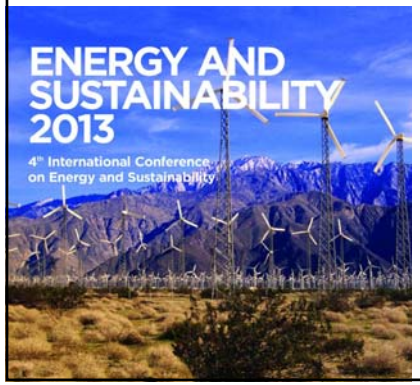
Sustainability of combustion and incineration of renewable fuels – example of Sweden



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The structure of this presentation

1. Introduction
2. Purpose and scope
3. Termo-chemical renewable energy utilization in Sweden
4. Legal aspects
5. Metabolism of combustion and incineration
6. Discussion and conclusions

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Is renewable energy sustainable?

- Tempting to conclude that the answer is yes
- But renewable energy is not sustaianble - at least not entirely - unless
  - Health and environment is protected
  - Associated other resources are protected and preserved, e. g. matter (materials) involved
  - Utilization is reasonably efficient – or else inefficiency may have to be compensated for by the use of non-renewable resources

Metabolism of an energy system

- Boundaries of energy system must be clearly defined in any system analysis
- Any thermochemical energy systems comprises
  - Energy and energy flow
  - Matter together with flow of matter
- Analyses must be comprehensive & include – or at least recognize – all parts of the system
- An energy system is a subsystem of the anthroposphere

Moving target

- The utilization of renewable thermochemical energy is undergoing extensive and rapid changes
- The relations between the various parts of such an energy system are complex
- =>
  - Difficult to obtain a comprehensive perspective
  - Easy to sub-optimize

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Purpose of the present work

- To illuminate important relations with regard to sustainability in a system of renewable thermochemical energy utilization

Scope of the present work

- Background on Swedish situation in a European perspective
- Legal aspects, including waste & by-products
- Fuel – combustion - flue gas cleaning – ash
- Analysis & discussion

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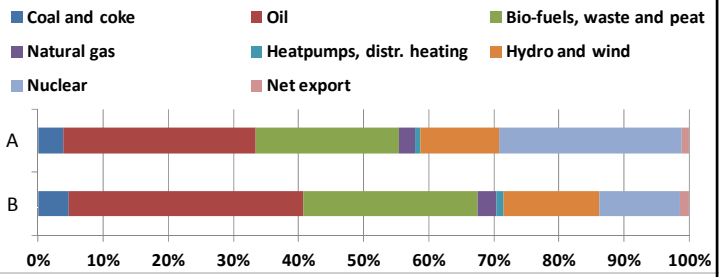
Energy input to Sweden in the year 2011

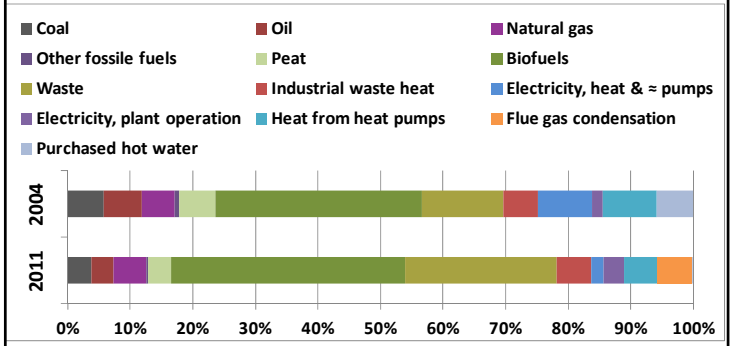


A: nuclear energy figured as total heat
B: nuclear energy figured as electricity output

Energy consumption in Sweden

- High as a result of
  - a cold climate in combination with
  - an energy intensive industry
- Champion in the world with 6.4 MWh/capita of nuclear electricity
  (see presentation at the previous conference)
- Champion in Europe with ≈ 40 % energy from renewable sources
  (Finland and Latvia second with ≈ 33 %)
- District heating: 6 MWh/capita & about half of the domestic and occupational heating

The Swedish district heating plants – sources for heat and electricity generation



Incineration (total population ≈ 9 M)

- Volumes of waste incinerated annually
  - 2.2 million tonnes of domestic waste
  - 3 million tons of other waste
- Value of incineration service:
  - ≈ 50 % for the destruction service, and
  - ≈ 50 % for the heat and electricity
- As a result of mainly incineration in combination with recycling (including ash), the volumes landfilled have decreased from
  - 6.1 Million tonnes in 1994
  - to only 1.5 million tonnes in 2011

Ash generation

- Ash content highly variable between the fuels
  - 0.5 % by weight in stem wood
  - ≤ 30 % by weight in waste
- A total of ≈ 1.5 million tonnes of ash are generated annually, mostly from incineration
- Most of it is utilized as construction and stabilization material in landfills
- Some is actually landfilled
- Only ≈ 2 % of all the ash is returned to the forest as a nutrient

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Purpose of legislation & permitting

- To protect health and the environment
- To support a sustainable development by facilitating
  - Recycling
  - Conservation of materials and energy
- To support the proportionality principle (e g with regard to cost)

⇔ allowance for companies to develop most practical solutions

Historically, many ideas on waste and by-products

- From previous directive of waste (annex 1) "*Categories of waste*":
  - "*Production or consumption residues not otherwise specified below*" …
  - "*Any materials, substances or products which are not contained in the abovementioned categories*"
- Recycled waste must be identical to product made of virgin material
- Recycled waste must contain no impurities
- Non-waste status only after put to use

Present EU directive of waste: Production residue is a by-product

a) *"further use of the substance or object is certain;*
b) *the substance or object can be used directly without any further processing other than normal industrial practice;*
c) *the substance or object is produced as an integral part of a production process; and*
d) *further use is lawful" ...*

Present EU directive of waste: Waste has become a product

a) *"the substance or object is commonly used for specific purposes;*
b) *a market or demand exists for such a substance or object;*
c) *the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and*
d) *the use of the substance or object will not lead to overall adverse environmental or human health impacts"*

Ongoing work at the EU Commission

- To issue EU regulations for various categories of waste in support of differentiation between waste and product
- The Commission has commissioned their Joint Research Centre to prepare the knowledge base needed
- Interim result on fuels: "*In case such criteria for the end-of-waste status have not been set at community level, Member States may decide case-by-case whether certain waste has ceased to be waste, taking into account the applicable case law*"

Swedish court case M7546-08 on a residue from reprocessing of paper

- Residue containing cellulose fiber together with ≈ 30 % plastics
- Company intended to burn bark together with residue in existing facility at site
- Main issue if residue is waste or by-product
- Lawyer focussed on rulings of EU court of justice
- County Authority & EPA focussed on technical issues, e. g. generation of dioxin
- No real attempts by lawyer to prove that classification as a product would render at least as good a protection of health and environment as that as waste
- EPA pointed out that classification as a product would provide no obstacle for the supervisory authority to prescribe appropriate precautionary measures

Ruling of the highest Environmental court in Sweden

- The residue is waste
- Consequence for the company: mainly to install monitoring equipment
- Will the ruling constitute a ”stopper” against classification as product & by-product?
- To be discussed at the end of this presentation

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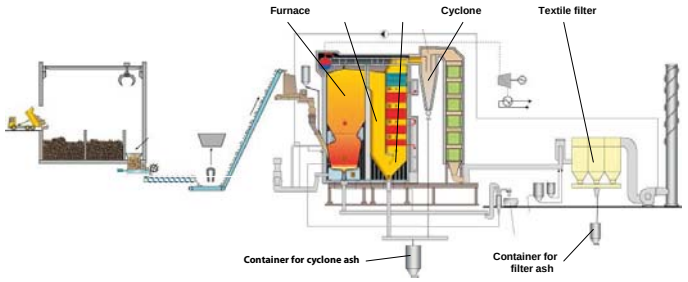
Example of district heating incineration facility

Torsviksverket
operated by
Jönköping Energi AB
at Jönköping
in southwest Sweden

Fly ash and other ashes



Fractional condensation of volatile elements and compounds.
Partial melting of the ash and consequent formation of reactive glass phase

Metabolism of combustion and incineration

- Complex systems
- Intensive research for many years
- Last ten years work in Sweden reviewed
- Parameters selected such that
  - All combustible matter oxidized
  - All burnable contaminants destroyed

Chlorine

- Associates to other elements differently
  - At different temperatures
  - At different water contents
- Associates itself readily with K, Na and Ca
- but also to e g Zn and Pb which renders them volatile in a furnace environment (⇔ enrichment in scale on tubes)
- Chlorine not balanced by other elements remains in fumes as HCl
- HCl removed by wet scrubbing or flue gas condensation

Sulphur

- Stable valence +IV at high temperature and +VI at low
- Tendency to oxidize at low temperature
  - Inefficient in the gas phase
  - Catalyzed by certain transition metal oxides
- Sulphur +VI is as esily removed as HCl
- Sulphur +IV is removed by
  - semi-dry or wet scrubbing
  - flue gas condensation alone not sufficient

Chlorine and sulphur

- Not only individual abundance but combination
  <= melting point minimum for ash
- => Cl/S ratio should be sufficiently low
- => fuel rich in Cl (e g domestic waste) is mixed with fuel rich in S (e g sewage sludge)

Transition and heavy elements

- Are partitioned between bottom and fly ash, differently for different elements, but usually higher concentrations in fly ash
- Are effeciently removed by electrostatic and mechanical filters used to capture the ash
- Presence varies with the type and source of the fuel, e g
  - As originates mostly from CCA-impregnated wood
  - Cu and Pb from cables & wiring

Possibility to use the ash

- Most important factor is presence and chemical form of transition and heavy elements
  (presentation on this at Waste Management 2012)
- Important also chemical & physical form of the ash

⇔Concentration of contaminants into minor fraction of the ash is important

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Characteristics of a sustainable system for thermochemical energy from renewable sources

1. protection of health and the environment
2. sustainable with regard to
   a) the fuels that should be renewable
   b) the substances exiting the system that should as far as is possible and reasonable be reused and re-circulated in the anthroposphere
3. efficient and cost effective

Sustainable fuels?

- Wood and paper are renewable fuels
- Measurements on fossil carbon content in waste varies, but examples include
  a) 12,6 %, and
  b) ≈ 2 %
- Fate of plastics
  - Feasible to incinerate – efficient energy utilization
  - Difficult to recycle as a material
  - Landfilling realistic but ≠ recycling
- Many unpleasant substances are destroyed
- Thus largely sustainable

Sustainable ash utilization?

- Not only fraction of total that is being recycled but quality in use
- Quality of utilization ⇔ content of contaminants is usually the bottleneck
- Requires qualification (e g sorting) of the fuel
  - Not only with regard to incinerator operation
  - But also to ash quality

Waste legislation & utilization

- Legislation for waste mainly directed towards protection
- Protection different in different cases
  - Classification as hazardous and non-hazardous is based on **content** of hazardous substances
  - Acceptance for landfilling is based on **availability** (leachability) of potentially detrimental elements
- => Waste legislation imprecise for utilization of ash and qualification of fuels

Product legislation & utilization

- CLP & REACH
- Tailored for utilization
- But additional legislation applies for incineration of waste

Is the court case a ”stopper”?

- Case mentioned by the court as an important presedent
- Health and environment has to be adequately protected regardless of classification as waste or by-product
- => Classification as product no easy fix to avoid responsibility

Is the court case a ”stopper”?

- Ruling does not mean that classification as product / by-product cannot be done in Sweden
- Instead it is for the owners and operators of the facilities to decide whether they wish to
  - qualify a fuel or an ash as a product now, or
  - await further developments at the EU Commission

Conclusions

- Sweden is the Champion, at least in the EU, on the utilization of renewable energy
- This practice is also sustainable
- Improvements are possible with regard to the substances exiting the system
- This requires e g further integration
  - between different areas of technical expertise: fuel, combustion and ash utilization, as well as
  - between lawyers, engineers and scientists

Acknowledgements

- Financial support for this work has been received from *The District Heating of Sweden*
- who have also consented to open publication of this material
- The work was carried out in collaboration with Signe Lagerkvist
  - who is a lecturer at the *Department of Law* at *Umeå University*
  - and who is now also affiliated to the *Land and Environment Court* at the *Umeå District Court*

Acknowledgements, continued

- This work is based on more than ten years of research financed by
  - The *Thermal Engineering Research Institute* (*Värmeforsk*)
  - The *Swedish Waste Management* (*Avfall Sverige*)
  - *Svenska Energiaskor AB* (which translates to: "Swedish Energy Ashes Inc.“)
  - *The District Heating of Sweden*
- Any inadequacies ⇔ the author