Training course MBT and project calculation

Project calculation

Part 1 **basics**

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Basics of project calculation

- **Capital expenditures (CAPEX)**

  - project engineering and applying for permission
  - pre-financing
  - buildings and infrastructure, sometimes property
  - mechanical engineering
  - putting the plant into operation

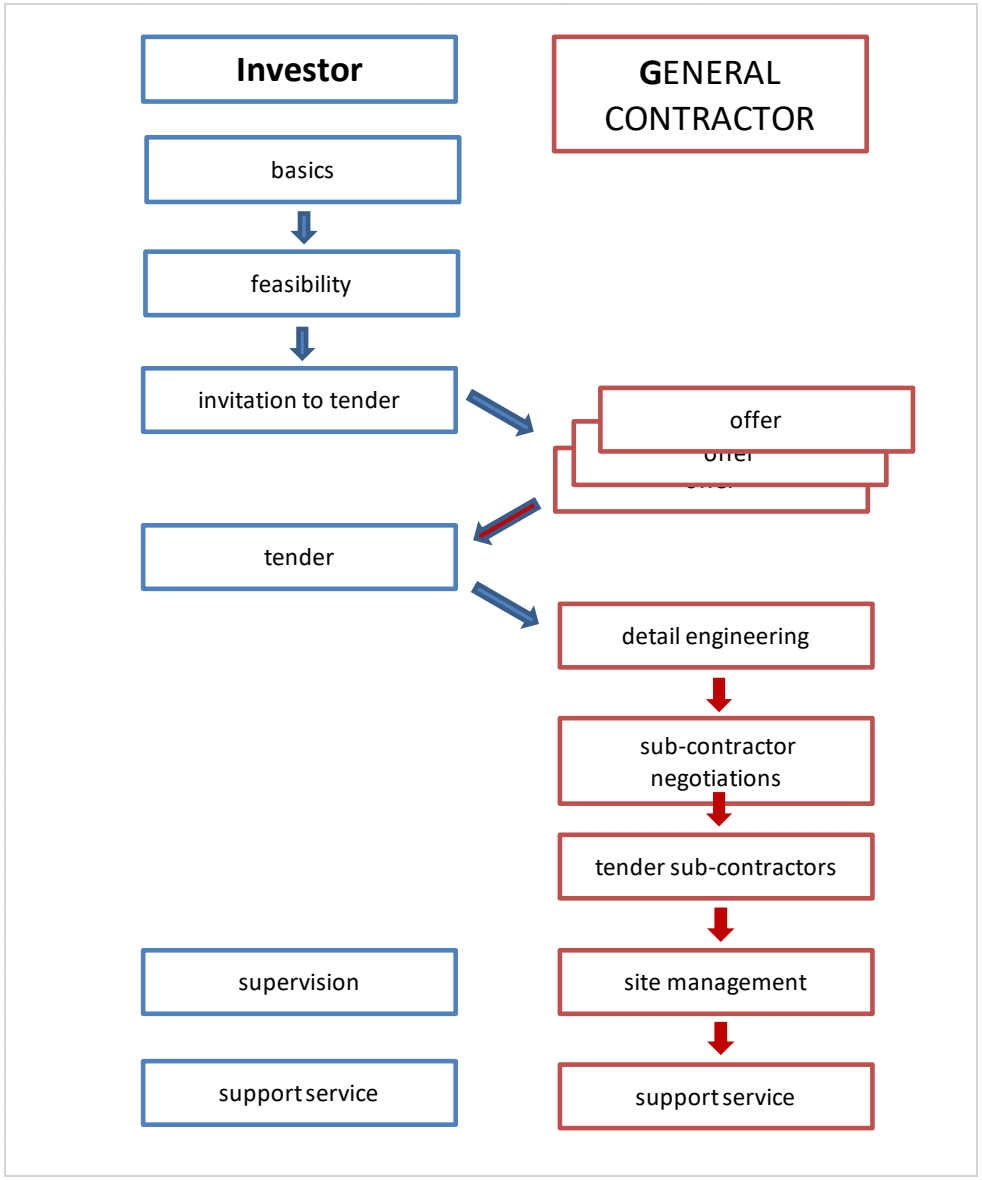
- **Operational expenditures (OPEX)**

  - staff
  - energy
  - repair and maintenance
  - revision of technical units
  - others like service contracts for safety installations etc.

project engineering and applying for permission

- What is the value of your project contribution as engineers?
- Engineering costs are related to the total expenditures, calculated as a percentage of the investment
- Getting an idea have a look in German HOAI (fee structure for Architects and Engineers)
- The structure of engineering differs depending of the type of projects. In every case the total work is necessary to realize projects but the responsibility is different (investor, plant operator, general contractor, sub-contractors …)

project engineering and applying for permission



Engineering is necessary for all project participants

Purchasing technical equipment demands clear and complete description of work and quality with high diligence

project engineering and applying for permission

	work phase	value [%]
1	basics	2
2	pre-feasibility	15
3	feasibility	30
4	applying for permission	5
5	detail engineering	15
6	preparing contracts for tender process	10
7	tender	5
8	supervision	15
9	support service	3

The relation of fees for work phases is proven except for the step “application for permission”, that is much more complicated in case of waste plants

Due to the competitive situation the calculation of fees for engineering the following table gives the maximum fee rates, reality is about 50 %

§44 Honorare für Grundleistungen bei Ingenieurbauwerken

(1) Die Mindest- und Höchstsätze der Honorare für die in § 43 und der Anlage 12 Nummer 12.1 aufgeführten Grundleistungen bei Ingenieurbauwerkensindinderfolgendenhonorartafelfürdenanwendungsbereichdes§41 festgesetzt:

HOAI

Technical requirements from low (I) to high (V)

Anrechenbare Kosten in Euro	Honorarzone I sehr geringe		Honorarzone II		Honorarzone III		Honorarzone IV		Honorarzone V	
	Euro		Euro		Euro		Euro		Euro	
25 000	3 449	4 109	4 109	4 768	4 768	5 428	5 428	6 036	6 036	6 696
35 000	4 475	5 331	5 331	6 186	6 186	7 042	7 042	7 831	7 831	8 687
50 000	5 897	7 024	7 024	8 152	8 152	9 279	9 279	10 320	10 320	11 447
75 000	8 069	9 611	9 611	11 154	11 154	12 697	12 697	14 121	14 121	15 663
100 000	10 079	12 005	12 005	13 932	13 932	15 859	15 859	17 637	17 637	19 564
150 000	13 786	16 422	16 422	19 058	19 058	21 693	21 693	24 126	24 126	26 762
200 000	17 215	20 506	20 506	23 797	23 797	27 088	27 088	30 126	30 126	33 417
300 000	23 534	28 033	28 033	32 532	32 532	37 031	37 031	41 185	41 185	45 684
500 000	34 865	41 530	41 530	48 195	48 195	54 861	54 861	61 013	61 013	67 679
750 000	47 576	56 672	56 672	65 767	65 767	74 863	74 863	83 258	83 258	92 354
1 000 000	59 264	70 594	70 594	81 924	81 924	93 254	93 254	103 712	103 712	115 042
1 500 000	80 998	96 482	96 482	111 967	111 967	127 452	127 452	141 746	141 746	157 230
2 000 000	101 054	120 373	120 373	139 692	139 692	159 011	159 011	176 844	176 844	196 163
3 000 000	137 907	164 272	164 272	190 636	190 636	217 001	217 001	241 338	241 338	267 702
5 000 000	203 584	242 504	242 504	281 425	281 425	320 345	320 345	356 272	356 272	395 192
7 500 000	278 415	331 642	331 642	384 868	384 868	438 095	438 095	487 227	487 227	540 453
10 000 000	347 568	414 014	414 014	480 461	480 461	546 908	546 908	608 244	608 244	674 690
15 000 000	474 901	565 691	565 691	656 480	656 480	747 270	747 270	831 076	831 076	921 866
20 000 000	592 324	705 563	705 563	818 801	818 801	932 040	932 040	1 036 568	1 036 568	1 149 806
25 000 000	702 770	837 123	837 123	971 476	971 476	1 105 829	1 105 829	1 229 848	1 229 848	1 364 201

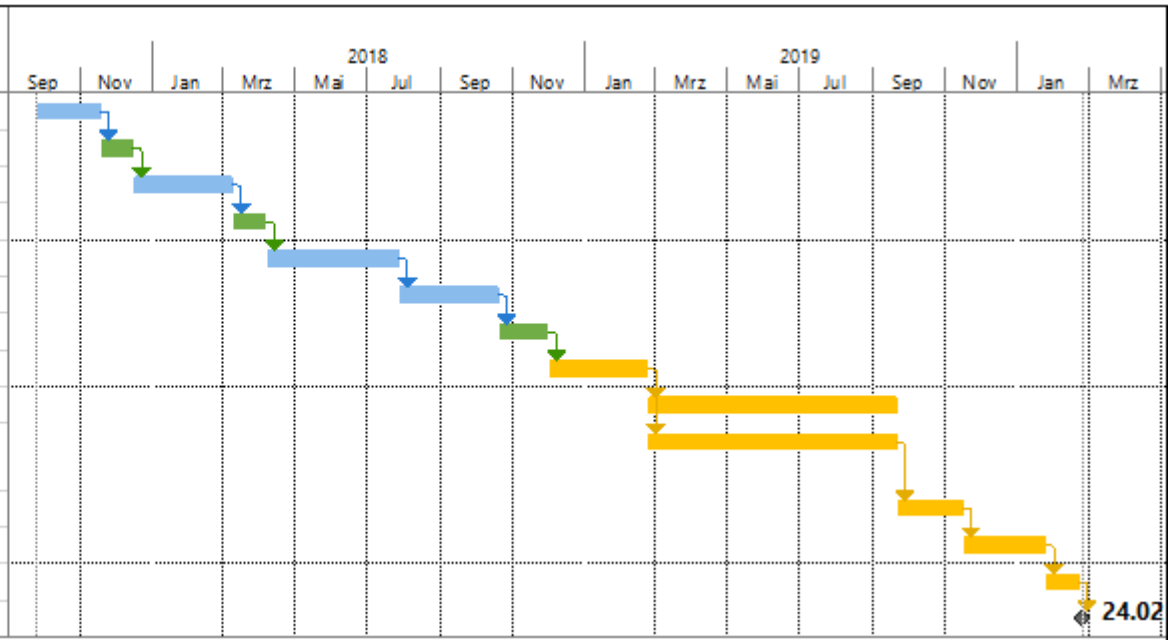
100 % fee for engineering from first step to the final step that ends when warranty is finished after 2 or 5 years depending on the contract

4. Umfang der Funktionsbereiche oder der konstruktiven oder technischen Anforderungen,

Pre-financing

- The preparation of a technical project takes time between the first idea and start of regular operation and revenues
- Expenditures are growing over the whole project time

Nr.	Vorg	Vorgangsname	Dauer
1		basic engineering	40 Tage
2		decission of investor to follow up	20 Tage
3		pre-feasibility study	60 Tage
4		investors decission to follow up	20 Tage
5		preparation of tender contract	80 Tage
6		tender process	60 Tage
7		contract with general contractor	30 Tage
8		detail engineering and sub-contract	60 Tage
9		construction phase	150 Tage
10		production and delivery of mechanical equipment	150 Tage
11		assembling of the plant	40 Tage
12		putting into operation	50 Tage
13		tests for acceptance	20 Tage
14		start of daily operation	1 Tag



Buildings and infrastructure

- (Waste) reception hall
- Operational building(s) of the treatment plant
- Building for employees
- Covered storage areas
- Outside storage areas
- Circulation area and petrol station
- Parking area for employees and service companies
- Reception area with weight bridges
- Dewatering and waste water treatment infrastructure
- Transformer station and other electrical infrastructure
- Structural analyses and permissions

Buildings and infrastructure

Waste Reception hall

Buildings and infrastructure

Operational buildings

- Cost calculation: 50 – 80 €/m³ building volume depending on quality (the more noise prevention, the more weighty the construction must be)
- Lifetime 20 – 30 years
- Example for building progress standard industrial building
- Example for building process of a specific plant construction

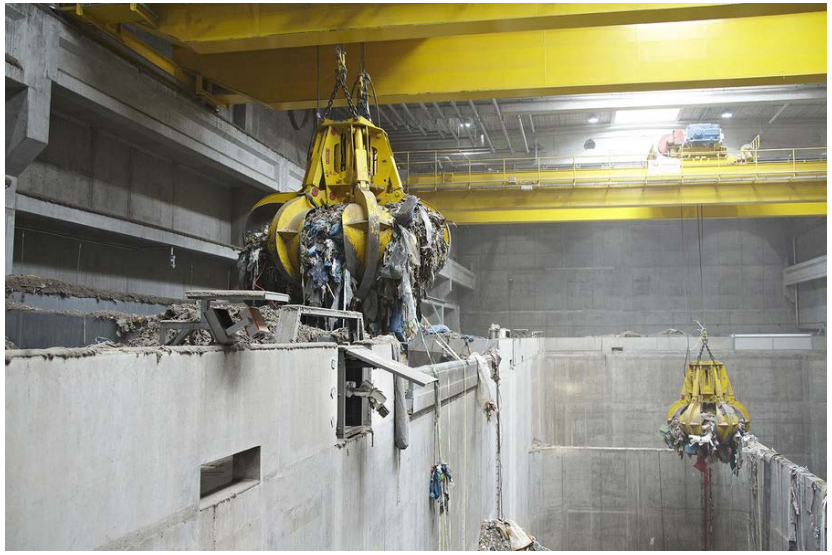
Fire water retention system


Smoke outlet

Operational buildings

Buildings and infrastructure

- Cost calculation: 100 – 200 €/m³ building volume for heavy concrete based constructions like incineration plants with underground bunkers or buildings with integrated cranes
- Lifetime 40 – 50 years



Buildings and infrastructure

Covered storage areas

Storage of hazardous materials

Buildings and infrastructure

Covered storage areas

- Cost calculation: 30 – 40 €/m³ building volume
- Lifetime 15 – 20 years
- No foundation necessary, construction on the circulation area sealed as asphalt or concrete area

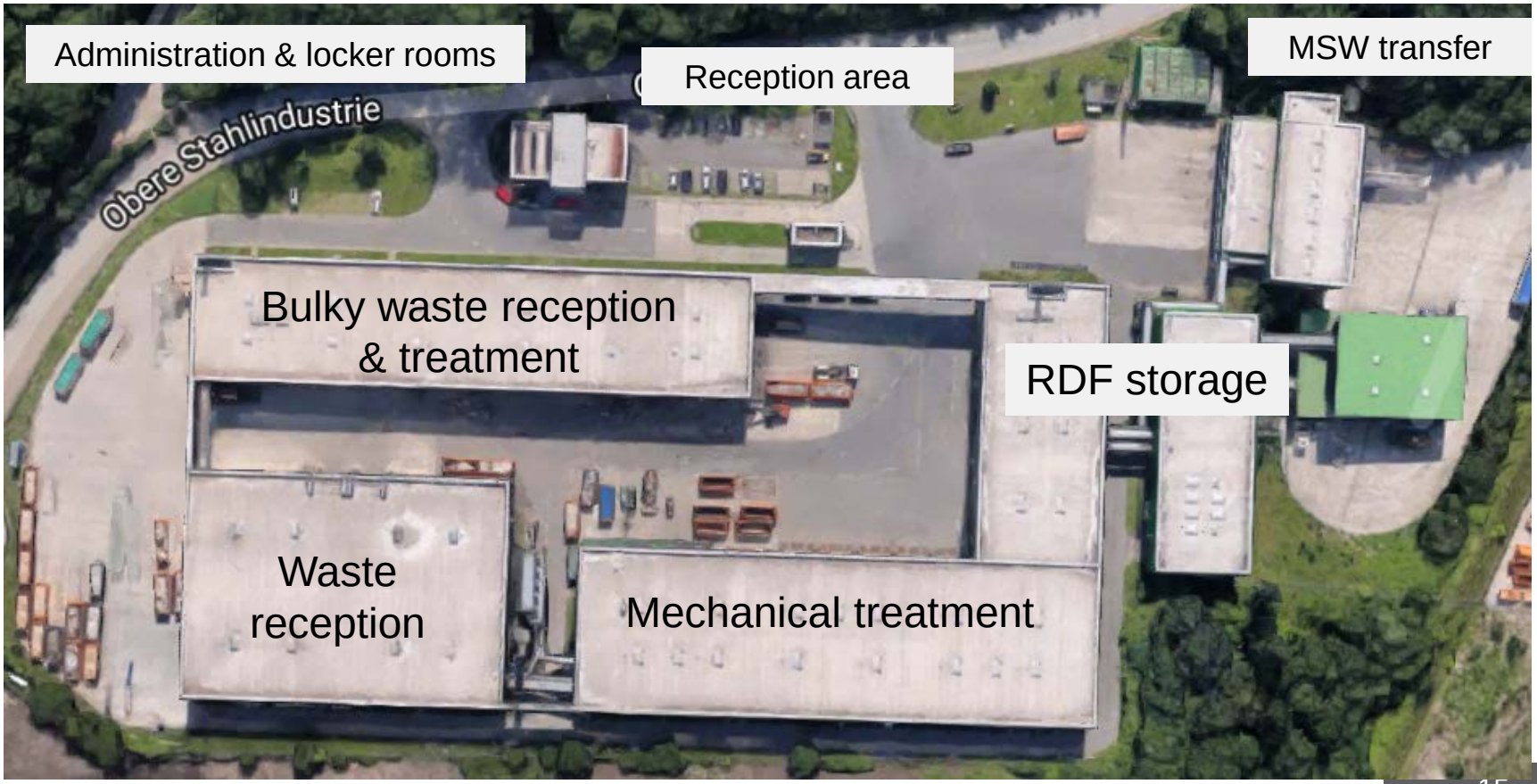
Buildings and infrastructure

Circulation areas

Buildings and infrastructure

- Cost calculation: 100 – 120 €/m² asphalt surface inclusive sewage system, concrete surface + 20 €/m²
- Lifetime 20 – 40 years

Circulation areas



Buildings and infrastructure

Dewatering infrastructure

Fire water pond

Settling pond

Clarifier

Cost calculation:

40 €/m² sealed circulation area, sometimes even for roof areas!

Buildings and infrastructure - an example

Dewatering infrastructure

Item	Cost ($)
Digester Components (Leachate collection slab, gas collection bag, heating elements, gas piping, etc.)	1,000,000
Building Superstructure	575,000
Engine Generator Set	200,000
Improved Base for Foundation	200,000
Mixing Platform	100,000
Biofilters	100,000
Food Storage Pad	50,000
Electrical Interconnection	75,000
Design, Permitting Support and Fees	50,000
Contingency	100,000
Table 2: Conceptual AD plant estimate (5,000 TPY Capacity).	Total 2,450,000

WasteAdvantage
The Advantage in the Waste and Recycling Industry

Mechanical Engineering

- **Cost calculation** for mechanical engineering has to take into account the following positions:
- Detail engineering based on flow sheet and purchasing components
- Steel construction and structural calculations
- Footbridges, stairs
- Electrical installations
- Assembly of all technical units
- Pre-service testing and initial start up

Mechanical Engineering

Steel construction and gateways/footbridges

- Cost calculation:

  800 – 1,000 €/m² footbridge and stairs

- Several 100 m footbridges to connect the aggregates for maintenance and visual control during operation can be possible

Mechanical Engineering

Mechanical Engineering

- Never trust budget price offers!
- Scope of delivery is always limited and the order party has to perform additional services not included in the price
- Prices depend on the conditions of contract (terms of payment, warranties, responsibility for interface construction etc…)
- **Please accept that your first calculation based on pre-feasibility cannot cover all cost positions, therefore mark it “cost-estimation”, add a percentage for contingencies (min. 10%, max. 25%) and show only rounded data like e.g. *9,600,000 €***

Electrical engineering

- Covers the basic installations you need to run a plant like wiring, switchboards, application and system programming and process control
- Covers safety equipment like emergency stop etc.
- <u>Cost calculation:</u>

  4,000 € - 6,000 € per electrical function depending on level of controllability (e.g. electronic frequency converter to adjust engine speed)
- Calculate additional installations like sites connection for power supply and transformer (min. 100,000 €/unit)

Pre-service testing and initial start up

- The General Contractor is responsible for putting a plant into operation with his own staff
- Calculate man power for several weeks (min. 4 weeks, actually better 3 month, in case of difficult processes 1 year or more is possible)
- Transfer of risks from contractor to the investor takes place after successful tests for acceptance!
- Contractor has to cover all costs for maintenance and wearing during his responsible time!
- Contractor must cover costs for changes when he cannot pass the tests for acceptance and has to continue the time for pre-service testing
- Contract penalties are risks in project calculations, to pay when he doesn´t meet a deadline

Mechanical Engineering

Position	calculation	
Mechanical engineering including all process units and conveyor technique	Offer of contractors, budget price offer	a
Steel construction	Rough estimation	b
Surcharge for contractors risks and reward	a + b	20 – 30 % (c)
Electrical engineering	Rough estimation	d
assembling	a + b + c + d	7 % (e)
Pre-service testing	Rough calculation	f
Total price equipment	a + b + c + d + e + f	g
contingencies		10 – 25 % (h)
final price for the Mechanical engineering		g + h

Capex calculation

- The operation of a plant over a long period repays the expenditures for the investment like a loan that must be repaid while the value of the investment wears off (**amortisation or depreciation**)
- A loan is characterized by the credit period and the interest
- Methodology for a rough calculation is the **annuity**
- The idea of annuity is that over the whole credit period the same amount of money is paid with different relations of interest and repayment
- Annuity $q^n=(1+p/100)^n$

  n = credit period or economic lifetime in years; q = interest in %
- The result of annuity calculation is a constant fixed rate of capital expenditures over lifetime that gives a first understanding of this cost position

Capex calculation

- Lifetime of the construction, infrastructure and mechanical engineering of a plant

Buildings and circulation area	20 years	a = 0,0736
Mechanical engineering	6 – **10** years	a = 0,1233
Mechanical engineering (thermal processes)	15 years	a = 0,0899
Mobile equipment (wheel loader, excavator, fork lift truck)	5 years or 10,000 h	a = 0,2246
Engineering, permission, projectmanagement	20 years	a = 0,0736

Annuity $q^n=(1+p/100)^n$ *[formula]*

n = credit period or economic lifetime in years

q = interest in %

- Annuity factors (a) for 4% interest depending on lifetime

Example for the annuity calculation

type of investment	lifetime/ depreciation	annuity factor	investment [T €]	annuity [T €/a]
buildings and circulation area	20	0,0736	4.000	294,4
Mechanical engineering	10	0,1233	5.500	678,15
mobile equipment	5	0,2246	500	112,3
engineering & project management	20	0,0736	500	36,8
			10.500	1121,65

- Financial lifetime and real lifetime aren´t the same
- Actually the real lifetime of mechanical engineering is 20 years and more
- The actual lifetime of mobile equipment is 10,000 h and re-investment is necessary
- Consider that there is **never a depreciation of the expenditures for properties**! Calculate a rent for property use in opex or capex for the loan

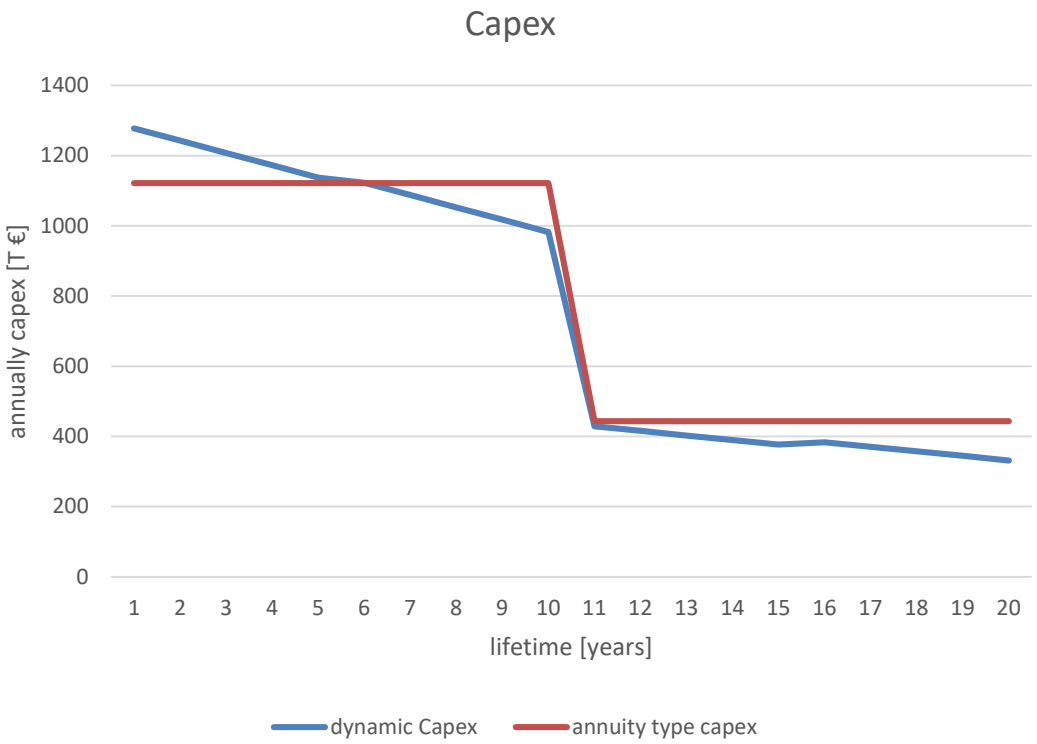
Actual Capex calculation

- The actual capex calculation considers the depreciation annually or monthly.
- In case of a loan for an investment both the residual debt and the amount of interest are decreasing while depreciation rate is of continuous value

	depreciation time	interest																				
year				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
buildings + project management	20	4%																				
loan value [T €]			4500	4275	4050	3825	3600	3375	3150	2925	2700	2475	2250	2025	1800	1575	1350	1125	900	675	450	225	0
depreciation [T €]				225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
interest [T €]				176	167	158	149	140	131	122	113	104	94,5	85,5	76,5	67,5	58,5	49,5	40,5	31,5	22,5	13,5	4,5
capex [T €]				401	392	383	374	365	356	347	338	329	320	311	302	293	284	275	266	257	248	239	230
Mechanical engineering																							
loan value [T €]	10		5500	4950	4400	3850	3300	2750	2200	1650	1100	550	0										
depreciation [T €]				550	550	550	550	550	550	550	550	550	550										
interest [T €]				209	187	165	143	121	99	77	55	33	11										
capex [T €]				759	737	715	693	671	649	627	605	583	561										
mobile equipment	5		500	400	300	200	100	0	400	300	200	100	0	400	300	200	100	0	400	300	200	100	0
loan value [T €]				100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
depreciation [T €]				18	14	10	6	2	18	14	10	6	2	18	14	10	6	2	18	14	10	6	2
interest [T €]				118	114	110	106	102	118	114	110	106	102	118	114	110	106	102	118	114	110	106	102
capex [T €]																							
total capex				1278	1243	1208	1173	1138	1123	1088	1053	1018	983	429	416	403	390	377	384	371	358	345	332

Capex calculation methods

- Financial lifetime and real lifetime aren´t the same
- Actually the real lifetime of mechanical engineering is 20 years and more
- The actual lifetime of mobile equipment is 10,000 h and re-investment is necessary



Total capex annuity type over 20 years:
15.6 Mio. €

Total capex dynamic type over 20 years:
15.1 Mio. €

Annuity calculation + 4 %

Useful for rough calculations

Capex calculation - uncertainty

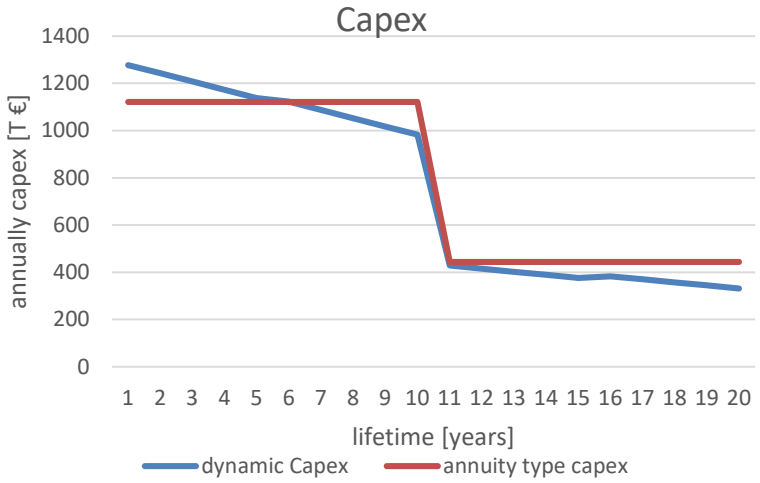
- You are not sure that your calculation of capex is ok? – Make clear that there are contingencies you cannot describe in the phase of pre-feasibility
- The difference in capex calculation in case of an annual throughput of 40,000 t is **+ 4 €/t** or + 14 % *(28 / 32 €/t Capex)*

type of investment	lifetime/ depreciation	annuity factor	investment [T €]	annuity [T €/a]
buildings and circulation area	20	0,0736	4.000	294,4
Mechanical engineering	10	0,1233	5.500	678,15
mobile equipment	5	0,2246	500	112,3
engineering & project management	20	0,0736	500	36,8
			10.500	1121,65

type of investment (version +)	lifetime/ depreciation	annuity factor	investment [T €]	annuity [T €/a]
buildings and circulation area	20	0,0736	5.000	368
Mechanical engineering	10	0,1233	6.500	801,45
mobile equipment	5	0,2246	500	112,3
engineering & project management	20	0,0736	500	36,8
			12.500	1281,75

Capex influence on technology

- After the depreciation of mechanical engineering the capex drops significantly (- 65% in the example)
- In competitive market situation “old” plants without depreciation have the advantage to offer better prices than “new” plants with modern technology
- Economic aspects are the most important drivers to avoid new investment because the disadvantage of depreciation costs is bigger than the advantages of higher efficiency of processes



Opex calculation

- Operational expenditures (OPEX)

  - staff
  - energy
  - repair and maintenance
  - revision of technical units
  - others like service contracts for safety installations etc.

- For calculation of opex you need a basic idea of the daily plant operation

  - operation time per day / per week (shifts)
  - main functions where staff is needed
  - material flows and effort for materials handling (logistics)
  - need for safety measures

Opex calculation – an example

Variable	Value	Comments
Base Year	2014	Costs estimates were made in current 2014 dollars and escalated based on the inflation factor identified below
Inflation Rate – Annual Escalation (for Energy, Labor, and Waste Collection)	2%	Based on recent Federal Reserve Board guidance
Organic Waste Received (Tons Per Year)	5,000	Based on model developed by ZWS
Annual Operating Costs ($)	3% of Capital	Estimated from information provided from AD developers
Annual Capital Repair and Replacement	1% of Initial Capital	Estimated from information provided from AD developers
Financing Cost	Interest Rate: 3.35% Term (Years): 20	Agency borrowing costs
Tipping Fees	$35.00 per ton	Assumed
Energy Sales Prices	$0.1044 per kilowatt hour	Assumed retail purchase price
Sale of Digestate	$0.00 per ton	Wholesale compost rates

staff calculation

- Different functions with different qualification and different salaries
- Don’t forget employers contribution to health insurance and pension insurance (*add 20 -25 % to gross salary* and check national conditions)
- Calculate additional expenditures to cover holiday and disease time *(20 % of staff costs)*

plant manager	50.000 €/a	1,0	50.000 €/a
admin staff	40.000 €/a	1,0	40.000 €/a
machine operator	40.000 €/a	2,0	80.000 €/a
technician	45.000 €/a	1,0	45.000 €/a
service staff	30.000 €/a	1,0	30.000 €/a
		6,0	245.000 €/a
add. staff resource	20,0%	1,20	49.000 €/a
total staff		13,20	**294.000 €/a**

Salary of a plant manager (MSc.)

- Example for Germany, single, no child, no church contribution

staff costs	**50.200 €/a**
employers contribution	8.200 €/a
gross salary	42.000 €/a
taxes	7.200 €/a
health insurance	3.500 €/a
pension insurance	3.950 €/a
long term care insurance	650 €/a
unemployment insurance	650 €/a
net wage	26.050 €/a

Staff costs versus robotics

energy calculation

- **Electrical energy**

  - sum up all consumers (mechanical engineering + buildings [e.g. 100 W/m²])
  - calculate the annual operation time of the plant
  - calculate the total energy consumption based on the installed electrical power (kW) inclusive an efficiency factor (80 %)
  - ask for the price industrial clients have to pay for electrical energy

    German example: domestic customers ~ 0.30 €/kWh

    commercial customers ~ 0.16 €/kWh

- *inst. el. power [kW] * 0.8 * time [hours/a] * price [€/kWh]*

energy calculation

- **Fuel for mobile equipment**

  - sum up driving power of all consumers [kW]

  - make a calculation of working time for the equipment [h/a]

  - estimate the average **o**perating **g**rade (~ 50 %)

  - Diesel engines consumption:

  *driving power [kW] * 0.190 [g/kW*h] * 0.5 * 0.86 [l/g] * time [hours/a] * price [€/l] (net price!)*

Repair and maintenance

- **Conveyor systems and functional units like sieves**

  2 %/a of the purchasing costs

- **Comminution systems**

  20 – 50 %/a of the purchasing costs

  e.g. waste shredder 400,000 € - annually maintenance depending on stress and operation time 80,000 – 200,000 €!

  Lifetime shafts & knifes ~ 3,000 h

  Lifetime cutting table ~ 5,000 h

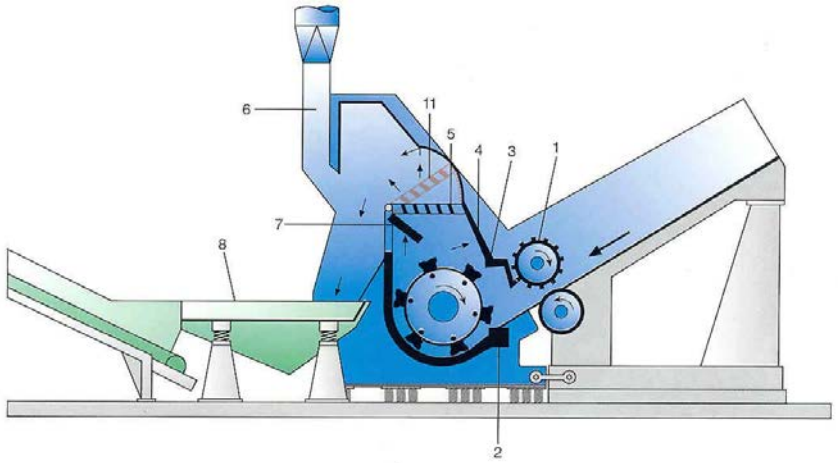
Repair and maintenance

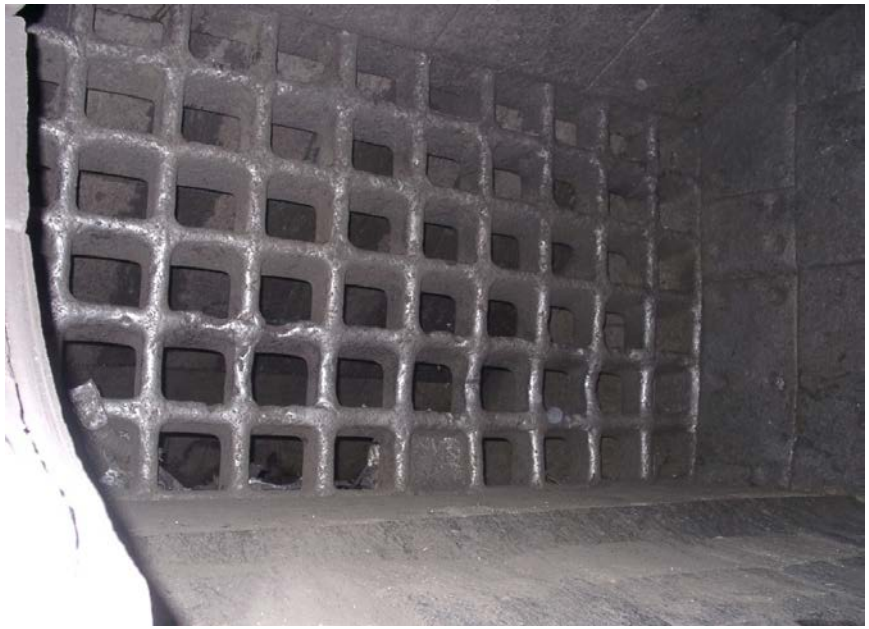
- **Comminution systems**

  e.g. scrap shredder 40 t/h

  Lifetime hammer ~ 4,000 t

  discharge grade ~ 100,000 t





Maintenance and Revision

- **Maintenance** can be worked out in short time like a shift or a weekend without any influence on the availability of a plant because receipt of input is possible every day
  e.g. glass recycling plant: continuous operation 24/7/365 with maintenance shifts triple a week, availability of 85 % or 7,500 h/a
- **Revision** means “plant out of operation” for weeks, storage of input material, abstinence of revenues ….
- Revision is obligatory for all thermal processes in periods of 12 to 24 months, but unusual for mechanical processing facilities
  e.g. waste incinerators realize an availability of > 90 % or more than 7,900 h/a

Exemplary Opex calculation

- Please use a pattern to calculate opex in an early stage of plant design to evaluate the probability of competitiveness

staff	6	workers	40.000	288.000
el. energy	1000	kW	1.700 h/a	218.000
fuel	250	kW	1.700 h/a	47.000
repair + maintenance				
mechanical engineering	2%	5.000.000		100.000
communition	30%	500.000		150.000
construction	2%	4.000.000		80.000
mobile equipment	7%	500.000		35.000
				918.000
miscellaneous	10%			92.000
				1.010.000
contingencies + rounding	10%			100.000
				1.110.000
throughput	t/a	40.000		**28 €/t**

Influencing variables

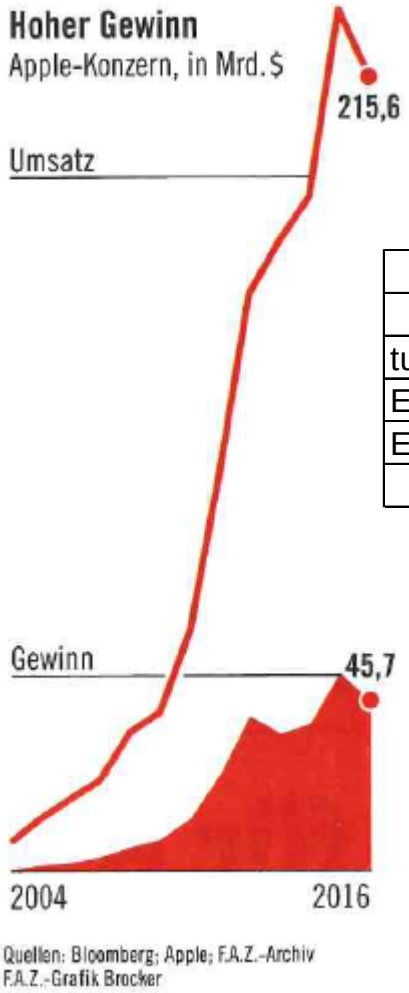
- All costs in the pattern have to be validated for each specific project
- Biggest influence by the capex variables interest and depreciation time
- Minor influence by flow sheet optimisation and resulting mass balances with product yield and residual mass flows

  Discussion of mass balances in the following assessment of MBT technologies

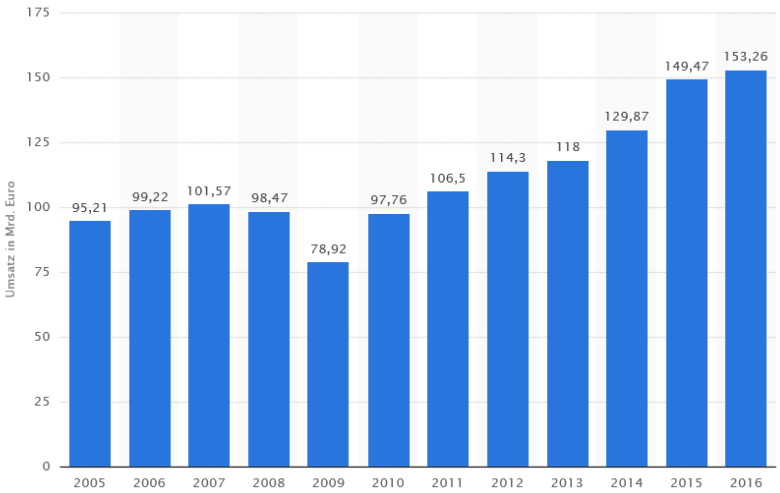
Net income of plant operation

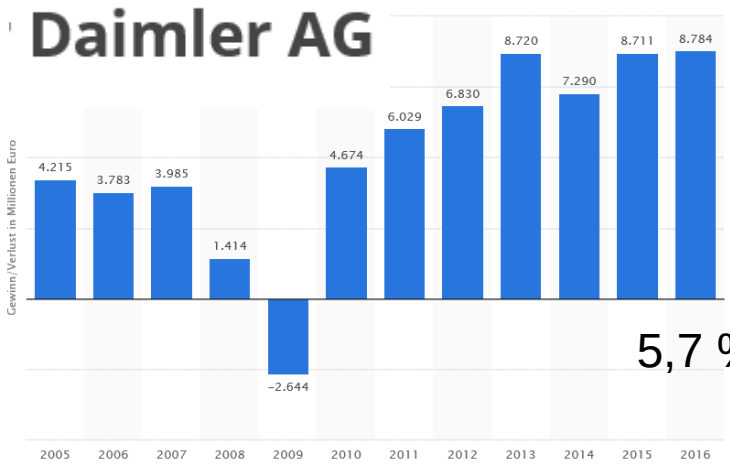
- All calculations without net income expectations and taxes
- Please discuss with investors what they expect as earnings after taxes (EAT) and earnings before interest and taxes (EBIT)
- If you work on a project for public use financed by fees the customers pay EAT usually is limited (e.g. 1%) because fees can be adapted to the actual economic situation and risks are limited.
- If a project is for a competitive market EAT must cover risks!

EAT examples



Veolia Environnement [Mio. €]	
2016	
turnover	24.390,20
EBIT	1.075,40
EAT	486,1
	2,0%





5,7 %

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