Increasing energy efficiency: A plant manufacturers view

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Abstract

To increase the energy efficiency of the waste-to-energy plants is the main challenge of each plant manufacturer. This article lists some current trends and picks- up three of them by mean of examples from current Keppel Seghers projects.

Keywords

Energy efficiency, waste management, RDF, CHP, dry FGC,

Energieeffizienz, Abfallmanagement, EBS, KWK, Trockene Abgasreinigung

1 Introduction

Whereas Waste-to-Energy plants of the 'first-generation' (built in the 1980s) were conceived as stand-alone facilities with the main purpose to get rid of waste, plants of later construction dates started to contain technical solutions to reduce (excessive) energy losses. The electricity produced however was still regarded as a by-product at most of WtE-sites. Modest plant (gross) efficiencies < 24% can be easily understood since the income of those WtE-plants – mostly owned and operated by authorities – was by far more dependent on gate fees than on revenues from electricity sale. As in a public context gate fees are indirectly being paid by the community through taxes or contributions on garbage bags, the viability of WtE-plants is in fact secured without a strong need for optimizing the energy output.

With climate issues currently gaining strong importance worldwide, focus is clearly set on increasing the energetic efficiency of industries and hence significantly reducing carbon footprints. In this article main trends of energy optimization are presented and three of them, used shortly by Keppel Seghers, will be described in detail.

2 Some methods of energy optimization

When observing the market some trends of energy optimization are existing, used more or less consequently by different technology suppliers. In this article some of them are being presented, starting with the beginning of the incineration process.

One of the main questions, when discussing about waste-to-energy plants is: are there any alternatives to burning waste? The mechanical-biological-treatment MBT is easy, cheaper than incineration and more accepted among politicians and citizens. There is only one right answer to this question: “yes, but ….” Even in the MBT after metals, inters and organic fractions are removed there is still more than 40% waste fraction left for treatment. This higher energetic waste, called refuse-derived fuel (RDF) can be used as input stream to the waste-to-energy plant making this system perfect. The enhanced quality of RDF, with high LHV > 11 MJ/kg, low chlorine content and only few inters allows operation of high- caloric incineration plant. We call it integrated waste management. An example of a successfully integrated waste management centre in Qatar is described in the block 2.1.

In addition to the high calorific value, RDF offers the good homogeneity, enabling smooth combustion on the grate. The constant thermal energy output and no emission peaks are the comfortable conditions for plant operators. The situation changes completely when using mixed waste. Depending on the waste composition, LHV, moisture, size and ash content change permanently. This is a challenge for the “state of the art” combustion control system. The control refers to all the equipment included in the combustion process i.e. furnace flue gas side, grate drive with hydraulic system, grate cooling, ash extractor, primary and secondary air, commands of the burners. The main aim is to achieve constant energy output and emission data inside of possible grate and boiler process tolerances. Thanks to high developed computer models it is possible to operate the plants on the cutting edge, however there is still room for improvement.

A new trend can be observed in Switzerland. Due to special landfill regulation concerning bottom ash, a special dry ash extractor has been developed by one of technology suppliers. The technical description of this process is not a part of this article. From the economical point of view savings from better bottom ash quality, also lower disposal cost and additional revenues coming from better metal recycling are expected. The tests are still running and it is too early to decide, if this technology will be interesting for plants in other countries.

The boiler, heart of the energy system offers high potential for increasing the energy efficiency. Since waste-fired boilers are design limited at high temperatures (due to Cl-induced corrosion near the superheating section) it is important to maximally exploit the low-temperature end of the WtE-process in terms of heat recovery. Here the corrosion by condensed SO_2 is considered an important parameter for design. An ensemble of flue gas conditions i.e. bulk gas temperature, partial pressure of SO_2(g) and % of moisture is determining for the (theoretical) dew point. Whether the condensation of SO_2 into aqueous H_2SO_4 droplets is effectively induced in the economizer section depends on the temperature of the tube contact surface and hence the boiler feedwater entering those tubes. For this reason WtE-boilers are up until now often designed with >130°C boiler feed water (BFW) temperature. Apart from experimental evidence, Keppel Seghers also builds on long time plant-scale experience with reduced boiler exit temperatures, strongly supporting the feasibility of a boiler concept with reduced outlet temperatures. Keppel Seghers references in Romonta (Amsdorf, Germany) and Newlincs (Grimsby, UK) are to be mentioned in this regard.

Clearly there is still a way to go if WtE-boilers are to be brought up to the efficiency level of power plant boilers. The strategy that crosses the mind in first instance is to create power plant 'look-a-likes' by applying increased steam parameters. Chlorine-induced corrosion is however complicating this strategy. An important part of the research by the "NextGenBioWaste"-network (funded by the European Commission under the "6th Framework Programme") brings together knowledgeable partners from throughout Europe to tackle a.o. this challenge. Ongoing R&D by (German) scientists, specialized companies and a limited number of plant operators helps to get a better understanding of Cl- and S-corrosion chemistry. In particular tools and methods to assess potential plant-scale corrosion damage in an early stage are interesting from a practical and design perspective. Steady progress is made in the development of boiler materials that allow raising the superheated steam parameters gradually above the WtE- 'standard' of 40 bar & ± 400°C in a sustainable and cost-effective way. Issues of particular importance in this regard are a.o. the iron content, Ni/Cr-ratio and application method accuracy of protection materials (inconel and spraycoating), composition of boiler tube steels. The current "state-of-the-art", superheated steam temperatures up to max. 430°C are considerable for a WtE-plant as economically sensible, thereby assuming the lifetime of superheaters not being sacrificed below two years. Obviously this is not to be generalized as market rates for waste, residues disposal, consumables, electricity, energy etc. – influencing the economical plant models – are everywhere different. Extreme parameters like in Amsterdam WFPP (130 bar / 480°C) are possible, however causing high investment costs as well as problems during commissioning and operation. The practical experience shows, whether this is the right way to improve energy efficiency.

A high potential for efficiency increase can be also found in the turbine. The improvements inside the steam turbine are the challenges for turbine manufacturers, but the turbine environment plays an important role for the total efficiency. In addition to the above mentioned higher steam parameters the condensate parameters can be reduced. This is possible by using water-cooled condensers, allowing steam condensation near vacuum i.e. 70 mbar / 39°C. The pre-condition for this method is the availability of closed or open cooling water circuit.

A significant strategy for future WtE-plants consists of building them in industrial areas, i.e. bring them to intensive energy consumers, where they can be maximally exploited as sources of industrial power. It allows 'upgrading' WtE-plants at once up to potential efficiency levels of 90%, i.e. about 3.5 times the current efficiency of an average 'stand alone' WtE-facility. The need of society to get rid of the waste can be consolidated in this way with the industrial need for energy. Political and public acceptance is likely to increase as WtE´s are being moved further away from residential areas and the treatment of industrial & commercial waste can be addressed at once by co-combustion in the plants. Operating a WtE as highly efficient CHP and selling also steam & heat to surrounding consumers further boosts up the profitability. An example of successfully built CHP in Amtfors/S is described in the block 2.2.

The overall energetic efficiency of WtE-plants can be also increased by optimizing the interface between boiler and flue gas cleaning. Experimental and medium-plant scale evidence support the possibility for reducing boiler outlet temperatures below the currently accepted 'standards'. Due to actual developments in EU energy policy, the chemical performance of flue gas cleaning systems needs to be more and more consolidated with thermal performance. Furthermore, striving for a high performance does not per definition require a complicated system. An all-dry FGC system coupled with a low-temperature boiler exit offers a financially interesting solution, combining gas cleaning performance and increased energetic efficiency with improved plant availability. An example of dry FGC system constructed in Runcorn/GB is described in the block 2.3.

2.1 Example: IWMC / Qatar

More and more countries around the world are limiting or even banning landfill, driving alternative waste solutions towards combinations of maximum recycling and alternative energy generation. The concept of "integrated waste management" is now emerging as mature strategy to cope with the ever- growing complexities of handling large volumes of solid waste. In an integrated waste management the concept of "waste" is replaced by a concept of "resource", combined with well-organized and controlled waste stream. A modern integrated waste management policy is based on combination of waste prevention and avoidance, maximized recycling of used goods, waste re-use, sorting an separate waste collection. Such a concept automatically results in minimized landfilling leaving only a final amount of municipal solid waste (MSW) for further treatment.

Integrated waste management centers separate the MSW into very specific remainder fractions, allowing optimal recycling and/or energy recovery of each specific waste stream. The organic fraction of the waste in an integrated waste management centre is sent to an aerobic or anaerobic process for recycling through composting and energy capture via digestion to biogas. The non-organic fraction that cannot be recycled or used for energy production from composting or digestion is considered for heat and/or generation through thermal production processes. This residual waste has an average heating value of about 15 MJ/kg and is called refuse-derived fuel (RDF). Other fractions such as inert steel, aluminum and ash residues are recycled from the municipal waste or re-used as sand or granulate for a multitude of construction purposes, as (non)-ferrous metals, as industrial salt, gypsum etc. Dedicated technologies ensure that every last fraction of the waste can be re-used.

In this way, in and integrated waste management centre, waste as resource is not only converted into valuable electricity and heating. It's a total and sustainable solution turning each waste fraction into most valuable resource.

Keppel Seghers is currently starting the first IWMC in the Middle East, in Qatar. After the final commissioning in 2010, 1.550 of waste per day will be recycled, composted and turned into energy, resulting in 180.000 MWh/a electricity. The schematic overview below shows the different elements of a typical IWMC.

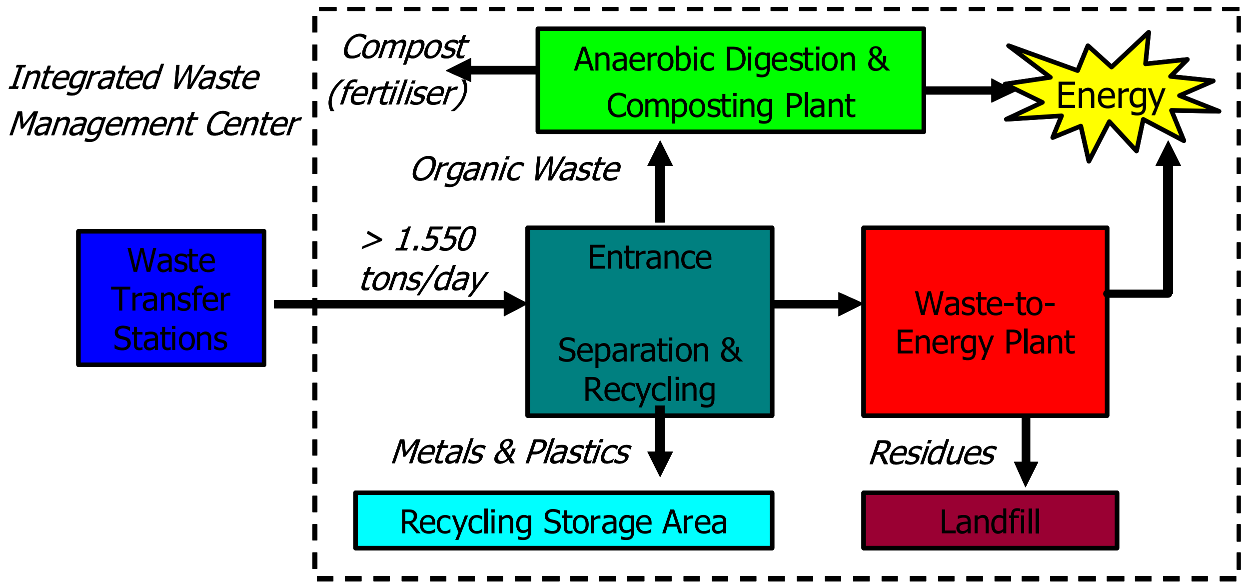

Figure 1 Integrated Waste Management Center as implemented in Doha (Qatar).

2.1.1 Waste reception

Waste enters the facility through the waste reception area and is stored in a bunker, sized to allow for adequate storage during peak delivery times. It is then transferred via an overhead crane to be treated mechanically through several size and density sorting processes.

2.1.2 Recycling

The aim of this stage is to separate the waste into two principal waste flows: wet (organic) and dry. The wet flow is taken to the organic treatment area. The dry fraction undergoes further sorting processes (optic, manual and magnetic) designed to recover the highest amount of recyclable materials.

2.1.3 Organic treatment

During organic treatment, the biodegradable fraction of the MSW is processed by means of an anaerobic digestion process, which results in the maturation of the dehydrated digestate into a clean marketable compost. The volatile biodegradable fraction is fed into the digester reactors, where it remains for 21 days. Biogas is produced in this module and the digestate is dewatered. Part of the liquid is sent back to the bioreactors and the rest to the water treatment installation for purification.

The dewatered digestate (solid material) can be composted in windrows. Since this material is highly concentrated, it is necessary to mix it with woody green waste and to turn it periodically until organic fraction stabilization and sterilization are achieved.

2.1.4 Thermal treatment

The reaming residue of the dry fraction is a combustible material that cannot be recycled. This waste fraction is sent to the advanced thermal recycling, means waste-to-energy installation. The steam produced in the boilers is sent to the turbine-generator to produce electricity.

After incineration process all inherent inert materials become a part of the bottom ash which, after being classified and matured, will be marketed as construction, fill or road base material, thereby reducing once again, the amount of residue to be disposed of the landfill.

2.1.5 Landfill

The non- marketable bottom ash and the residual fraction of the gas cleaning by-products will be kept separate and will require disposal at a landfill.

2.1.6 Water and air control

In order to accomplish an overall control of all air and water emissions both wastewater and odour-treatment systems are an integrated part oft the IWMC. The wastewater treatment plant receives and treats the entire facilities contamined water and returns clean water the various modules that require process water.

2.2 Example: Amtfors / Sweden

The plant is designed for the combustion of MSW, containing about 20-35 wt% moisture. With waste from Norwegian and Swedish origin, the composition is rather similar to the European average with an LHV between 8 – 14 MJ/kg. A limited amount of waste (max.15%) can be replaced in the future by demolition wood. As the pulp for the paper production in the paper factory is supplied from elsewhere, no pulp waste rejects will be added to the waste.

The main purpose of the WtE-CHP is the supply of process steam 6 bar. A flow of about 23 tons per hour must keep up the normal production of two paper machines. A district heating system requires 0.6 – 2.5 MWth, depending on the season of the year, with exceptional peak demands up to 4 MWth. A few smaller consumers are also tied into the steam cycle but as they consume negligible amounts of energy they are further not being discussed. Under nominal (average) plant operation the superheated steam from the boiler (40 barg, 380°C) is fed into the HP-stage of the turbine, where it is expanded to a pressure of 6 barg. About 2/3rd of the total steam flow is exported to the paper mills, while the remaining 1/3rd continues its expansion through the LP-stage of the turbine down to a backpressure of 1.2 bara. A water-cooled condenser releases the heat into the district heating at 90°C. When normal heat supply to the district heating is required (2.5 MWth or less) this temperature is adequate. However, in winter times when the heat demand can peak up to 4 MWth, supply at an elevated temperature of 120°C is required. In these cases steam at 217°C is taken from the 6 barg steam header to heat up the water from the DH in a separate heat exchanger.

WtE-boilers are inherently slow reacting steam generators with a typical range for thermal ‘tuning’ between 70 and 100% (excl. auxiliary fuel). However, sudden fluctuations in steam demand of +/- 50% are common for the paper factory. Measures for securing steam flow under these conditions are thus absolutely required. An accumulator allows storage of steam when more steam/heat is produced by the WtE-boilers than consumed, whereas the back-up boiler is used in those situations when demand rises more than production with the steam accumulator depleted.

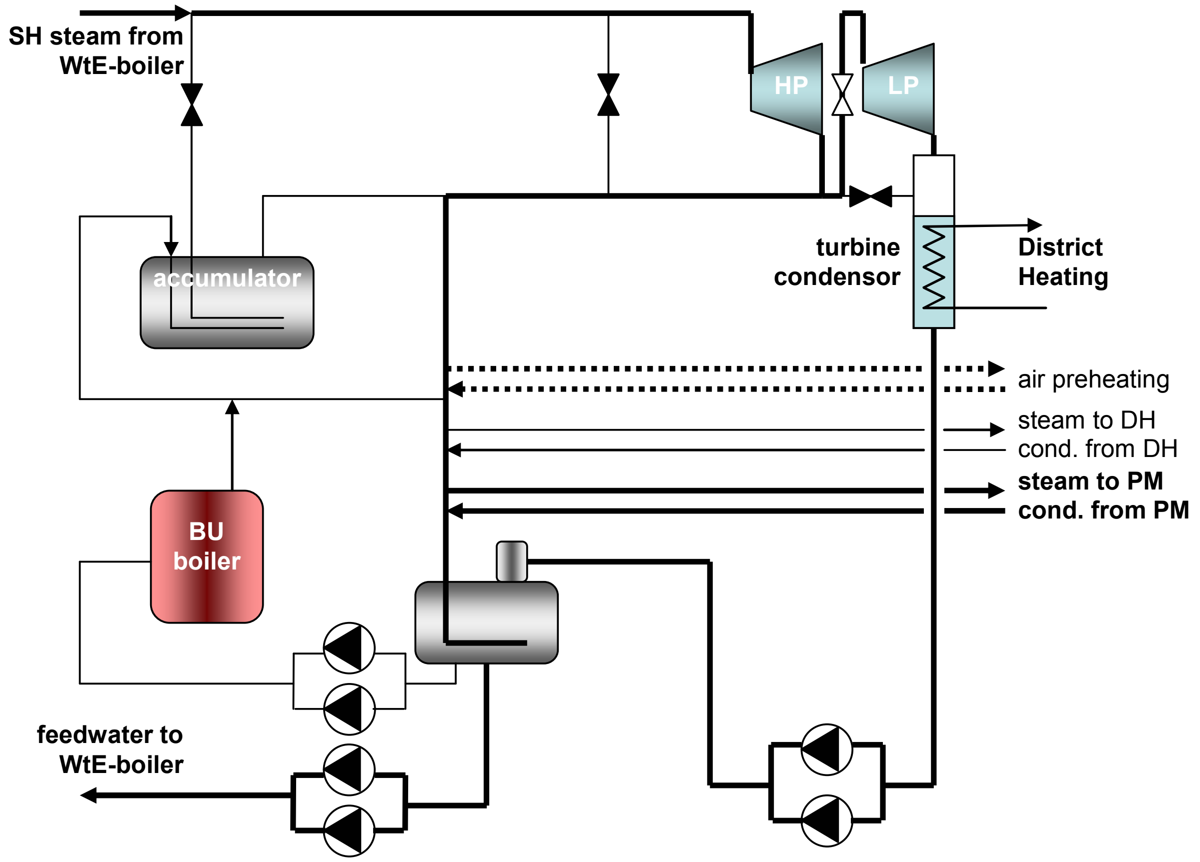

Figure 2 Steam cycle of the Åmotfors WtE-CHP including steam accumulation and back-up capacity.

2.3 Example: GMWA Runcorn / GB

The double full dry system turned out to be advantageous in NPV over other types of systems considered (s.a. bicarbonate, combination of SW+single dry), mainly due to the heat recovery 'bonus' associated with 145°C flue gas temperature at the boiler exit and the avoidance of remote boiler parts. The operation philosophy of the system copes with the knowledge that lime in dry conditions is slower reacting towards SO_2 in the flue gas than in moisturized conditions. The first stage (= reactor & bagfilter 1) takes the 'average' load of HCl and SO_2, whereas the second stage (= reactor & bagfilter 2) is used as a 'police filter' to capture peaks in pollutants.

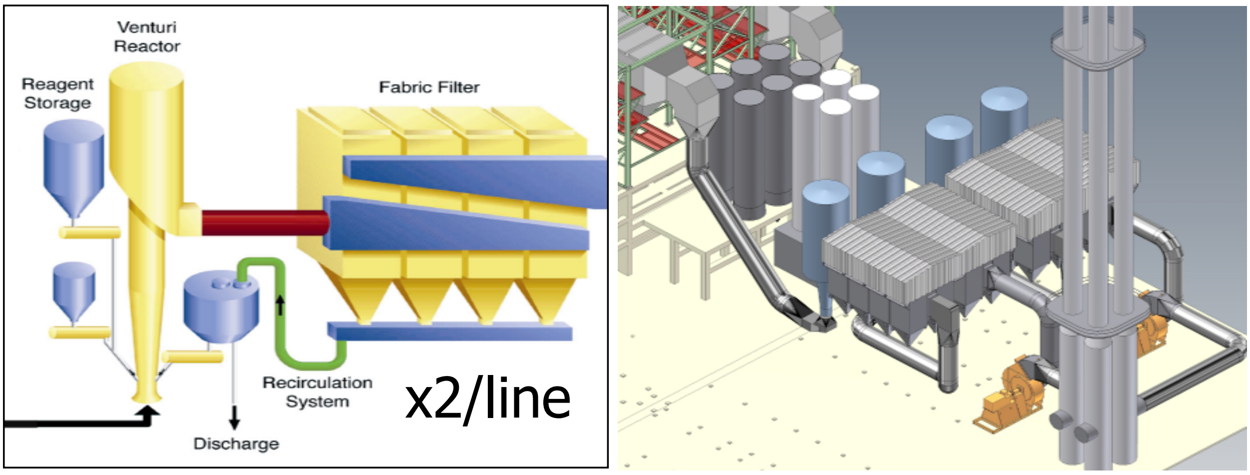

Figure 3 Keppel Seghers Double-dry FGC system with integrated lime buffer and recirculation system (a) principle, (b) as designed for GMW.

The integrated and recycling lime buffer allows for a robust and autonomous operation of the FGC-systems, using a reagent that is well-available on the market and results in well-accepted residues for disposal. And through the absence of water, related operational problems i.e. clogging, screw blocking, corroding residues at low temperature are being avoided. In the context of a CHP-application on one of England's largest industrial chemical sites, the Keppel Seghers double dry system contributes in this way to a maximally secured energy supply.

In Figure 4 a relative financial comparison between basic FGC-types is presented (selected). All FGC configurations considered are capable of treating flue gas with a high Cl/S-ratio. The combination of a semi-wet lime reactor with a single dry lime stage is thereby taken as reference for comparison. Investment costs are considered as 'single shot' and also include for differences in boiler surface and eventual other process equipment for each respective case. Maintenance and (net) operation costs are accumulated values over 15 years and reflect a.o. the expenses for chemicals, utilities, filter sleeves and disposal costs (UK market). Sales bonuses from steam & electricity are deducted from the operation costs for each scenario accordingly. Although financial incentives are set in place in the UK for optimizing the energetic output of WtE-plants, these benefits are not encalculated.

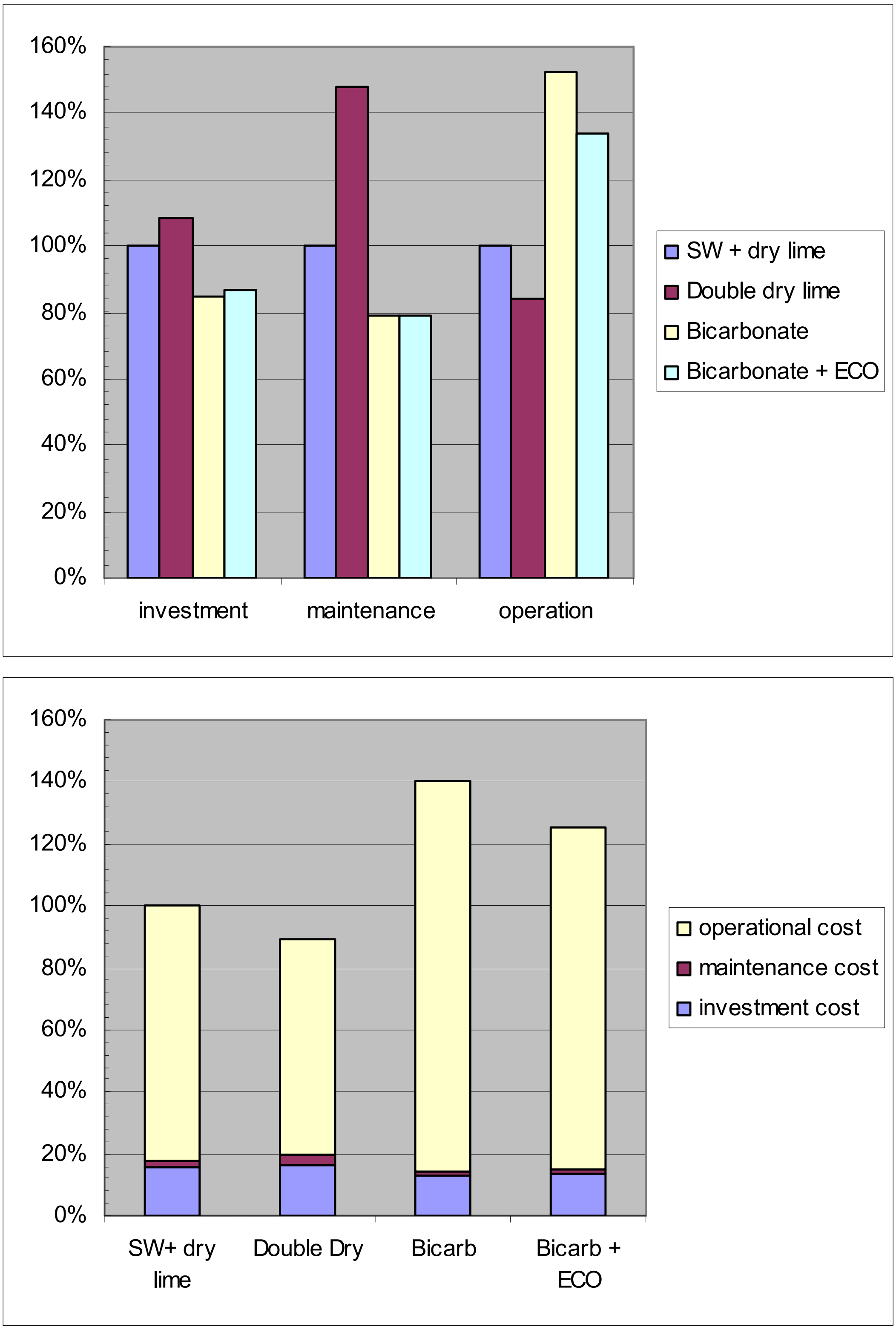

Figure 4 *Financial comparison of 4 selected cases over a time of 15 years: 1) semi-wet + dry lime, 2) double dry lime, 3) bicarbonate and 4) bicarbonate with external economizer before stack. Although the investment and the maintenance (= filter sleeves) costs are relatively higher for a double dry system (a), the low operational expenses turn the overall cost picture in favor of the double dry lime system (b). The combination of lime as reagent and the energy bonus at a flue gas temperature of 145°C offers a sound investment perspective.*

3 Conclusion

The path is characterized by the fact that it is went. There is no golden rule on the way to better efficiency of waste-to-energy plants. Only the combination of many little pieces can contribute to a better result and satisfied customers, politicians and in the end our environment. We are still improving and working on better concepts to live up to this challenge and are happy, that the public acceptance of waste-to-energy plants is improving every year.

4 Literature

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