Outotec in a nutshell
Local operations, global presence

Wide supplier network with established long-term relationships

- 4,200 employees
- Deliveries to more than 80 countries
- Experts of over 60 nationalities
- Sales MEUR 1,058 in 2016
- R&D, sales and service centers in 34 countries

Sales split:
- Metals related solutions, 72%
- Energy & environm. solutions, 12%
- Other materials, 16%
60 years of fluidised bed technology

BFB = Bubbling Fluidized Bed

CFB = Circulating Fluidized Bed

[Diagram showing fluidized bed technology with labels for BFB and CFB]
Outotec Fluidized Bed technology in various applications

- Alumina calcining
- Iron ore reduction
- Gold roasting
- Zinc roasting
- Combustion
- Gasification
Type of Technology, applicability to hazardous wastes?

Each fuel / waste has it’s “own / best” technology:

1. (Untreated) Municipal Waste → Grate Furnace
2. RDF, biomass, pretreated waste → Grate Furnace or Fluidized Bed
3. Hazardous Waste → Rotary Kiln
4. Hospital Waste → Rotary Kiln or small standardized units
5. Sludge → Stationary Fluidized Bed
6. Larger power stations → Circulating Fluidized Bed
Is Gasification/Pyrolysis an alternative?

There are a lot of examples in the past that alternatives of waste treatment failed, especially if they tried to produce a clean fuel gas:

1. Thermoselect
2. Siemens Schwel-Brenn-Verfahren
3. Noell KRC

And now 20 years later ➔ Teeside plasma gasification technology

Financial Times 05. April 2015

“Teeside investor drops £300m renewables project”
Thermal processing in Outotec's fluidized bed

Bulk materials:
- Sludge
- Biomass
- RDF / Rejects
- Oil Shale
- … and others

**Tailored design:**
- Bubbling or circulating FB
- FB thermal oxidizers
- FB advances stage gasifier
- FB gasifiers

Applications:
- Power Production
- Process Heat
- Fertilizer
- Environment
Size and Cost of Plants
Size for sludge incineration plants

- Minimum economical feasible
  - 30,000 t/a (10,000 tDS/a)

- Largest single line: Lünen/Germany
  - 360,000 t/a (100,000 tDS/a)

- Largest plant in EU: Moerdijk/Netherlands
  - 420,000 t/a (110,000 tDS/a)
Size for WtE plants

- RDF Throughput: 50,000 – 400,000 t/a
- Electrical production: 5 – 40 MWel
Costs

• Sludge incineration plants:
  Gate Fees 50 – 120 €/t dewatered sludge
  Good designed plants are operating without supporting fuel and producing enough electricity for own consumption

• WtE plants:
  Gate Fees 20 – 70 €/t RDF +
  income from electrical production (subsidized if gate fee is too low) +
  income from heat supply (e.g. district heating)
Cost for Waste to Energy cases (WtE)

Rough capex cost (full EPC cost in Europe) according to the graph (+/- 30%)

O&M cost (annual) roughly 5% of capex price including both Outotec O&M and customer’s costs, like insurance, grid connection, etc.
Electricity generation and sales revenues I

Quick calculation of project output:

Case facts:

Fuel: 200 000 t/a waste with CV 12MJ/kg
Gate fee: 50 €/ton
Electricity price: 80 €/MWh (8 €/cent/kWh)

Output calculation:

Waste per h throughput: 200 000 / 7500 = 26,7t/h → 7,41kg/s
Electricity output: 7,41*12*efficiency = 22 – 24MW from generator terminals
Note: efficiency 25 – 27,5% depending on the equipment selection, location, fuel, etc.

Net electricity output: ~80% of gross = 0,8 * 22 – 24MW = 17,6 – 19,2MW
Electricity generation and sales revenues II

Income:

Electricity: 7500h/a * 19,2MW * 80€/MWh = 11,52M€
Gate fee: 200 000 * 50€/ton = 10M€
Total income: 22,5 M€

Cost:

Capex cost: 6 M€/MW (for 24 MW gross) * 24 MW = 144 M€
Opex cost: 5% of capex = 7,2 M€ / a

Case economics:

Income: 22,5 M€
Opex: - 7,2 M€
Depreciation: - 14,4M€ / a (10 years)
Profit: 0,9M€ / a, would this be enough to invest?
Staffing for Incineration Plants

• Administration: Manager, Secretary, Bookkeeping
• Head of operation
• Process engineer
• Electrical engineer
• Instrumentation and Control engineer
• 3-5 operators per shift
• 2-5 for maintenance
• 2-3 helpers on day shift

Examples
• SNB Brabant Moerdijk: Total 45 employees
• Zurich in combination with WWTP: Total 9 employees
Plants in the world and in Turkey
(Selected References)

**Massafra, Italy:**
Technology: BFB
Fuel: RDF
Year: 2013
Data: 60.5 tph steam, 46 Bar, 400° C

**Plainfield Renewable energy**
Technology: Advanced Staged Gasifier
Fuel: Wood, C&D waste
Year: 2013
Data: 55 t/h 108 bar, 512 C

**Hereford, Texas USA**
Technology: BFB
Fuel: Cattle manure and Cotton gin waste
Year: 2008
Data: 104.6 MWh, 121.1 tph steam, 10.67 Bar

**ERZ Zurich**
Technology: Sewage sludge Incineration plant
Fuel: 100 kt/a of sewage sludge
Year: 2015
Data: Full EPC delivery 0.9 MWe + 5 MWth

**Enefit, Estonia**
Technology: CFB
Fuel: Oil shale
Year: 2012
Data: 290,000 t oil /a, 35 MW, 126 tph, 450 C, 41 bar

**Modern Karton, Turkey**
Technology: BFB (EPC)
Fuel: 450 kt/a
Biological- and paper sludge, rejects
Year: 2015
Data: 30 MWe
96 t/h @ 530C, 62 bar
Municipal sewage sludge, Swiss

Fuel: Sewage sludge
Throughput: 100,000 t/a
Steam: 9 t/h, 450 °C, 60 bar
Heat: 5 MWth
Completion 2016
Residues from paper industry, Turkey

Fuel: Rejects and sludge
Throughput: 400,000 t/a
Steam: 95 t/h, 530 °C, 60 bar
Turbine: 28 MW_{el}
Completion: 2015
RDF incineration plant, UK

Fuel: RDF
Throughput: 100,000 t/a
Steam: 54.6 t/h, 400 °C, 46 bar
Turbine: 12.6 MWel
Completion: 2017
Emissions
# Typical Raw Gas Emissions for a Fluidized Bed Sludge Incineration Plant

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>0 - 50</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>SO₀ as SO₂</td>
<td>1'500 – 5'000</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>HCl</td>
<td>100 – 500</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>HF</td>
<td>0.5 – 5</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Dust</td>
<td>50’000 – 100’000</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>TOC</td>
<td>0 – 10</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>NO₀ as NO₂</td>
<td>40 – 400</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Cd + TI</td>
<td>Fixed on dust</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Hg (30-50% as Hg°)</td>
<td>0.5 -1.5</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V</td>
<td>Fixed on dust</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Dioxin/Furan as T. E.</td>
<td>&lt;&lt; 0.1</td>
<td>ng/m³ STP</td>
</tr>
</tbody>
</table>
# Emission Limit Values for Flue Gas

<table>
<thead>
<tr>
<th>Parameter</th>
<th>EU (daily average)</th>
<th>Switzerland (daily average)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>50</td>
<td>50</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>SO(_x) as SO(_2)</td>
<td>50</td>
<td>50</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>HCl</td>
<td>10</td>
<td>20</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>HF</td>
<td>1</td>
<td>2</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Dust</td>
<td>10</td>
<td>10</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>TOC</td>
<td>10</td>
<td>10</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>NO(_x) as NO(_2)</td>
<td>200</td>
<td>80</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>NH(_3)</td>
<td>10 (with SNCR)</td>
<td>5</td>
<td>mg/m³ STP</td>
</tr>
</tbody>
</table>

### During sampling time

<table>
<thead>
<tr>
<th>Parameter</th>
<th>EU (daily average)</th>
<th>Switzerland (daily average)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd</td>
<td>0,05</td>
<td>0,1</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Cd + Tl</td>
<td>0,05</td>
<td></td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Hg</td>
<td>0,05</td>
<td>0,1</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Pb + Zn</td>
<td></td>
<td>1</td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V</td>
<td>0,5</td>
<td></td>
<td>mg/m³ STP</td>
</tr>
<tr>
<td>Dioxin/Furan as T. E.</td>
<td>0,1</td>
<td>0,1</td>
<td>ng/m³ STP</td>
</tr>
</tbody>
</table>
Time Schedule
### Time Schedules for different Sludge Incineration Plants (selected, typical)

<table>
<thead>
<tr>
<th>Plant Location</th>
<th>Tender</th>
<th>Contract Effective</th>
<th>Start of Erection</th>
<th>First Sludge incinerated</th>
<th>PAC Provisional Acceptance Certificate</th>
<th>Period from order until first sludge (month)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>05.2002</td>
<td>12.2002</td>
<td>03.2004</td>
<td>03.2007</td>
<td>06.2007</td>
<td>51</td>
<td>incl. 12 month permitting</td>
</tr>
<tr>
<td>Russia</td>
<td>05.2004</td>
<td>01.2005</td>
<td>09.2005</td>
<td>07.2007</td>
<td>05.2008</td>
<td>30</td>
<td>3 month delay building permit</td>
</tr>
<tr>
<td>UK</td>
<td>04.2006</td>
<td>04.2007</td>
<td>06.2008</td>
<td>11.2009</td>
<td>01.2010</td>
<td>31</td>
<td>delay on cooling water (client)</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>05.2009</td>
<td>10.2010</td>
<td>01.2012</td>
<td>04.2015</td>
<td>05.2016</td>
<td>54</td>
<td>large and complex plant</td>
</tr>
<tr>
<td>China (tender spec.)</td>
<td>11.2015</td>
<td>03.2016</td>
<td>05.2017</td>
<td>08.2017</td>
<td>12.2017 (incl. 3 months operation)</td>
<td>17</td>
<td>unrealistic challenge</td>
</tr>
</tbody>
</table>
Simplified Time Schedule, SIP Zürich

**TENDER PHASE**
- Proposal Evaluation (ERZ)
- Contract Award (ERZ)
- Application for Planning Permission
- Examination by Authorities (Zürich)
- Regular Referendum (Zürich)

**ENGINEERING**
- Team Lineup
- Constitutive Organisation
- Basic Engineering
- Detail Engineering / Process
- Detail Engineering / Mechanical
- Detail Eng. / Piping + Valves
- Detail Engineering / Elecr., Instr. + Control
- Detail Eng. / Solid + Steel Structure

**PROCUREMENT / DELIVERY**
- RFQ and Award Procedure
- Civil Subcontracting
- Process Equipment
- Piping + Valves
- Electrical, Instrumentation + Control

**SITE / CONSTRUCTION**
- Excavation and Fundament Works
- Building Construction
- Assembly Process Equipment
- Installation Piping + Valves
- Installation Electrical + Control
- Erection of Insulation

**COMMISSIONING**
- Cold Commissioning
- Warm Commissioning
- Operating Test + Performance Tests

**COMPLETION PHASE**
- As-built Documentation, Final Works
- Warranty Period

- Application for Planning Permission
- Provisional Building Permit, 19.02.13
- Final Building Permit, 12.03.13
- Approval by Referendum, 03.03.13
- Full Validity of Contract
- HAZOP Study
- Corner Stone Ceremony
- Start of Commissioning
- Commercial Operation / Import of all Sludge

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Local Supply
Possible localization from the total investment

- Min local (civil, structural steel, design institute, Utilities, …)
- Min import (technology equipment, engineering)

Depending on the financial model, the degree of import / localization may differ.
Zurich: Incinerator Shell fabricated in Turkey
Zurich: In operation on time & on budget !!
How to come to best Lifetime cost
Optimization of Lifetime Cost should be considered during planning

- **Electrical power**
  (if power consumption of the plant is higher than production, costs for electrical power import are relevant)

- **Possible benefit of heat export** (district heating, etc.)

- **Unit rates for other consumables** (water, gas, ...)

- **Unit rates for chemicals** (NaOH, Ca(OH)$_2$, ...)

- **Unit rates for disposal of residues** (ash, residues, waste water, ..)

- **Depreciation period**

- **Interest rates**

- **Staff costs**

Specific costs and possible benefits to be defined within tender
Issues related to site selection

Waste to Energy Plants:

1. **Transport**: Access to roads and close to waste collection area
2. **Energy connection**: District heating net or other heat consumer available
3. **Airport**: Could have an influence on stack height

Sludge Incineration:

1. **Transport**: Dewatered sludge contains 70-80% water ➔ Transport should be short as possible, best location would be the Waste Water Treatment Plant (WWTP)
2. **Vapor Condensate**: For autothermic incineration sludge is predried ➔ vapor condensate has COB & BOD load which needs treatment, best location close to a WWTP
Chimney height and area covered by the plant

The chimney height depends mainly:

1. Location of the plant
2. Height of buildings around
3. Next airport
4. The immission distribution calculation based on emissions from the plant, the existing immissions, air exchange, …..

⇒ Typically values are 25 m up to 100 m
Ash Management

• Ash from sludge incineration contains 10–20 % of $P_2O_5$

• Worldwide phosphate resources are limited and located in “unsafe” areas e.g. Morocco

• Phosphate is essential for living and can not be subsidised

• Outotec’s Ashdec process converts these ashes into a marketable fertilizer
Future: P-Recovery ASH DEC Plant
ASH DEC ➔ converts Ash to Fertiliser

- P: phosphorus
- Ca: calcium
- Mg: magnesium
- Si: silicon
- Fe: iron
- Al: aluminium

HM: heavy metals (cadmium, lead, mercury and excessive loads of copper and zinc)

MgCl₂ + Ash → Process → Fertiliser

1000°C

Adam, C., 2008
Which data is needed for preparing proper investment

1. Plant Site Location and Conditions
2. Feedstock Quantity and Quality (details next slides)
3. Emission and Noise Standards
4. Required Standards (DIN, ASME, …)
5. Available Utilities
6. Battery limits
7. Scope of supply and services
8. Required storage capacities
9. Requests from authorities
10. Architectural requests
11. …
# Feedstock Quantity & Size

<table>
<thead>
<tr>
<th>缜密材料 (RDF)</th>
<th>单位</th>
<th>参考材料 (设计案例)</th>
<th>范围 (最小 – 最大)</th>
</tr>
</thead>
<tbody>
<tr>
<td>质量流量 RDF</td>
<td>t/年</td>
<td></td>
<td></td>
</tr>
<tr>
<td>质量流量 RDF</td>
<td>t/时</td>
<td></td>
<td></td>
</tr>
<tr>
<td>湿度 - 含量</td>
<td>w-%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>灰分含量</td>
<td>w-%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>热值，LHV (接收)</td>
<td>kJ/kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>热值，LHV (干燥基础)</td>
<td>kJ/kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>总热值，HHV (干燥基础)</td>
<td>kJ/kg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RDF 粒径大小</th>
<th>值</th>
<th>单位</th>
<th>备注</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>&lt; 100</td>
<td>mm</td>
<td>最大尺寸在所有三个维度</td>
</tr>
<tr>
<td>90%</td>
<td>&lt; 75</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>低于 10%</td>
<td>&lt; 6</td>
<td>mm</td>
<td></td>
</tr>
</tbody>
</table>
## Feedstock Quality

<table>
<thead>
<tr>
<th>Fuel (RDF)</th>
<th>Unit</th>
<th>Reference fuel (Design Case)</th>
<th>Range (Min – Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemical Analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>% d.b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>% d.b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>% d.b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>% d.b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td>% d.b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorine</td>
<td>% d.b</td>
<td>&lt; 1.0</td>
<td></td>
</tr>
<tr>
<td>Fluorine</td>
<td>% d.b</td>
<td>&lt; 0.1</td>
<td></td>
</tr>
<tr>
<td>Ash content:</td>
<td>% d.b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>%</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Physical Property</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Bulk Density RDF</td>
<td>kg/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tramp material (Non combustibles)</td>
<td>w-% dry</td>
<td>&lt;3.5</td>
<td></td>
</tr>
<tr>
<td>Ferrous and non-ferrous metals</td>
<td>w-% dry</td>
<td>&lt;1.2</td>
<td></td>
</tr>
<tr>
<td>Glass content</td>
<td>w-% dry</td>
<td>&lt;2</td>
<td></td>
</tr>
<tr>
<td>Alkalines</td>
<td>%</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>Hg</td>
<td>mg/kg dry solids</td>
<td>&lt;2</td>
<td></td>
</tr>
<tr>
<td>Cd + Tl</td>
<td>mg/kg dry solids</td>
<td>&lt;10</td>
<td></td>
</tr>
<tr>
<td>Ash Shrinking temperature</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial ash deformation temperature</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial ash softening point:</td>
<td>°C</td>
<td>&gt; 1090</td>
<td></td>
</tr>
</tbody>
</table>
## Cost distribution percentages of plant components

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>15 – 20 %</td>
</tr>
<tr>
<td>Mechanical Equipment</td>
<td>30 – 35 %</td>
</tr>
<tr>
<td>Mechanical Equipment (proprietary)</td>
<td>5 %</td>
</tr>
<tr>
<td>Electrical and Instrumental Equipment</td>
<td>5 – 10 %</td>
</tr>
<tr>
<td>Civil and Steel Construction</td>
<td>15 – 20 %</td>
</tr>
<tr>
<td>Erection</td>
<td>10 %</td>
</tr>
<tr>
<td>Start up</td>
<td>5 %</td>
</tr>
</tbody>
</table>
Sludge Incineration Plant
Zurich / Switzerland
Proprietary Bed Cleaning and Reinjection System

Automatic removal of agglomerates or any tramp materials from the bed during continuous operation

Bed media reinjection
Bed media bucket elevator
Automatic bed drawdown system
Bed drawdown slidegates
Vibrating conveyor & screen cleans bed media