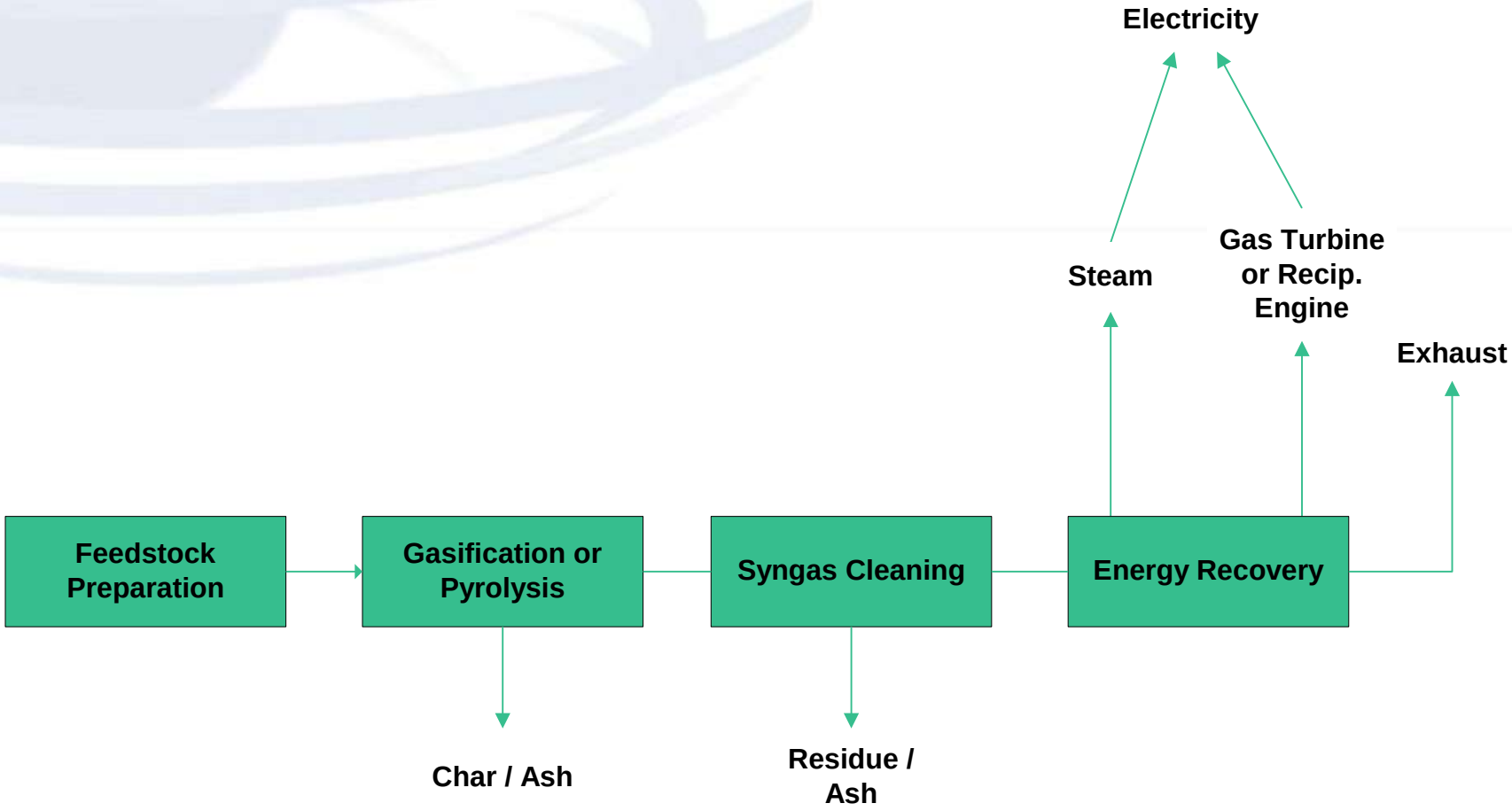
Refuse derived fuel (RDF)

- Solid waste made into homogenous fuel
  - Can be sold and used off site, replacing other fuels such as coal or gas
  - Used by:
    - Cement kilns
    - Industry power boilers
    - Dedicated WTE plants

Advanced thermal technologies

- Gasification and pyrolysis
  - Converts solids into synthetic gas
  - Gas is cleaned before combustion or other uses
  - Complex technology
- Plasma
  - Ultra high temperature process, total organics destruction
  - Makes synthetic gas
  - Creates vitrified slag
  - Lowest residuals

Advanced thermal technologies: gasification/pyrolysis



Pros and cons of advanced thermal technologies

Pros

- Few air emissions during syngas generation
- Lower CO_2 generated when syngas formed
- Ash can be vitrified with some processes
- Recovery of energy from waste
- Better environmental perception

Cons

Syngas must be cleaned, leaving residues

- CO_2 formed when syngas burned
- Vitrification has high energy requirement/cost
- Often lower energy recovery efficiency than conventional combustion systems
- No real environmental advantages over combustion if syngas is used for heat/power

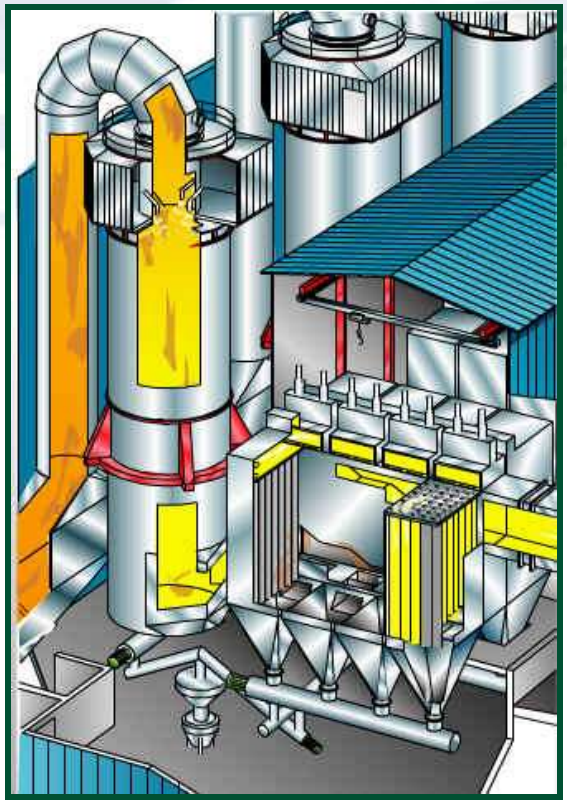
Major Components at WTE Plants

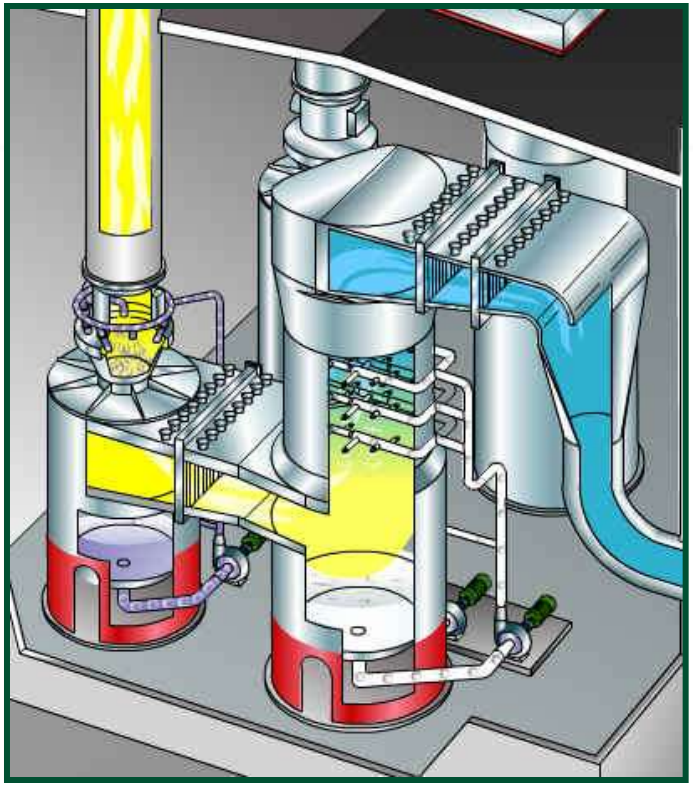
- Heat recovery
  - Conventional steam boiler technology
    - Generates steam
    - Steam used to generate electricity using steam turbine generator
    - Steam used for industrial process or heating
  - Synthetic gas can be cleaned and fired directly
    - In a reciprocating engine
    - In a gas boiler
    - In a gas turbine
    - Syngas can be raw material for chemical process

Major Components at WTE Plants (2)

- Air pollution control
  - Mature technology.
    - Systems available to meet most stringent air emission standards
    - Custom matched to combustion technology
  - WTE most highly regulated form of waste management
  - Emission standards more stringent than for most coal fired power plants or industrial boilers

Semi-dry, dry, and wet scrubbers





Major Components at WTE Plants (3)

- Solid Residues:
  - Conventional combustion
    - Metals recovered and recycled
    - Bottom ash and fly ash,
      - 25% by weight and 10% by volume of treated waste
      - Bottom ash suitable for road base, landfill cover or disposal
      - Fly ash usually needs to be stabilized before disposal
  - Advanced Combustion
    - Slag with varying amounts of fixed carbon, up to 30% by weight
    - Slag may be reduced by reprocessing
    - Plasma systems have almost no residue

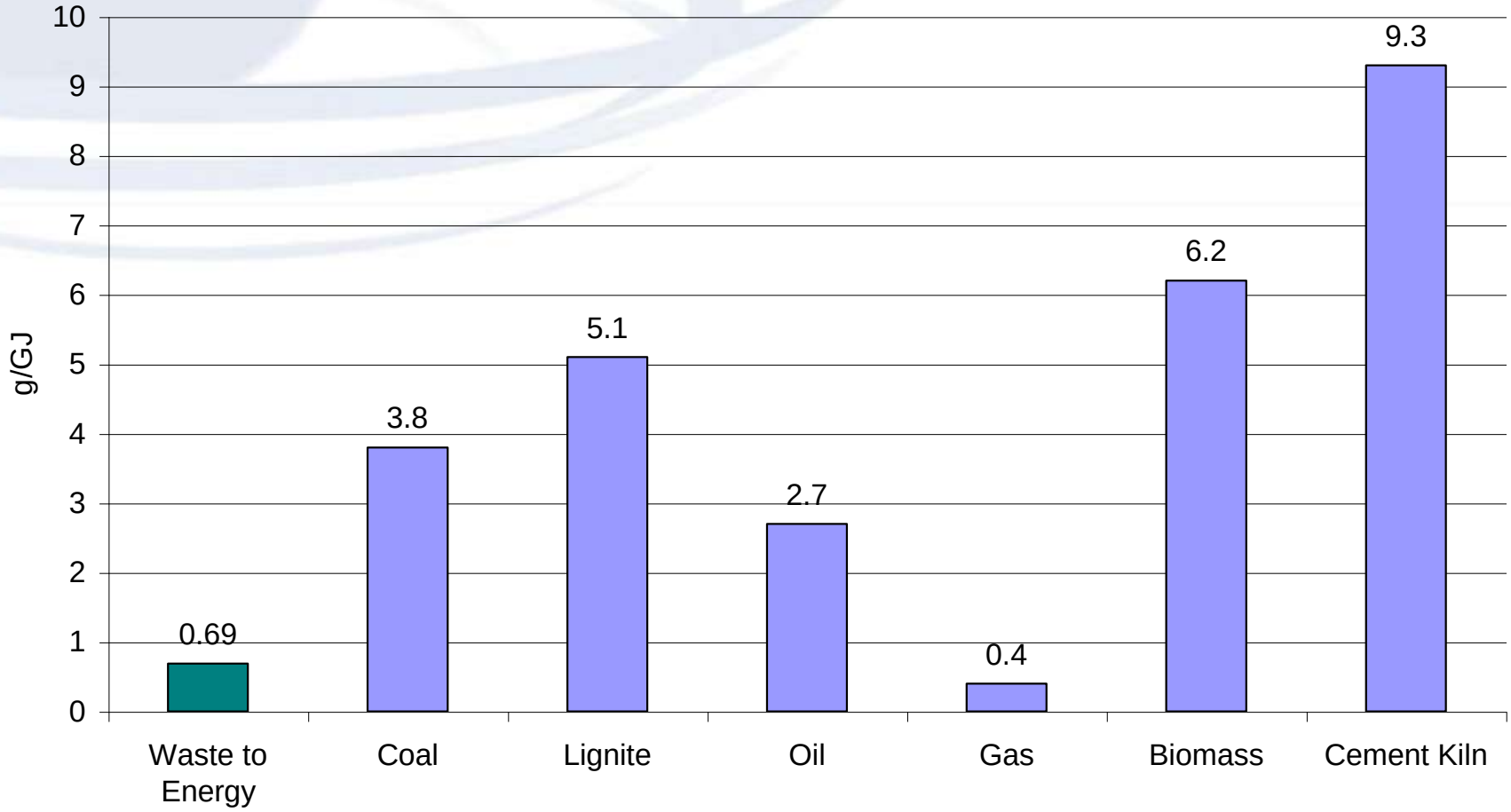
Air Emissions

- WTE most highly regulated form of waste management
- Most countries have very strict standards
- EU and Ontario A7 guidelines considered to be the most stringent in the world
- Technologies have been developed and are applied to meet these standards
- In Europe, emissions from WTE are so low, that they are often considered irrelevant compared to industrial and transportation sources

Comparison of Relevant Air Emissions from Selected Combustion Technologies

- Paper presented by Helmut Rechberger and Gerald Schoeller, Technical University of Vienna, 2006 CEWEP Congress
- Extensive emissions comparisons based on energy production (mg/GJ)
- WTE figures from 50 existing WTE facilities in Europe
- Cement kiln data from Association of German Cement Kilns
- Other data from literature

Comparison of Dust/Particulate Emissions



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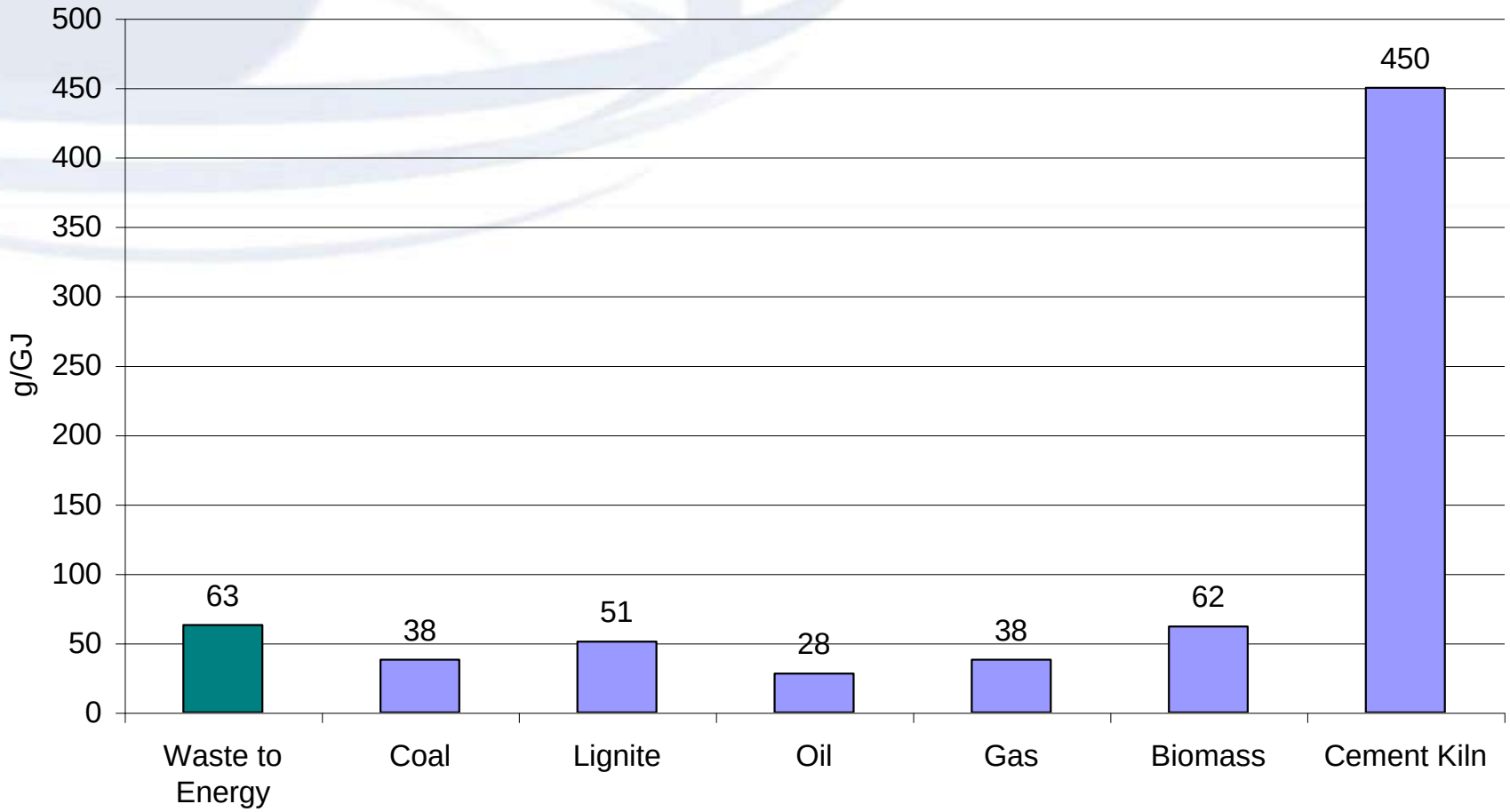
Comparison of NO_x Emissions



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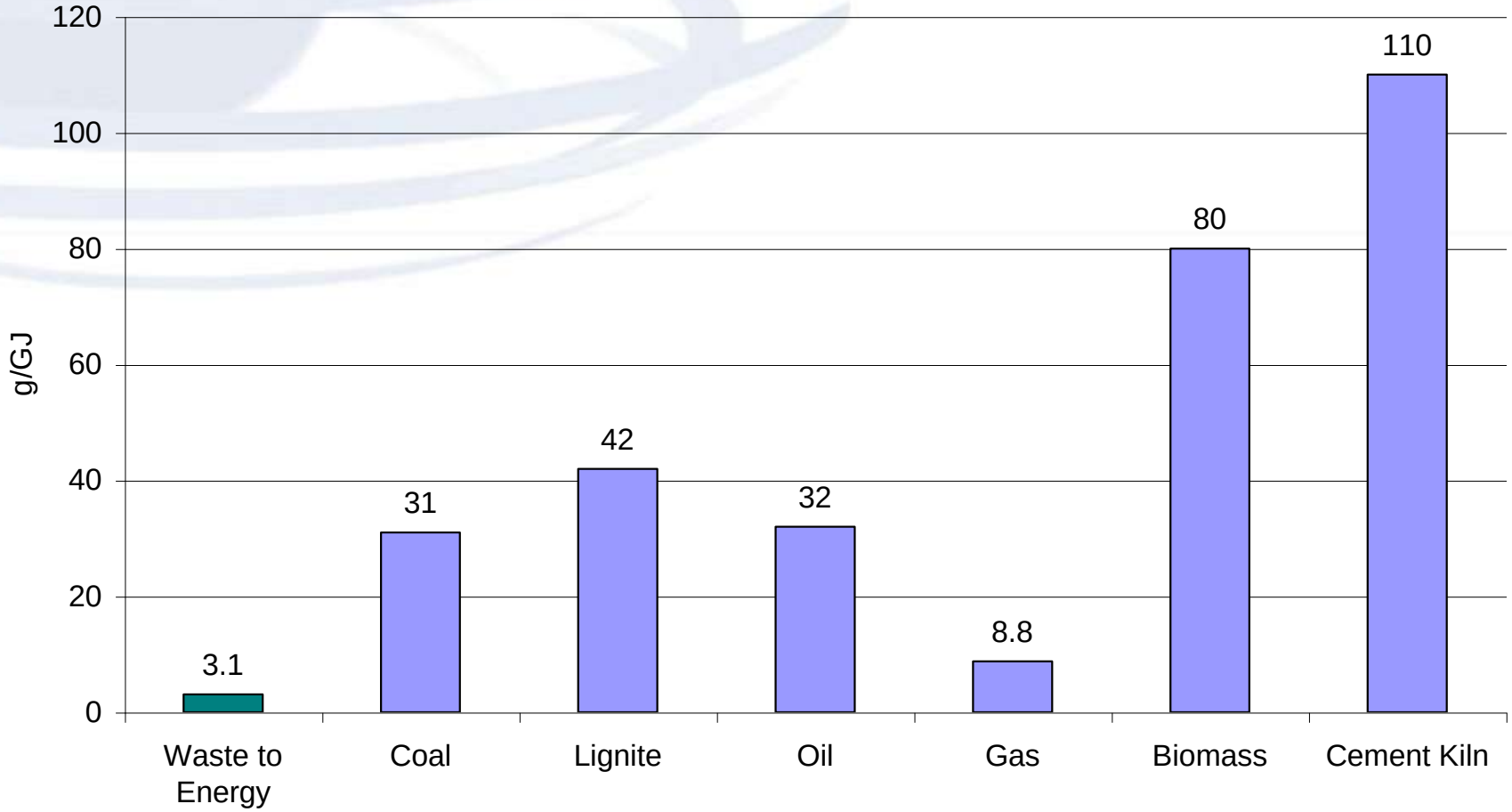
Comparison of SO_2 Emissions



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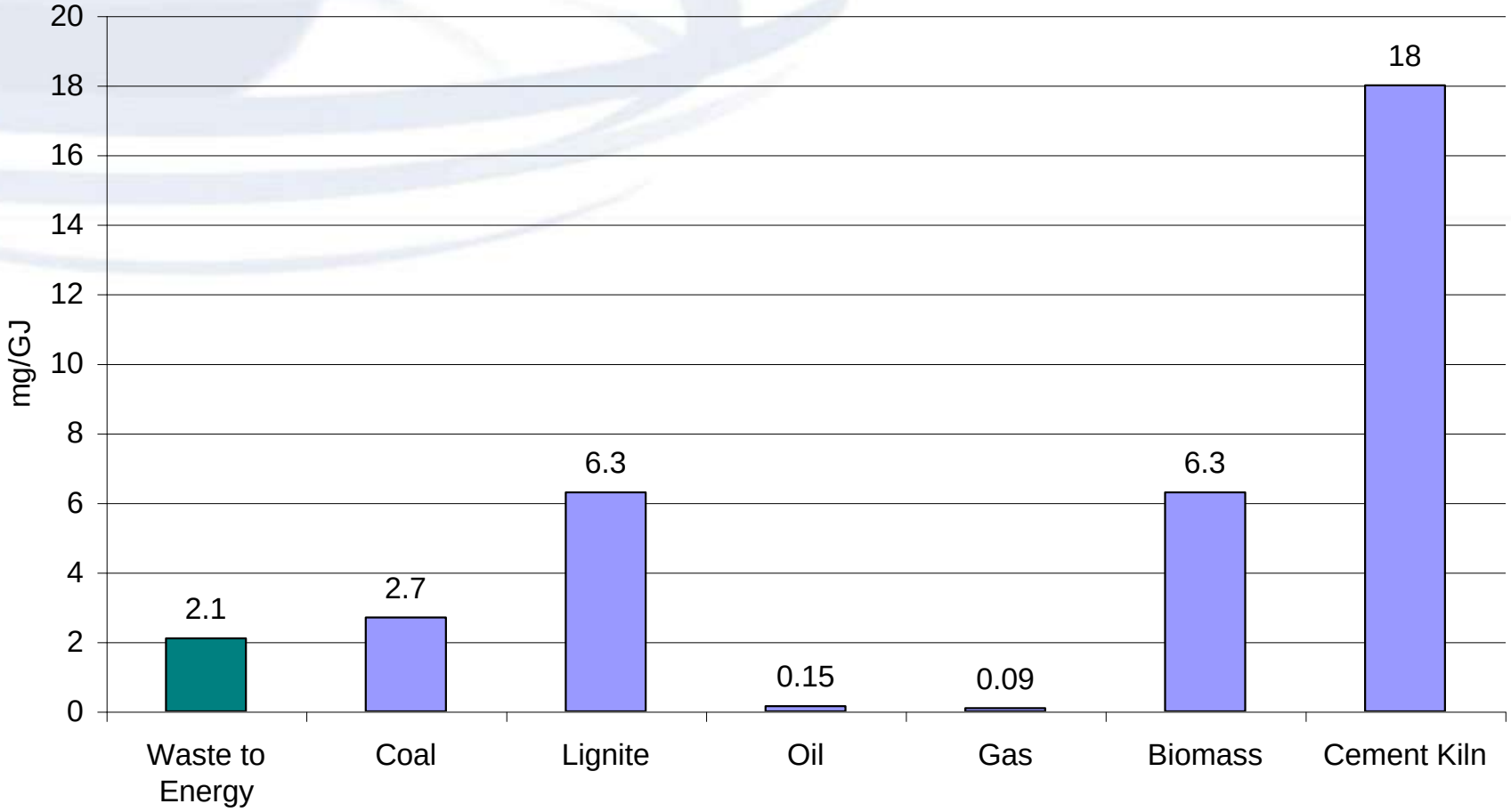
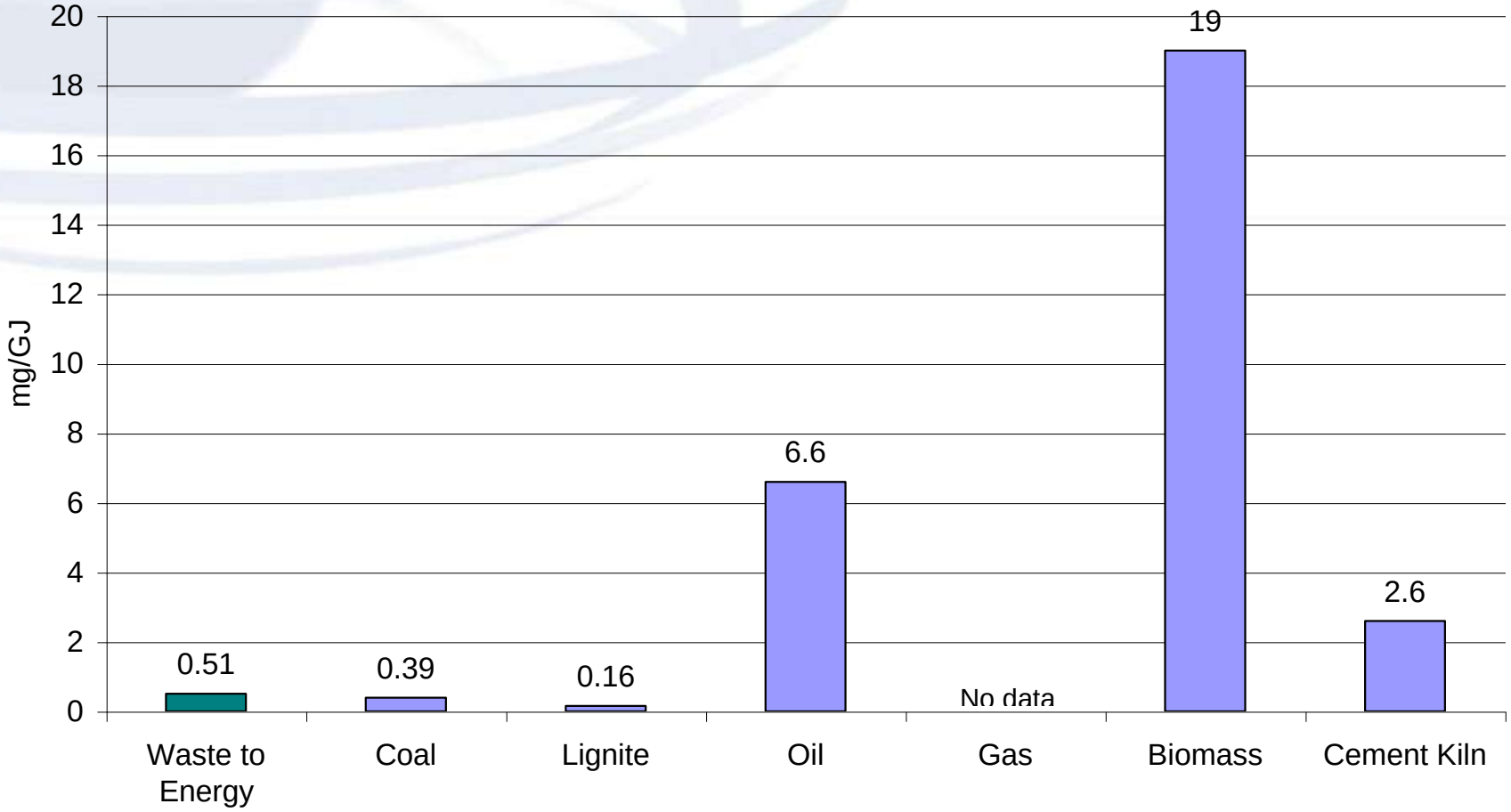
Comparison of Mercury Emissions



Comparison of Cadmium Emissions



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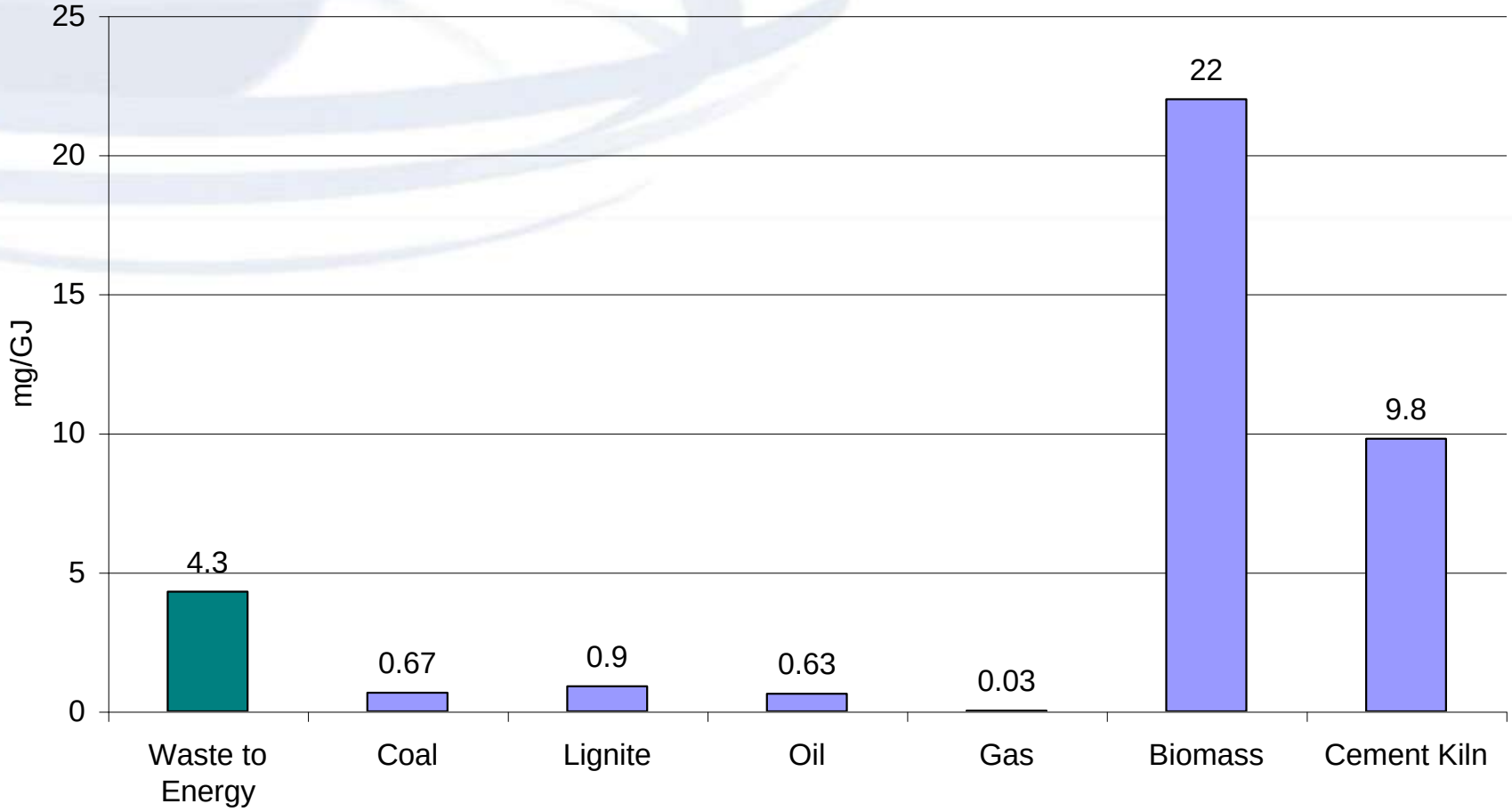
Comparison of PCDD/F Emissions



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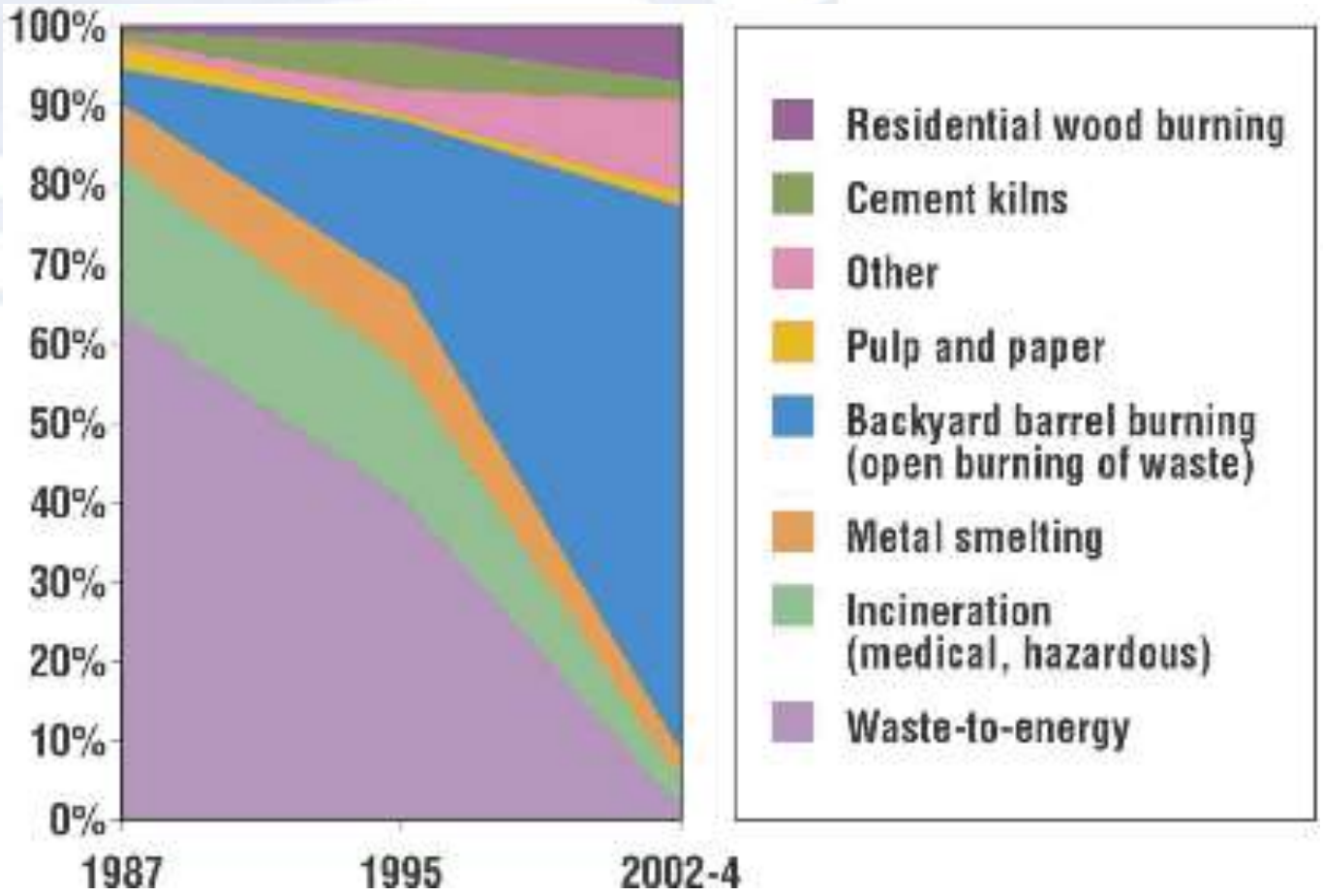
Notes to emissions slides

- Values shown in previous slides are for existing facilities, some of which are older
- Newer facilities are made to meet more stringent emission targets
- Metro Vancouver's Burnaby WTE facility often has no detectable dioxins
- New technologies exist to remove mercury from flue gas

Dioxin Emissions in the USA



Source:
(P. Deriziotis, MS Thesis, Columbia University, 2003; data by U.S. EPA)

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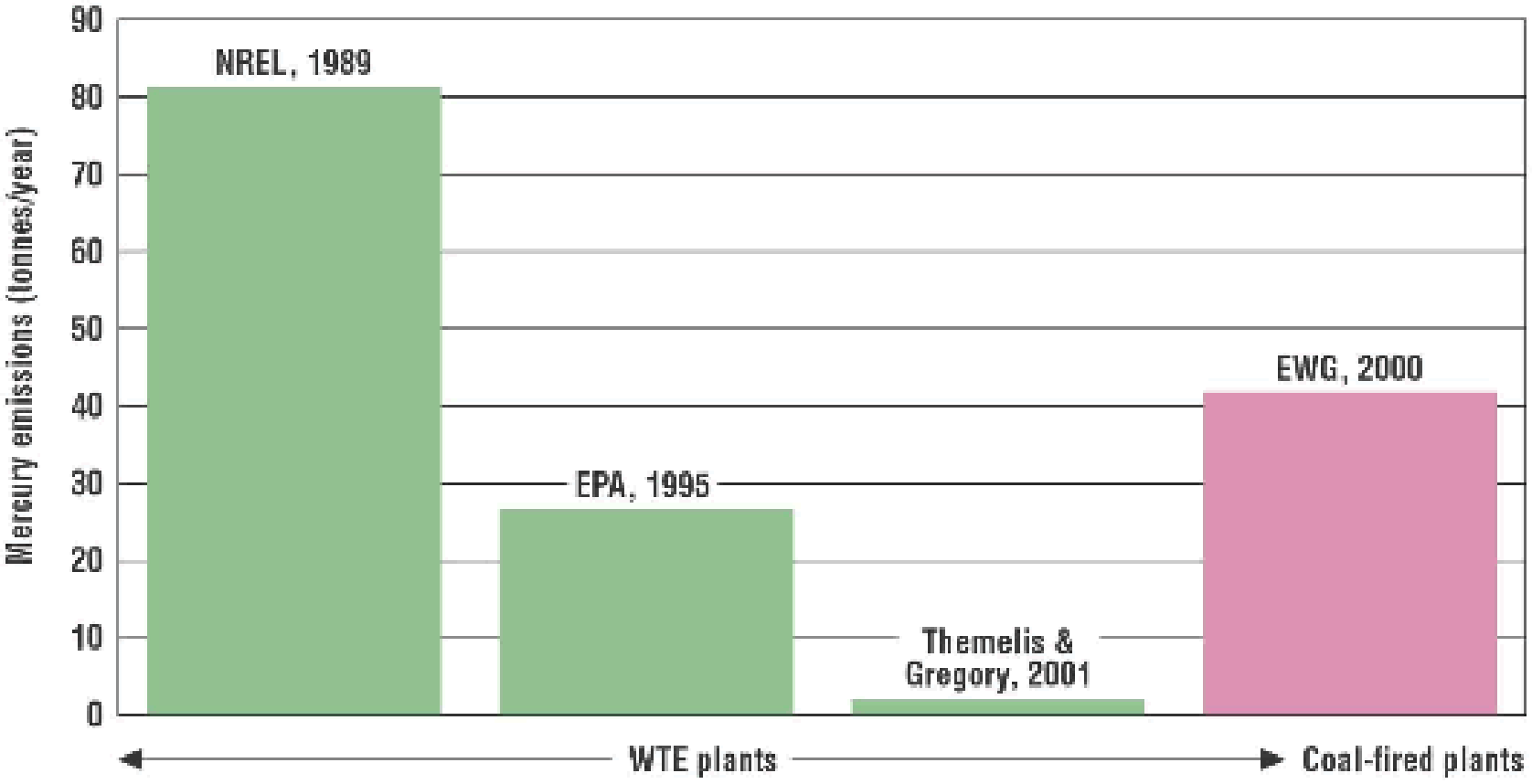
Reduction of Mercury from WTE in the USA



Source: Waste-to-Energy Research and Technology Council (WTERT)

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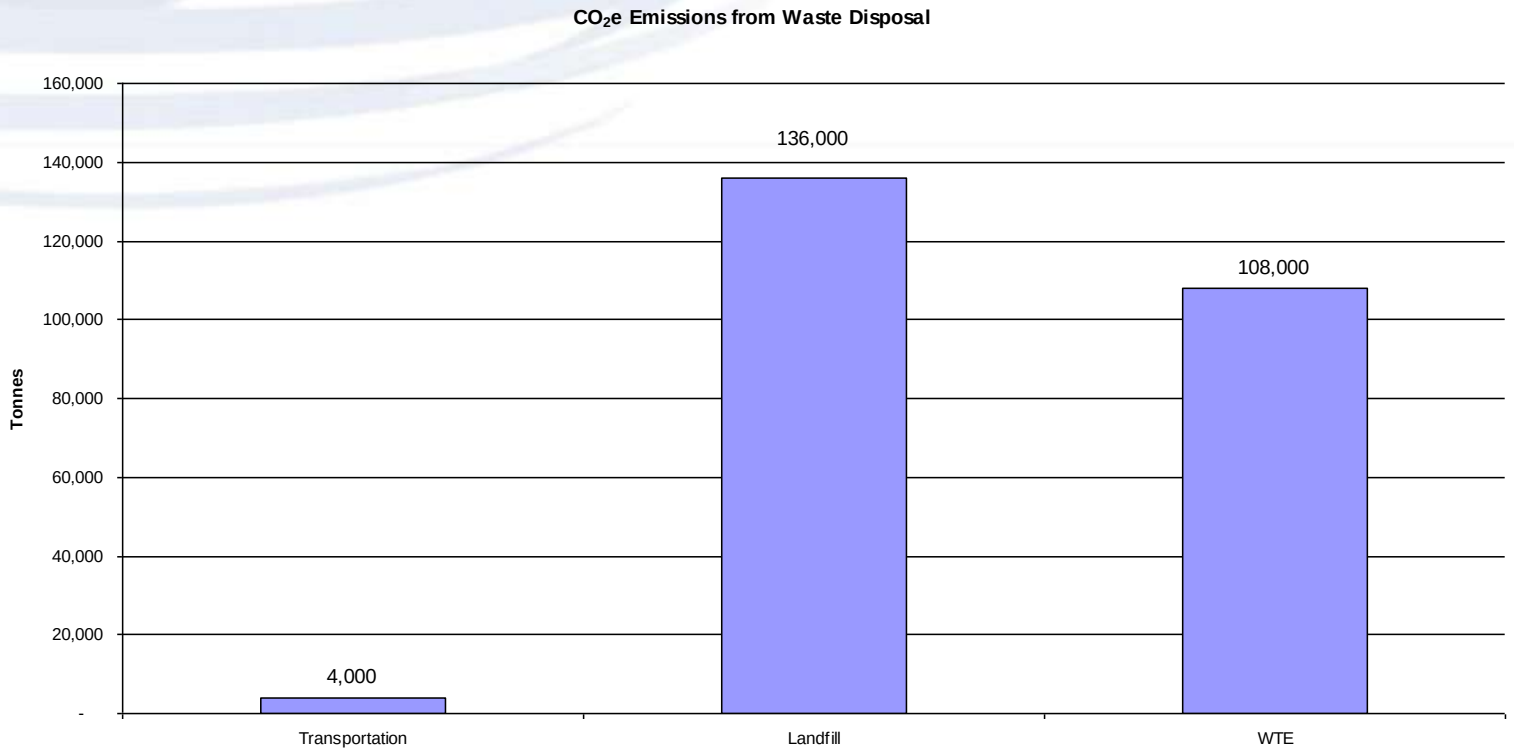
Ffact Management Consultants. Waste to Energy and the revision of the Waste Framework Directive. Opportunities to reduce climate change by using energy from waste. FF/KW/2006.023-final. Delft, January 2007

Carbon Dioxide (CO_2)

- WTE emits CO_2 like any other combustion process
- 40 to 60% is biogenic and is therefore part of the active carbon cycle
  - Unlike CO_2 from fossil fuels, this does not count as contributing towards climate change
- Electricity from WTE reduces the need to generate power from other sources (fossil fuels, nuclear)
- Generally, WTE results in less CO_2 equivalents than landfilling
- One European study calculated that in the EU:
  - WTE emits 0.348kg CO_2 eq. / kg of waste
  - Landfills emit 0.69 kg CO_2 eq. / kg of waste

CO_2 of Transportation and WTE



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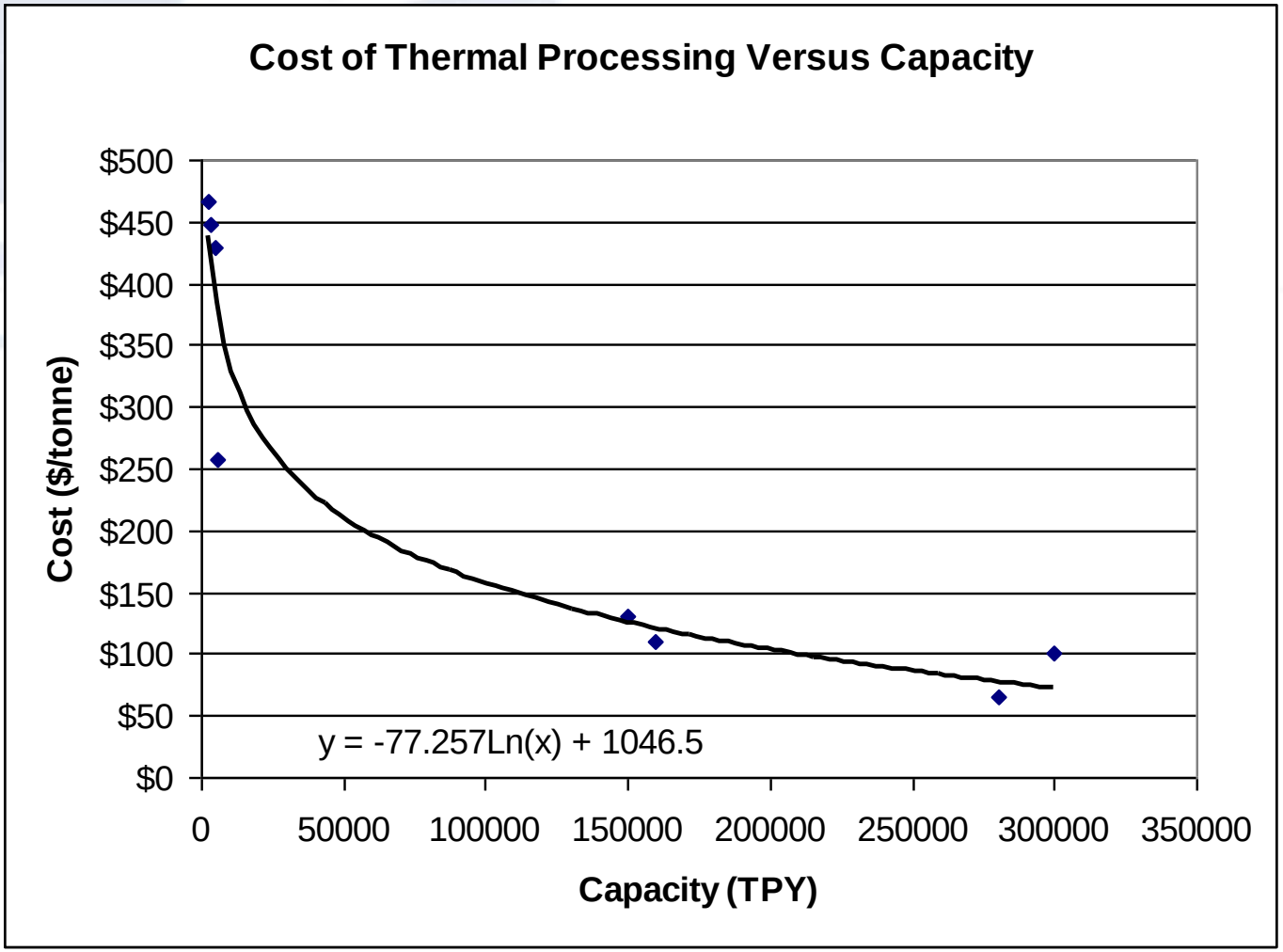
Costs of WTE

- High initial capital costs
- Operating costs generally offset by energy sales (for larger facilities)
- Tipping fees must generally cover capital repayment
- Once paid for, WTE can be revenue generator
- Facility life 20 to 50 years

Revenues from WTE

- Tipping fees
- Electricity sales
- Steam sales (cogeneration, if available)
- District heat (if feasible)
- Recycled metals from ash or upfront processing
- CO_2 credits (future)

Economies of Scale for WTE



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Political/social acceptance of WTE as diversion

- Europe
  - In practice used as diversion
  - Looking for official recognition to capitalize on tax credits
- USA
  - In some states considered renewable fuel
  - In other states not recognized as diversion
- Japan
  - Over 90% of solid waste combusted, mostly for energy
- Canada
  - Alberta recognizes WTE as diversion, Ontario does not, BC is undecided

Issues: Opposition and hurdles

- Negative public perception
- Lack of public awareness of technological progress and high regulated standards
- Large initial investment needed
- Higher operating costs than most local landfills
- Need for long term waste supply contracts

Issues: Opposition and hurdles (2)

- Full cost accounting and long term benefits rarely considered
- Waste has not yet been defined as renewable energy in Canada
- GHG credits are difficult to define and do not flow into the economics calculations

Current use of thermal treatment

- In Canada:
  - Burnaby, BC
    - 280,000 TPY, mass burn
  - Quebec City, QC
    - 280,000 TPY, mass burn
  - Algonquin Peel, ON
    - 150,000 TPY, multiple unit modular
  - Wainwright, AB
    - 6,000 TPY, single unit modular

Burnaby, BC Mass Burn Facility

- 800 tonnes per day

Burnaby Mass Burn Facility

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Algonquin Peel Modular System

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Wainwright Modular Facility

Wainwright Facility

- Showing the process steam line for energy utilization

WTE in the USA

- 65 mass burn plants
  - 20 million tonnes per year capacity total
- 9 modular and 10 RDF plants
  - About 5 million tonnes per year capacity
- 15 RDF plants
  - 6 million tonnes per year
- 13% of USA waste managed by WTE

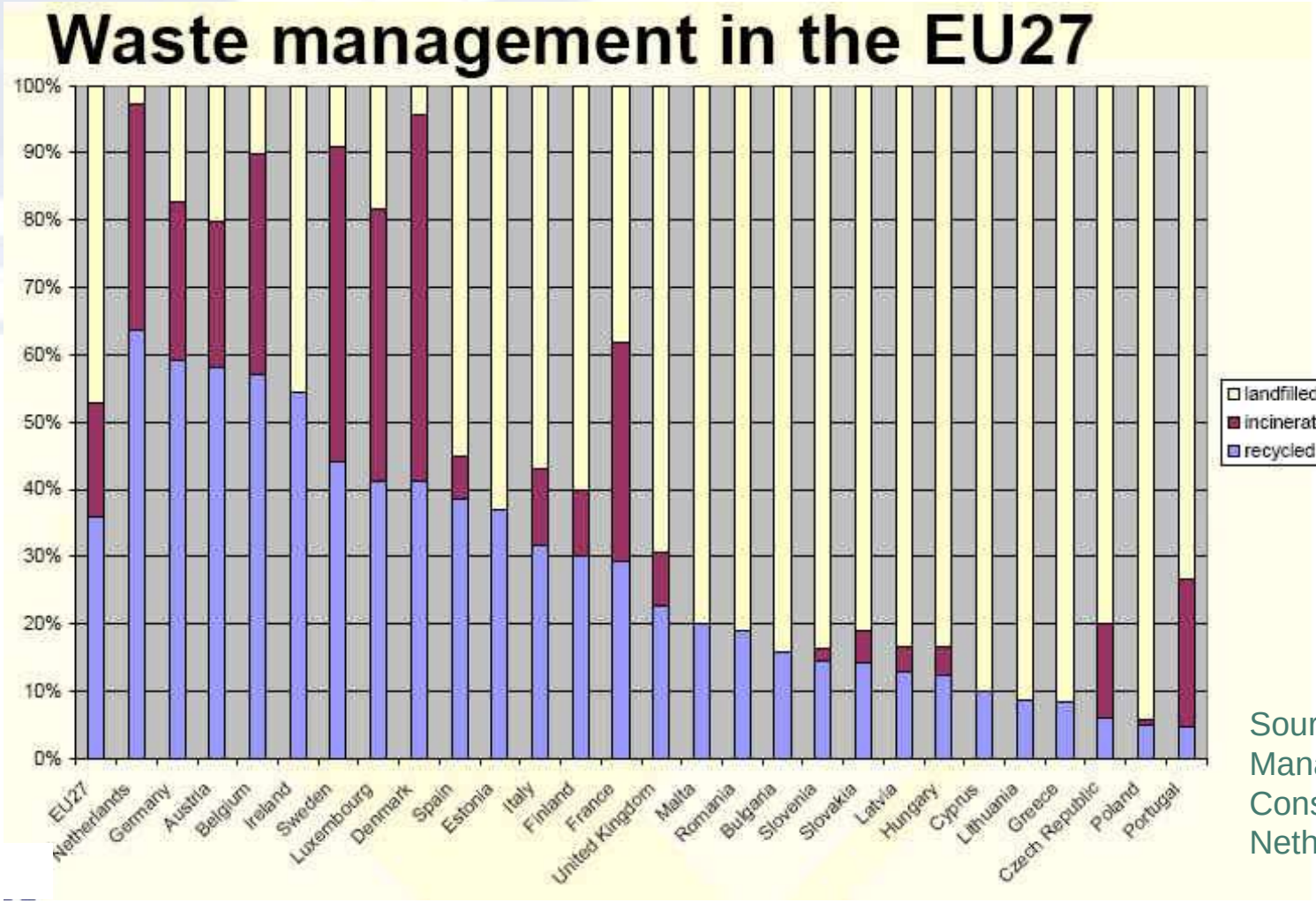
Comparison of WTE with selected Renewable Energy Sources in USA

- Energy Source
  - Geothermal
  - WTE
  - Landfill gas
  - Wood/biomass
  - Solar thermal
  - Wind
- % of Renewable energy
  - 28%
  - 28%
  - 14%
  - 17%
  - 2%
  - 11%

WTE in Europe

- More than 370 WTE plants with total annual capacity over 53 million tonnes
- Average EU recycling rate 36% - long term goal 60%
- EU WTE rate 17%
- Landfilling in EU 48%
- Landfill Directive progressively prohibits landfilling of organic materials
- High cost of energy = good revenue from heat and electricity
- Carbon credits enhance economics of WTE and help meet national reduction goals

WTE, Recycling and Landfilling in Europe



Source: Fact Management Consultants, Netherlands

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Isle of Man, UK

- 200 tonnes per day

Lille, France

Karlsruhe, Germany

- Gasification Plant (shut down, but similar operating facilities in Japan)

Paris, France

- 350 tonnes per day

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Vienna Austria

- Designed by famous artist Hundertwasser

The Japan Experience

- Very strict land disposal guidelines
  - No raw waste
  - No ash without stabilization
- Over 90 % of solid waste combusted, mostly with energy recovery
- 2300 combustion facilities in Japan
- 23 WTE facilities in Tokyo
- High standards for social integration and environmental performance
- Double typical north American/European costs

Japanese WTE and Sludge burning plants side by side

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Future of thermal treatment

- Rising energy costs will make WTE attractive for power generation/heat utilization
- Increasing costs and long-term environmental concerns with landfills will support WTE
- Energy recovery increasingly recognized as logical and integral part of WM process
- Waste increasingly recognized as renewable energy with GHG benefits
- European legislation supports WTE as opposed to landfilling

Future challenges of thermal treatment

- Education required to achieve a balanced public perception and acceptance
- Increasing thermal efficiencies
- Finding markets for heat
- Reducing operating costs and increasing revenues from sale of energy
- Regionalization required to achieve economies of scale
- Regulatory and policy support needed
- Acceptance of WTE as renewable energy

Remember,

WASTE TO ENERGY

NOT

ENERGY TO WASTE