IS IT ENERGY RECOVERY – OR JUST WASTE DISPOSAL?

FACTS AND MYTHS AROUND THE INFAMOUS R1 FORMULA

NMC 2023

13th Enviromanagement Congress

„Waste Metrics“

Štrbské Pleso, High Tatras, Slovakia

October 2-3, 2023

UVP

Environmental Management and Engineering

Helga Stoiber

UVP Environmental Management and Engineering

Since the 1990s, we have been a **leading Austrian consulting and engineering company** in the field of waste management, with special focus on

- **Waste-to-energy** and **Biomass-to-energy**, including energy efficiency, air pollution abatement etc.
- Monitoring and remediation of **landfill sites and contaminated industrial sites,**
- **Waste management concepts, Studies & Reports**
- **Trainings and capacity building**



Heimo ZIMMERMANN

Albert ZSCHETZSCHE

Helga STOIBER

UVP WtE Reference Projects – Examples (1)

Concept, Feasibility Study, Basic Engineering, EIA Permitting:

RVL Lenzing 1K8 (1998)

110 MW
300,000 t/a

EVN Dürnrohr 1+2 (2003)

2 x 60 MW
360,000 t/a

ENAGES Niklasdorf (2003)

40 MW
145,000 t/a

UVP WtE Reference Projects – Examples (2)

Concept, Feasibility Study, Basic Engineering and EIA Permitting:

RHKW Linz (2012)

76 MW
275,000 t/a

Norske Skog K9 (2022)

49 MW
250,000 t/a

General Planners in Construction Phase:

SKN Nettingsdorf Black Liquor Boiler (2020)

185 t/h HP steam

UVP‘s White Books on Waste-to-Energy

BIELA KNIHA ENERGETICKÉHO ZHODNOCOVANIA ODPADOV V SLOVENSKEJ REPUBLIKE ÚDAJE, ČÍSLA, FAKTY

AUSTRIA (1999, 2009, 2015)

https://www.bmk.gv.at/themen/klima_umwelt/abfall/Kreislaufwirtschaft/verwertung/studien/weissbuch.html

SLOVAKIA (2020)

https://www.ewia.sk/wp-content/uploads/2021/03/biela-kniha.pdf

ENERGY EFFICIENCY

Energy Efficiency of Waste Incineration (1)

1. **Energy Efficiency = Output / Input**

2. This applies
   - to electricity: **Electrical Energy Efficiency**
   - to heat: **Thermal Energy Efficiency**
   - to both: **Overall Energy Efficiency,** also called "**Energy Utilization**"

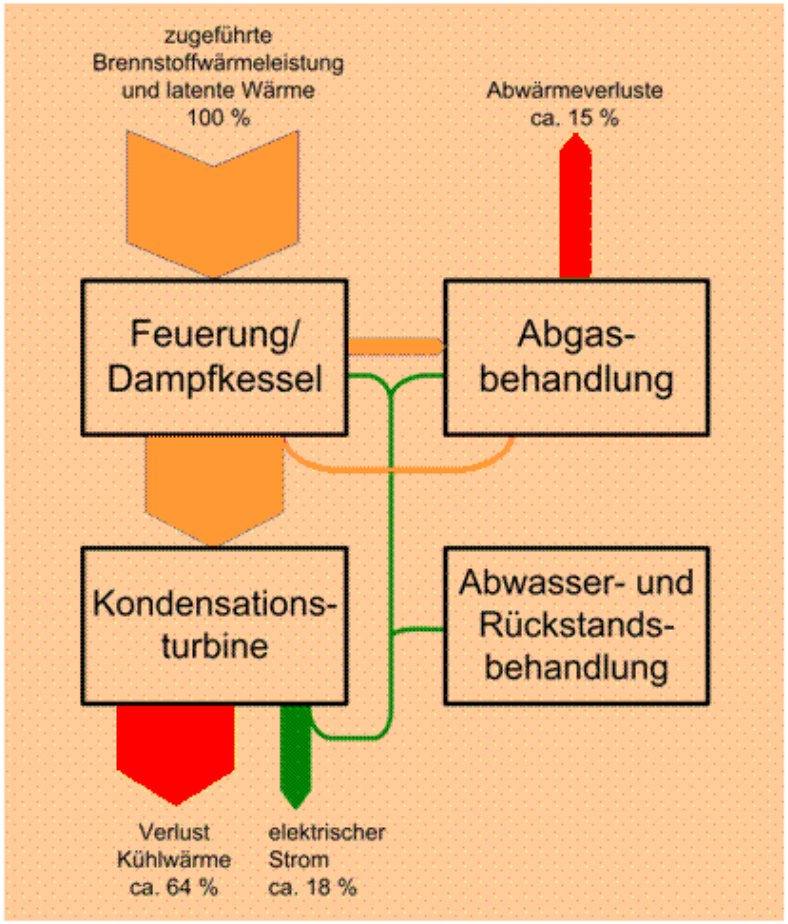
   For all of them applies:

3. **Gross Energy Efficiency** includes **all energy produced**, also the installation's own energy consumption.

4. **Net Energy Efficiency** includes **only the energy that is delivered to external consumers.**

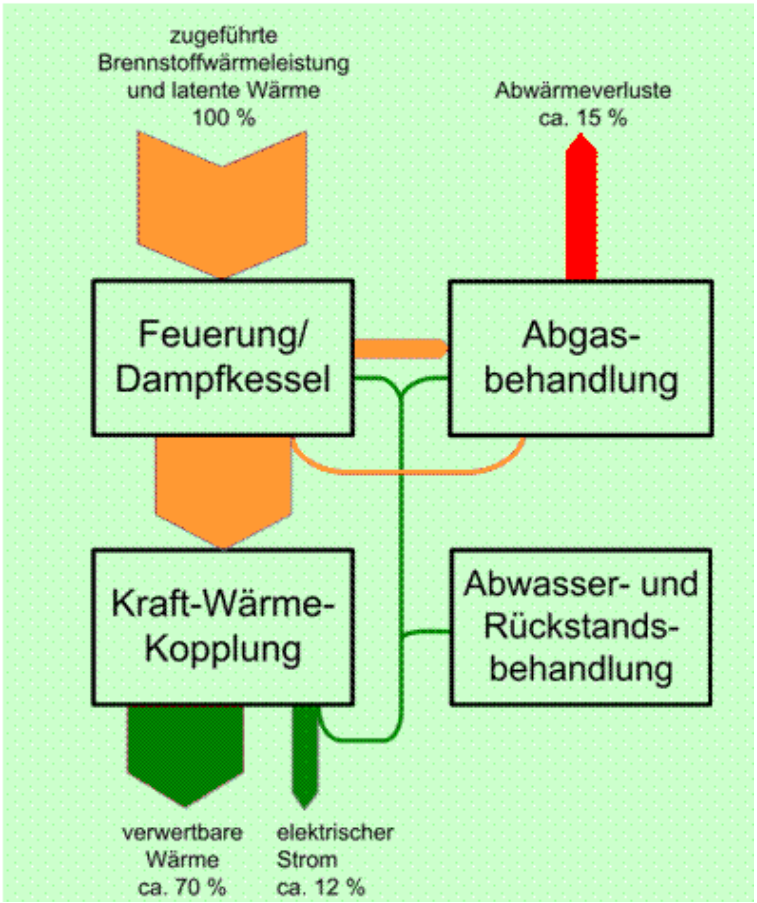
Energy Efficiency of Waste Incineration (2)

WI with Condensing Turbine



Energy utilization 20 %,
modern installations up to 26 %

WI with CHP



Energy utilization approx. 80 %,
with Flue Gas Condensation and
Heat Pump > 100 % possible

Determination of Energy Efficiency in WI

Various standards exist for the determination of („true“) energy efficiency values, e.g.

- German standard
  VDI 3460 Part 2 “Emission control - Thermal waste treatment - Energy conversion” (2014)

- European standard
  DIN EN 12952-15 “Water tube boilers and auxiliary installations - Part 15: Acceptance tests” (2003)

- Guidelines by German FDBR Fachverband für Dampfkessel-, Behälter und Rohrleitungsbau e.V. (Association for Steamboiler, Container and Piping Construction)
  FDBR-Richtlinie „Abnahmeversuche an Abfallverbrennungs-anlagen mit Rostfeuerung“ („Acceptance Tests for Grate-fired Waste Incinerators“) (2000)

R1 FORMULA

History of the R1 Formula (1)
Disposal and Recovery

(1975)

Directive 75/442/EEC on Waste
(No longer in force → replaced by WFD 2008/98/EC)

ANNEX IIA
DISPOSAL OPERATIONS

ANNEX IIA

DISPOSAL OPERATIONS

NB: This Annex is intended to list disposal operations such as they occur in practice. In accordance with Article 4 waste must be disposed of without endangering human health and without the use of processes or methods likely to harm the environment.

D 1 Deposit into or onto land (e.g. landfill, etc.)

D 2 Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)

D 3 Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)

D 4 Surface impoundment (e.g. placement of liquid or sludgy discards into

(...)

D 10
Incineration on land

ANNEX IIB
RECOVERY OPERATIONS

ANNEX IIB

RECOVERY OPERATIONS

NB: This Annex is intended to list recovery operations as they occur in practice. In accordance with Article 4 waste must be recovered without endangering human health and without the use of processes or methods likely to harm the environment.

R 1 Use principally as a fuel or other means to generate energy

R 2 Solvent reclamation/regeneration

R 3 Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)

R 4 Recycling/reclamation of metals and metal compounds

(...)

R 1
Use principally as a fuel or other means to generate energy

History of the R1 Formula (2)
Incineration and Co-incineration

(2000)

Directive 2000/76/EC on the incineration of waste
(No longer in force → replaced by IED 2010/75/EU, Chapter IV and Annex VI)

Art. 3 „Definitions“

5. ‘co-incineration plant’ means any stationary or mobile plant whose main purpose is the generation of energy or production of material products and:

— which uses wastes as a regular or additional fuel; or

— in which waste is thermally treated for the purpose of disposal.

History of the R1 Formula (3)
Incineration and Co-incineration

(2000)

Directive 2000/76/EC on the incineration of waste
(No longer in force → replaced by IED 2010/75/EU, Chapter IV and Annex VI)

Art. 3 „Definitions“

4. ‘incineration plant’ means any stationary or mobile technical unit and equipment dedicated to the thermal treatment of wastes with or without recovery of the combustion heat generated. This includes the incineration by oxidation of waste as well as other thermal treatment processes such as pyrolysis, gasification or plasma processes in so far as the substances resulting from the treatment are subsequently incinerated.

In which case is waste incineration D10 or R1?

History of the R1 Formula (4)
ECJ Judgements on waste shipment

(2003)

Example: ECJ Judgment C-458/00 against Luxemburg

Failure by a Member State to fulfil its obligations,
raising unjustified objections to certain shipments of waste to another Member State to be used principally as a fuel

Case: Shipment of household and similar waste to France

Example: ECJ Judgment C-228/00 against Germany

Failure by a Member State to fulfil its obligations (...) on the **supervision and control of shipments of waste within, into and out of the European Community**

Case: Waste shipment to cement kiln in Belgium

→ Necessity to set up rules for distinction of R1 and D10

History of the R1 Formula (5)
Energy efficiency is relevant for BAT

(2006)

BREF WI (2006 - no longer in force, reviewed version published in 2019)

Chapter 3.5: Proceedings to determine the energy efficiency of waste incinerators

1. Define the **system/calculation boundary**
2. Account for all **energy inputs**
3. Account for **re-circulating energy flows**
4. Decide whether to simply add energy outputs or use **equivalence factors** to account for their relative value?

From:	Multiply by:			
To:	**GJ**	**MWh**	**MWh_e**	**MWh_{th}**
GJ	1	0.2778	0.1056	0.2528
MWh	3.6	1	0.3800	0.9100
MWh_e	9.4737	2.6316	1	-
MWh_{th}	3.9560	1.0989	-	1
Gcal	4.1868	1.163	0.4421	1.0583

→ **f ~ 2,6 for electricity**
→ **f ~ 1,1 for heat**

It is important to understand that equivalence values are not exact coefficients or conversion factors. They provide an estimate of the energy that is required to produce the energy externally.

History of the R1 Formula (6)
Energy efficiency is relevant for BAT

(2006)

Chapter 3.5: Formula for the Plant Efficiency Potential Pl_{ef}

The plant efficiency potential (Pl_{ef}) provides a figure that compares the energy exported from the process and the energy that the process itself requires for its operation:

$$Pl_{ef} = (O_{exp}-(E_f + E_{imp}))/(E_f + E_{imp} + E_{circ})$$

Where:

E_f = *annual energy input to the system by non-waste fuels that add to steam production (GJ/yr)*

E_{imp} = *annual imported energy (Note: energy from the treated waste (E_w) is not included)*

E_{circ} = *annual energy circulated (i.e. that generated by, but used in, the installation)*

O_{exp} = *annual exported energy (combined total of heat plus electricity as equivalents)*

Note: Because different types of energy (electricity and heat) are added all figures calculated as equivalents at the consumption.

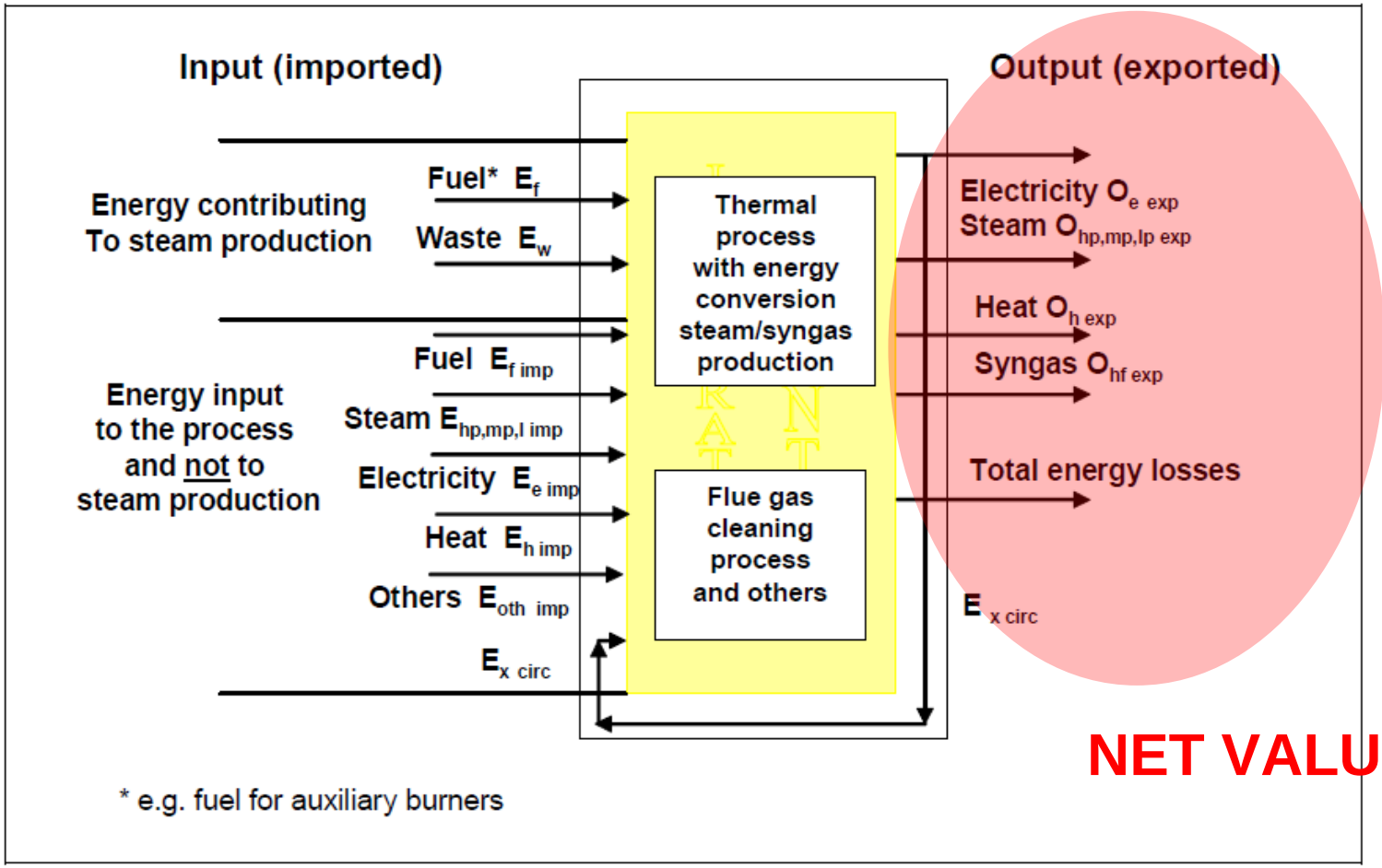
- Energy from waste fuel is not considered → rather some kind of characterization of the installation
- Why is E_{circ} in the denominator...?
- O_{exp} is EXPORTED energy → the result is a **NET efficiency**

History of the R1 Formula (7)
Energy efficiency is relevant for BAT

(2006)

BREF WI (2006 - no longer in force, reviewed version published in 2019)

Annex 10.4: Balance Sheet for Energy Efficiency Calculation



R1 Formula (1)

(2008)

(Waste Framework Directive 2008/98/EC)

- Annex I: **Disposal Operations D1-D15**, including **D1 Incineration on Land**
- Annex II: **Recovery Operations R1-R13**, including **R1 Use principally as a fuel or other means to generate energy**
- **Energy Efficiency = [Ep - (Ef + Ei)]/[0.97 x (Ew + Ef)**
  - Ep … Energy produced (**f=1,1 for heat, f=2,6 for electricity**)
  - Ef …. Energy contained in the fuel
  - Ew …Energy contained in the treated waste
  - Ei …. Energy imported

≥ 0,60 for existing plants → R1
≥ 0,65 for new plants → R1

R1 Formula (2)

(2008)

- **The R1 Formula is a footnote to the WFD**

ANNEX II

RECOVERY OPERATIONS

R 1 Use principally as a fuel or other means to generate energy (*)

(*) This includes incineration facilities dedicated to the processing of municipal solid waste only where their energy efficiency is equal to or above:
— 0,60 for installations in operation and permitted in accordance with applicable Community legislation before 1 January 2009,
— 0,65 for installations permitted after 31 December 2008,
using the following formula:
Energy efficiency = (Ep - (Ef + Ei))/(0,97 × (Ew + Ef))
In which:
Ep means annual energy produced as heat or electricity. It is calculated with energy in the form of electricity being multiplied by 2,6 and heat produced for commercial use multiplied by 1,1 (GJ/year)
Ef means annual energy input to the system from fuels contributing to the production of steam (GJ/year)
Ew means annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year)
Ei means annual energy imported excluding Ew and Ef (GJ/year)
0,97 is a factor accounting for energy losses due to bottom ash and radiation.
This formula shall be applied in accordance with the reference document on Best Available Techniques for waste incineration.

R1 Formula (2)

(2008)

- Applies only to waste **incineration**, not to co-incineration
- Applies only to incineration of **municipal solid waste,** not for hazardous waste, hospital waste, sewage sludge, or industrial waste.
- **Old installation**, if permitted before 01.01.2009: **R1 ≥ 0,60**
- **New installation**, if permitted after 31.12.2008: **R1 ≥ 0,65**
- **The R1 formula defines a GROSS value (*)**
- **It is not an efficiency in the technical/physical sense, but a „performance indicator“ and a political formula.**
- **Therefore, the R1 value is not given as a percentage.**

R1 Formula (3)

(2011)

GUIDANCE PAPER (not legally binding)

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
ENVIRONMENT

GUIDELINES

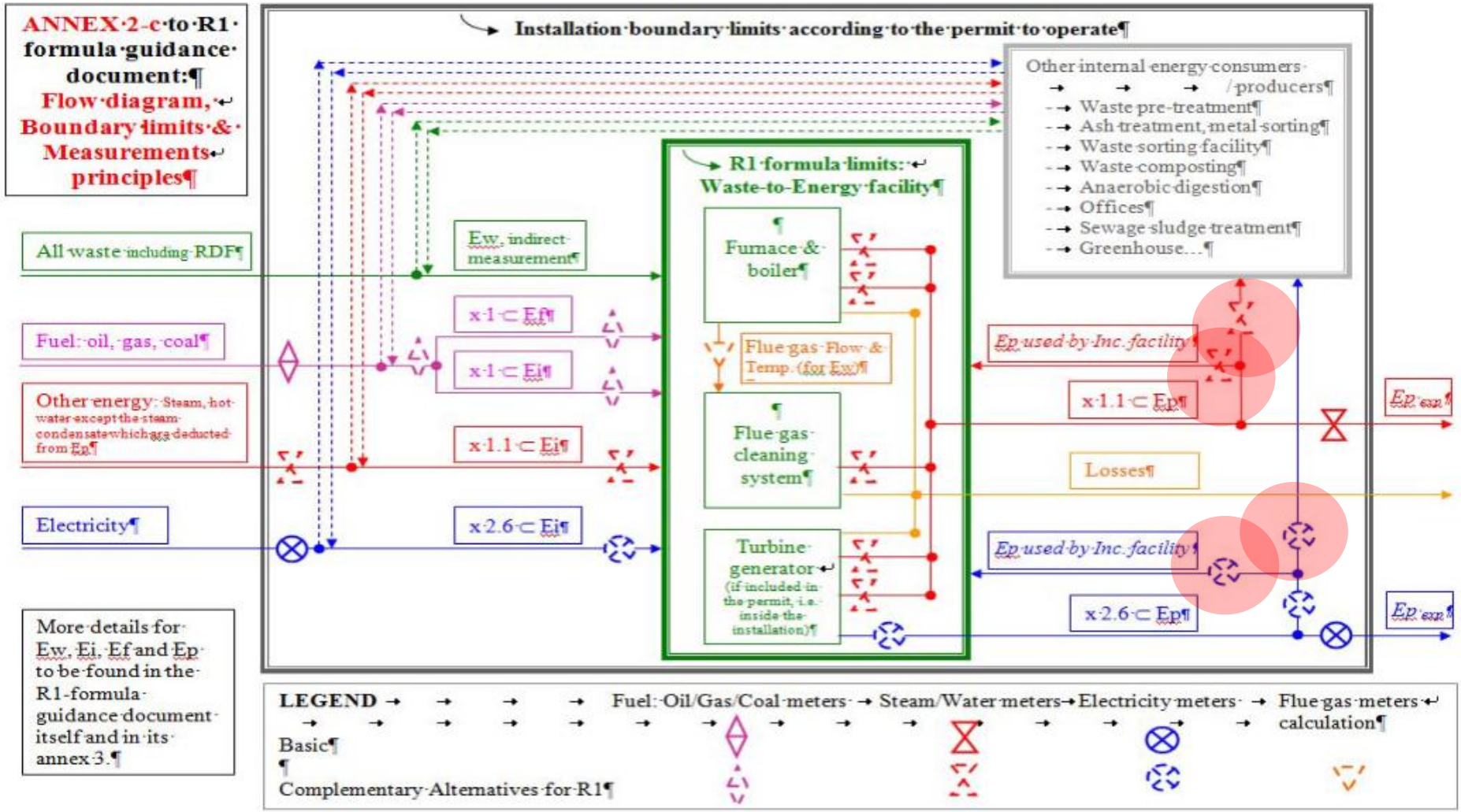
ON THE INTERPRETATION OF THE R1 ENERGY EFFICIENCY FORMULA FOR INCINERATION FACILITIES DEDICATED TO THE PROCESSING OF MUNICIPAL SOLID WASTE ACCORDING TO ANNEX II OF DIRECTIVE 2008/98/EC ON WASTE[1]

Link: https://ec.europa.eu/environment/pdf/waste/framework/guidance.pdf

R1 Formula (4)

GUIDANCE PAPER (not legally binding)

(2011)



ure 4: Position of measurement devices to determine energy flows relevant for the R1 calculation

GROSS VALUE

R1 Values of Austrian Waste Incinerators (2020)

Waste Incinerator	Techn.	Input [MW_{th}]	Since Year	R1 Value	R1 Limit
ENAGES Niklasdorf	BFB	40	2004	0,85	0,60
WAV (2 MSWI)	Grate	28,5 + 80	1995, 2006	0,84	0,60
FCC Zistersdorf	Grate	57,8	2009	0,69	0,60
KRV Arnoldstein	Grate	33	2004	0,89	0,60
RHKW Linz	BFB	72	2011	**1,17**	0,60
RVL Lenzing	CFB	110	1998	0,76	0,60
WE Flötzersteig	Grate	3 x 23	1963 (2006)	0,72	0,60
WE WSO4	BFB	45	2003 (2011)	0,72	0,60
WE Spittelau	Grate	89	1971 (2015)	**1,21**	0,60
WKU Pfaffenau	Grate	2 x 40	2008	**1,13**	0,60
EVN Dürnrohr (3 MSWI)	Grate	2 x 60 + 90	2004, 2010	0,84	0,60

Source: Umweltbundesamt Report REP-0830 (2022)
https://www.umweltbundesamt.at/fileadmin/site/publikationen/rep0830.pdf

Thank you for your attention!

UVP Environmental Management and Engineering GmbH
Lassallestrasse 42/12a, 1020 Vienna, Austria

Helga Stoiber
Senior Partner
Thermal Waste Treatment and Project Management

phone +43 (0)1 214 95 20 18
mobile +43 (0)660 18 78 947
email helga.stoiber@uvp.at

Think Globally • Work Locally

http://www.uvp.at

Chemistry and Energy Release of Waste Incineration

Combustible Compounds:

$C + O_2 \rightarrow CO_2$ $\quad \Delta H > 0 \rightarrow$ **exothermal**

$2\,H + \frac{1}{2}\,O_2 \rightarrow H_2O$ $\quad \Delta H > 0 \rightarrow$ **exothermal**

$N + O_2 \rightarrow NO_2$ $\quad \Delta H > 0 \rightarrow$ **exothermal**

$S + O_2 \rightarrow SO_2$ $\quad \Delta H > 0 \rightarrow$ **exothermal**

Water: No reaction, but evaporation

$H_2O\,(l) \rightarrow H_2O\,(g)$ $\quad \Delta H < 0 \rightarrow$ **endothermal**

Ash (Inert Material): No chemical reaction

Heating Value (Calorific Value) (1)

Lower Heating Value (LHV) or
Net Calorific Value (NCV):

Water is assumed to be in the gaseous state.

Higher Heating Value (HHV) or
Gross Calorific Value (GCV):

Water is assumed to be in the liquid state.

Difference = evaporation (condensation) heat of H_2O

HHV > LHV

Heating Value (Calorific Value) (2)

Lower Heating Value LHV (Net Calorific Value NCV) calculated according to the Boie Formula (2)

LHV [MJ/kg] =

$$= 34{,}8 * m_C + 93{,}8 * m_H + 6{,}25 * m_N - 10{,}8 * m_O - 2{,}45 * w$$

With:

m_C	Mass content of carbon	in [kg C / kg fuel]
m_H	Mass content of hydrogen	in [kg H / kg fuel]
m_N	Mass content of nitrogen	in [kg N / kg fuel]
m_O	Mass content of oxygen	in [kg O / kg fuel]

Additional increments for sulphur, chlorine...