The Role of Waste-to-Energy in Sustainable Waste Management considering the 20-20-20 Goals of the EU for 2020 [2030] and overall Environmental and Economic Benefits based on Experience in Austria and the EU

- 20% [40%] less GHG – Emissions
- 20% [27%] more Renewable Energy
- 20% [27%] more Energy Efficiency

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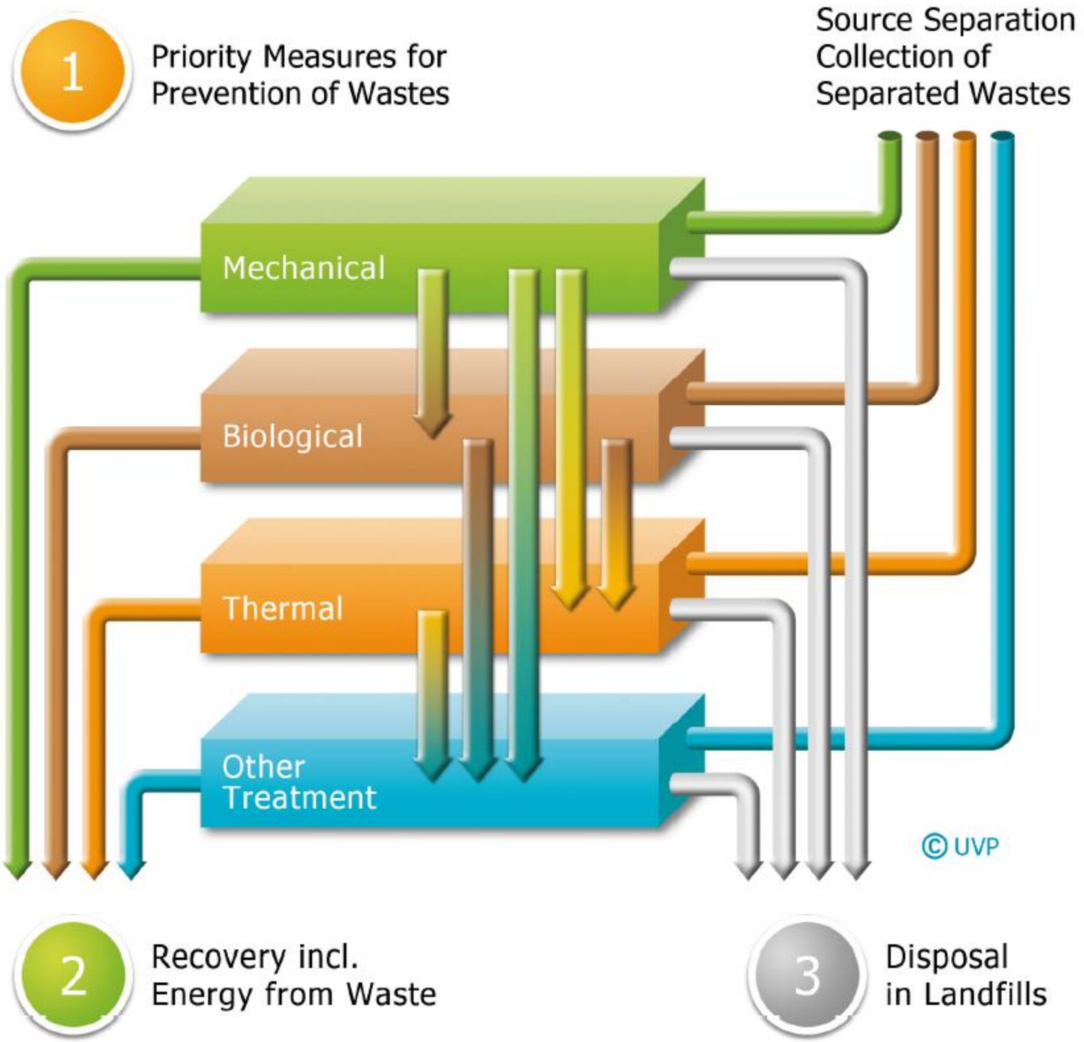
Think Globally • Work Locally

Environmental Consulting & Engineering for Future-oriented Integrated Systems for Sustainable Waste Management



Different technologies are needed for specific wastes in an integrated treatment system.

Successful project design must be based on 1st and 2nd Law of Thermodynamics !

Our project designs are profitable for our clients and good for the environment.

(UVP, since 1991)

Historic Situation: Recovery and Combustion of Landfill-Gas for some Energy Recovery (Example Rautenweg, Vienna, 2000)

Recovery of landfill-gas from the old municipal landfill in Vienna allows for production of 7,908 kWh electricity per hour, i.e. approx. 60 Million kWh per year (around 2000)

1 ton of garbage generates approx. 100 - 200 m³ gas with approx. 6 kWh/m³

(recovered landfill gas is approx. factor 5 to 6 less than the calorific value of the waste!)

Large Waste-to-Energy (Incineration) Facilities in Austria

Austria (approx. 8 Mio. people) Bulgaria (approx. 8 Mio. people)

Large facilites for thermal treatment of waste in Austria:

- 15 fluidized bed incinerators
- 14 grate systems
- 3 rotary kilns (for hazardous wastes)
- 9 cement kilns with co-firing of waste fuels (oil, tires, plastics)

Subtotal: **41 facilities in operation**

Planned projects:

- 5 fluidized bed incinerators
- 1 grate system

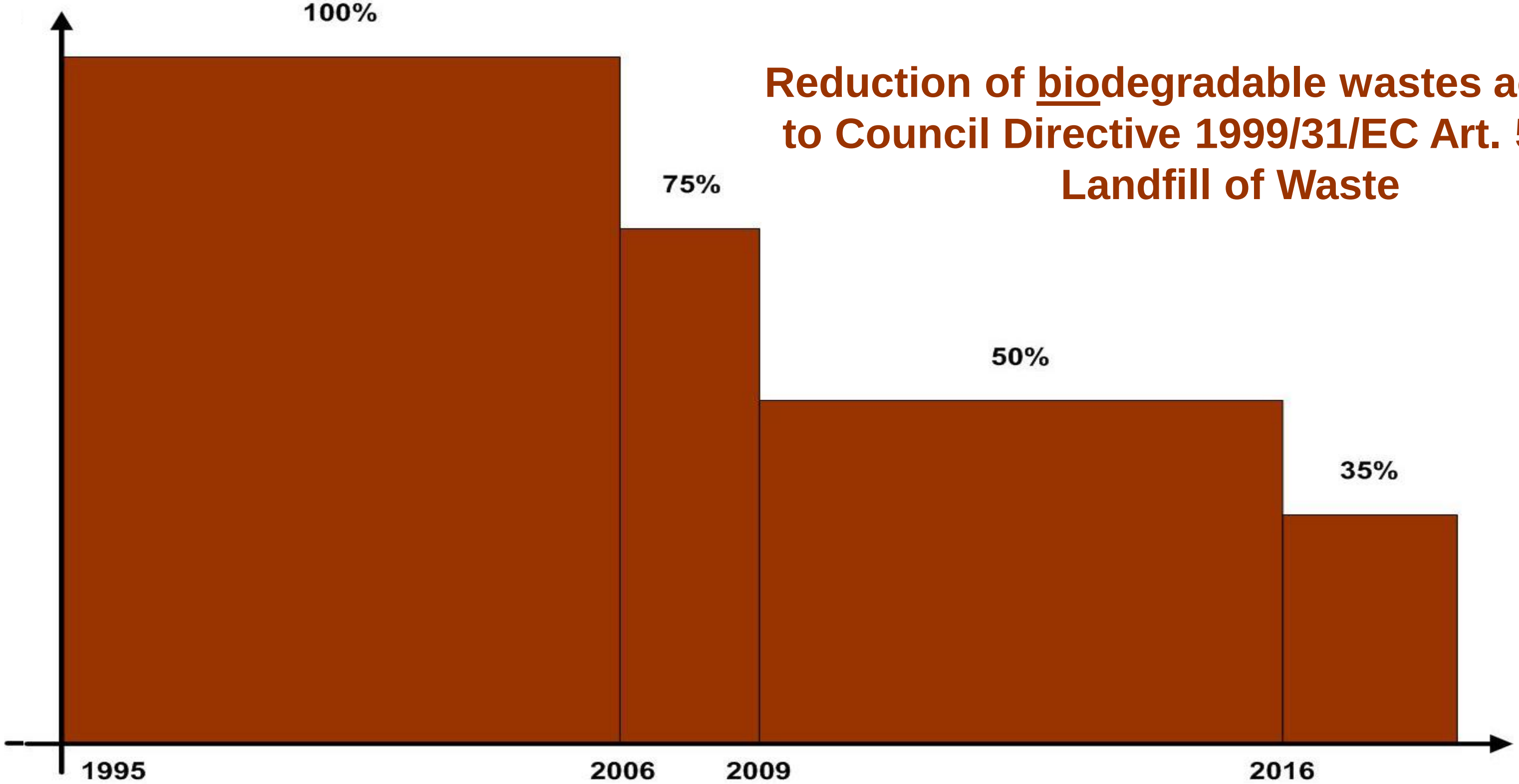
Subtotal: **6 facilities planned**

Please note: Cement kilns take special wastes only, maximum about 20 % of total wastes for incineration

EU - Limitation for Solid Waste Disposal in Landfills

DIRECTIVE 2008/98/EC of 19 November 2008 on waste:

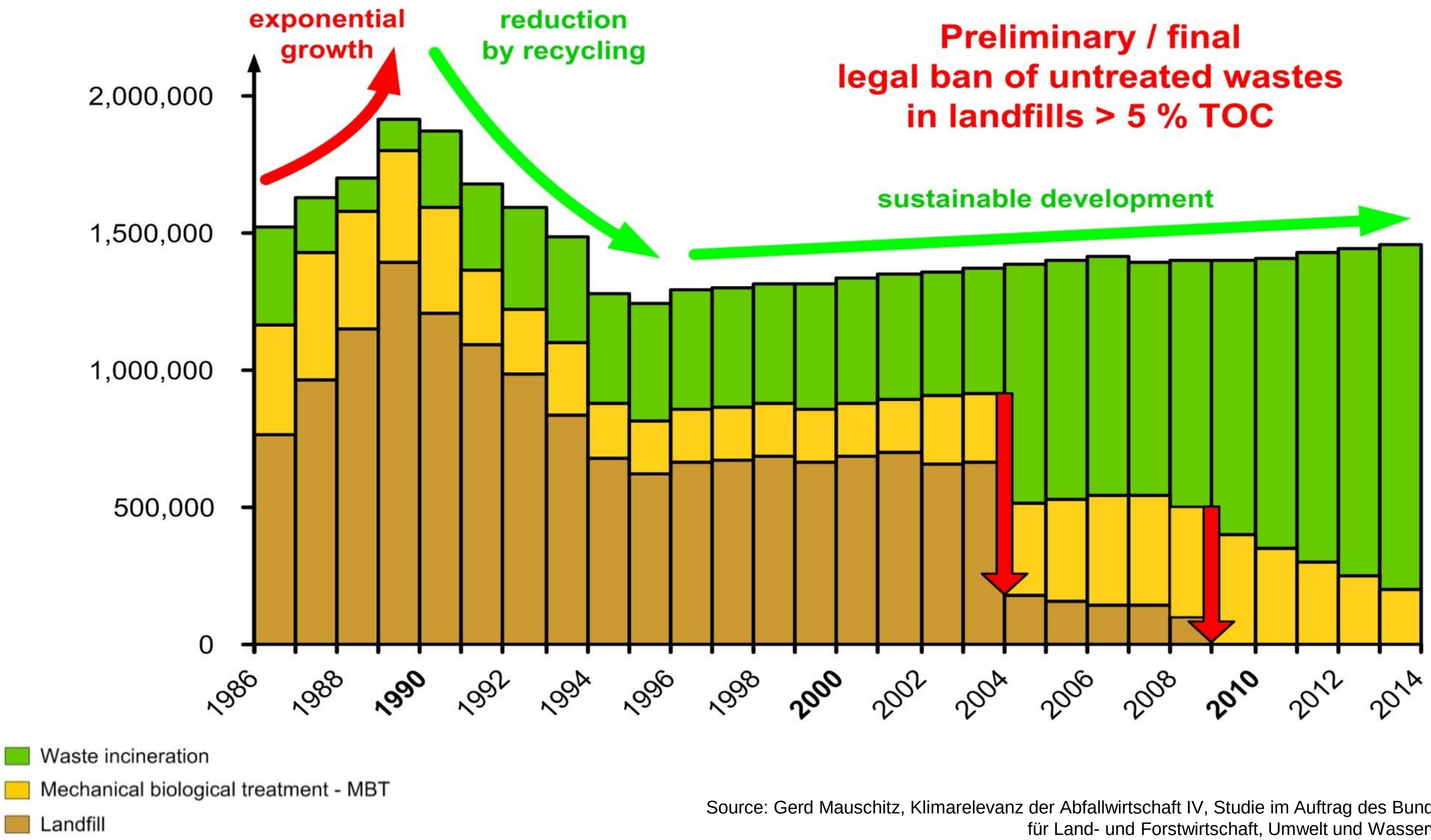
… that waste prevention should be the first priority of waste management, and that re-use and material recycling should be preferred to energy recovery from waste, where and insofar as they are the best ecological options.



Reduction of biodegradable wastes according to Council Directive 1999/31/EC Art. 5 on the Landfill of Waste

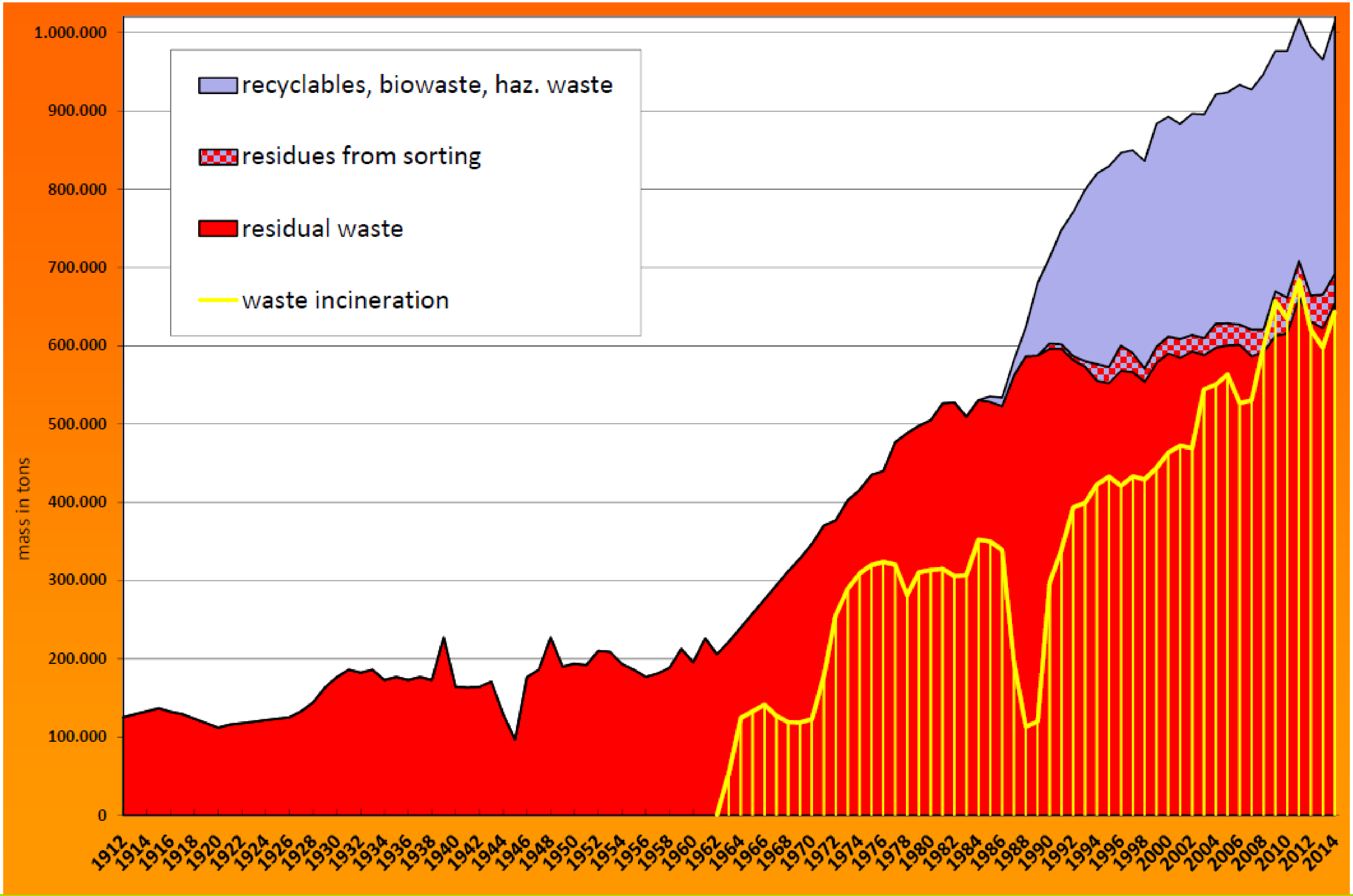
Energy Recovery and Disposal of Residual Municipal Solid Waste: 30 Years of Development in Austria

Residual Municipal Solid Waste collected in Austria
Figures in tons per year



Source: Gerd Mauschitz, Klimarelevanz der Abfallwirtschaft IV, Studie im Auftrag des Bundesministeriums für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2010

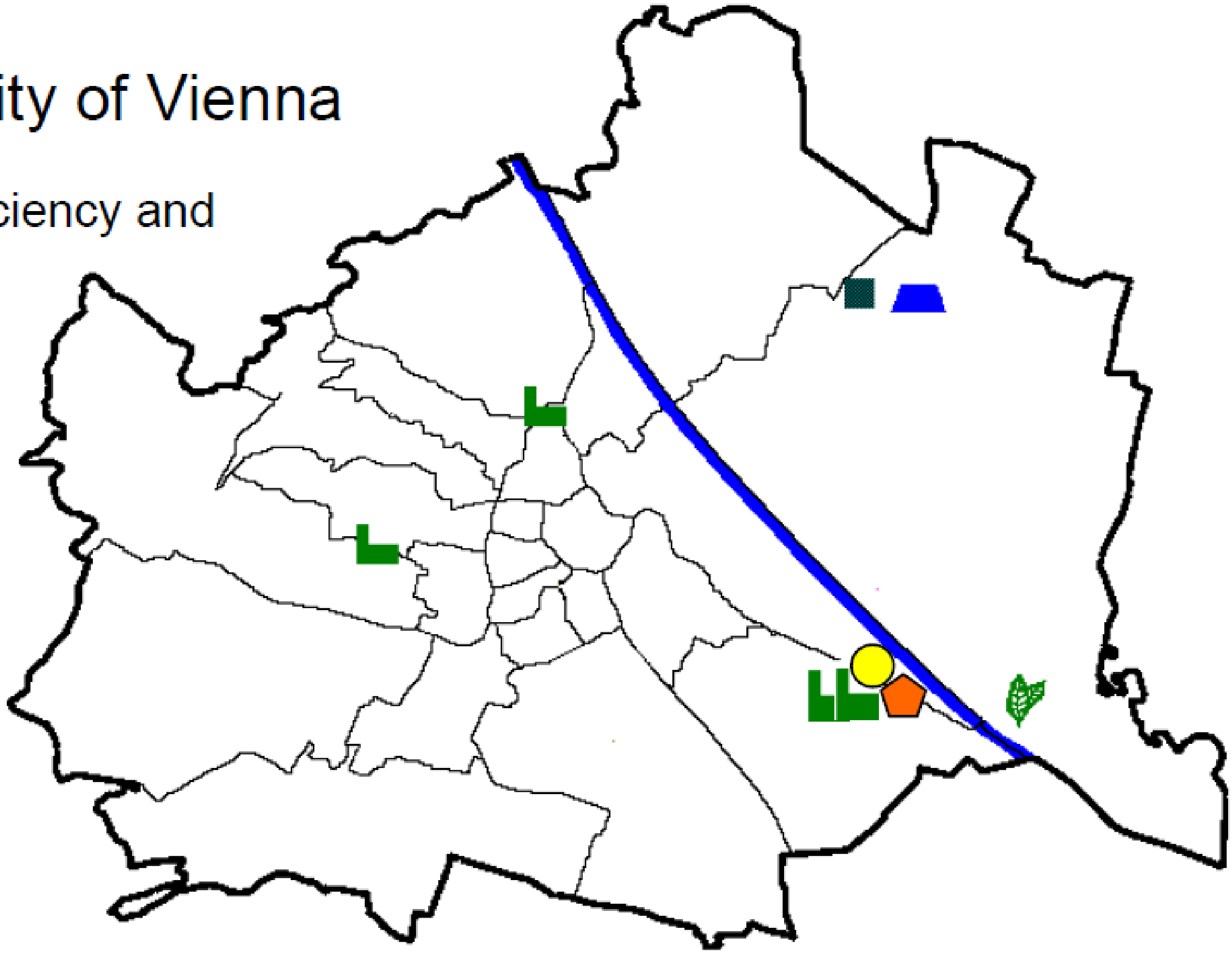
Collection and Treatment of Municipal Solid Waste in Vienna since 2012 (Source: MA 48, 2016)



Integrated Municipal Waste Treatment Plants in Vienna in 2015

- situated in Vienna
- operated by the City of Vienna

=> high level of self-sufficiency and short distances



Landfill site Rautenweg

Incineration plants

Waste logistic center (inkl. bale storage)

fermentation plant

Waste treatment plant (e.g. treatment of slags)

composting plant

Composting Plant Lobau, Vienna, Austria

- Start of operation: 1991
- Open air composting
- Surface 5,2 ha
- Treatment capacity:
  150.000 t/a (input)
- Compost production:
  50.000 t/a (output)
- Favourable location
- High economic efficiency

Source: Wojciech Rogalski, „Biowaste Management in Vienna", ISWA Beacon Conference 2012

Municipal Waste-to-Energy: Positive Example
The Municipal Waste Incineration Plant Spittelau, Vienna

Start of operation:	1971
(Re-) Start up:	1989
Re-vamping boilers:	2013/15
Site:	City of Vienna
Technology:	Grate firing
Fuel capacity:	2 x 44.5 MW
Efficiency:	approx. 76 % (co-generation of electricity and district heat)
Steam production:	2 x 60.5 t / h (40 bar, 400°C)
Average waste throughput:	250,000 t / a
Fuel:	residual municipal solid waste

Atmospheric Emissions for thermal waste treatment in Austria and Switzerland:

Values given in mg/m^3_N (11% O_2, dry; for PCCD/F in ng/m³)

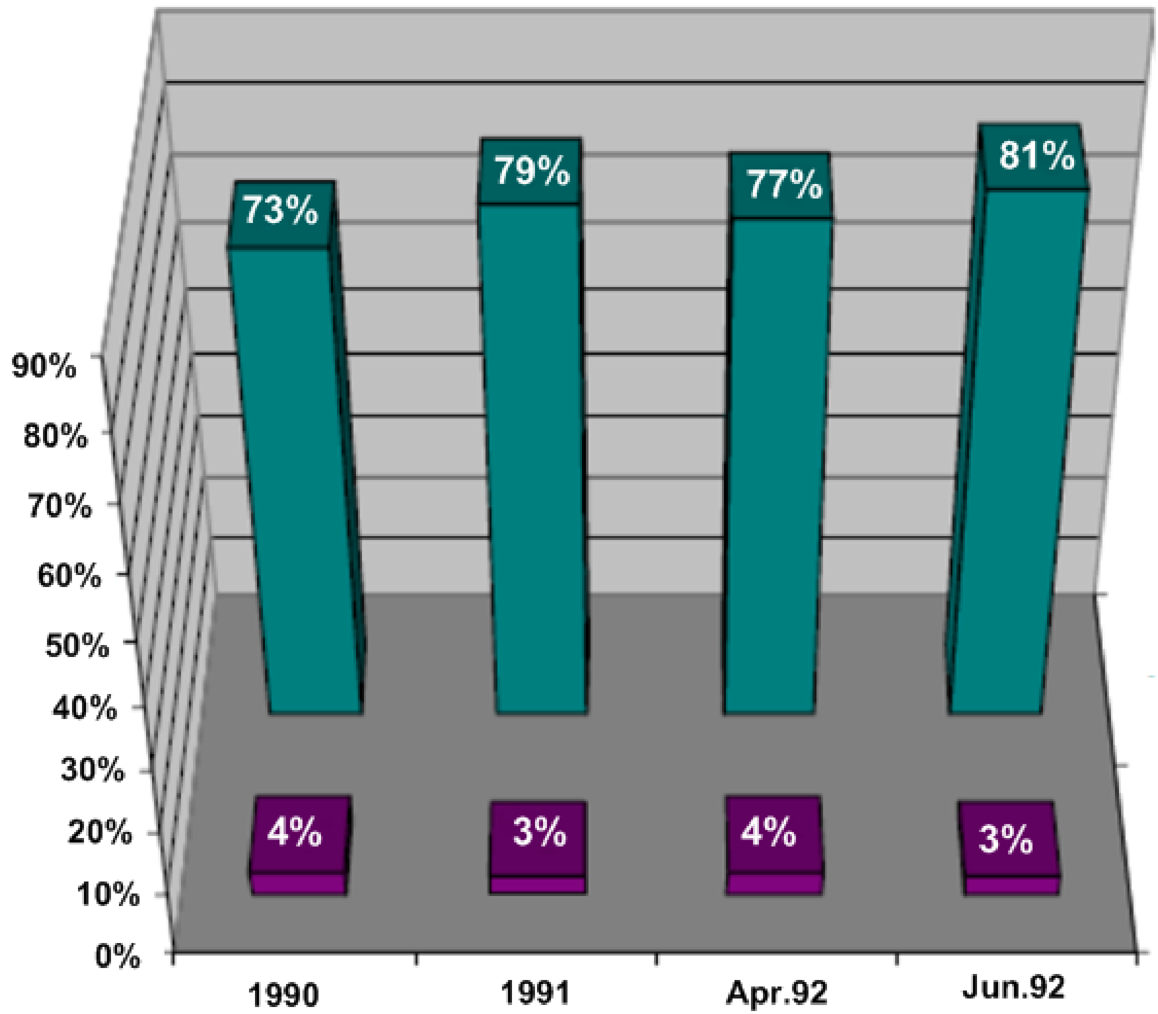
	Dust	Cd	HCl	SO_2	NO_x	Hg (=> 1/100)	PCDD/F* (=> 1/1000)
1970	**100**	**0.2**	**1,000**	**500**	**300**	**0.5**	**50**
1980	**50**	**0.1**	**100**	**100**	**300**	**0.2**	**20**
1990	**1**	**0.005**	**5**	**20**	**100**	**0.01**	**0.05**
2000	**1**	**0.001**	**1**	**5**	**40**	**0.005**	**0.05**

Source: Vogg (values for 1970 - 1990); RVL (values for 2000)

Legal Emission Standards 1994 in Austria compared to September 2011 Emission Guidelines for MSW in British Columbia:
(Bold numbers for ½-Hour Average, *cursive numbers for Daily Average values***):**

AT 1994	**8**	**0.05**	**7**	**50**	**70**	**0.05**	**0.1**
BC 2011	**9**	**0.007**	*10*	*50*	*190*	*0.02*	**0.08**

"Published" vs. "Public" Opinion on Waste-to-Energy in Vienna

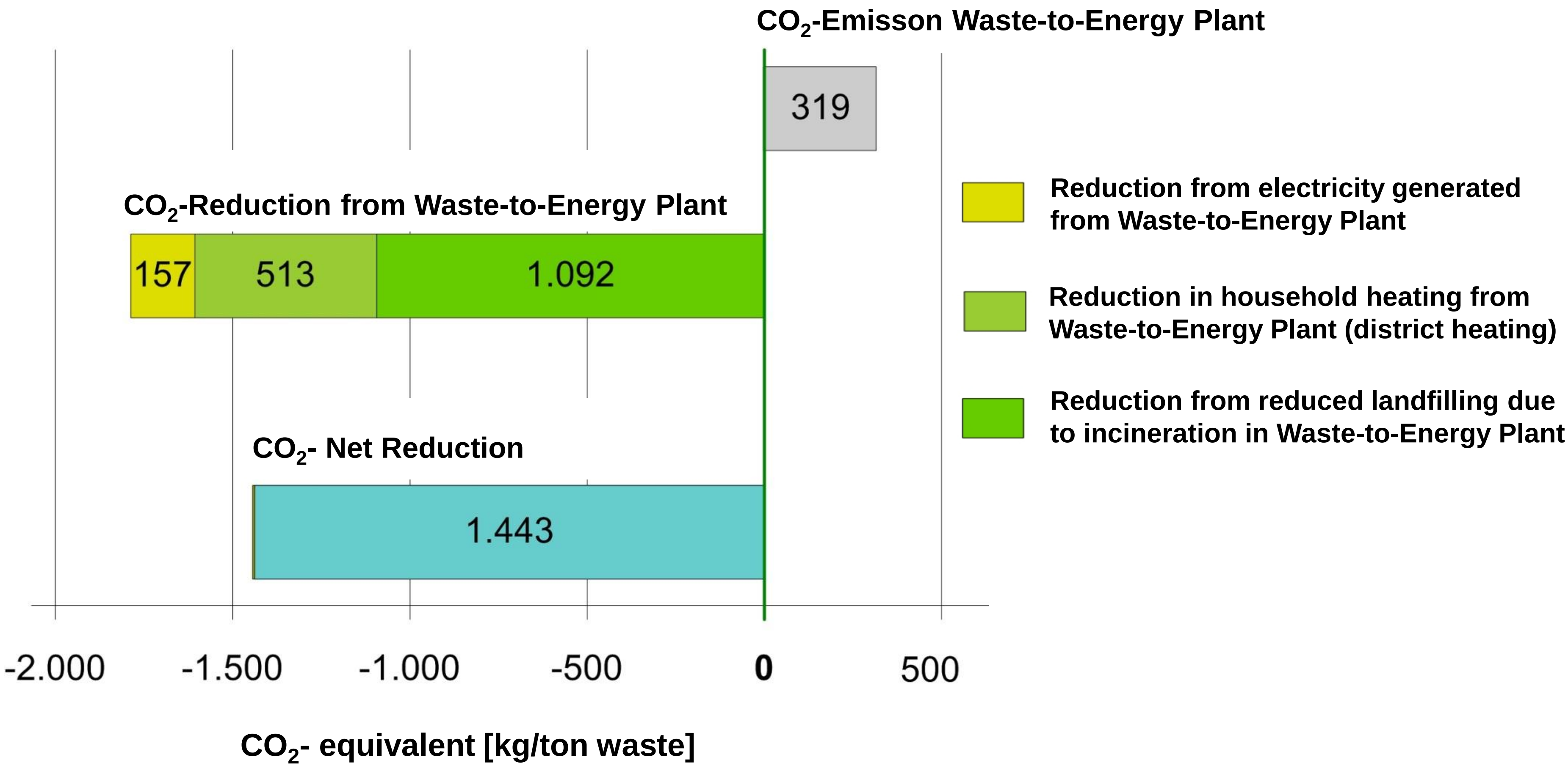


For Waste-to-Energy with district heating

Against incineration

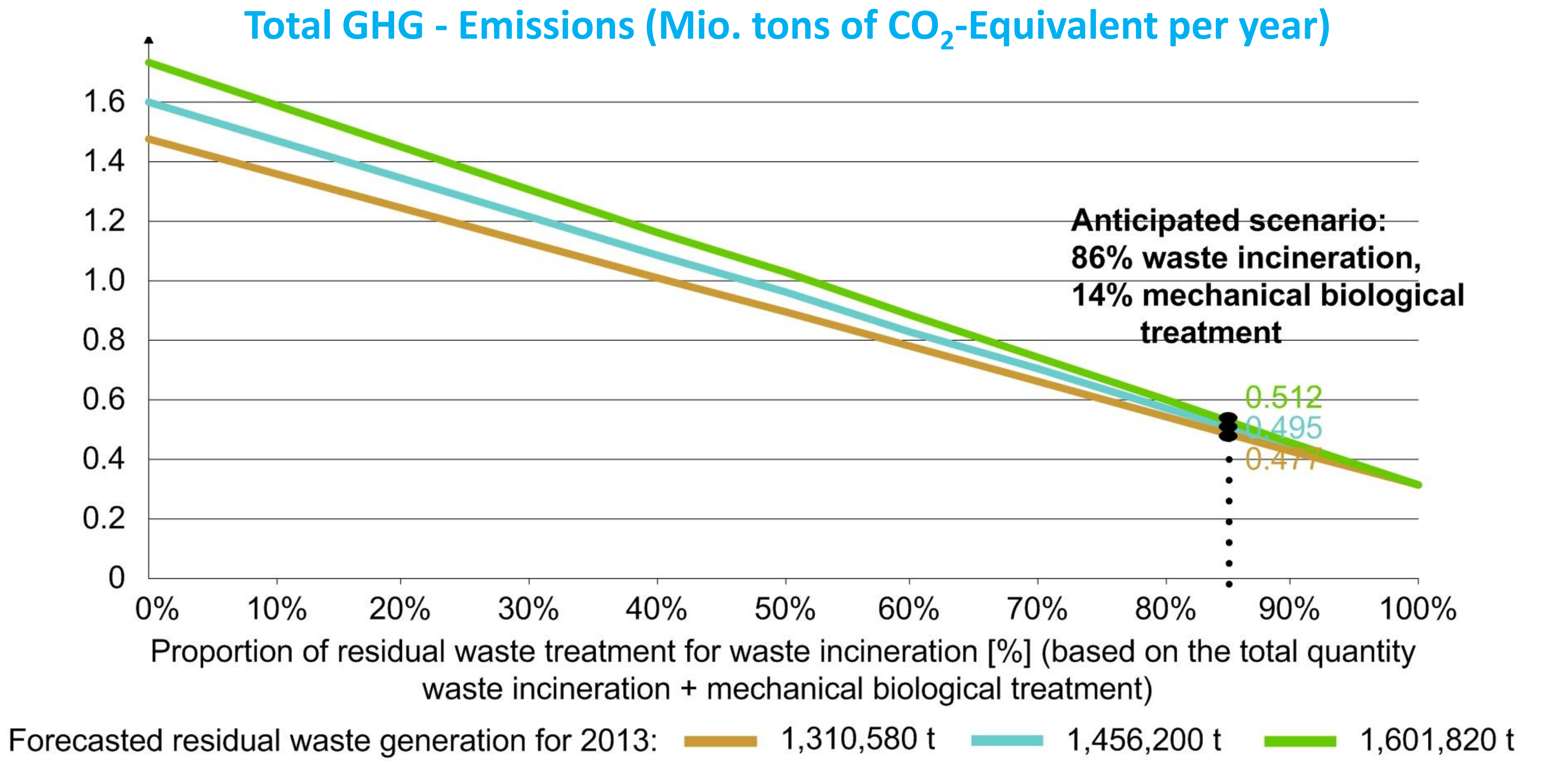
Source: Löffler, MA22, Vienna

Reduction of Greenhouse - Gas Emissions by Municipal Waste Incineration in Vienna



Source: Kirchner, IIR Conference: Efficient future Waste Treatment Technologies, 2008

Forecasted GHG – Emissions for the Treament of Residual Waste for the Year 2013 in Austria (TU Vienna, 2009)

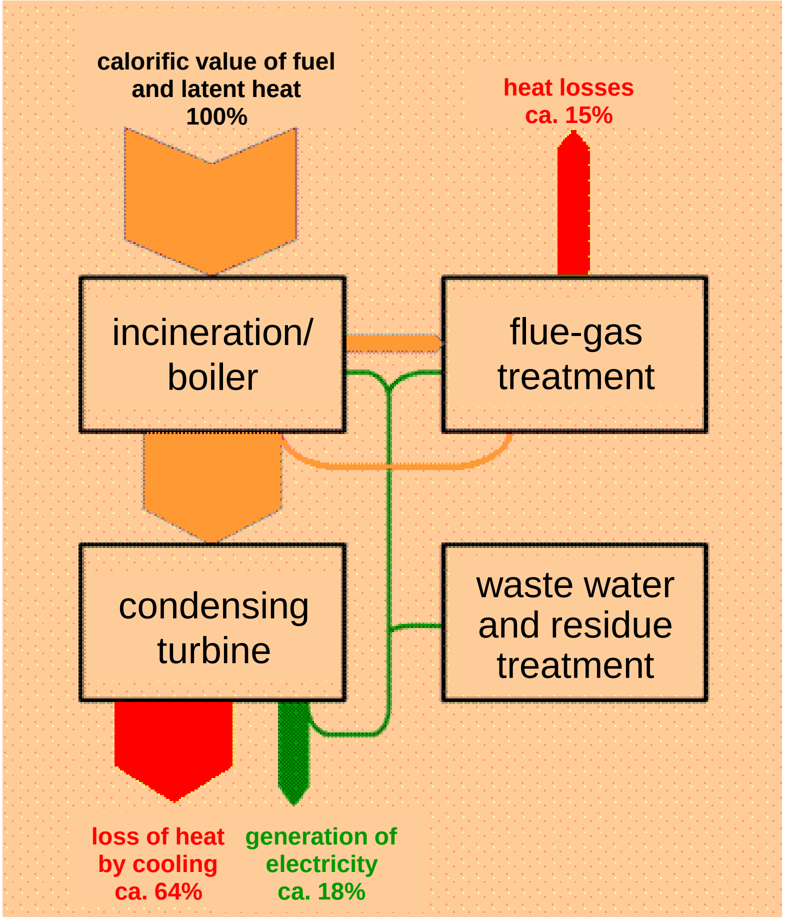


Source: Gerd Mauschitz, Klimarelevanz der Abfallwirtschaft IV, Studie im Auftrag des Bundesministeriums für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, TU Wien, 2009

GHG – Emissions from MBT with combustion of high calorific fractions are about 1 ton more per ton of MSW compared to WtE !

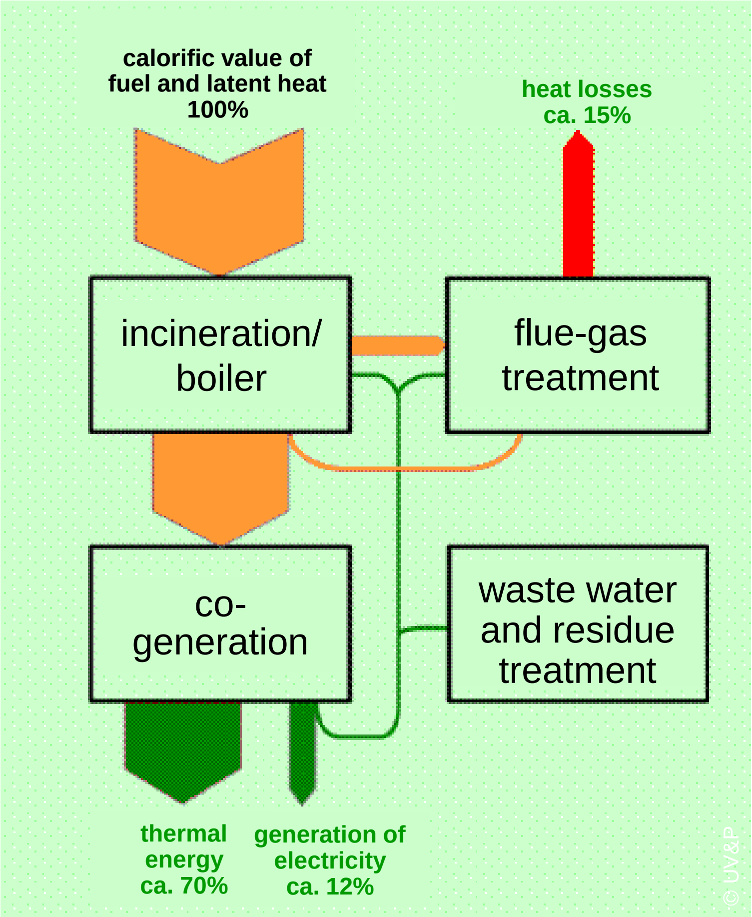
Site-specific Options for Utilization of Energy
The 3 most important Criteria in any Real Estate: Site, Site, Site!

Condensing Turbine (electricity only)



Energy utilization approx. 20 %

Co-Generation (electricity + heat)



Energy utilization approx. 80 %

Integrated Waste-to-Energy at the Industrial Site of Lenzing in the Tourist and (Organic) Farming Region of Salzkammergut, Austria

The waste-to-energy plant RVL is integrated in the industrial site of Lenzing in Upper Austria with advanced environmental technology to protect the natural environment (incl. organic farming) in the famous tourist region around Lake Attersee.

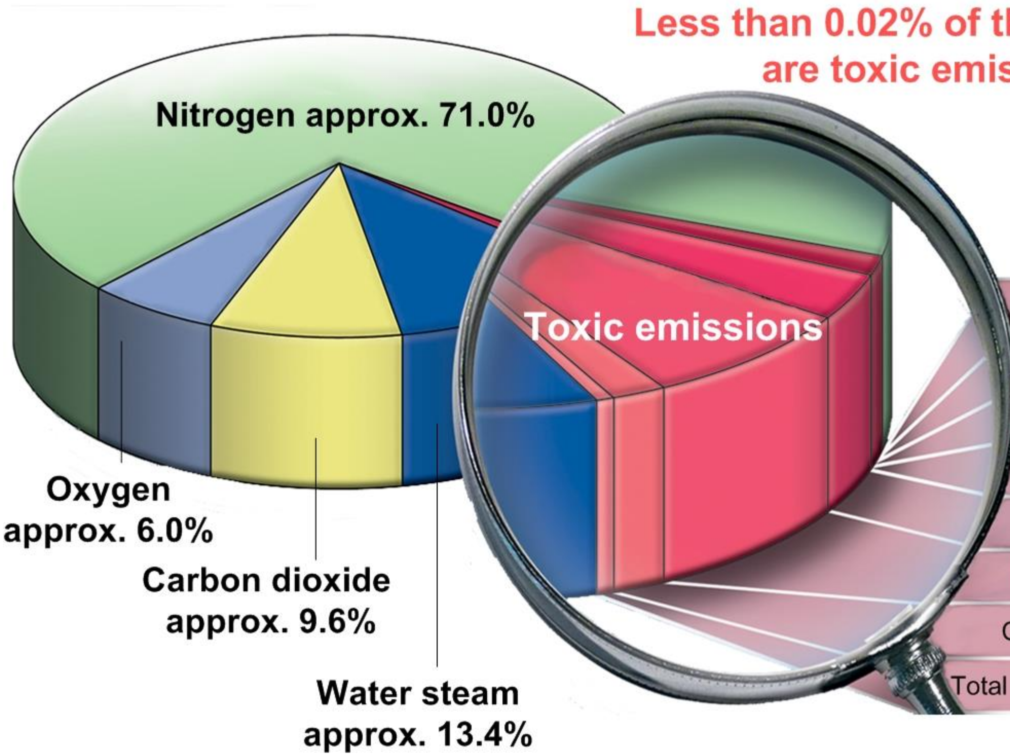
<u>The 3 arguments in public discussions / acceptance:</u>

1. Energy demand (90 MW)

2. Reduction of odour (H_2S, CS_2)

3. No landfilling (300.000 t / a)

Control of Flue-Gas from Waste Incineration (Example: RVL Lenzing, in operation since 1998)



Comparison of emission limits: Figures in mg/Nm³ (11 % O_2, dry)

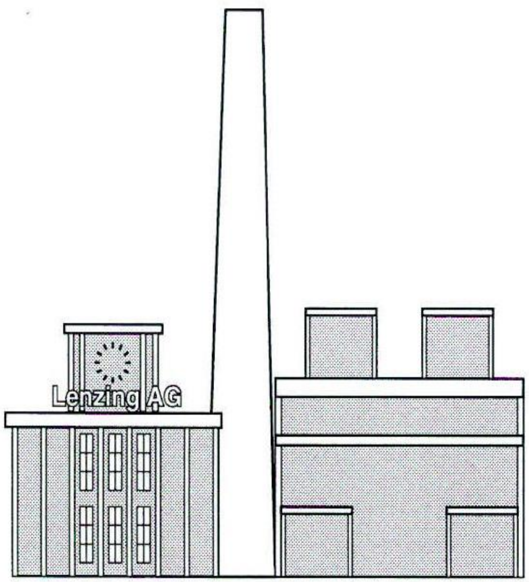
	EU-Directive 2000/76	AVV BGBl. 389/2002	RVL Lenzing	
			Project 1994	Measured values 2002
Particulates	10	10	8	0.6
Mercury Hg	0.05	0.05	0.05	0.007
Hydrogen chloride HCl	10	10	7	0.8
Hydrogen fluoride HF	1	0.7	0.3	0.02
Sulfur dioxide SO_2	50	50	50	4.1
Nitrogen oxides NO_X	400	100*)	70	41.6
Carbon monoxide CO	100	100	50	2.3
Total organic carbon TOC	10	10	8	0.6

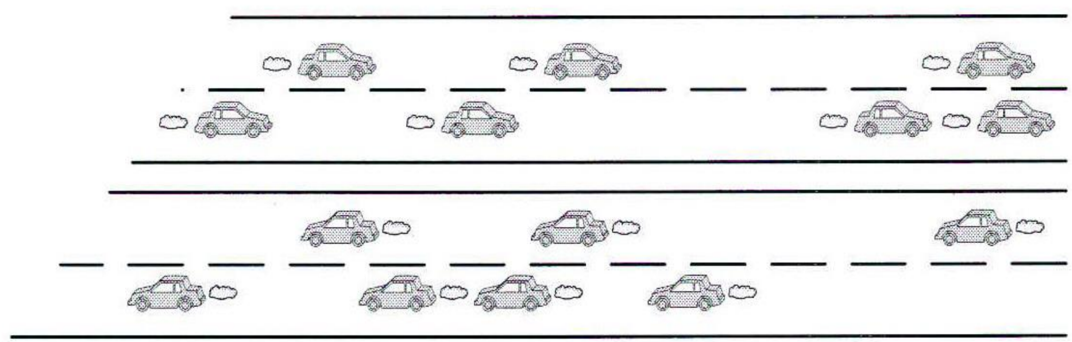
* if > 6 tons waste per hour

Efficiency of Controlled Combustion and Integrated Multi-stage Flue-Gas Cleaning (Example RVL, UV&P 1994)

Comparison of organic compounds from incineration plant / cars on the road

Incineration plant = 14 cars





Calculation:

Car exhaust contains ca. 20 g C-org / kg fuel

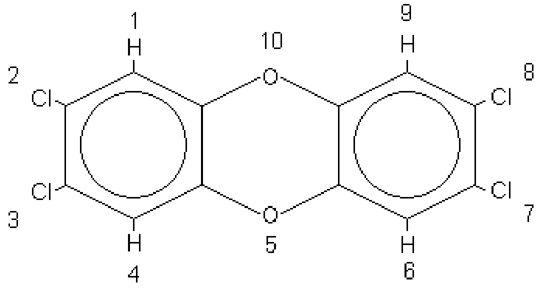
(Source: Schopp G., Ö. Chemz. 1993/9)

Flue gas of the incineration plant with multi-stage flue gas cleaning contains less than 1,980 g C-org / h

(Source: Expertise ZAMG, 22.12.1993)

Cleaned flue-gas of an incineration plant contains less organic compounds than the exhaust of 14 cars

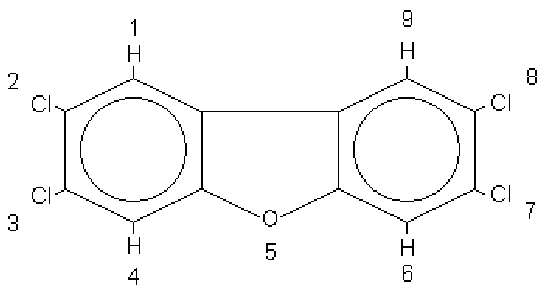
Balance of “Dioxins“ in Waste Incineration according to State-of-the-Art Technology



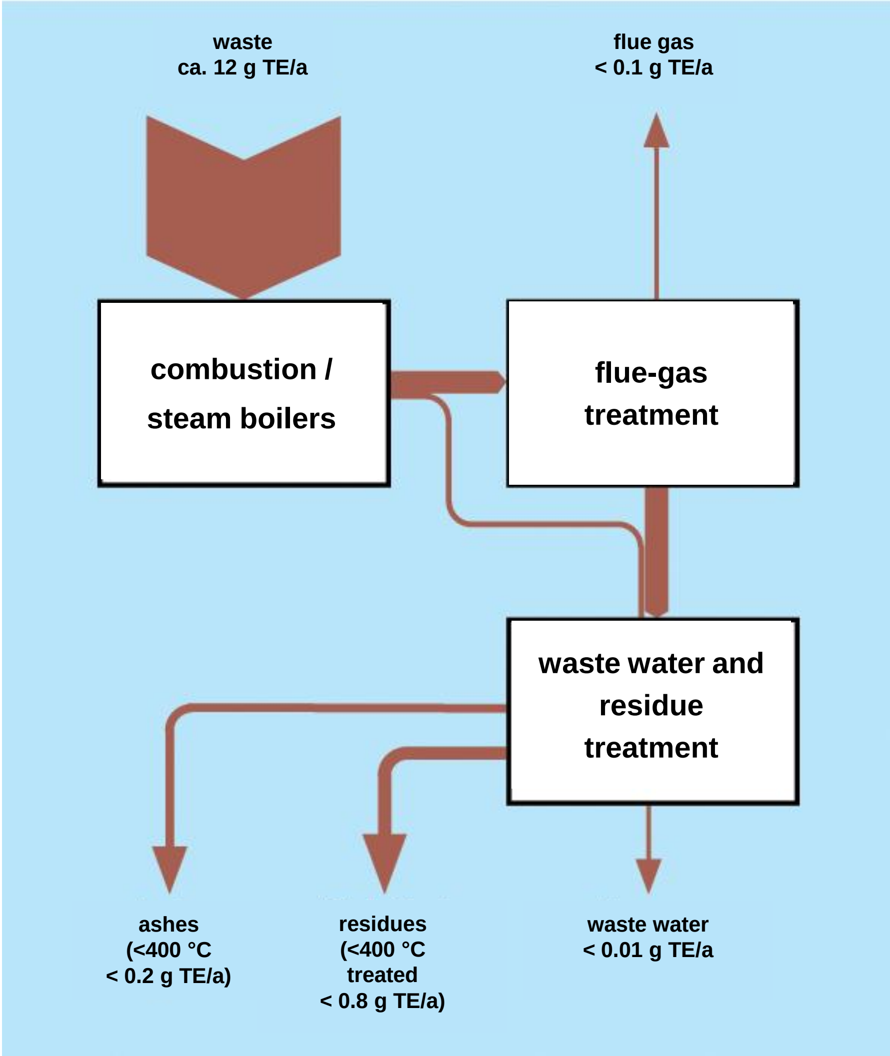
2,3,7,8-Tetrachlordibenzo-p-Dioxin

The emission limit for “dioxins“ is also the essential parameter for higher molecular halogenated organic substances and POPs persistant organic pollutant. The sum of “dioxin-emissions“ of a thermal treatment plant according to state-of-the-art technology is significantly below the amount of dioxins already contained in waste prior to treatment.

g TE / a = g Toxicity Equivalent 2,3,7,8 TCDD per year



2,3,7,8-Tetrachlorodibenzofuran

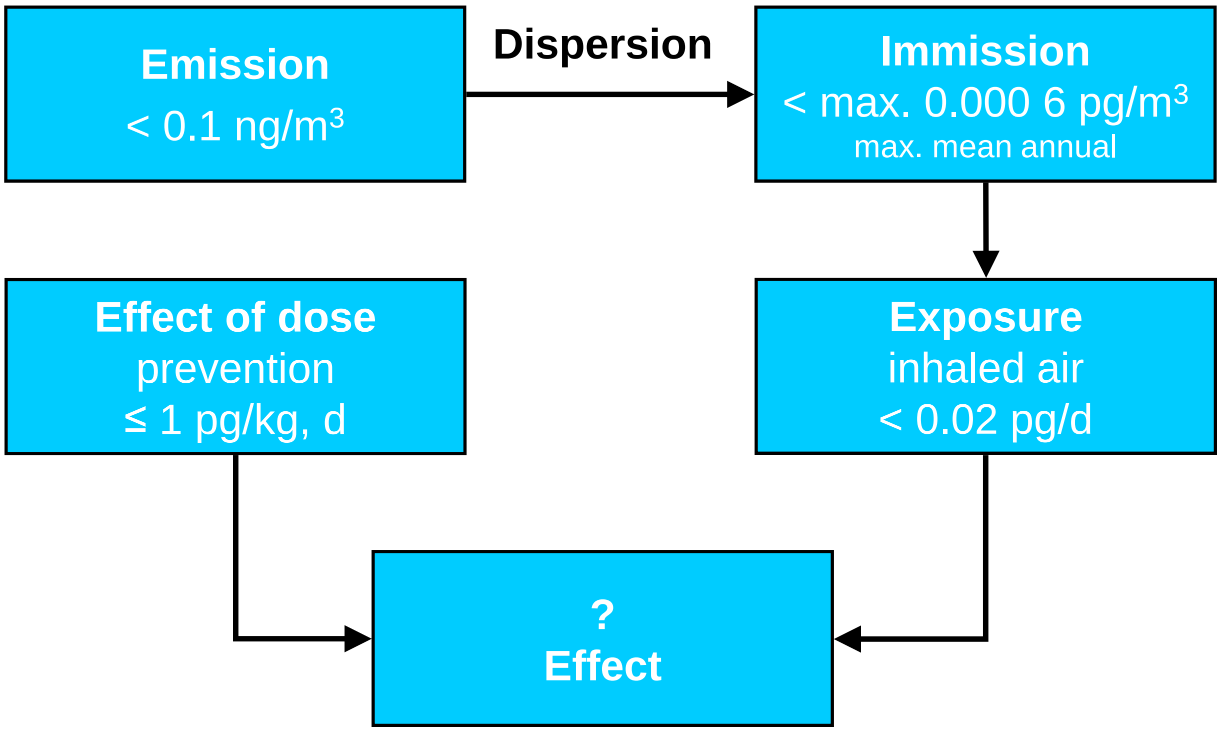


Calculation for an example of a waste incineration project: UV&P, 1996

Risk Assessment for Atmospheric Emission of "Dioxins" (Example: RVL Lenzing, 1994)

1 ng $=10^{-9}$ g = 0,000 000 001 g

1 pg $= 10^{-12}$ g = 0,000 000 000 001 g



Risk assessment:

The precautionary protection standard (federal health bureau, Berlin) is 1 pg / kg weight and day (factor 1,000 safety compared with NOEL - No Observeable Effect Level). In the worst case a person inhales 0,012 pg dioxin with ca. 20m^3 air per day. In comparison the protection standard for a 60 kg person is 60 pg/day. Therefore the inhaled maximum is less than $^1/_{1000}$ of the protection standard. Thus the additional risk can be considered irrelevant.

No increased health risk due to very small concentrations of dioxins in the cleaned flue-gas of the waste incineration facility.

Illustration for Risk Assessment regarding “Dioxins“ (Example RVL Lenzing, 1994)

Assumption: **3 cigarettes per day** = marginal value of impact (no effect observable)

Thus the **precautionary** protection standard (=1/1,000) is equivalent to **1 cigarette per year**.

Conclusion : An incineration plant with multi-stage flue gas cleaning is factor 1,000 below the (precautionary) protection standard

thus = equivalent to 1 additional cigarette in 1,000 years

Long-term Monitoring of „Dioxins“ in Spain:
„… no additional health risk for the population living nearby“

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Long-term monitoring of dioxins and furans near a municipal solid waste incinerator: human health risks

Lolita Vilavert[1], Martí Nadal[1], Marta Schuhmacher[1,2] and José L Domingo[1]

Abstract

Since 1996, a wide surveillance programme has been developed to get overall information on the impact of a municipal solid waste incinerator (MSWI) in Tarragona (Catalonia, Spain). The concentrations of polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) have been periodically measured in soil and vegetation samples collected at locations in the incinerator surroundings. Furthermore, air PCDD/F levels have been also monitored by using active and passive sampling devices, generating a huge amount of information regarding the environmental status of the zone. In the last survey (2009–2010), mean PCDD/F levels in vegetation, soil and air were 0.06 ng I-TEQ kg^{-1}, 0.58 ng I-TEQ kg^{-1} and 10.5 fg WHO-TEQ m^{-3}, respectively. Both soil and herbage showed a notable reduction in the PCDD/F concentrations in comparison with the baseline study, with this decrease only being significant for soils. In contrast, PCDD/F values in air remained similar during the whole assessment period. Human exposure to PCDD/Fs was evaluated under different scenarios, and the associated non-carcinogenic and carcinogenic risks were assessed. The hazard quotient was below unity in all cases, while cancer risks were under 10^{-6}, which is lower than the maximum recommended guidelines. The current results clearly show that the MSWI of Tarragona does not produce additional health risks for the population living nearby.

Waste-to-Energy Plant ENAGES Integrated within the Site of the Paper Industry in Niklasdorf, Austria

Planning (UV&P):	1994/95
Start up:	2003
Technology:	Fluidized bed
Fuel capacity:	40 MW
Steam production:	46 Mg/h (40 bar, 400°C)
Average waste throughput:	approx. 100,000 Mg/a
Fuels:	RDF, municipal, commercial and production wastes, sewage sludge

RHKW Reststoffheizkraftwerk in the City of Linz, Upper Austria: Co-Generation / District heating based on Waste Derived Fuel

stack (180 m – existing)

Mechanical waste processing and intermediate storage

power plant including fluidized bed boiler

Pipe conveyor for waste transport from fuel storage to power plant

Planning (UV&P):	2006/07
Start Up:	2011
Technology:	Fluidized bed
Fuel capacity:	72 MW
Efficiency:	ca. 80 % (co-generation)
Steam production:	89 t / h (42 bar, 420°C)
Waste throughput:	up to 800 t / d
Fuels:	Municipal and commercial waste, sewage sludge, screening wastes

Complete "Burn-out" of Solid Residues from Combustion in a Fluidized Bed

Material Recovery from Thermal Waste Treatment in a Fluidized Bed System (e.g. < 650 °C for Recovery of Al)

Material Recovery:

Residues from Waste Incineration in a Fluidized Bed

Source: Panowitz / Metran

Practical Examples for Economic Discussions

We have calculated this for you

Source: Martin GmbH, SYNCOM presentation in Arnoldstein, 26-27 April 2006

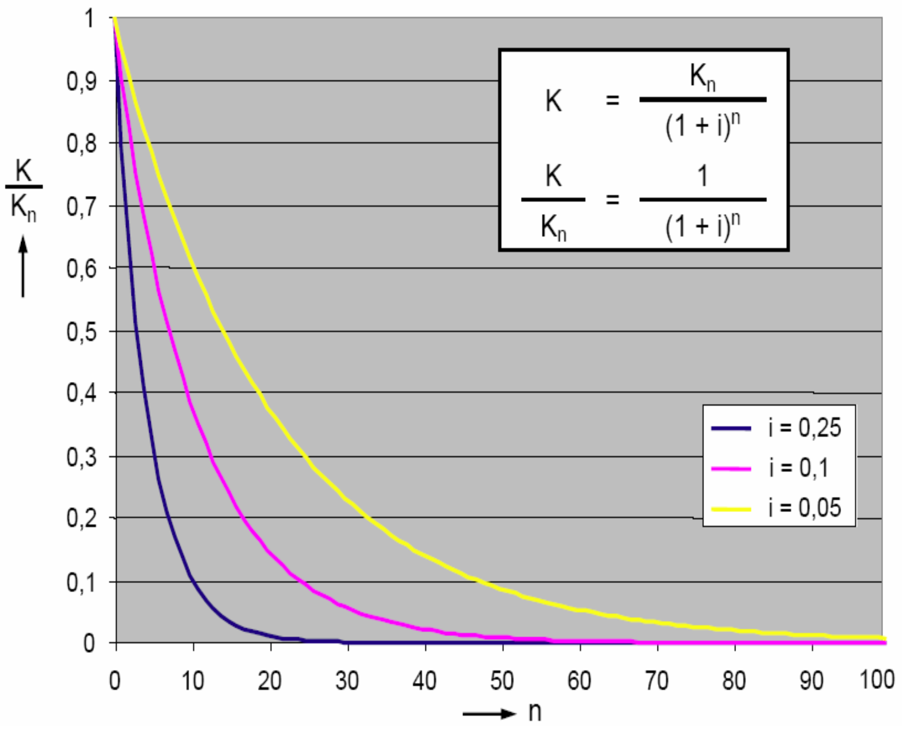
Investment Decisions based on NPV Net Present Values calculated for available Alternatives

- **The 1st Law of Thermodynamics**
  → Mass and Energy Balances
- **The 2nd Law of Thermodynamics**
  → Entropy / Downcycling
- **Fundamental Economic Decisions**
  → Net Present Value NPV (K)

$$K = (R_0 - E_0) + \frac{R_1 - E_1}{(1+i)} + \frac{R_2 - E_2}{(1+i)^2} + \ldots + \frac{R_n - E_n}{(1+i)^n}$$

- **Macro-economic Effects**
  → Losses by external costs
- **Ethics (Rules to live by)**
  → The 10 Commandments (Moses)

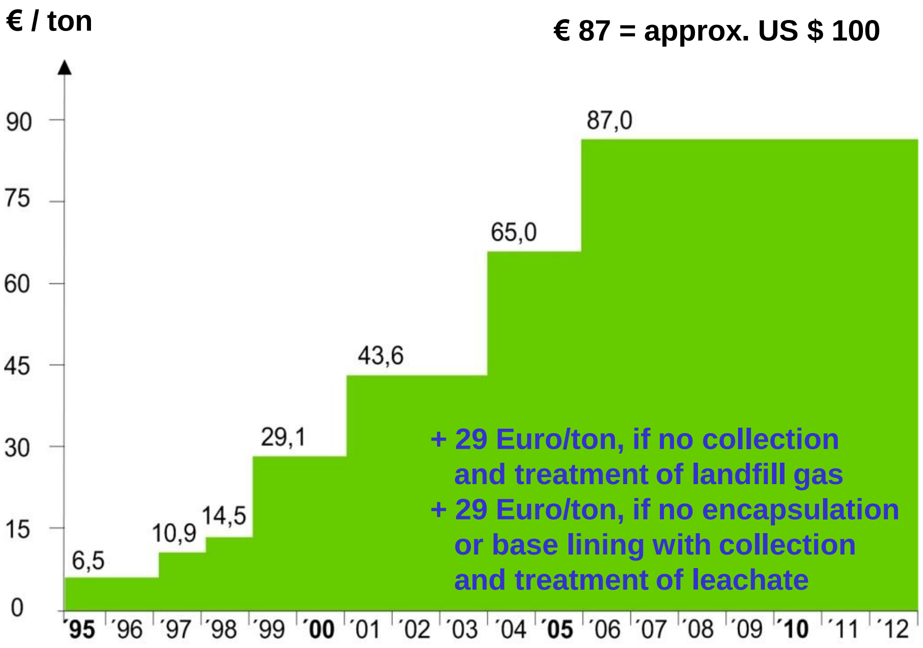
Discounting of the future - Effect of the chosen interest rates (i) on the Net Present Value for future cash flows



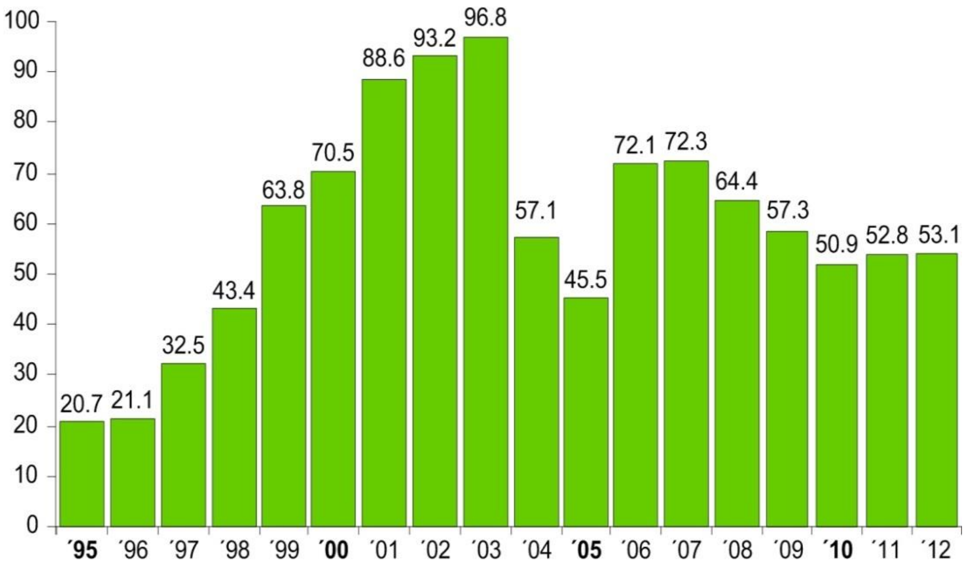
Development of the Special Landfill Tax in Austria

The development of waste management in Austria towards reduction of landfilled waste as well as recycling and recovery has been effectively supported by a special landfill tax

Landfill tax in € / ton of waste (e. g. municipal waste)



Revenue from landfill tax in Million € / a (total revenue per year)



3 criteria:

- Foreseeable for (at least 10) 20 years
- Environmental standard of the landfill
- Quality of waste to be landfilled

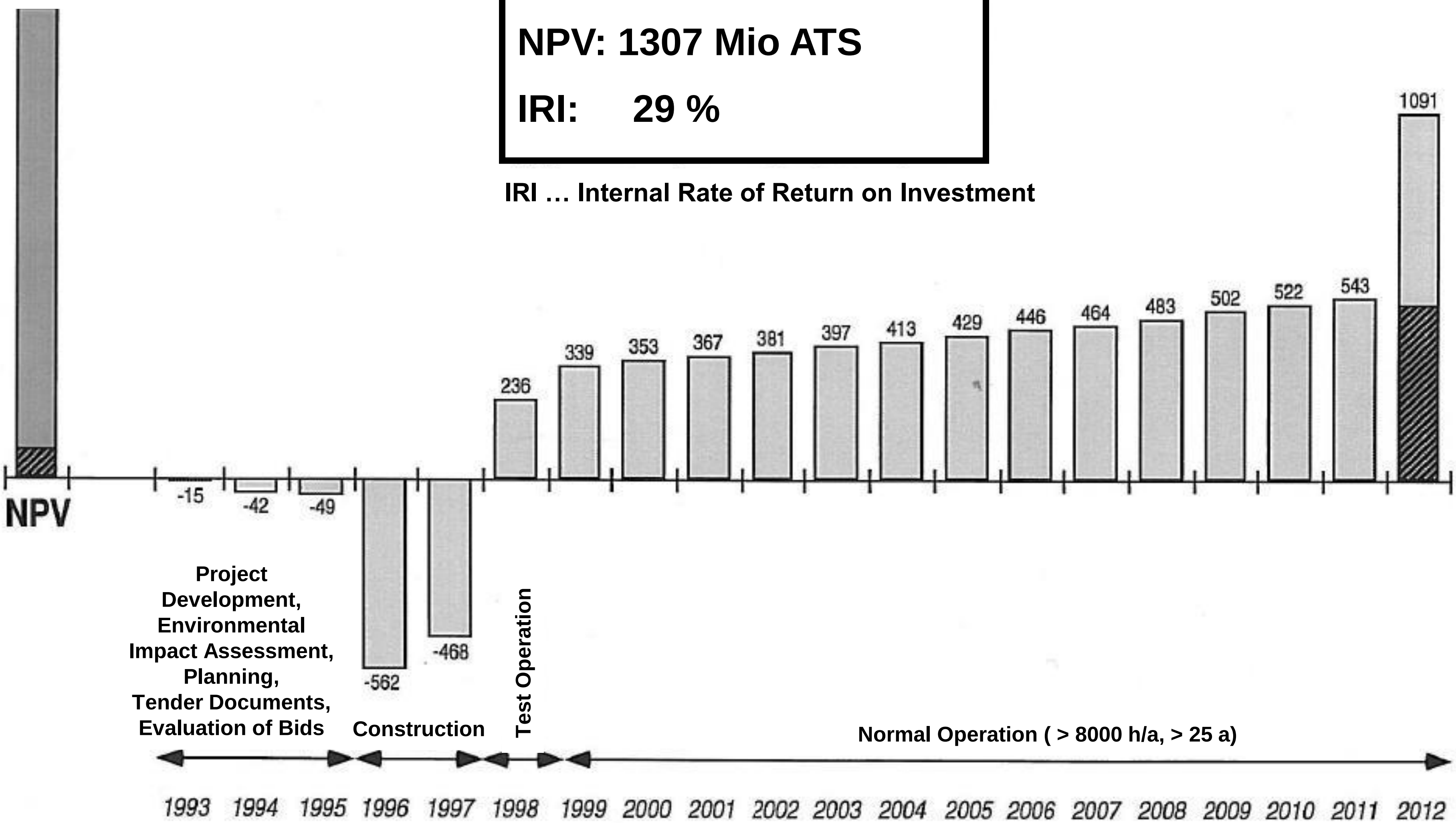
Example for NPV-Analysis – Project Development "LASER" Waste-to-Energy for Industrial Co - Generation (UV&P 1993)

1307 Mio ATS (13,74 ATS = 1 €)

NPV: 1307 Mio ATS

IRI: 29 %

IRI … Internal Rate of Return on Investment



Precaution against New "Miraculous" Technologies

The **technical concept** should be based on:

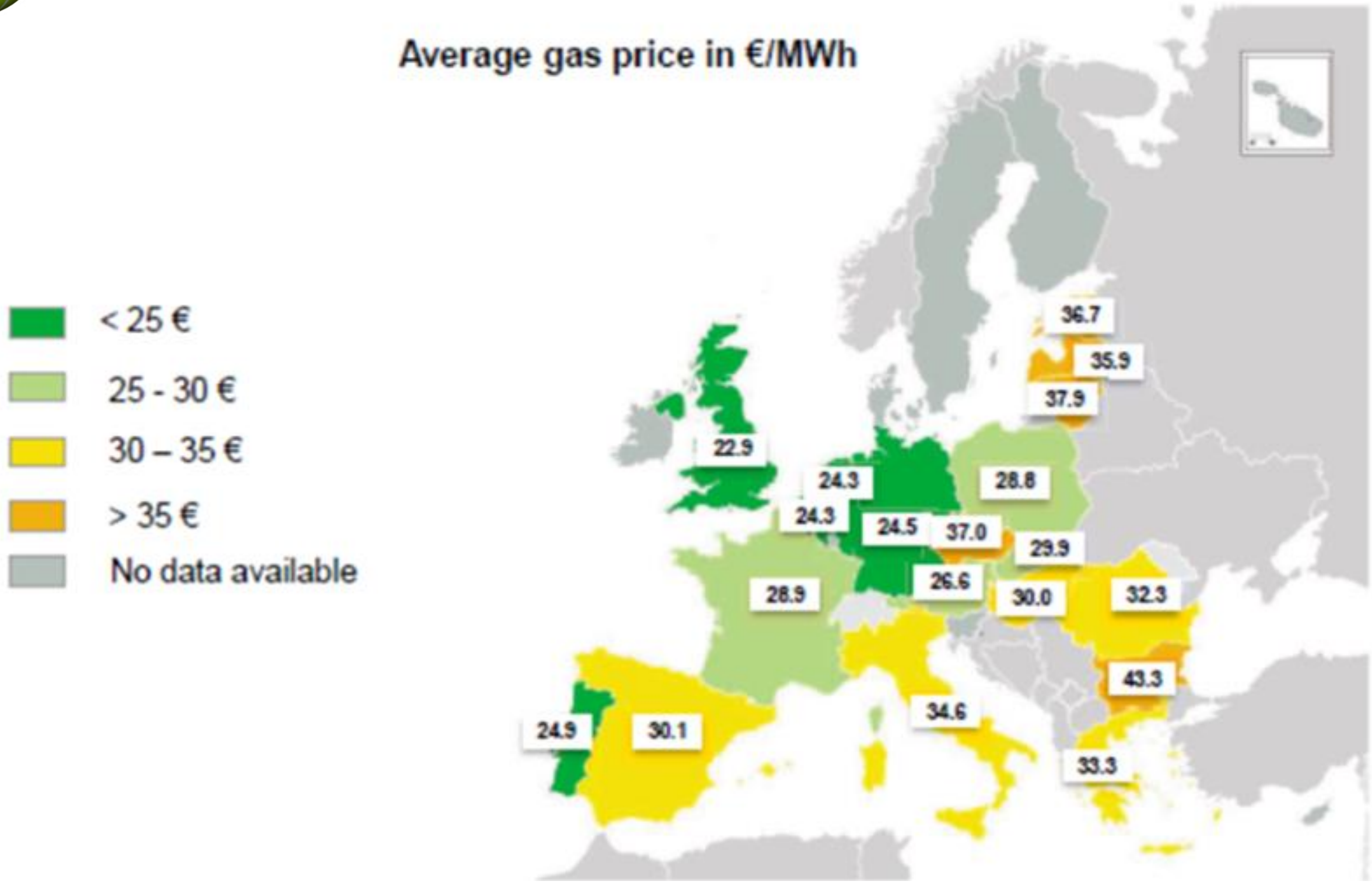
- State-of-the-art technology (BAT) for such types of waste
- Proof of successful technical operation of a similar type and size of facility (e.g. > 80% of requested thermal capacity) over a minimum period of 3 years

The **financial risks** for installation of unproven technology are significant and have to be legally well-defined and financially secured.

The following scenarios must be considered:

1. Costs for immediate upgrading in case of insufficient performance
2. Costs for installation of a system according to state-of-the-art in case of a continuous failure
3. Costs for alternative treatment of waste during incomplete or malfunctioning of the overall system.

Gas prices vary significantly across the EU region depending on the level of Competition



Source: "Energy challenges and policy", European Commission, May 2013

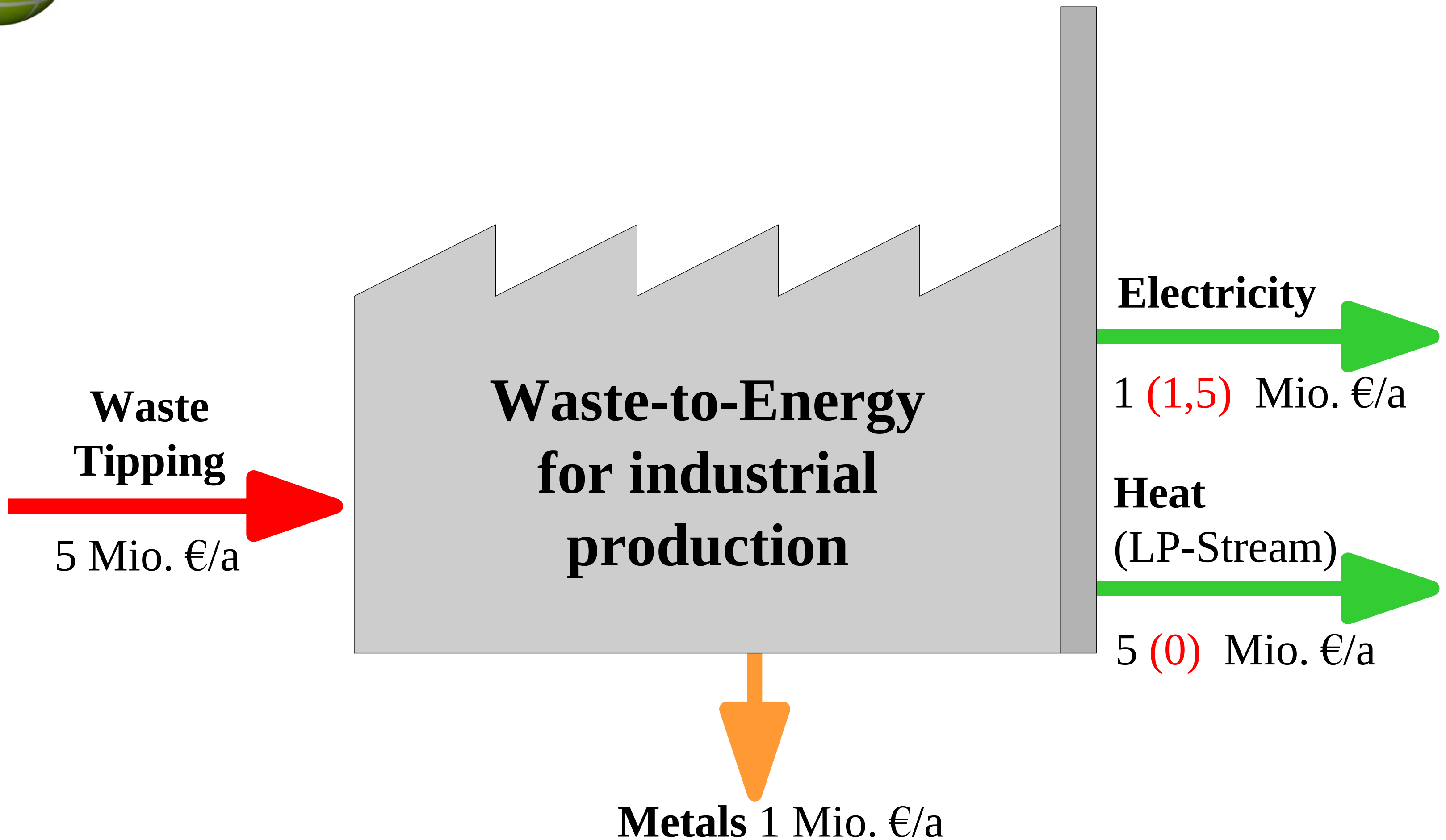
ISWA International Study Tour Waste-to-Energy June 19-25, 2016
Vienna – visiting 11 Faclities in Czech Republic, Hungary, Austria

<u>Seminar and Technical Tour to 11 Plants and Facilities in Operation</u>

Vienna ⇨ Niklasdorf ⇨ Wopfing ⇨ Brno ⇨ Budapest ⇨ Dorog ⇨ Vienna

Practice Seminar on Sustainable Waste Management in Europe based on Prevention, Recycling, Recovery, Treatment, and Intermediate Storage - without any disposal of untreated wastes exceeding 5 % TOC (Total Organic Carbon) in landfills

Typical Revenues in 2014 for Waste-to-Energy in a small 40 MW BFB – Boiler with Integration to an Industrial Site in Austria

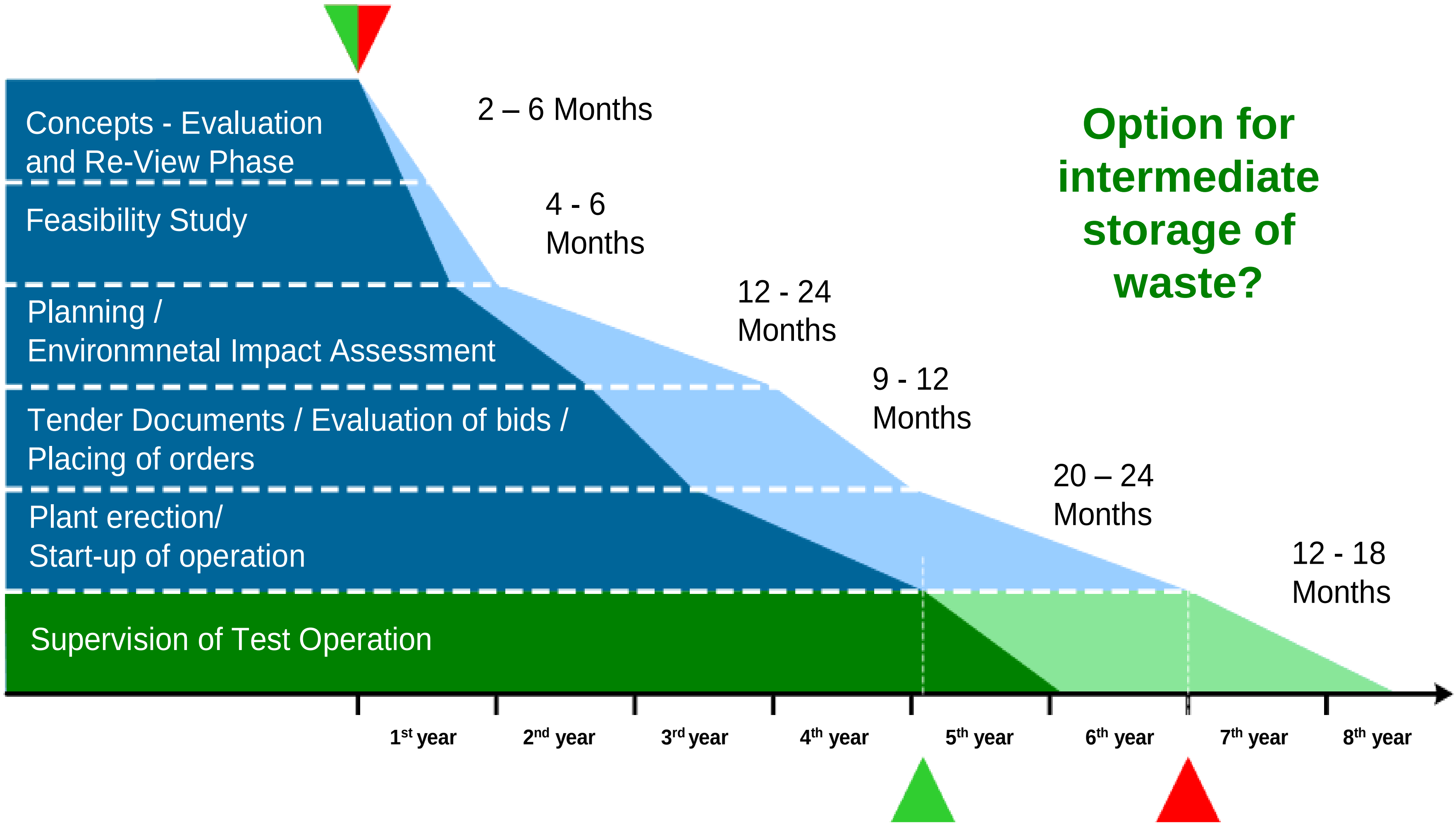


The 3 most important criteria in real estate is: **site, site, site**

Source: Pusterhofer, October 2014

Activities and Time Schedule for Project Implementation of Large Waste-to-Energy Treatment Projects

Necessary time from project start until start-up of operation: min. 4 to approx. 6 years

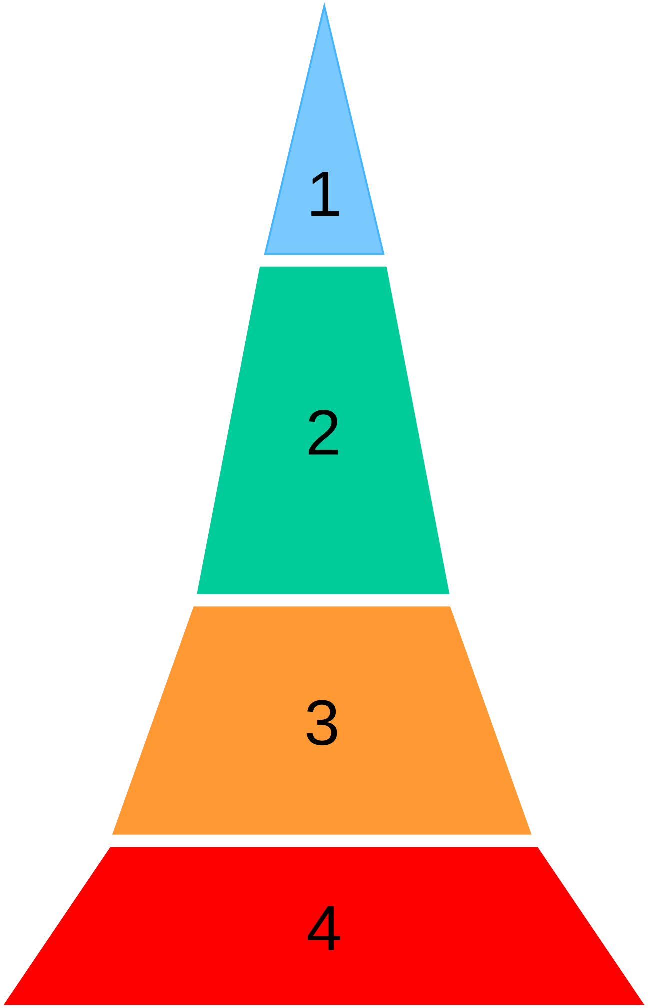


Example for State-of-the-Art Intermediate Storage of Wastes in Plastic-wrapped Bales: Thermal Capacity (MW) = (MJ/kg)*(kg/s)

Foto: W. Kletzmayr, 2006

Calorific value of 1 bale of RDF equals 2 to 3 barrels of crude oil.

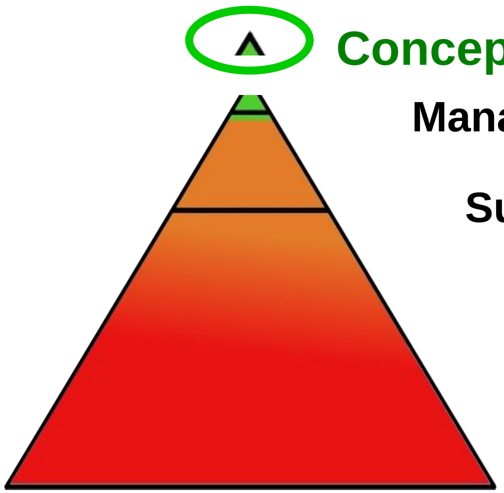
Technical cooperation with local institutions and firms:



1. **Concept**
   - Analyses of Status-Quo and Prognosis
   - Master-Plan for Project Implementation
   - General Concept for Project Design
2. **Planning, Procurement**
   - Project Design
   - Feasibility Study
   - Environmental Impact Assessment
   - Basic Engineering
   - Tender Documents
   - Evaluation of Bids
3. **Construction**
   - Detail Engineering
   - Project Control
   - Training of Operating Personnel
   - Supervision of Start-up
4. **Operation**
   - Maintenance Supervision
   - Environmental Audit

Overall Costs for Project Development, Implementation and Operation of a Waste-to-Energy Plant

Typical Cash-flow of large Waste-to-Energy Plants over Lifetime (e.g. in Austria: RVL Lenzing, EVN Lower Austria, RHKW Linz)



Concept- and Feasibility Studies approx. 0.2 – 0.5 Mio. Euro

Management, Consulting & Engineering approx. 10 Mio. Euro

Supply and Construction approx. 100 – 200 Mio. Euro

Operation and Maintenance of Plant: Turnover (approx. 40 years lifetime) approx. 600 – 2,000 Mio. Euro

Recommendation:
The determining factor for future success is the competent development and systematic evaluation of relevant technical alternatives and feasibility studies by independent expert teams in cooperation with local partners (costs < 0,01-0,1%!)

Typical Mistakes in the Development of Waste Management based on Experience in Europe

	Principle	Practical examples for violation of principles
1	**Awareness**	Ignorance may cause substantial economic losses to present and future generations, health hazards and general environmental degradation (e.g. waste dumps: out of sight – out of mind)
2	**1st Law of Thermodynamics** (balances of mass and energy)	Technologies with technically foreseeable faults (e.g. inappropriate selection of sites with lack of utilization of heat from waste incineration)
3	**2nd Law of Thermodynamics** (increase of entropy)	Technologies with technically foreseeable faults (e.g. stranded investments in waste sorting plants for recycling of municipal garbage)
4	**Economic feasibility of project**	Lack of consideration of waste markets, of economies of scale and of necessary cooperation
5	**Public information** and social acceptance of project	Lack of information and/or investment in public credibility of project applicants may prevent even environmentally friendly projects because of the "NIMBY-syndrome" (Not In My Back-Yard)
6	**Civil law and civil conduct**; **Control and enforcement of law**	Fraud, corruption, overregulation, ignorance, Laissez-faire in enforcement of environmental law and standards by governmental authorities
7	**Foreseeable political development based on sustainability and legal justice**	Increasing bureaucratic costs and stranded investments caused by unforeseen political changes with subsequent frequent changes of regulations and/or of enforcement (e.g. delay of enforcement action; permits for waste export)

And don‘t make the mistake …

And don’t make the mistake …
Source: Stadtreinigung Hamburg-2008