Climate Change
with
Waste to Energy

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2017

Contents

Chapter 1: What determines the Earth's climate?

The Earth's climate system is complex.

It involves the interaction of the earth's atmosphere, land surfaces, and oceans, along with the snow and ice as well as the activity of humans.

Most of us would refer to climate as "the weather". However, the term climate refers more specifically to the long-term averages in temperature, rain and wind.

The climate system is driven by solar radiation (sunlight) – that is the amount of sunlight reaching the earth as well as the amount that is reflected or retained.

When the sun's energy reaches the earth's atmosphere, some is reflected back into space.

It is estimated that as much as 30% of the radiation which reaches the earth's atmosphere is reflected back – mostly as a result of clouds and small particles in the air known as aerosols (IPCC, 2013).

The remainder passes through the atmosphere and is absorbed by things on the earth's surface such as the land and ocean.

It is then re-emitted as radiant heat. Some of this radiant heat is absorbed and re-emitted by the atmosphere in a process known as the greenhouse effect.

The greenhouse effect is created by a layer of gasses which act as a blanket, preventing all of the radiant heat from escaping and passing back into space.

Water vapour and carbon dioxide are the primary greenhouse gases.

The earth's average temperature is determined by the overall balance between the amount of incoming energy from the sun and the amount of radiant heat that makes it through the atmosphere and is emitted to space.

Another crucial feature of the climate system is that the sun's energy is not distributed evenly. This leads to temperature differences – with the equatorial tropics being considerably warmer than the northern ice fields of Greenland.

The atmosphere and oceans act to balance this discrepancy by transporting heat via natural phenomena such ocean currents, atmospheric circulation, evaporation, and rain.

Over te years, many scientists have proposed that this natural balance has been altered as a result of the human activity. This has resulted in changes to the amount of heat within the earth's atmosphere.

We experience this as changing weather patterns. This is also commonly referred to as "global warming" or "climate change".

The human influence on climate

Climate change can also be caused by human activities, such as the burning of fossil fuels and the conversion of land for forestry and agriculture.

These activities change the land surface and alter the Earth's atmosphere by causing changes in the amounts of greenhouse gases, aerosols (small particles), and cloud.

The largest known contribution comes from the burning of fossil fuels, which releases carbon dioxide gas to the atmosphere.

For instance, the amount of carbon dioxide in the atmosphere has increased by about 35% in the industrial era, all of which has been attributed to human activity (Government of Canada, 2015).

Carbon dioxide – being one of the primary greenhouse gases - can influence both the amount of incoming energy and the amount of outgoing energy.

The build-up of greenhouse gases in the atmosphere has therefore led to an enhancement of the natural greenhouse effect.

It is this human-induced enhancement of the greenhouse effect that is of concern because ongoing emissions of greenhouse gases have the potential to warm the planet to levels that have never been experienced in the history of human civilisation (IPCC, 2013).

Already we have seen that, since the beginning of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence.

And this impact is already believed to greatly exceed any changes resulting from natural processes, such as solar changes and volcanic eruptions.

Chapter 2: The history of climate change

The history of climate change is a relatively short in view of the overall history of the earth.

Nonetheless, it was the Ancient Greeks who first documented their suspicions that the climate could change over time (Glacken, 1967).

Theophrastus, a pupil of Aristotle, told how the draining of marshes had made a particular locality more susceptible to freezing, and speculated that lands became warmer when the clearing of forests exposed them to sunlight.

Renaissance and later scholars saw that deforestation, irrigation, and grazing had altered the lands around the Mediterranean since ancient times; they thought it plausible that these human interventions had affected the local weather (Neumaan, 1985).

More modern research indicates that the primary influences on climate began in the 1700s – with the beginning of the industrial era.

Below is a brief timeline summary of the key events which have contributed climate change as well as important scientific discoveries.

1712

The invention of the first widely-used steam engine by Thomas Newcomen paves the way for the Industrial Revolution and industrial scale use of coal.

1800

The world's population reaches one billion.

The level of carbon dioxide gas (CO2) in the atmosphere, as later measured in ancient ice, is about 290 ppm (parts per million).

The Industrial Revolution is in full swing as the use of coal increases as does land clearing for agriculture.

1824

French physicist Joseph Fourier is the first to describe the Earth's natural "greenhouse effect".

He calculates that the Earth would be far colder if it lacked an atmosphere.

1860

Irish physicist John Tyndall builds on Fourier's theory to show that water steam and certain other gases create the greenhouse effect.

1886

Karl Benz releases the first car - the Motorwagen.

1896

Swedish chemist Svante Arrhenius postulates that coal burning will enhance the natural greenhouse effect. He suggests that a doubling of atmospheric C02 levels will lead to rise of a few degrees Celsius. This model remains current.

1900

Knut Angstrom discovers that even at the tiny concentrations found in the atmosphere, CO_2 strongly absorbs parts of the infrared spectrum.

1920-1925

The discover and opening of oil fields in Texas and the Persian Gulf which leads to cheaper oil products.

1927

Carbon emissions from fossil fuel burning and industry reach one billion tonnes per year.

1930

Human population reaches two billion.

1938

Research by Guy Callendar shows that temperatures had risen over the previous century. He also shows that CO_2 concentrations had increased over the same period, and suggests this caused the warming.

1955

US researcher Gilbert Plass analyses in detail the infrared absorption of various gases. His conclusions support Arrhenius' suggestion that a doubling of CO_2 concentrations would increase temperatures by 3-4C.

1956

Norman Phillips produces a somewhat realistic computer model of the global atmosphere.

Physicist Gilbert Plass calculates that adding CO_2 to the atmosphere will have a significant effect on the radiation balance.

1957

US oceanographer Roger Revelle and chemist Hans Suess show that seawater will not absorb all the additional CO_2 entering the atmosphere, as many had assumed.

1958
Telescope studies show a greenhouse effect raises temperature of the atmosphere of Venus far above the boiling point of water.

Charles David Keeling begins systematic measurements of atmospheric CO_2 at Mauna Loa in Hawaii and in Antarctica. Within four years, the project - which continues today - provides the first unequivocal proof that CO_2 concentrations are rising.

1960
Human population reaches three billion.

Keeling accurately measures CO_2 in the Earth's atmosphere and detects an annual rise. The level is 315 ppm. Mean global temperature (five-year average) is 13.9°C.

1965
A US President's Advisory Committee panel warns that the greenhouse effect is a matter of "real concern".

1966
Emiliani's analysis of deep-sea cores and Broecker's analysis of ancient corals show that the timing of ice ages was set by small orbital shifts, suggesting that the climate system is sensitive to small changes.

1967
International Global Atmospheric Research Program established, mainly to gather data for better short-range weather prediction, but including climate.

Manabe and Wetherald make a convincing calculation that doubling CO_2 would raise world temperatures a couple of degrees.

1968
Studies suggest a possibility of collapse of Antarctic ice sheets, which would raise sea levels catastrophically.

1969
Nimbus III satellite begins to provide comprehensive global atmospheric temperature measurements.

1970
First Earth Day. Environmental movement attains strong influence, spreads concern about global degradation.

Creation of US National Oceanic and Atmospheric Administration, the world's leading funder of climate research.

Aerosols from human activity are shown to be increasing swiftly. Bryson claims they counteract global warming and may bring serious cooling.

1971

SMIC conference of leading scientists reports a danger of rapid and serious global change caused by humans, calls for an organized research effort.

1972

Ice cores and other evidence show big climate shifts in the past between relatively stable modes in the space of a thousand years or so, especially around 11,000 years ago.

Droughts in Africa, Ukraine, India cause world food crisis, spreading fears about climate change.

First UN environment conference, in Stockholm. Climate change hardly registers on the agenda, which centres on issues such as chemical pollution, atomic bomb testing and whaling. The United Nations Environment Programme (UNEP) is formed as a result.

1974

Serious droughts since 1972 increase concern about climate, with cooling from aerosols suspected to be as likely as warming; scientists are doubtful as journalists talk of a new ice age

1975

Human population reaches four billion.
US scientist Wallace Broecker puts the term "global

warming" into the public domain in the title of a scientific paper.

Warnings about environmental effects of airplanes leads to investigations of trace gases in the stratosphere and discovery of danger to ozone layer.

Manabe and collaborators produce complex but plausible computer models which show a temperature rise of several degrees for doubled CO2.

1976

Studies show that CFCs (1975) and also methane and ozone (1976) can make a serious contribution to the greenhouse effect.

Deforestation and other ecosystem changes are recognized as major factors in the future of the climate.

1977

Scientific opinion tends to converge on global warming, not cooling, as the chief climate risk in next century.

1978

Attempts to coordinate climate research in US end with an inadequate National Climate Program Act, accompanied by rapid but temporary growth in funding.

1979
US National Academy of Sciences report finds it highly credible that doubling CO_2 will bring 1.5-4.5°C global warming.

World Climate Research Programme launched to coordinate international research.

1981
Election of Reagan brings backlash against environmental movement to power. Political conservatism is linked to skepticism about global warming.

Hansen and others show that sulfate aerosols can significantly cool the climate, raising confidence in models showing future greenhouse warming.

Some scientists predict greenhouse warming "signal" should be visible by about the year 2000.

1982
Greenland ice cores reveal drastic temperature oscillations in the space of a century in the distant past.

Strong global warming since mid-1970s is reported, with 1981 the warmest year on record

1983
Reports from US National Academy of Sciences and Environmental Protection Agency spark conflict, as greenhouse warming becomes prominent in mainstream politics.

1985
Ramanathan and collaborators announce that global warming may come twice as fast as expected, from rise of methane and other trace greenhouse gases

Villach Conference declares consensus among experts that some global warming seems inevitable, calls on governments to consider international agreements to restrict emissions

Antarctic ice cores show that CO2 and temperature went up and down together through past ice ages, pointing to powerful biological and geochemical feedbacks.

Broecker speculates that a reorganization of North Atlantic Ocean circulation can bring swift and radical climate change.

1986
Meltdown of reactor at Chernobyl (Soviet Union) cripples plans to replace fossil fuels with nuclear power.

1987
Montreal Protocol agreed, restricting chemicals that damage the ozone layer. Although not established with climate change in mind, it has had a greater impact on greenhouse gas emissions than the Kyoto Protocol.

1988
Intergovernmental Panel on Climate Change (IPCC) formed to collate and assess evidence on climate change.

Toronto conference calls for strict, specific limits on greenhouse gas emissions; UK Prime Minister Thatcher is first major leader to call for action.

Ice-core and biology studies confirm living ecosystems give climate feedback by way of methane, which could accelerate global warming.

1989
Fossil-fuel and other U.S. industries form Global Climate Coalition to tell politicians and the public that climate science is too uncertain to justify action.

Carbon emissions from fossil fuel burning and industry reach six billion tonnes per year.

1990

First IPCC report says world has been warming and future warming seems likely.

IPCC produces First Assessment Report. It concludes that temperatures have risen by 0.3-0.6C over the last century, that humanity's emissions are adding to the atmosphere's natural complement of greenhouse gases, and that the addition would be expected to result in warming.

1991

Mt. Pinatubo explodes; Hansen predicts cooling pattern, verifying (by 1995) computer models of aerosol effects.

1992

At the Earth Summit in Rio de Janeiro, governments agree the United Framework Convention on Climate Change. Its key objective is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". Developed countries agree to return their emissions to 1990 levels.

1995

IPCC Second Assessment Report concludes that the balance of evidence suggests "a discernible human influence" on the Earth's climate. This has been called the first definitive statement that humans are responsible for climate change.

1997

Toyota introduces Prius in Japan, first mass-market electric hybrid car; swift progress in large wind turbines and other energy alternatives.

Kyoto Protocol agreed. Developed nations pledge to reduce emissions by an average of 5% by the period 2008-12, with wide variations on targets for individual countries. US Senate immediately declares it will not ratify the treaty.

1998

A "Super El Niño" makes this an exceptionally warm year, equaled in later years but not clearly exceeded until 2014. Borehole data confirm extraordinary warming trend.

1998

Strong El Nino conditions combine with global warming to produce the warmest year on record. The average global temperature reached 0.52C above the mean for the period 1961-90 (a commonly used baseline).

1999

Ramanathan detects massive "brown cloud" of aerosols from South Asia.

2001
Third IPCC report states baldly that global warming, unprecedented since the end of the last ice age, is "very likely," with highly damaging future impacts.

Bonn meeting, with participation of most countries but not US, develops mechanisms for working towards Kyoto targets.

2003
Numerous observations raise concern that collapse of ice sheets (West Antarctica, Greenland) can raise sea levels faster than most had believed.

2004
First major books, movie and art work featuring global warming appear.

2005
Kyoto treaty goes into effect, signed by major industrial nations except US. Work to retard emissions accelerates in Japan, Western Europe, US regional governments and corporations.

2006
China overtakes the United States as the world's biggest emitter of CO2.

2007
Fourth IPCC report warns that serious effects of warming have become evident; cost of reducing

emissions would be far less than the damage they will cause.

Greenland and Antarctic ice sheets and Arctic Ocean sea-ice cover found to be shrinking faster than expected.

2008
Climate scientists (although not the public) recognize that even if all greenhouse gas emissions could be halted immediately, global warming will continue for millennia.

2009
Many experts warn that global warming is arriving at a faster and more dangerous pace than anticipated just a few years earlier.

Copenhagen conference fails to negotiate binding agreements.

2012
Controversial "attribution" studies find recent disastrous heat waves, droughts, extremes of precipitation, and floods were made worse by global warming.

2013
An apparent pause or "hiatus" in global warming of the atmosphere since 1998 is discussed and

explained; the atmosphere is still warming, and the oceans have continued to get rapidly warmer.

2015

Researchers find collapse of West Antarctic ice sheet is irreversible, will bring meters of sea level rise over future centuries.

Paris Agreement: nearly all nations pledge to set targets for their own greenhouse gas cuts and to report their progress.

Mean global temperature is 14.7°C, the warmest in thousands of years. Level of CO2 in the atmosphere reaches 400 ppm, the highest in millions of years.

Chapter 3: The current state of climate change

According to the most recent report by the Intergovernmental Panel Warming on Climate Change (2015), the changes to the climate system is unequivocal and unprecedented.

The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased (IPCC, 2015)

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850.

In the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years.

Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010.

Over the past two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent.

The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia.

Over the period 1901 to 2010, global mean sea level rose by 0.19 metres.

Atmospheric concentrations of carbon dioxide (CO_2), methane and nitrous oxide began to rise around two hundred years ago and current levels are unprecedented in at least the last 800,000 years.

The concentration of CO_2 has increased from 280 parts per million (ppm) before 1800, to 396 ppm in 2013.

This history of greenhouse gas concentrations has been established by a combination of modern measurements and analysis of ancient air bubbles in polar ice.

In just a few hundred years, carbon dioxide concentrations have increased by 40%, primarily from fossil fuel emissions and secondarily from net land use change emissions.

This surplus carbon dioxide is being added to the atmosphere faster than it can be taken up by the land biosphere and the oceans.

The Global Carbon Project found that, of the total carbon dioxide emissions, 25% was absorbed by the ocean – resulting in the rising acidity of sea water – and 30% was taken up on land, largely by increased plant growth stimulated by rising atmospheric CO_2 and increased nutrient availability.

The other 45% of emissions accumulated in the atmosphere. These changes to the carbon cycle are known from measurements in the atmosphere, on land and in the ocean, and from modelling studies (Australian Academy of Science, 2015).

These statistics all point to a continuing rise in climate change impacts including rising seas levels and temperatures with dire consequences for the world as we know it.

Scientists now believe that even a complete halt to all carbon emissions would still take many years to reverse the current situation.

It is clear that industrialised nations need to radically change both policy and popular opinion with regards to the use of carbon fuels.

Chapter 4: The global political response to climate change

Historically, the politics of climate change dates back to several conferences in the late 1960s and the early 1970s under NATO and President Richard Nixon.

The history of climate change politics

1979 saw the world's first World Climate Conference.

1985 was the year that the Vienna Convention for the Protection of the Ozone Layer was created and two years later in 1987 saw the signing of the Montreal Protocol under the Vienna convention.

This model of using a Framework conference followed by Protocols under the Framework was seen as a promising governing structure that could be used as a path towards a functional governance approach that could be used to tackle broad global multi-nation/state challenges like global warming.

One year later in 1988 the Intergovernmental Panel on Climate Change was created by the World

Meteorological Organization and the United Nations Environment Programme to assess the risk of human-induced climate change.

Margaret Thatcher in1988 strongly supported IPCC and in 1990 was instrumental to found the Hadley Centre for Climate Prediction and Research in Exeter.

1991 saw the publishing of the book The First Global Revolution by the Club of Rome report which sought to connect environment, water availability, food production, energy production, materials, population growth and other elements into a blueprint for the twenty-first century: political thinking was evolving to look at the world in terms of an integrated global system not just in terms of weather and climate but in terms of energy needs, food, population, etc.

1992 was the year that the United Nations Framework Convention on Climate Change (UNFCCC) was agreed at the Earth Summit in Rio de Janeiro and the framework entered into force 21 March 1994. The conference established a yearly meeting, a conference of the parties or COP meeting to be held to continue work on Protocols which would be enforceable treaties.

1995 the IPCC's Second Assessment Report: Climate Change 1995 and in 1996 the European Union adopt a goal of limiting temperature rises to a maximum 2 °C rise in average global temperature.

1997 saw the creation of the Kyoto Protocol under the United Nations Framework Convention on Climate Change (UNFCCC) in a very similar structure as the Montreal Protocol was under the Vienna Convention for the Protection of the Ozone Layer which would have yearly meetings of the members or CMP meetings. However, in the same year, the US Senate passed Byrd–Hagel Resolution rejecting Kyoto without more commitments from developing countries.

Since the 1992 UNFCCC treaty, global CO_2 emissions have risen significantly and developing countries have grown significantly with China replacing the United States as the largest emitter of greenhouse gases.

Below is a brief timeline of key events in the global politics of climate change:

1969

NATO tried to establish a third civil column and planned to establish itself as a hub of research and initiatives in the civil region, especially on environmental topics.

Daniel Patrick Moynihan, Nixons NATO delegate for the topic named acid rain and the greenhouse effect as suitable international challenges to be dealt by NATO.

NATO had suitable expertise in the field, experience with international research coordination and a direct access to governments.

After an enthusiastic start on authority level, the German government reacted skeptically. The initiative was seen as an American attempt to regain international terrain after the lost Vietnam War.

The topics and the internal coordination and preparation effort however gained momentum in civil conferences and institutions in Germany and beyond during the Brandt government.

1972

Nobel Prize winners Willy Brandt and Olof Palme stated that enhanced international research cooperation on the greenhouse topic was necessary.

1979

First World Climate Conference

1987

Brundtland Report was released – targeting multilateralism and interdependence of nations in the search for a sustainable development path.

The report placed environmental issues firmly on the political agenda; it aimed to discuss the environment and development as one single issue.

1987

The Montreal Protocol on restricting ozone layer-damaging CFCs demonstrates the possibility of coordinated international action on global environmental issues.

1988

The Intergovernmental Panel on Climate Change is established to coordinate scientific research into the risk of human-induced climate change.

1992

The United Nations Framework Convention on Climate Change was formed to "prevent dangerous anthropogenic interference with the climate system.

1996

The European Union adopts the target of a maximum 2 °C rise in average global temperature.

1997

Kyoto Protocol agreed.

2001

The United States withdraws from the Kyoto negotiations.

2005

Kyoto Protocol comes into force (not including the US or Australia).

The European Union Emissions Trading Scheme is launched.

Climate change makes it onto the agenda for discussion at the G8 Summit.

2006

The Stern Review is published. It is the first comprehensive contribution to the global warming debate by an economist and its conclusions lead to the promise of urgent action by the UK government to further curb Europe's CO_2 emissions and engage other countries to do so.

2009

US House of Representatives passes the American Clean Energy and Security Act.

2015

World leaders meet in Paris, France for the 21st Conference of the Parties of the UNFCCC. 187 countries eventually signed on to the Paris Agreement.

The current global political response to climate change

The primary mechanism for the world, as a combined whole, to tackle global warming continues to be the United Nations Framework Convention on Climate Change (UNFCCC).

However, since the 1960s, there has been frustration from many nations over the efficacy of this forum.

There is a current, perceived lack of progress since the treaty was first signed nearly 20 years ago, with the agreement doing little to curb global greenhouse emissions.

Todd Stern – the US Climate Change envoy – has expressed the challenges with the UNFCCC process as follows:

"Climate change is not a conventional environmental issue...It implicates virtually every aspect of a state's economy, so it makes countries nervous about growth and development.

This is an economic issue every bit as it is an environmental one."

He went on to explain that, the United Nations Framework Convention on Climate Change is a multilateral body concerned with climate change and can be an inefficient system for enacting international policy.

Because the framework system includes over 190 countries and because negotiations are governed by consensus, small groups of countries can often block progress.

The Kyoto Protocol

The first time the world came together in a binding agreement to fight climate change was in 1997 in Japan. The conference birthed the Kyoto Protocol which set targets for reductions in greenhouse gas emissions in a bid to evade the consequences of climate change.

This protocol was extended at the 2012 Doha climate change talks. There, parties to the Kyoto Protocol agreed to an extension to 2020.

Participants in the extension to the Kyoto Protocol have taken on targets for the period 2013-2020, and include Australia, the European Union, and a number of other developed countries.

Canada, an original signatory to Kyoto, withdrew in 2011 and The United States – who never ratified the Kyoto Protocol – have cine been joined by New Zealand, Japan, Russia, Belarus, and Ukraine who have stated that they would not sign up to a second Kyoto Protocol commitment period or extension due lack of commitments from the developing world which today include the world's largest carbon dioxide emitters.

Japan and New Zealand also added that their country's CO2 emissions are minor when compared to the emissions of China, The United States, and the European Union.

As a result, the international view of the Kyoto Protocol has grown dim, with some pundits going so far as to label it complete failure.

Others have argued that the consensus driven model could be replaced with a majority vote model. However, that model would likely drive disagreement at the country-level-ratification by countries who disagreed with any global treaties that might passed through a majority vote at such restructured institutions.

Voluntary emissions reductions

The perceived slow process of efforts for countries to agree to a comprehensive global level binding agreements has led some countries to seek voluntary steps and focus on alternative high-value voluntary activities like the creation of the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants by the United States, Canada, Mexico, Bangladesh, and Sweden which seeks to regulate short-lived pollutants such as methane, black carbon and hydrofluorocarbons (HFCs) which together are believed to account for up to 1/3 of current global warming but whose regulation is not as fraught with wide economic impacts and opposition.

These voluntary steps are seen by some as a new model where countries pledge to voluntarily take action against global warming outside of international treaties or obligations to other parties.

The Paris Agreement

The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gases emissions mitigation, adaptation and finance. It was agreed last year, and will come into effect in 2020.

As of November 2016, 193 UNFCCC members have signed the treaty, 109 of which have ratified it.

After the European Union ratified the agreement in October 2016, there were enough countries that had ratified the agreement that produce enough of the world's greenhouse gases for the agreement to enter into force. The agreement went into effect on 4 November 2016.

The aim of this agreement, is to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

(b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production;

(c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate resilient development.

The agreement is to be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

A copy of the 29 articles from the Framework Conference on Climate Change has been attached at **Appendix A**.

Chapter 5: Waste – why it matters?

Poorly managed waste has an enormous impact on health, local and global environment, and economy; improperly managed waste usually results in down-stream costs higher than what it would have cost to manage the waste properly in the first place.

The global nature of waste includes its contribution to GHG emissions, such as methane from the organic fraction of the waste stream, and the increasingly global linkages of products, urban practices, and the recycling industry

Where does our waste come from?

Developed countries produce more waste per capita because they have higher levels of consumption.

There are also higher proportions of plastics, metals, and paper in the municipal solid waste stream and higher labour costs (Diaz, et al 2006).

According to the UNEP's Solid Waste Management report (2005), as countries continue developing, there is a reduction in biological solid waste and ash.

Per capita waste generation in OECD countries has increased by 14% since 1990, and 35% since 1980 (Wikipedia).

Waste generation generally grows at a rate slightly lower than GDP in these countries.

Developed countries consume more than 60% of the world industrial raw materials and only comprise 22% of the world's population.

Meanwhile, developing nations have their own issues. While they produce lower levels of waste per capita, they have a higher proportion of organic material in the municipal solid waste stream which is responsible for the GHG methane.

If measured by weight, organic (biodegradable) residue constitutes at least 50% of waste in developing countries.

Labour costs are relatively low but waste management is generally a higher proportion of municipal expenditure.

As urbanization continues, municipal solid waste grows faster than urban populations because of increasing consumption and shortening product life spans.

In some instances, waste is even transported between countries for disposal which can create problems in the country receiving the waste.

For example, electronic waste is commonly shipped to developing countries for recycling, reuse or disposal.

The Basel Convention is a Multilateral Environmental Agreement to prevent problematic waste disposal in countries that have weaker environmental protection laws.

The Convention has not prevented the formation of e-waste villages.

The amount of urban waste being produced is growing faster than the rate of urbanisation, according to the World Bank's report *What a Waste: A Global Review of Solid Waste Management.*

The report states that by 2025 there will be 1.4 billion more people living in cities worldwide, with each person producing an average of 1.42kg of municipal solid waste (MSW) per day – more than double the current average of 0.64kg per day.

Annual worldwide urban waste is estimated to more than triple, from 0.68 to 2.2 billion tonnes per year.

The top producers of MSW were small island nations, including Trinidad & Tobago (14.40 kg/capita/day), Antigua and Barbuda (5.5kg) and St. Kitts and Nevis (5.45kg), Sri Lanka (5.10kg), Barbados (4.75kg), St Lucia (4.35kg) and the Solomon Islands (4.30kg). Guyana (5.33kg) and Kuwait (5.72kg) also scored highly.

New Zealand (3.68kg), Ireland (3.58kg), Norway (2.80kg), Switzerland (2.61kg) and the United States (2.58kg) were the top five producers in the developed world.

The countries producing the least urban waste were Ghana (0.09kg) and Uruguay (0.11kg).

The worldwide average is 1.2kg. That means the typical person living in a developed country produces about their own body weight in rubbish every three months.

The World Bank defines municipal solid waste as including 'non-hazardous waste generated in households, commercial and business establishments, institutions, and non-hazardous industrial process wastes, agricultural wastes and sewage sludge. In practice, specific definitions vary across jurisdictions.'

Overall, it is estimated that the world will generate 2.6 trillion pounds of rubbish.

So where does it all go?

Almost half of it is "organic" waste and most of it goes into landfills.

This consists of mostly food and paper. Organic trash – including food we eat, food animals eat, horticultural waste - makes up about half of global solid waste and paper and plastic add another 27%.

In both rich and poor countries, the vast majority of our waste goes into landfills where it's (often) covered up.

A very small share of waste in the World Bank's data - which, the authors admit, was difficult to collect for this category - went to recycled or composted waste.

"Africa's collected waste is almost exclusively dumped or sent to landfills," the report said.

In 1999 the World Bank published *What a Waste: Solid Waste Management in Asia* (Hoornweg and Thomas 1999), with an estimate of waste quantities and composition for Asia. In the intervening decade more accurate and comprehensive data became available for most regions of the world.

OECD-country estimates are typically reliable and consistent— added to these were comprehensive studies for China and India and the Pan-American Health Organization’s study for Latin America.

Therefore a global update of the 1999 report is possible, and timely.

Municipal solid waste managers are charged with an enormous task: get the waste out from underfoot and do so in the most economically, socially, and environmentally optimal manner possible.

Solid waste management is almost always the responsibility of local governments and is often their single largest budget item, particularly in developing countries.

Solid waste management and street sweeping is also often the city’s single largest source of employment.

Additionally, solid waste is one of the most pernicious local pollutants — uncollected solid waste is usually the leading contributor to local flooding and air and water pollution. And if that task were not large enough, local waste management officials also need to deal with the integrated and international aspects of solid waste.

Managing municipal solid waste is an intensive service.

Municipalities need capacities in procurement, contract management, professional and often unionized labor management, and ongoing expertise in capital and operating budgeting and finance.

MSW also requires a strong social contract between the municipality and community. All of these skills are prerequisites for other municipal services.

The original *What a Waste Report* provided waste estimates for South and East Asia. This waste stream represents about 33% of the world's total quantities.

Most growth predictions made in *What a Waste: Solid Waste Management in Asia* were reasonably accurate and in most cases, even taking into account the recent economic contraction, waste growth estimates were conservative.

This is especially true in China. In 2004, China surpassed the US as the world's largest waste generator.

In 2030, China will likely produce twice as much municipal solid waste as the United States.

Solid waste is inextricably linked to urbanization and economic development. As countries urbanize, their economic wealth increases.

As standards of living and disposable incomes increase, consumption of goods and services increases, which results in a corresponding increase in the amount of waste generated.

Solid waste is generally considered an 'urban' issue. Waste generation rates tend to be much lower in rural areas since, on average, residents are usually poorer, purchase fewer store-bought items (which results in less packaging), and have higher levels of reuse and recycling.

Today, more than 50 percent of the world's population lives in cities, and the rate of urbanization is increasing quickly.

By 2050, as many people will live in cities as the population of the whole world in 2000.

This will add challenges to waste disposal. Citizens and corporations will likely need to assume more responsibility for waste generation and disposal, specifically, product design and waste separation.

Also likely to emerge will be a greater emphasis on 'urban mining' as the largest source of materials like metal and paper may be found in cities.

Waste is mainly a by-product of consumer-based lifestyles that drive much of the world's economies.

In most cities, the quickest way to reduce waste volumes is to reduce economic activity—not generally an attractive option.

Solid waste is the most visible and pernicious by-product of a resource-intensive, consumer-based economic lifestyle.

Greenhouse gas emissions, water pollution and endocrine disruptors are similar by-products to our urban lifestyles.

The long term sustainability of today's global economic structure is beyond the scope of this paper.

However, solid waste managers need to appreciate the global context of solid waste and its interconnections to economies and local and global pollution.

As countries, particularly India and China, continue their rapid pace of urbanization and development, global solid waste quantities are projected to increase considerably.

Meanwhile, low-income countries continue to spend most of their budgets on waste collection, with only a fraction going toward disposal.

This is the opposite in high-income countries where the main expenditure is on disposal.

Similarly, rates of recycling are increasingly influenced by global markets, relative shipping costs, and commodity prices.

Global Waste Management Practices

The last two decades have brought a new challenge for waste management: the growing vagaries of global secondary materials markets.

In solid waste management there is no 'trhowing away'.

When 'throwing away' waste, system complexities and the integrated nature of materials and pollution are quickly apparent.

Landfills require land availability, and siting is often opposed by potential neighboring residents.

Solving one problem often introduces a new one, and if not well executed, the new problem is often of greater cost and complexity.

Locally, waste collection vehicles are large sources of emissions and both incineration and landfilling contribute GHG emissions.

Uncollected waste can provide breeding areas and food to potentially disease carrying vectors such as insects and rodents, with their associated health and nuisance issues.

Waste management cannot be effectively managed without due consideration for issues such as the city's overall GHG emissions, labor market, land use planning, and myriad related concerns.

Despite progress in solid waste management practices since the World Bank's *What a Waste Report* was published, fundamental institutional, financial, social, and environmental problems still exist.

Although each country and city has their own site-specific situations, general observations can be made across low-, middle-, and high-income countries.

The average city's municipal waste stream is made up of millions of separate waste items. In many cases, items in a city's waste stream originated from other countries that have countless factories and independent producers.

Some of the larger waste fractions, such as organics (food and horticultural waste) and paper are easier to manage, but wastes such as multi-laminates, hazardous (e.g. syringes), and e-waste, pose disproportionately large problems.

Industry programs, such as voluntary plastic-type labeling, are largely ineffective (no facilities exist to differentiate containers by numbers, either mechanically or by waste-worker) and deposit-return systems often meet industry and consumer resistance.

Hybrid, ad hoc, and voluntary take-back programs are emerging, however they are generally inefficient and municipalities are often forced to subsidize the disposal costs of these items.

Many municipal recycling programs in Europe and North America were started with the recycling markets relatively close to source.

More recently, marketing of secondary-materials has emerged as a global business. The price paid per tonne of waste paper in New York City is often based on what the purchase price is in China.

The majority of waste recycled in Buenos Aires, for example, is shipped to China.

The volatility of secondary materials prices has increased, making planning more difficult.

The price is often predictive of economic trends, dropping significantly during economic downturns (when a city is least able to afford price drops).

Waste collection

As mentioned above, current global MSW generation levels are approximately 1.3 billion tonnes per year, and are expected to increase to approximately 2.2 billion tonnes per year by 2025.

This represents a significant increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years.

However, global averages are broad estimates only as rates vary considerably by region, country, city, and even within cities.

Waste generation rates are influenced by economic development, the degree of industrialization, public habits, and local climate.

As such, waste collection must be determined by local influences and policy.

Waste collection is the collection of solid waste from point of production (residential, industrial commercial, institutional) to the point of treatment or disposal.

generally speaking, MSW is collected in several ways:

1. House-to-House: Waste collectors visit each individual house to collect garbage. The user generally pays a fee for this service.

2. Community Bins: Users bring their garbage to community bins that are placed at fixed points in a neighborhood or locality. MSW is picked up by the municipality, or its designate, according to a set schedule.

3. Curbside Pick-Up: Users leave their garbage directly outside their homes according to a garbage pick-up schedule set with the local authorities (secondary house-tohouse collectors not typical).

4. Self Delivered: Generators deliver the waste directly to disposal sites or transfer stations, or hire third-party operators (or the municipality).

5. Contracted or Delegated Service: Businesses hire firms (or municipality with municipal facilities) who arrange collection schedules and charges with customers. Municipalities often license private

operators and may designate collection areas to encourage collection efficiencies.

Collected MSW can be separated or mixed, depending on local regulations.

Generators can be required to separate their waste at source, e.g., into “wet” (food waste, organic matter) and “dry” (recyclables), and possibly a third stream of “waste,” or residue.

Waste that is un-segregated could be separated into organic and recycling streams at a sorting facility. The degree of separation can vary over time and by city. ‘Separation’ can be a misnomer as waste is not actually separated but rather is placed out for collection in separate containers without first being ‘mixed’ together.

Often, especially in developing countries, MSW is not separated or sorted before it is taken for disposal, but recyclables are removed by waste pickers prior to collection, during the collection process, and at disposal sites.

The degree of source separation impacts the total amount of material recycled and the quality of secondary materials that can be supplied.

Recyclables recovered from mixed waste, for example, tend to be contaminated, reducing marketing possibilities.

However, source separation and separate collection can add costs to the waste collection process.

Collection programs need to be differentiated by type of generator. Often more attention is devoted to residential waste even though this is usually less than 50% of the total waste stream.

Waste generated by the commercial sector tends to be collected better, because of more efficient containerization and purpose-built vehicles, and benefits from the collection of fees.

Residential waste collection, on the other hand, tends to be more expensive to collect per tonne as waste is more dispersed.

Higher income countries tend to have higher collection efficiency although less of the solid waste management budget goes towards collection.

In low-income countries, collection services make up the bulk of a municipality's budget (as high as 80 to 90% in many cases), yet collection rates tend to be much lower, leading to lower collection frequency and efficiency.

In high income countries, although collection costs can represent less than 10% of a municipality's budget, collection rates are usually higher than 90% on average and collection methods tend to be mechanized, efficient, and frequent.

While total collection budgets are higher, they are proportionally lower as other budget items increase.

The degree and sophistication of waste picking influences overall collection.

In cities like Buenos Aires, waste pickers tend to remove recyclables after the waste is placed curbside.

The resulting scattered waste is more costly to collect: in some cases the value of recyclables are less than the extra costs associated with collecting the disturbed waste.

In some cities informal waste pickers have strong links to the waste program and municipally sanctioned crews can be prevented from accessing the waste as informal waste pickers process the waste.

Waste pickers can be formally or informally organized into groups or unions with varying degrees of autonomy and political voice.

Containerization is an important aspect for waste collection, particularly from residential generators.

If waste is not set out for collection in closed containers it can be disturbed by vermin such as dogs and rats, and it can become water-logged, or set afire.

Frequency of collection is an important aspect readily under a municipality's control. From a health perspective, no more than weekly collection is needed.

However in some cities, largely because of culture and habituation, three-times per day residential collection is offered (e.g. Shanghai).

Good waste collection programming requires an ongoing iterative approach between collection crews and generators (usually households).

Therefore, waste generators should be aware of the true costs of collection, and ideally be charged for these directly.

Waste composition

Waste composition is influenced by factors such as culture, economic development, climate, and energy sources; composition impacts how often waste is collected and how it is disposed.

Low-income countries have the highest proportion of organic waste.

Paper, plastics, and other inorganic materials make up the highest proportion of MSW in high income countries.

Although waste composition is usually provided by weight, as a country's affluence increases, waste volumes tend to be more important, especially with regard to collection: organics and inerts generally decrease in relative terms, while increasing paper and plastic increases overall waste volumes.

In the municipal solid waste stream, waste is broadly classified into organic and inorganic.

Waste composition is influenced by many factors, such as level of economic development, cultural norms, geographical location, energy sources, and climate.

As a country urbanizes and populations become wealthier, consumption of inorganic materials (such as plastics, paper, and aluminum) increases, while the relative organic fraction decreases.

Generally, low and middle-income countries have a high percentage of organic matter in the urban waste stream, ranging from 40 to 85% of the total.

Paper, plastic, glass, and metal fractions increase in the waste stream of middle- and high-income countries.

In high-income countries, an integrated approach for organic waste is particularly important, as organic waste may be diverted to water-borne sewers, which is usually a more expensive option.

Geography influences waste composition by determining building materials (e.g. wood versus steel), ash content (often from household heating), amount of street sweepings (can be as much as 10% of a city's waste stream in dry locations), and horticultural waste.

The type of energy source in a location can have an impact on the composition of MSW generated. This is especially true in low-income countries or regions where energy for cooking, heating, and lighting might not come from district heating systems or the electricity grid.

Climate can also influence waste generation in a city, country, or region. For example, in Ulan Bator, Mongolia, ash makes up 60% of the MSW generated in the winter, but only 20% in the summer (UNEP/GRID-Arendal 2004).

Precipitation is also important in waste composition, particularly when measured by mass, as un-containerized waste can absorb significant amounts of water from rain and snow. Humidity also influences waste composition by influencing moisture content.

Waste disposal data

Landfilling and thermal treatment of waste are the most common methods of MSW disposal in high-income countries.

Although quantitative data is not readily available, most low- and lower middle-income countries dispose of their waste in open dumps.

Several middle-income countries have poorly operated landfills; disposal should likely be classified as controlled dumping.

Waste disposal data are the most difficult to collect. Many countries do not collect waste disposal data at the national level, making comparisons across income levels and regions difficult.

Furthermore, in cases where data is available, the methodology of how disposal is calculated and the definitions used for each of the categories is often either not known or not consistent.

For example, some countries only give the percentage of waste that is dumped or sent to a landfill, the rest falls under ‘other’ disposal.

In other cases, compostable and recyclable material is removed before the waste reaches the disposal site and is not included in waste disposal statistics.

Chapter 6: Waste and the impact on climate change

Waste and climate change may seem like separate issues, but they are actually very closely linked.

Firstly, waste is a clear indicator of how much of our natural resources we're using.

The cheaper and more abundant our resources, the more we use them and so in turn, the more waste we generate.

The disposal and treatment of waste can also produce emissions of several greenhouse gases (GHGs), which contribute to global climate change.

The most significant GHG gas produced from waste is methane. It is released during the breakdown of organic matter in landfills. Other forms of waste disposal also produce GHGs but these are mainly in the form of carbon dioxide (a less powerful GHG).

Even the recycling of waste produces some emissions (although these are offset by the reduction in fossil fuels that would be required to obtain new raw materials).

Waste prevention and recycling help address global climate change by decreasing the amount of greenhouse gas emissions and saving energy (Environmental Protection Agency).

Some of the most popular ways dispose of waste are:

Composting

This is an option for organic materials such as food scraps, yard waste and agricultural waste.

Composting is the natural biological breakdown of organic material.

During the process of aerobic composting (in the presence of oxygen), microorganisms consume the organic matter and release heat and carbon dioxide (CO2).

However, most of the carbon contained in the organic matter is retained in the compost and therefore not released into the atmosphere.

Composting is a waste management system that creates a recycled product that can be used in place of inorganic fertilizer.

The net GHG emission is reduced because the energy intensive fertilizer production and associated GHGs are reduced.

Combustion

Combustion releases both carbon dioxide and nitrous oxide (around 300 time more potent a GHG than carbon dioxide, but making up only a small percentage of the total emissions).

Energy released during combustion can be harnessed and used to power other processes, which results in an offset of GHG emissions from a reduction fossil fuel use.

In addition combustion diverts waste from landfill, reducing the amount of methane produced.

However burning garbage also produces waste in the form of ash.

Most of this ash is sent to landfill but some is used to make products like building materials and road base.

Landfilling

Landfill is the most common waste management practice and involves burying waste.

This results in the release of methane from the anaerobic decomposition of organic materials.

Methane is around 20 times more potent as a GHG than carbon dioxide. If the disposal of organic matter were decreased (for example by composting or combustion) it would be possible to reduce the amount of methane emissions.

However, landfill methane is also a source of energy, and some landfills capture and use it for energy. In addition, many materials in landfills do not decompose fully, and the carbon that remains is sequestered in the landfill and not released into the atmosphere.

All of these methods still involve the production of GHG. As mentioned above, the two major greenhouse gases – carbon dioxide and methane - are by-products of the waste we create as well as the means in which we get rid of it.

Carbon dioxide from waste

Carbon dioxide is the most abundant of these greenhouse gases and is produced when we burn fossil fuels to generate energy.

We use this energy to heat our houses, mine and extract natural resources, manufacture goods and products and transport them. These products then end up in landfill.

Wasting things means using energy to replace them. For example, when we dump aluminium cans in landfill, we have to make new cans from raw materials. This uses large amounts of energy and releases large amounts of carbon dioxide. The alternative, making new cans from recycled cans, only requires 5 percent as much energy.

Methane from waste

Methane, the other major greenhouse gas, is the major concern of the waste industry.

Methane is generated from the breakdown of organic matter such as food scraps, garden organics, wood and paper in landfill.

This is the majority of mixed solid waste from western households. Methane is at least 21 times more potent than carbon dioxide, which significantly adds to the greenhouse effect causing climate change.

Methane from solid waste accounted for 86.5 percent of the total greenhouse gas emissions from the waste sector in 2005-07.

Waste contribution to the greenhouse effect

The waste sector is a low generator of greenhouse gases.

In 2005, 3-5 per cent of global greenhouse gas emissions were generated by the waste sector.

Methane from landfills represents 12% of total global methane emissions (EPA 2006).

Landfills are responsible for almost half of the methane emissions attributed to the municipal waste sector in 2010 (IPCC 2007).

The level of methane from landfills varies by country, depending on waste composition, climatic conditions (ambient temperature, precipitation) and waste disposal practices.

Organic biomass decomposes anaerobically in a sanitary landfill. Landfill gas, a by-product of the anaerobic decomposition is composed of methane (typically about 50%) with the balance being carbon dioxide and other gases. Methane, which has a Global Warming Potential 21 times greater than carbon dioxide, is the second most common greenhouse gas after carbon dioxide.

Greenhouse gas emissions from waste management can readily be reduced.

Within the European Union, the rate of GHG emissions from waste has declined from 69 mtCO_2e per year to 32 million tCO_2e per year from 1990 to 2007 (ISWA 2009).

This is because, despite contributing relatively low levels of GHG, the waste sector is in a unique position to move from being a minor source of global emissions to becoming a major saver of emissions.

Although minor levels of emissions are released through waste treatment and disposal, the prevention and recovery of wastes (i.e. as secondary materials or energy) avoids emissions in all other sectors of the economy.

The UNEP report on Waste and Climate Change (2010) suggested that a holistic approach to waste management would have positive consequences for GHG emissions from the energy, forestry, agriculture, mining, transport, and manufacturing sectors.

Therefore, an increasingly key focus of waste management activities is to reduce GHG emissions.

The UNEP is already undertaking various programs and projects to assist its member countries to achieve improved waste management.

These programs and projects focus on three key areas of waste management:

- Sustainable consumption and production
- E-waste management
- Converting waste agriculture biomass and waste plastics into useful energy and/or material resources, and management of hazardous waste.

Greenhouse Gas Mitigation Opportunities

Efforts to reduce emissions from the municipal solid waste sector include:

- generating less waste
- improving the efficiency of waste collection
- expanding recycling
- methane avoidance (aerobic composting, anaerobic digestion with combustion of produced methane and capture, treatment and use of landfill gas)

Energy generated from methane combustion can displace other fossil fuels either as a process energy resource or as electricity.

Policy Recommendations for Reducing GHG Emissions

Governments have a range of policy options to encourage waste management practices that will reduce greenhouse gas emissions.

Practical approaches that could be applied in most cities include:

Public education to inform people about their options to reduce waste generation and increase recycling and composting.

Pricing mechanisms, such as product charges can stimulate consumer behavior to reduce waste generation and increase recycling.

A product charge is a cost assessment added to the price of a product and is tied to the cost of the desired waste management system.

Consumers would pay for the waste management service when they buy the product.

The fees collected would be directed to municipalities relative to the waste generated.

An example of this economic mechanism is an excise tax on tires assessed by most states in the US.

Another is the policy in some Australian and European grocery stores which charge for plastic bags in grocery stores (whereas it is free to bring your own).

Product charges are a policy mechanism often better implemented by regional or national governments.

Another pricing mechanism well suited to urban areas is user charges tied to quantity of waste disposed. Consumers who separate recyclables pay a lower fee for waste disposal.

This pricing policy can work well in locations where waste collection is from individual households so that waste quantities for disposal can be readily monitored.

However, it may not be practical in many areas in developing countries, particularly in those where there are communal collection points associated with multi-unit households (such as apartment user charges tied to quantity or volume).

Preferential procurement policies and pricing to stimulate demand for products made with recycled post-consumer waste.

For example, use of compost in public parks and other property owned by cities.

Waste Reduction Design of longer-lasting and reusable products leads to reduced consumption.

Composting/Anaerobic Digestion

Institute composting programs ideally with source separated organics. As with recyclables source separated materials reduce the contamination associated with recovery from mixed waste.

Compost the organic material after digestion to produce a useful soil conditioner and avoid landfill disposal.

Finished compost applied to soils is also an important method to reduce GHG emissions by reducing nitrogen requirements and associated GHG emissions.

Incineration/Waste-to-energy/ Refuse–Derived Fuel (RDF)

Use the combustible fraction of waste as a fuel either in a dedicated combustion facility (incineration) with or without energy recovery or as RDF in a solid fuel boiler.

Landfill Capture the methane generated in disposal sites and flare or use as a renewable energy resource.

These are some of the strategies which can be used in combination in order to creative a positive reduction in the waste sector's contribution to climate change.

Waste disposal options

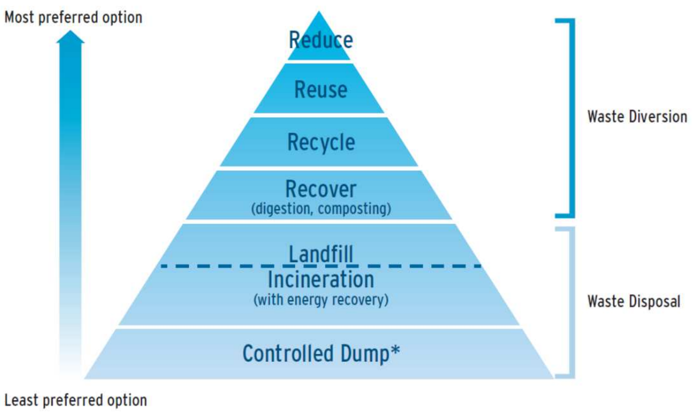
The waste management sector follows a generally accepted hierarchy.

The earliest known usage of the 'waste management hierarchy' appears to be Ontario's Pollution Probe in the early 1970s.

The hierarchy started as the 'three Rs' — reduce, reuse, recycle — but now a fourth R is frequently added — recovery.

The hierarchy responds to financial, environmental, social and management considerations.

The hierarchy also encourages minimization of GHG emissions. See below for the waste hierarchy.



The waste sector can save or reduce GHG emissions through several activities (UNEP, 2010):

Reducing

or avoiding the use of primary materials for manufacturing through waste avoidance and material recovery (i.e. the GHG emissions associated with the use of primary materials – mostly energy-related – are avoided).

Waste or source reduction initiatives (including prevention, minimization, and reuse) seek to reduce the quantity of waste at generation points by redesigning products or changing patterns of production and consumption.

A reduction in waste generation has a two-fold benefit in terms of greenhouse gas emission reductions.

First, the emissions associated with material and product manufacture are avoided.

The second benefit is eliminating the emissions associated with the avoided waste management activities.

Recycling

The key advantages of recycling are reduced quantities of disposed waste and the return of materials to the economy.

In many developing countries, informal waste pickers at collection points and disposal sites recover a significant portion of discards.

In China, for example, about 20% of discards are recovered for recycling, largely attributable to informal waste picking (Hoornweg et al 2005).

Related GHG emissions come from the carbon dioxide associated with electricity consumption for the operation of material recovery facilities.

Informal recycling by waste pickers will have little GHG emissions, except for processing the materials for sale or reuse, which can be relatively high if improperly burned, e.g. metal recovery from e-waste.

Recovery

Producing energy that substitutes or replaces energy derived from fossil fuels (i.e. the emissions arising from the use of waste as a source of energy are generally lower than those produced from fossil fuels).

This can be done in different ways – with the most common being:

- **Aerobic Composting and Anaerobic Digestion**

  Composting with windrows or enclosed vessels is intended to be an aerobic (with oxygen) operation that avoids the formation of methane associated with anaerobic conditions (without oxygen).

  When using an anaerobic digestion process, organic waste is treated in an enclosed vessel.

  Often associated with wastewater treatment facilities, anaerobic digestion will generate methane that can either be flared or used to generate heat and/or electricity.

  Generally speaking, composting is less complex, more forgiving, and less costly than anaerobic digestion.

  Methane is an intended by-product of anaerobic digestion and can be collected and combusted.

  Experience from many jurisdictions shows that composting source separated organics significantly reduces contamination of the finished compost, rather than processing mixed MSW with front-end or back-end separation.

- **Incineration**

  Incineration of waste (with energy recovery) can reduce the volume of disposed waste by up to 90%.

  These high volume reductions are seen only in waste streams with very high amounts of packaging materials, paper, cardboard, plastics and horticultural waste.

  Recovering the energy value embedded in waste prior to final disposal is considered preferable to direct landfilling — assuming pollution control requirements and costs are adequately addressed. Typically, incineration without energy recovery (or non-autogenic combustion, the need to regularly add fuel) is not a preferred option due to costs and pollution.

  Open-burning of waste is particularly discouraged due to severe air pollution associated with low temperature combustion.

  Indeed, depending on which GHG accounting convention is used, the waste sector is capable of generating a net GHG benefit through waste avoidance, material recovery, and energy recovery.

Every waste management practice generates GHG, both directly (i.e. emissions from the process itself) and indirectly (i.e. through energy consumption).

However, the overall climate impact or benefit of the waste management system will depend on net GHGs, accounting for both emissions and GHG savings.

Below are outlined key impacts of primary waste management approaches as outlined in UNEP, 2010.

Landfill

In the majority of countries around the world, controlled and uncontrolled landfilling of untreated waste is the primary disposal method.

Methane emissions from landfill represent the largest source of GHG emissions from the waste sector, contributing around 700 Mt CO2-e (estimate for 2009) (Bogner et al 2007).

In comparison, the next largest source of GHG emissions from the management of solid wastes is incineration, estimated to contribute around 40 Mt CO2-e (2009 data estimated in Bogner et al (2007)).

Reduction in the quantity of biodegradable municipal waste landfilled can significantly reduce greenhouse impacts.

For example, from 1990 to 2005, Germany gradually banned the practice of landfilling untreated organic waste.

By 2012, this ban is anticipated to result in a saving of approximately 28.4 million tonnes of CO2-e due to avoided methane emissions from landfill (Dehoust et al 2005).

Due to diversion of waste from landfilling and recovery of LFG, emissions of landfill methane from OECD countries are predicted to remain relatively stable if current trends continue.

Thermal treatment or incineration

Thermal waste treatment refers to mass-burn incineration.

The majority of studies assume that energy is recovered from the thermal treatment of waste, either as heat or electricity, which can equate to a considerable GHG saving.

Approximately 130 million tonnes of waste are currently incinerated across 35 countries (Bogner et al 2007).

Japan, Denmark, and Luxembourg treat >50% of the waste stream through incineration.

France, Sweden, the Netherlands and Switzerland also have high rates of incineration (Bogner et al 2007).

Incineration is only applied in a limited capacity in the remainder of the OECD countries.

At the global level, the climate impact of incineration is minor compared to that of landfilling, contributing around 40 Mt CO2-e in the current year (Bogner et al 2007)10.

Direct emissions from facilities are predominantly fossil and biogenic CO2.

In addition, there are downstream greenhouse gas savings due to energy generation.

The estimated GHG impact of thermal waste treatment processes, such as incineration, depends in large part on the energy source(s) assumed to be replaced by energy generated through the process.

However studies (Dehoust et al, 2005) have shown that the greenhouse gas emissions from incineration-driven power halved the contribution to greenhouse gas emissions when based on the assumption that it was replacing coal-fuelled energy.

Estimations of the climate impact of incineration with energy recovery also depend on whether electricity, heat or combined heat and power (CHP) are assumed to be produced.

European waste incinerators are reported to have conversion efficiencies of 15-30% for electricity and 60-85% for heat, with efficiency based on the % conversion of the lower heating value of the waste into energy (Astrup et al 2009).

In Northern Europe it is fairly common to find district heating networks powered by waste incinerators. Areas of Central and Eastern Europe also have the necessary infrastructure to utilise heat.

The UK has examples of incinerators providing heat to adjacent industries (i.e. a latex plant) – industrial heat usage is in many cases more attractive than district heating.

Recycling

After waste prevention, recycling has been shown to result in the highest climate benefit compared to other waste management approaches.

An ideal waste management strategy combines waste reduction, followed by recycling and energy production from the remaining waste to replace coal-based energy.

Recommendations for effective reduction of greenhouse gases through waste management

In its 2010 study on Waste and Climate Change (UNEP, 2010) the authors do not identify a single 'best' waste management approach, in terms of climate benefit, for global application.

Rather, a combination of strategies – including reducing waste, recycling what can be reused and replacing carbon or coal based fuel sources with energy derived from waste – would deliver the greatest benefits.

What is integrated solid waste management and how can it help?

Integrated solid waste management (ISWM) is a framework which reflects the need to approach solid waste in a comprehensive manner with careful selection and sustained application of appropriate technology, working conditions, and establishment of a 'social license' between the community and designated waste management authorities (most commonly local government).

It integrates some or even all of the strategies outlined in the previous section.

ISWM is based on both a high degree of professionalism on behalf of solid waste managers; and on the appreciation of the critical role that the community, employees, and local (and increasingly global) ecosystems have in effective ISWM.

ISWM should be driven by clear objectives and is based on the hierarchy of waste management: reduce, reuse, recycle — often adding a fourth 'R' for recovery.

These waste diversion options are then followed by incineration and landfill, or other disposal options.

Components of an Integrated Solid Waste Management Plan

An Integrated Solid Waste Management plan should include the following sections:

- All municipal policies, aims, objectives, and initiatives related to waste management

- The character and scale of the city, natural conditions, climate, development and distribution of population

- Data on all waste generation, including data covering both recent years and projections over the lifetime of the plan (usually 15-25 years). This should include data on MSW composition and other characteristics, such as moisture content and density (dry weight), present and predicted

- Identify all proposed options (and combination of options) for waste collection, transportation, treatment, and disposal of the defined types and quantities of solid wastes (this must address options for all types of solid waste arising)

- Evaluation of the Best Practical Environmental Option(s), integrating balanced assessments of all technical, environmental, social, and financial issues

- The proposed plan, specifying the amount, scale, and distribution of collection, transportation, treatment and disposal systems to be developed, with proposed waste mass flows proposed through each

- Specifications on the proposed on-going monitoring and controls that will be implemented in conjunction with facilities and practices and ways in which this information will be regularly reported

- Associated institutional reforms and regulatory arrangements needed to support the plan

- Financial assessment of the plan, including analysis of both investment and recurrent costs associated with the proposed facilities and services, over the lifetime of the plan (or facilities)

- All the sources of finance and revenues associated with developing and operating the plan including estimated subsidy transfers and user fees

- The requirements for managing all non-MSW arisings, what facilities are required, who will provide them and the related services, and how such facilities and services will be paid for

- The proposed implementation plan covering a period of at least 5-10 years, with an immediate action plan detailing actions set out for the first 2-3 years

- Outline of public consultations carried out during preparation of the plan and proposed in future

- Outline of the detailed program to be used to site key waste management facilities, e.g. landfills, compost plants, and transfer stations

- An assessment of GHG emissions and the role of MSW in the city's overall urban metabolism.

Chapter 6: How we can use waste for energy

What is waste to energy?

Waste-to-energy (WTE) is a reliable energy source and makes an essential contribution to security of energy supply.

It is the process of generating energy in the form of electricity and/or heat from the primary treatment of waste. WTE is a form of energy recovery.

Most WTE processes produce electricity and/or heat directly through combustion, or produce a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuels.

Waste-to-Energy technology is one of the most robust and effective alternative energy options to reduce CO2 emissions and to save limited fossil fuel resources used by traditional power plants.

Waste-to-Energy plants produce electricity, district heating or cooling for homes and businesses, and steam for industrial processes.

The heat and electricity delivered to houses, public buildings and industry replaces fossil fuels used by conventional power plants.

Waste-to-Energy Plants therefore help to reduce CO_2 emissions.

Also, about 50% of the energy produced by Waste-to-Energy Plants is renewable. EU legislation considers the biodegradable fraction of municipal and industrial waste as biomass, and thereby a source of renewable energy.

Waste-to-Energy plants can also operate 24 hours a day, 7 days a week, 365 days per year, thereby supplying reliable base-load energy to the electricity grid.

On the basis that about 88 million tonnes of household and similar waste that remains after waste prevention, reuse and recycling, were treated in Waste-to-Energy Plants across Europe in 2014, 38 billion kWh of electricity and 88 billion kWh of heat can be generated.

Then between 9 - 48 million tonnes of fossil fuels (gas, oil, hard coal and lignite) emitting 24 – 48 million tonnes of CO_2 can be substituted annually. Replacing these fossil fuels, Waste-to-Energy Plants can supply annually about 17 million inhabitants with electricity and 14 million inhabitants with heat.

This is the equivalent to the entire population of Denmark, Finland and Lithuania that can be supplied with electricity and heat throughout the year. In order to move away from Europe's high dependence on fossil fuels we should explore the cost effective and available alternative energy option: Waste-to-Energy.

Waste-to-Energy is a hygienic means of treating waste (destroying viruses and bacteria), which prevents polluted or degraded materials from entering the recycling-process and then into new products.

The combustion process cleans and separates metals and inerts from mixed waste, which could not otherwise be recycled. As a result further recycling of these metals is possible. Please see the section on Waste-to-Energy and Resource Efficiency for further information

Types of Waste to energy plants

The most common waste to energy process is incineration.

Energy recovery from the combustion of municipal solid waste is a considered a key part of the non-hazardous waste management hierarchy, which ranks various management strategies from most to least environmentally preferred.

Energy recovery ranks below source reduction and recycling/reuse but above treatment and disposal.

Confined and controlled burning, known as combustion, can not only decrease the volume of solid waste destined for landfills, but can also recover energy from the waste burning process.

This generates a renewable energy source and reduces carbon emissions by offsetting the need for energy from fossil sources and reduces methane generation from landfills.

Incineration, the combustion of organic material such as waste with energy recovery, is the most common WTE implementation.

All new WTE plants in OECD countries incinerating waste (residual MSW, commercial, industrial or RDF) must meet strict emission standards, including those on nitrogen oxides (NOx), sulphur dioxide (SO2), heavy metals and dioxins. Hence, modern incineration plants are vastly different from old types, some of which neither recovered energy nor materials. Modern incinerators reduce the volume of the original waste by 95-96 percent, depending upon composition and degree of recovery of materials such as metals from the ash for recycling.

Incinerators may emit fine particulate, heavy metals, trace dioxin and acid gas, even though these emissions are relatively low from modern incinerators. Other concerns include proper management of residues: toxic fly ash, which must be handled in hazardous waste disposal installation as well as incinerator bottom ash (IBA), which must be reused properly.

Critics argue that incinerators destroy valuable resources and they may reduce incentives for recycling. The question, however, is an open one, as countries in Europe recycling the most (up to 70%) also incinerate their residual waste to avoid landfilling.

Incinerators have electric efficiencies of 14-28%.

In order to avoid losing the rest of the energy, it can be used for e.g. district heating (cogeneration). The total efficiencies of cogeneration incinerators are typically higher than 80% (based on the lower heating value of the waste).

The method of using incineration to convert municipal solid waste (MSW) to energy is a relatively old method of WTE production.

Incineration generally entails burning waste (residual MSW, commercial, industrial and RDF) to boil water which powers steam generators that make electric energy and heat to be used in homes, businesses, institutions and industries.

One problem associated with incinerating MSW to make electrical energy is the potential for pollutants to enter the atmosphere with the flue gases from the boiler.

These pollutants can be acidic and in the 1980s were reported to cause environmental damage by turning rain into acid rain. Since then, the industry has removed this problem by the use of lime scrubbers and electro-static precipitators on smokestacks.

By passing the smoke through the basic lime scrubbers, any acids that might be in the smoke are neutralized which prevents the acid from reaching the atmosphere and hurting the environment.

Many other devices, such as fabric filters, reactors, and catalysts destroy or capture other regulated pollutants.

According to the New York Times, modern incineration plants are so clean that "many times more dioxin is now released from home fireplaces and backyard barbecues than from incineration.

According to the German Environmental Ministry, "because of stringent regulations, waste incineration plants are no longer significant in terms of emissions of dioxins, dust, and heavy metals".

The Incineration Process

At a typical MSW combustion facility, MSW is unloaded from collection trucks and placed in a trash storage bunker.

An overhead crane sorts the waste and then lifts it into a combustion chamber to be burned. The heat released from burning converts water to steam, which is then sent to a turbine generator to produce electricity.

The remaining ash is collected and taken to a landfill where a high-efficiency baghouse filtering system captures particulates.

As the gas stream travels through these filters, more than 99 percent of particulate matter is removed.

Captured fly ash particles fall into hoppers (funnel-shaped receptacles) and are transported by an enclosed conveyor system to the ash discharger.

They are then wetted to prevent dust and mixed with the bottom ash from the grate.

The facility transports the ash residue to an enclosed building where it is loaded into covered, leak-proof trucks and taken to a landfill designed to protect against groundwater contamination.

Ash residue from the furnace can be processed for removal of recyclable scrap metals.

WTE technologies other than incineration

There are a number of other new and emerging technologies that are able to produce energy from waste and other fuels without direct combustion.

Many of these technologies have the potential to produce more electric power from the same amount of fuel than would be possible by direct combustion.

This is mainly due to the separation of corrosive components (ash) from the converted fuel, thereby allowing higher combustion temperatures in e.g. boilers, gas turbines, internal combustion engines, fuel cells.

Some are able to efficiently convert the energy into liquid or gaseous fuels:

- Gasification: produces combustible gas, hydrogen, synthetic fuels

- Thermal depolymerization: produces synthetic crude oil, which can be further refined
- Pyrolysis: produces combustible tar
- Plasma arc gasification or plasma gasification process (PGP): produces rich syngas including hydrogen and carbon monoxide usable for fuel cells or generating electricity to drive the plasma arch, usable vitrified silicate and metal ingots, salt and sulphur
- Anaerobic digestion: Biogas rich in methane
- Fermentation production: examples are ethanol, lactic acid, hydrogen
- Mechanical biological treatment (MBT)
- MBT + Anaerobic digestion
- MBT to Refuse derived fuel

Global WTE developments

During the 2001-2007 period, the WTE capacity increased by about four million metric tons per annum. Japan and China built several plants that were based on direct smelting or on fluidized bed combustion of solid waste.

In China there are now about 434 WTE plants (2016).

Japan is the largest user in thermal treatment of MSW in the world with 40 million tons.

Some of the newest plants use stoker technology and others use the advanced oxygen enrichment technology.

There are also over one hundred thermal treatment plants using relatively novel processes such as direct smelting, the Ebara fluidization process and the Thermo- select -JFE gasification and melting technology process.

In Patras, Greece, a Greek company just finished testing a system that shows potential. It generates 25kwatts of electricity and 25kwatts of heat from waste water.

In India its first energy bio-science center was developed to reduce the country's green house gases and its dependency on fossil fuel.

As of June 2014, Indonesia had a total of 93.5MW installed capacity of WTE, with a pipeline of projects in different preparation phases together amounting to another 373MW of capacity.

Biofuel Energy Corporation of Denver, CO, opened two new biofuel plants in Wood River, NE, and Fairmont, MN, in July 2008.

These plants use distillation to make ethanol for use in motor vehicles and other engines. Both plants are currently reported to be working at over 90% capacity.

Fulcrum BioEnergy incorporated located in Pleasanton, CA, is currently building a WTE plant near Reno, NV.

The plant is scheduled to open in early 2010 under the name of Sierra BioFuels plant.

BioEnergy incorporated predicts that the plant will produce approximately 10.5 million gallons per year of ethanol from nearly 90,000 tons per year of MSW.

Waste to energy technology includes fermentation, which can take biomass and create ethanol, using waste cellulosic or organic material.

In the fermentation process, the sugar in the waste is changed to carbon dioxide and alcohol, in the same general process that is used to make wine.

Normally fermentation occurs with no air present.

Esterification can also be done using waste to energy technologies, and the result of this process is biodiesel. The cost effectiveness of esterification will depend on the feedstock being used, and all the other relevant factors such as transportation distance, amount of oil present in the feedstock, and others.

Gasification and pyrolysis by now can reach gross thermal conversion efficiencies (fuel to gas) up to 75%, however a complete combustion is superior in terms of fuel conversion efficiency.

Some pyrolysis processes need an outside heat source which may be supplied by the gasification process, making the combined process self-sustaining.

How can Waste-to-Energy plants contribute to resource efficiency

In cooperation with recycling, Waste-to-Energy Plants help to divert waste that is not good enough for recycling from landfilling and use it to generate energy.

However 28% of Municipal Solid Waste (MSW) across the EU 28 is still landfilled, although landfill gasses (methane) contribute significantly to global warming (equaling 25 times CO2).

Those countries that have most successfully reduced dependence on landfill have done this by combining recycling, biological treatment (e.g. composting and anaerobic digestion), and Waste-to-Energy.

Waste-to-Energy (WTE) plants efficiently and safely treat the waste that remains after household waste is sorted for recycling. As a major part of this residue is biodegradable, the energy produced is regarded as partly renewable.

Renewable energy, also termed regenerative energy, describes energy on lasting sources, which are considered inexhaustible by human standards.

The basic principle of the utilization of renewable energy of processes taking place in which our environment energy is branched off and is brought to the technical use.

The renewable energies are divided into: solar energy, wind energy, hydro-electric power, geothermal and bio-energy.

Renewable energy sources show a slight strain to the environment and are considered inexhaustible.

Inexhaustibly means two things: either the available "energy quantity" is so large, that it cannot be exhausted through human utilization (suns energy) or it currently renews itself and continuously (biomass) expiring in processes yet over a long period on the earth.

Waste represents a local, cost-effective, secure and sustainable energy that is already used in some parts of Europe for heating and cooling networks, allowing them to deliver affordable energy and reducing primary energy consumption.

In January 2010 the German Environment Ministry (BMU) published a study on "Climate Protection Potential in the Waste Management Sector - Examples: Municipal Waste and Waste Wood".

It states that, in Germany, "Since untreated municipal waste is no longer landfilled emissions of gases harmful to the climate from waste management have been reduced by a total of approximately 56 million tonnes.

The former burden from waste management amounted to about 38 million tonnes CO2 equivalents in 1990, whereas in 2006 the figure had dropped to minus 18 million tonnes.

This corresponds to the annual CO2 emissions of 7.7 million passenger vehicles, almost 20 percent of all vehicles registered in Germany."

In the study they state "The possible EU 27 reduction potentials for 2020 compared with 2007 range from 142 to 192 million t CO2 eq/a depending on the scenario and the effective gas capture rate assumed.

This corresponds to 24% or 32% of the additional reduction of 600 million t CO_2 eq needed to achieve the joint reduction target for 2020.

From a climate protection point of view, a strict ban on landfill of untreated waste following the example set by Germany, Austria or Switzerland would make the crucial contributions to improving the climate protection balance of the waste management sector.

It is also an essential precondition for significant optimisation in the EU 27."

Waste-to-Energy fulfils a number of different yet important roles:

- By treating household and similar waste that remains after waste prevention and recycling Waste-to-Energy plants help avoid the methane, a very potent greenhouse gas (GHG), which would have been created if the waste was landfilled.

- Waste-to-Energy and Recycling are complementary waste treatment methods. Household and similar waste should be sorted at source and the clean materials should be sent to high quality recycling. The remaining waste, that cannot be recycled in a technically or economically viable way, should be used to generate energy. In order to divert waste from landfill both Recycling and Waste-to-Energy should be part of a "joined up thinking" approach to sustainable waste management.

- The energy produced in Waste-to-Energy plants also contributes to climate protection and security of energy supply, by replacing fossil fuels that would have been used to produce this energy in conventional power plants.

- A significant part of the waste treated in Waste-to-Energy plants is biogenic – biomass – which means that about half of the energy produced by Waste-to-Energy plants is renewable energy. This is also the case when bio-waste is separated at source, as there is still a significant amount of biogenic waste which is too polluted for high quality composting.

  A paper by the German Federal Environment Agency (UBA) concluded that waste incineration does not oppose waste prevention but rather should complement it.

  "The prevention principle continues to take priority over recycling and disposal of waste", said UBA President Prof. Dr. Andreas Troge.

  "Thermic valorisation of waste, however, is an unavoidable chapter in sustainable waste management.

Waste incineration plants play an important role in climate protection and saving natural resources".

These were the findings of tests carried out by UBA and various environmental research institutes.

"*As waste is indeed incurred in our consumer society, thermal valorisation of waste which is not otherwise redeemable will also continue to be necessary and useful.*

A comparison across Europe shows that countries with progressive waste management systems in place have both a high proportion of waste incineration as well as high rates of materials recycling, as for example in Denmark and the Netherlands, where waste incineration does not impede high rates of recycling".

"*Waste incineration is an ecological means of waste disposal when waste is not otherwise redeemable.*

The energy generated at waste incineration plants could replace fossil fuels such as coal or oil, saving about 9.75 million tonnes carbon dioxide (CO2) in Germany annually…"

The UBA also states that the energy content of residual waste from human settlements is about 50 percent biogenic content, which can be classed as carbon dioxide-neutral.

The UBA emphasizes, however, that it continues to be of prime importance, "*to avoid waste as much as possible, and this requires greater materials efficiency in manufacturing*"

We can no longer afford to waste our resources, which is why it is an essential part of a sustainable circular economy.

What is the R1 formula?

As described above the Waste Framework Directive (WFD) sets out the waste hierarchy and enshrines it in law.

It requires that a waste management route defined as recovery should be used ahead of an alternative that is classified as disposal.

Exceptions can be made (see below) but this general principle makes it important to know whether a process is considered recovery or disposal.

Historically the Waste Framework Directives have included annexes which set out lists of what are considered to be recovery or disposal operations.

Each is given a number and a letter: R for recovery, D for disposal.

In the current directive the classifications of particular relevance to energy from waste are:

• R1 – Use principally as a fuel or other means to generate energy

• D10 – Incineration on land

What this means is that where waste is burnt as a fuel to generate energy it can potentially be considered a recovery operation (R1) but where the purpose of incineration is to get rid of waste, it is considered D10 and hence disposal.

All municipal waste incinerators were and are deemed as disposal activities (D10) unless and until they are shown to meet the requirements of R1. This is why the term R1 often crops up in the debate about how good an energy from waste plant might be and how it compares to other options.

In 2003, the European Court of Justice made two judgements that established principles to differentiate between R1 operations and D10 operations. To be classed as an R1 operation the process must meet the following criteria:

- The combustion of waste must generate more energy than the consumption of energy by the process itself;

- The greater part of the waste must be consumed during the operation;
- The greater amount of the energy generated must be recovered and used (either as heat or electricity);
- The waste must replace the use of a source of primary energy

These judgements superseded the previous standards used by Member States (such as calorific value of waste, quantity of harmful substances and energy efficiency of the process) without addressing the specifics of classifying a plant so still did not ensure a consistent application of the WFD across Europe.

For municipal solid waste, which includes all the waste collected from households, the EU has gone further by defining what it considers to be sufficient for recovery status under R1.

The WFD includes a formula relating to the efficiency of the combustion plant.

A municipal waste combustion plant can only be considered to be a recovery operation under R1 if it generates energy and the plant meets the efficiency thresholds calculated using the R1 formula.

The Revised WFD now specifies that incineration facilities dedicated to the processing of municipal solid waste can be classified as R1 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 1st January 2009
- 0.65 - for installations permitted after 31st December 2008

R1 formula calculates the energy efficiency of the municipal solid waste incinerator and expresses it as a factor (as seen above).

This is based on the total energy produced by the plant as a proportion of the energy of the fuel (both traditional fuels and waste) which is incinerated in the plant.

It can only be considered recovery if the value of this factor is above a certain threshold.

It is important to note that the calculated value arrived at via the R1 formula is not the same as power plant efficiency which is typically expressed as a percentage.

This helps ensure that all plants that want to be classed as recovery in the EU will meet a minimum standard of environmental performance.

As waste can only cross national boundaries for recovery not disposal it also ensures only the more environmentally sound plants can compete internationally for waste derived fuel.

The requirement to apply the R1 formula means that lower efficiency municipal energy from waste plants are classed as disposal (D10) even if they are generating useable energy.

However, with the right combination of overall efficiency and biogenic content in the waste, an energy from waste plant which does not qualify for R1 status may still be a better environmental option than landfill.

Similarly, in line with the right fuel, right technology argument set out above, a plant meeting the R1 formula does not in itself necessarily mean it is the best solution for all waste streams.

R1 status is not mandatory for energy from waste plants and will not be part of an environmental permit.

Irrespective of whether the plant is classed as a Recovery (R1) plant or Disposal (D10) plant, operation under the Environmental Permitting Regulations require that plants recover as much energy as practicable.

The distinction between having R1 status or having a plant being classified as a disposal facility is important for planning purposes and in the application of the proximity principle.

It is therefore important that operators strive towards demonstrating that energy from waste is a recovery operation according to the WFD definitions.

This also means that only those waste to energy plants which provide a measurable benefit are able to be classified as recovery sources.

Guidance in using R1

Even when the formula is used there is still considerable scope for variation in its use.

Comprehensive guidance has been produced by the European Commission to ensure a consistent interpretation and a harmonised application of the R1 formula across the EU which specifies:

- Definitions of the energy terms Ef, Ew and Ei
- The system boundaries
- Qualification in on an annual basis and verified with plant data ('annual average')
- R1 status must be tested after 'major' plant modification or after a maximum of 10 years

- R1 value is to be calculated using plant design data for new plants
- R1 value must be verified in using plant performance tests for new plants

The guidance was issued by the European Commission's DG Environment on 1st July 2011.

The Scope of the R1 Formula

Annex II of the WFD restricts the scope of the formula to "incineration facilities dedicated to the processing of Municipal Solid Waste" so it does not apply to plants that are dedicated to incineration or co-incineration of hazardous waste, hospital waste, sewage sludge or industrial waste.

It is also crucial that the formula is applied to the correct parts of the EfW process and that the 'system boundaries' are set correctly.

The system boundaries that are used will have considerable implications on the energy streams that are calculated as Ef, Ew and Ei in the efficiency calculation.

Therefore, the 'system boundaries' are clearly defined in the guidance as the 'functional incineration unit' not the installation according to the IPPC permit.

The functional incineration unit is set as the incineration oven(s), the boiler(s), and the incineration flue gas cleaning system and, often, energy transformation and recovery equipment such as heat exchangers feeding a district heating or cooling network and/or turbine generator.

Issues with the R1 Formula

Climate - the use of heat instead of electricity significantly increases the R1 value achieved. The ability for an installation to use the heat produced is very much dependent on climate. For example, heating degree day (HDD) values- a quantitative indices that reflects the demand for energy to heat homes and businesses - vary hugely across Europe, with Portugal having 1302 while Finland has 5823.[2]

Location - An installation located in a rural area is unlikely to find efficient use for its produced heat. However, industrialised areas are unvaryingly heat consumers, so plants located in urban or industrialised areas have a far higher probability of finding a heat client and improving their R1 rating.

Size - Larger plants are often more efficient due to economies of scale.

Advantages

Energy from Waste (EfW) plants being classified as recovery rather than disposal.

The R1 formula will facilitate Energy from Waste moving up the waste hierarchy.

Chapter 7: The way of the future

Energy from waste is an evolving sector that bridges a number of markets and also contributes to a number of Government objectives.

To develop a clear vision for the future both governments and the WTE sector need to understand and give due consideration to the key principles which underpin policies now and are expected to remain critical in the future.

Governments should encourage developers to consider these principles as a key part of the decision making process around future development of new projects and operation of existing plant.

This means that from a sector viewpoint infrastructure proposals, technologies and services that are aligned with these principles should be on a much firmer footing and more robust to future policy than those which are not.

The principles required to underpin policy

I. Energy from waste must support the management of waste in line with the waste hierarchy.

II. Energy from waste should seek to reduce or mitigate the environmental impacts of waste management and then seek to maximise the benefits of energy generation.

III. Government support for energy from waste should provide value for money and make a cost effective contribution to UK environmental objectives in the context of overall waste management and energy goals.

IV. Government will remain technology neutral except where there is a clear market failure preventing a technology competing on a level footing.

Energy from waste within the waste hierarchy

Government should focus on the long term role for energy from waste both as a waste management tool and as a source of energy.

To be consistent with the first principle this long term role needs to be based on energy from waste that at least constitutes recovery not disposal as per the R1 formula or a similar technique.

This should therefore be a key consideration for both new and existing projects.

To be classed as recovery, energy from waste facilities must meet the requirements set out in the waste framework directive, for example through attainment of R1 status.

Energy from waste must at the very least not compete with recycling, reuse and prevention and should ideally support them.

At the same time recovery through energy from waste needs to be pulling waste out of less environmentally sound disposal routes, particularly landfill but also incineration with insufficient energy recovery.

Governments need to consider there is potential room for growth in both recycling and energy recovery – at the expense of landfill.

The composition of residual waste is by its nature defined by the waste that is prevented or taken out to be reused or recycled.

As recycling becomes economic and practical for a wider range of waste types the composition of that which remains will inevitably change.

Any long term approach to waste management needs to take into account the fact the picture is not static and be flexible to it.

The energy from waste sector needs to think beyond its own boundaries. It must be flexible to changing waste composition or drive recycling and/or collection processes that allow it to manipulate the composition of residual waste (the energy from waste feedstock) without acting as a brake on activities higher up the hierarchy.

Meeting the requirements of the hierarchy will be an important test for any policy or project aiming to increase the waste going to energy recovery and/or the energy produced from it.

Reducing the environmental impacts and maximising the energy

The second principle is about ensuring that energy recovery is the best solution for the residual waste going to it, and then where this is the case that the most is made of the resource it represents.

This means understanding and potentially manipulating the nature of the residual waste and ensuring it is suitably matched to the right type of process and energy outputs to minimise the environmental impact.

Where this can't be done the impact needs to be mitigated. A key component of this environmental impact is the relative greenhouse gas emissions.

Long term changes in the energy mix being offset by energy from waste have significant consequences for the relative merits of energy from waste versus landfill.

There is a balance point where as energy decarbonises, increasing efficiency alone is no longer sufficient to ensure in carbon terms energy from waste is better than landfill, with the biogenic content of the waste feedstock becoming critical.

This is particularly important for electricity only generation as electricity is expected to decarbonise most rapidly, and within the lifetime of existing energy from waste infrastructure.

To properly meet the second principle moving away from this balance point is critical for the long term sustainability of mixed waste energy recovery.

Maximising the efficiency of existing electricity only plants will delay reaching the balance point.

However, the sustainable lifetime of an electricity only plant may still be limited, and extending it beyond that originally envisaged may not be beneficial.

This could be addressed by removing more fossil material from the waste stream thus avoiding the use of waste with insufficient biogenic content to deliver environmental benefits.

Energy outputs such as heat and transport fuels are expected to decarbonise much more slowly than electricity. In addition delivery of heat from energy from waste can be done at much higher efficiencies than electricity only.

Plants that operate in combined heat and power (CHP) mode will therefore be able to continue to be superior to landfill, with longer plant lifetimes and using waste streams with a much wider range of biogenic content into the foreseeable future.

A key consideration therefore needs to be focussing on development of energy outputs beyond electricity, both for new plants and ensuring existing plants that are ‘CHP ready’ become ‘CHP in use’.

This way, there will be a consistent rationale across both waste and energy policy for steering waste towards the most efficient plants and increasing focus on these outputs (and by implication moving away from an electricity only energy from waste model).

Unless the energy output can be effectively used then there is no benefit from maximising its production.

Ensuring sites for energy from waste are available that allow potential connection to heat customers is an essential part of maximising the benefits.

The UK's updated national planning policy "Planning for Sustainable Waste Management" is an example of this, encouraging local authorities to consider siting, through their local plans, energy from waste facilities in areas which allow them to use heat as an alternative or additional energy output to electricity.

The principles would be expected to apply as much to the production of waste fuels as to their use and policy would be expected to reflect this.

Therefore the production of RDF should be part of minimising the environmental impacts of waste management.

This means:

- ensuring the hierarchy is applied and the need to maintain biogenic content in the fuel fraction is not done at the cost of potential recycling
- encouraging greater understanding of the biogenic content
- increasing biogenic content through removal of fossil waste not addition of biogenic waste and

ensuring material if exported delivers a better environmental outcome than domestic disposal.

Fossil based residual wastes, e.g. plastics that cannot be recycled, do not decompose in the same way as biogenic material in landfill.

For these waste streams conventional energy from waste will almost always deliver a negative carbon balance compared to landfill.

However, they represent a potential resource that in line with the hierarchy should ideally be recovered not disposed of.

Advanced processing into energy sources that deliver lifecycle benefits compared to use of raw materials offer a potentially sustainable way to do this. If this is not possible the option of conventional energy recovery and carbon pricing exists for non-municipal waste facilities.

Government support for energy from waste

Government has to ensure that it delivers value for money to encourage this industry. This includes direct funding through grants, loans, incentives etc. or more indirect methods such as communications campaigns.

The cost effectiveness of carbon reduction is one important measure in assessing this. There is no automatic link between the cost of managing the waste or producing energy and emissions reductions.

While waste as a fuel is not encumbered with the carbon cost of its production any processing once it becomes waste, does have an impact.

In particular the combustion of mixed waste releases a substantial amount of fossil emissions from what can be an otherwise relatively inefficient process.

However, unlike other biomass which is produced specifically for energy production, residual waste has an alternative fate in landfill that has its own negative environmental impact.

The assessment is therefore not straightforward but the principle needs to apply.

The way of the future is undoubtedly a combination of waste management strategies to best minimise the impact of waste on climate change.

In summary, this includes:

1) waste minimisation
2) recycling
3) waste to energy.

The deployment of all strategies effectively eliminates the amount of waste going to landfill (and therefore the release of methane into the atmosphere) as well as effectively utilising more resistant waste in a way that creates a net positive or at least neutral impact on the environment.

Recycling and waste to energy

The United States generates the most trash in the world – at about 390 million tons of trash every year.

Meanwhile, it recycles and composts about 94 million tons of that waste, or roughly one-quarter.

Even if the US doubled its rate of recycling, there would still be hundreds of millions of tons of post-recycled, post composted solid waste.

What you do with it is the question, and there are two options: dump it in a landfill or burn it/gasify it for energy.

For many years, countries such as the US and Australia, have prioritised dumping but modern science is now showing this is the most polluting alternative.

Things are very different in green-conscious Europe. While the US has just 89 WTE facilities, Europe has 420 and is building more. Northern Europe, the most environmentally-conscious part of the continent, is also where the most WTEs are located.

WTE construction in the US is being held back by fears that burning trash will cause people to reduce their recycling effort or will put dangerous toxins into the environment. But are those fears supported by the evidence?

Evidence shows recycling and WTE are complimentary

Energy from waste is not just about waste management.

The energy it produces is a valuable domestic energy source contributing to energy security.

As a partially renewable energy source it can also contribute to our renewable energy targets which are aimed at decarbonising energy generation.

It has the added advantage that it is non-intermittent, so it can complement other renewable energy sources such as wind or solar.

Energy outputs

Most of the energy from waste is currently produced in the form of electricity.

However, more and more plants are also looking to use the heat generated. This is known as combined heat and power.

More innovative technologies have the potential to also transform the waste into other energy products such as transport fuels or substitute natural gas.

The Government provides a number of different financial incentives to help drive growth in energy from waste, particularly for the more novel technologies and energy outputs beyond electricity.

These along with the effective use of heat have the potential to deliver higher overall efficiency and therefore deliver the Government's goal of more energy from less waste.

It is certainly true that maximum recycling effort should be put in to remove all recyclables and compostables before the remaining waste is disposed of in a landfill or a WTE facility.

But the worry that WTEs reduce recycling rates does not appear to be borne out by the evidence, which shows that to the contrary, they tend to be associated with *increased* recycling effort.

The five European nations with the highest recycling rates—Germany, the Netherlands, Austria, Belgium, and Sweden—also have among the highest WTE usage, to the point that they have reduced landfill use to *less than one percent* of their waste. Sweden even competes to import waste. While this is questionably desirable, it does not appear to have reduced their recycling effort, which is higher than the twenty two other European nations.

Swedish case study

In fact, when it comes to recycling, Sweden is incredibly successful.

Just four percent of household waste in Sweden goes into landfills.

The rest winds up either recycled or used as fuel in waste-to-energy power plants.

Burning the garbage in the incinerators generates 20 percent of Sweden's district heating, a system of distributing heat by pumping heated water into pipes through residential and commercial buildings.

It also provides electricity for a quarter of a million homes.

Sweden is also believed to recover the most energy from each ton of waste in the waste to energy plants, and energy recovery from waste incineration has increased dramatically just over the last few years.

Sweden’s waste recycling program is so successful that the country is producing much less burnable waste than it needs.

They now have more capacity than the production of waste in Sweden which has resulted in them importing waste from other countries.

Sweden has been importing about eight hundred thousand tons of trash from the rest of Europe per year to use in its power plants.

The majority of the imported waste comes from neighboring Norway because it’s more expensive to burn the trash there and cheaper for the Norwegians to simply export their waste to Sweden.

In the arrangement, Norway pays Sweden to take the waste off their hands and Sweden also gets electricity and heat.

The ashes and heavy metals from the incineration process are then and the ashes exported back to Norway to go to landfill.

Despite case studies such as these, landfilling remains the principal way of disposal in most western countries.

WTE uptake in the US

In America, by contrast, where environmental groups frequently portray the issue as an either/or choice between recycling and WTEs, both rates are much lower, and a whopping 69 percent of US municipal solid waste winds up in landfills.

As in Europe, the trend of increased recycling rates in communities that use WTE also holds in the US, where communities that have a WTE plant show higher recycling rates than the national average.

Finally, recycling itself is not without waste. For example, recycling mixed paper leaves a 15 percent residue that itself has to be disposed of somehow.

Clearly, recycling and WTE can and do go hand-in-hand in a responsible waste management plan, and co-promotion by environmental groups would likely increase both WTE and recycling, both of which are preferable to landfilling in the waste management hierarchy.

Clean air technology cuts emissions to near-zero

While trash burners once did put dangerous toxins into the air, in the last ten years WTE pollution control technology has become so advanced that the most common and dangerous toxins have been almost completely eliminated, something that the environmental groups who still oppose WTEs rarely mention.

Under the Clean Air Act, WTE facilities are required to be equipped with the most modern air pollution control technology available to ensure that smokestack emissions are safe for human health and the environment.

This new equipment must meet or exceed the EPA's Maximum Achievable Control Technology (MACT) Standards.

WTE plant emissions are far below the limits the EPA set as safe, and get better all the time.

The Minneapolis WTE facility, for example, uses the following process to control their emissions:

- Air is injected into the boiler to control nitrogen oxide emissions.

- Activated carbon is injected into the exhaust gases to control mercury.
- Flue gases then pass through a dry scrubber, where a lime slurry is injected to control sulfur dioxide and hydrochloric acid.
- Combustion gases pass through a bag house containing a series of fabric filters to remove particulate matter (ash), metals and dioxins.
- Emissions are monitored on a continuous basis for multiple pollutants.

Testing shows the ash to be non-toxic and it is widely used

WTEs reduce the volume of trash by about 90 percent, leaving about 10 percent in the form of ash that still needs to be landfilled unless it can be used elsewhere.

Opponents often argue that the ash is toxic, but the EPA developed a test called the Toxicity Characteristic Leaching Procedure that tests the ash with an acidic liquid, causing any of forty identified contaminants, or reactive metals such as cadmium, to leach out.

If these metals are found in amounts greater than a fraction of a percent, the ash is considered hazardous.

Scientists have tested ash from every WTE facility in the country over the course of several years, and the tests have consistently shown that the ash is non-hazardous.

Consequently, about 3 million tons of concrete-like ash, or more than one-third of all WTE residue, are being reused annually as roadbed material, as daily and final landfill cover, as an aggregate in road construction, as an additive to asphalt, in the construction of artificial reefs, and in cement blocks.

WTE operators are actively looking for other ways to reuse the concrete-like ash renewably instead of disposing of the balance in landfills. Mixing it into concrete is one solution that offsets the production of cement, which otherwise accounts for 5% of the world's carbon emissions.

The big one: WTEs fight climate change

Burning trash puts large amounts of carbon dioxide into the atmosphere. And the atmosphere is already at a dangerously high 400 parts per million of carbon dioxide—higher than it has been in at least 600,000 years. 350 parts per million is the maximum level many climate scientists consider safe and sustainable, which is still considerably higher than the roughly 290 ppm it was at the beginning of the industrial revolution.

Classed as low-carbon, renewable energy.

But it turns out that while WTEs do emit greenhouse gases, they emit far fewer GHGs on a ton-for-ton basis than America's current practice of landfilling. In fact, 31 state pollution control agencies and two US territories now class WTEs as renewable energy and as preferable to landfilling.

To understand why, consider a ton of post-recycled, post-composted trash in either of two scenarios: landfilled, or burned for energy with pollution capture technology.

Half of post-recycled MSW is part of the carbon cycle already

First, roughly 53 percent of post-recyled, post-composted trash is still derived from organic materials and so is part of Earth's carbon cycle anyway.

Burning it does not increase the atmosphere's carbon load.

One ton MSW burned *prevents* one ton GHGs

Burning the remaining 47 percent, which is derived from petroleum carbon, prevents other, worse emissions.

According to the EPA, every ton of garbage processed at a WTE facility actually prevents approximately one ton of emitted carbon-dioxide equivalent from going into the atmosphere.

Methane is a far worse GHG

One way this happens is by reducing landfilling. Landfills are the US's largest emitter of methane, a very potent greenhouse gas.

According to the United Nations Intergovernmental Panel on Climate Change's Fourth Assessment on Climate Change, in a 20-year window methane is 72 times more potent a greenhouse gas than cardon dioxide.

Capped landfills now have the technology to capture methane, but only about 34 percent of that methane is actually used to generate electricity.

The rest leaks away or is flared off, and nothing at all is captured for the first few decades that a landfill sits open while being filled.

Metal recycling is built in to WTE

Next, post-recycled trash still contains millions of tons of metals that are sent to landfills.

At a WTE facility, those metals are automatically reclaimed and recycled as a part of its normal filtration process.

This saves the time, materials, energy, emissions and environmental disruption of mining for an equivalent amount of new minerals.

The WTE operator Covanta Energy recycled 415,000 tons of ferrous and 16,800 tons of non-ferrous metals in 2012 alone—enough steel to build 28 Brooklyn Bridges and and enough aluminum to produce over one billion beverage cans.

The aluminum that is reclaimed by WTEs from the already post-recycled waste is particularly important.

Recycling one ton of aluminum prevents a whopping 13.7 tons of GHG emissions, compared to 4.3 tons for office paper and 2.5 tons for newspaper.

Recycling a ton of ferrous metal prevents 1.7 tons of GHG emissions. None of this is recaptured when a truck tips its load into a landfill.

Cutting waste transportation cuts carbon

WTE facilities are sited close to where the waste is generated, in or near urban areas.

This eliminates much of the carbon emitted by hauling waste to a distant landfill. In 2011, New York City spent more than $300 million transporting its trash by train and truck— roughly 12,000 tons a day—to landfills as far as 300 miles away, emitting tons more carbon and wearing down roads and vehicles in the process. In some cases, such as e-waste, the US is now even exporting its waste to third world countries, vastly compounding its carbon contribution.

Energy generated offsets fossil fuels

WTE facilities generate heat and electricity, reducing the burning of fossil fuels for those same purposes. For example, the Minneapolis WTE facility currently generates enough electricity to power 25,000 homes, and enough steam to heat 1,500. Their proximity also means less heat and electricity are lost in transit.

Lower carbon than fossil fuel. According to the EPA burning municipal solid waste (MSW) in WTEs emits less carbon dioxide per megawatt hour than fossil fuels, including natural gas.

New gasification technologies coming online promise even greater energy capture and lower emissions than WTE by incineration.

The way forward for waste to energy

If companies do undergo this transformation, they will still need business models that can turn a profit. One solution is turning waste into energy.

According to market analyst Grand View Research, the global market for turning rubbish into power is expected to reach $37.64bn by 2020.

While most of the growth to date has been in thermal technologies, biological technologies could provide a major breakthrough.

Improve recyclability

Another hurdle for manufacturers is the recyclability of materials.

Reusing a basic metal such as copper is easy enough but recycling sophisticated plastics or other complex materials requires a completely different approach.

The use of all materials requires consideration of how it can be reused or recycled at the end of its usefulness.

Closing these “resource loops” is essentialto reducing waste.

Convincing consumers

It’s not just business that needs to change. Between now and 2025, public attitudes to waste require a radical overall too. Half of the food produced around the world ends up in the bin according to the Institution of Mechanical Engineers.

Some countries, like Korea, are already finding clever ways to convince residents to reduce their waste.

They are given cards which include a chip holding the name and address of the cardholder.

Residents scan their identification card, then dispose of their rubbish in a smart bin with a built-in weighing scale, and are simply billed for the corresponding waste.

Retailer responsibility

Responsibility for consumer-related recycling shouldn’t fall entirely on consumer shoulders.

Retailers that sell unrecyclable packaging should also be encouraged to change.

This particularly applies to the fast food, beverage, and consumer packaged goods sectors.

Chapter 8: Waste to energy success stories

To date there have been a number of successful examples of waste to energy plants which are leading the way in promoting a shift away from landfill practices.

These include the following cases studies which are featured on the Confederation of European Waste to Energy Plants (CEWEP) website:

Heat from Waste used for Paper production in Canton Lucerne, Switzerland

A Waste-to-Energy (WTE) facility in Canton Lucerne, has shown that Waste-to-Energy can provide reliable heat for industries.

The plant produces 155,000 MWh of electricity per year – which corresponds to the needs of approximately 38,000 households – while taking great care of minimizing its impact on the local environment. The plant features:

- State of the art, dry flue gas cleaning system with injection of sodium bi-carbonate and activated carbon in the flue gas stream, followed by catalytic reduction of nitrogenous oxide and electrostatic dedusting. Thanks to the dry flue gas treatment, there is absolutely no release of wastewater in the neighbouring Reuss river.

- Cooling with air condensers, thus no heat discharge in the Reuss river.
- Compensatory measures such as the re -aturation of surrounding fens
- Minimal traffic noise through optimised transport concept.
- The plant is close to the highway, thus truck traffic across residential areas can be completely avoided.
- Waste can also be delivered directly by freight train.

The most significant feature of Renergia is its value for the local industry. The plant was built next to the local Perlen Paper AG paper mill where the heat from the waste processing will be used in the production lines in order to dry the paper.

The proximity of the two facilities allows an energy efficiency of 70%. By using heat from waste rather than from fossil fuel, the mill reduces the costs of its heating process, and saves 40 million liters of oil per year.

Overnight hot water storage optimizes energy supply from Waste-to-Energy plant in Magdeburg, Germany

The municipality-owned SWM (Städtische Werke Magdeburg) is building an overnight hot water storage facility close to the local Waste-to-Energy (WTE) plant Rothensee in order to uncouple peak load electricity and heat supply.

The facility will support the district heating delivery for Magdeburg and as a result the Rothensee WTE facility, which is jointly owned by SWM and EEW Energy from Waste, will be able to focus on increasing its electricity production.

The new hot water storage facility will allow an optimization of the operation of the district heat supply.

Surplus heat during the night will be stored. With its capacity of 240 MWh 10,000 households in Magdeburg can be heated for 8 hours.

Due to the programmed uncoupling of peak load electricity and heat supply the operation of the WTE plant Rothensee will be even more efficient, i.e. electricity production can be significantly raised during peak demand.

The Rothensee WTE plant and SWM will cooperate closely to manage the storage facility.

This is an important step towards a better security of supply and connections to new district heat customers and areas.

The storage facility will start operation by November 2016. The project will cost about €5m.

The storage facility has the following advantages:

- Prevention/reduction of energy supply from fossil fuel fired power plants
- Additional electricity production during peak demand
- Reduction of impact from production fluctuation
- Stabilising plant operation
- Reducing impact of daily/hourly fluctuation in electricity prices
- Extension of SWM's district heating network.

Waste-to-Energy helps to reduce CO2 emissions in Rotterdam, Netherlands

By working together, the Waste-to-Energy plant operator AVR, the grid manager Stedin, and the chemical producer Emerald Kalama Chemical BV support Rotterdam's goal to reduce its carbon-based emissions.

Since 2007, the Rotterdam Climate Initiative aims to transform the city into a landmark for clean energy while developing its growth and attractiveness.

In that context, Rotterdam aims to reduce its CO_2 emissions by 50% of 1990 levels by 2025.

In order to help the city reach this goal, AVR, Stedin, and Em erald Kalama Chemical developed together a 2 km steam pipeline.

For this project, called "Greener steam", AVR provided the steam from waste incineration, Stedin designed and build the grid, and Emerald Kalama Chemical was the first consumer of the steam, which the company uses for its toluene-based production process.

"Greener steam" has helped Rotterdam reduce its CO_2 emissions by 25,000 tonnes each year since 2012, and has saved 15 million cubic metres of natural gas usage annually.

The grid network is estimated to reduce the CO_2 emissions up to 400,000 tonnes per year when fully implemented.

The project was awarded a European Responsible Care Award in Energy Efficiency in 2014 by Cefic, the European Chemical Industry Council.

The lighting of the Cologne cathedral

The famous symbol of the German city of Cologne - its cathedral the “Kölner Dom” - is now illuminated at night using energy generated from the city’s Waste-to-Energy Plant AVG (Abfallverwertungsgesellschaft Köln).

The “Kölner Dom” is a UNESCO world heritage site since 1996 and annually receives more than 6 million visitors from Germany and abroad.

“It was a pleasure for us to take over the sponsorship of illuminating the cathedral for the next three years”, AVG’s Managing Director Andreas Freund said on 24th November 2011 at the official switching on ceremony attended by the mayor of Cologne, the cathedral’s provost and other local dignitaries .

“From the waste bin to the centre of peoples’ hearts”, he stated, recalling that the gothic “Dom” is the most beloved and admired symbol of the city of Cologne.

The Waste-to-Energy Plant in Cologne annually processes more than 700,000 tonnes of waste that is not suitable for recycling and generates about 440 million kilowatt hours of energy: electricity and steam.

From this about 350 million kilowatt hours of electricity are supplied to the local RheinEnergie power grid.

This is enough to supply a quarter of the citizens of Cologne with electricity from their waste.

"This is not only efficient recycling, but an up-cycling process. We generate a high quality product – energy", the AVG's Manager said.

Whereas for Dr. Norbert Feldhoff, provost of the cathedral, the illumination of the cathedral using energy from waste reminds him of the old myth of the "phoenix rising from the ashes" - a symbol of rebirth.

Wood Fired Combined Heat and Power Plant (Germany)

In 2001, a new biomass fired combined heat and power (CHP) plant fuelled by forestry and wood residues from sawmills was commissioned in the town of Pfaffenhofen, Germany (population approximately 22,000).

The plant produces process steam, process heat, district heat, and space and process cooling, as well as electricity and was regarded as one of the most innovative and advanced plants in Germany.

The plant supplies a newly erected district heating grid with steam and hot water. The maximum thermal power output is 32.5 MW, supplying heat via a district heating network to a hospital, schools, and other public and private buildings.

Furthermore, the plant delivers process steam for a large biological baby food factory. The plant supplies 6.1MW electricity for the grid and the calorific value of the fuel is 9.07 MJ/kg (moisture content 45%).

Total investment costs totalled €49 million and were financed by a combination of private finance, equity, government investment grants and bank loans.

In 2000 the Federal Government adopted the new Renewable Energy Sources Act. The Act provides guaranteed, absolute minimum feed-in tariffs that the grid operator has to pay for a period of 20 years after commissioning the plant.

The introduction of this new law improved the cost effectiveness of the plant significantly. When the plant was commissioned in 2001 it was eligible for a feed in tariff of 9.3 Eurocents/kWh.

The amendments to the Renewable Energy Sources Act in 2004 saw further bonuses to be paid on top of the regular feed-in tariff provided the electricity is exclusively produced from wood and other replenishing raw materials.

The ability of the plant to secure heat customers and sell almost all of the residual heat to domestic and commercial users further improved the project economics.

The plant was originally designed to combust forest and sawmills residues, using an initial ration of 30 per cent wood chips and 70 per cent sawmill residues.

However, by 2003 this ratio was reversed due to changes in pricing and improved fuel logistics.

Since 2004 the plant uses exclusively forest residues (90 per cent) and woodchips from landscape protection and management (10 per cent). This was due to a subsidy for electricity produced in plants exclusively using wood and other replenishing raw materials that was introduced in 2004

Benefits:

- Annual CO_2 savings of 65,000-70,000 tonnes o 90% of ash is reused in the agricultural and forest sector as a fertiliser
- Local employment created in fuel supply chain

Success Factors:

- On-going political commitment and support by the municipal and district authorities
- Ability of boiler to combust different types of fuel, enabling a switch to a more cost effective fuel
- Fuel supply risk is minimised by using a large number of suppliers
- Supported by The German Federal Ministry of Environment via its Investment Programme for Reduction of Environmental Loads .

Wood Waste Gasification – Austria

The Güssing Biomass CHP Plant (Austria), which started operation in 2002, is one of the most successful demonstration plants in Europe.

It consists of a steam-blown fluidised bed gasifier to produce nitrogen-free biogas for electricity generation and district heating distributed in the city of Güssing.

The plant achieves an electrical production of 2 MW from 8 MW of input biomass, through a biomass gasifier coupled with an Internal Combustion (IC) gas engine with an electrical efficiency of 25% and a heat efficiency of almost 50%.

The gasification plant produces 4.5 MW of heat for the local district heating network.

In the gasification zone, at approximately 850°C, the biomass is gasified with steam. By using steam instead of air, the resulting gas has a lower tar content and a higher heating value (12 MJ/Nm3).

The gas engine is a turbo-charged “Otto”-type engine from GE Jenbacher that had been specially adapted to the properties of the producer gas.

More than 45% of the surrounding area of Güssing is forested. Ownership of the forestry is divided up between several hundred farmers.

The municipality ensures that the farmers manage their area of forest.

The plant uses agricultural and forestry residues and wood from the region with a moisture content of 20-30%.

The quantity of fuel consumed is approximately 2,300 kg/hour. The plant consists of a dual fluidized bed steam gasifier, a two-stage gas cleaning system, a gas engine with an electricity generator and a heat utilisation system.

The cost of the demonstration plant was approximately €10M, with €6M funded nationally and by the European Union.

Operation costs are approximately 15% of the investment costs. The district heating system is 27 km in length and services 300 houses, 50 building public building and 10 industrial applications.

Electricity is sold to the local electrical grid operator for which a feed-in tariff is received. The plant produces enough electricity to meet the entire needs of the city.

The energy framework in Austria ensures the economic efficiency of the plant. Whilst fuel costs are high, this is offset by the high feed in tariffs for electricity.

Benefits:

- 93% reduction in Co2 emissions
- Creation of 1,000 new jobs in a small town of only 4,000 people
- The Gϋssing CHP-plant enables the complete renewable energy supply to the city

- The use of local raw material ensures a higher price is paid
- The city"s energy supply is now independent from fossil fuels and the associated price fluctuations .

Success Factors:

- Sufficient sources of biomass available locally
- Independent company formed to collect and transfer waste wood from farmers
- Biomass secured in long term contracts o Municipality
- Municipality supported investment in research and development
- European Centre for Renewable Energy was formed to coordinate the development, and to continue to develop solutions for regional and community based renewable energy generation and use.

Australia's first waste to energy plant

The development of an Australian designed, grid-connected project converts waste into electricity in the WA town of Port Hedland.

The 17MW project – one of two Australian designed waste-to-gas facilities developed in Western Australia by local company New Energy Corporation – diverts around 100,000 tonnes of waste from landfill, and converts it into renewable energy.

At full capacity, the Port Hedland plant is able to produce enough energy to power the equivalent of 21,000 homes in the Pilbara.

Unlike other developed countries, Australia was slow to embrace waste-to-energy technology.

The ACT operates a 3MW facility that generates electricity from landfill gas, and is looking to offer feed-in tariffs for up to 23MW of waste-to-energy power plants as part of its plans to source 90 per cent of its electricity needs from renewables by 2020.

The two WA projects, were backed by the Clean Energy Finance Corporation, via a collective $50 million in debt finance.

The second project, at Rockingham near Perth, will be the state's first municipal waste-to-gas project and is due to open in 2017.

Port Hedland Mayor, Kelly Howlett, has been quoted in Australian media as saying she was enthusiastic about New Energy choosing the Pilbara town as its Australian launch site.

"Converting household and industrial waste to energy to power a town makes a lot of sense and is obviously a big win for the environment," Howlett said.

"This is the first waste-to-energy plant in Port Hedland – it will provide a world-class recycling and materials recovery facility which generates cost competitive and low-emission energy using Australian-developed low temperature gasification technology."

Howlett said Port Hedland has agreed to support the development of the project by directing much of the town's future waste to the plant, including industrial and hazardous waste, household and green waste, tyres, timber and recyclable products.

Chapter 9: Potential impact of widespread use of waste to energy plants

The above examples highlight the potential of waste to energy processes for a wide range of industries and environments.

The potential for waste-to-energy plants, in combination with sound waste minimisation and recycling strategies – to reduce the impact of waste on GHG emissions is enormous and could, potentially, reduce the impact to zero.

If there's one thing on which all waste experts will agree it's that the linear make-use-dispose model on which we built our society needs ditching for good.

It's all about going "circular" these days. But weaving our economic systems into one harmonious, never-ending bundle of recycling and reuse is no easy task.

By 2025, it is anticipated that waste disposers won't be burying or burning people's rubbish as they do today.

These companies will merge into what has been dubbed the "reprocessing industry", where the central role is not to dump stuff but to return valuable resources to manufacturers.

A similar rethink is required of designers and manufacturers too.

The goods of today need to be seen as the raw materials of tomorrow.

When that happens, products will begin to be made with a view to lasting longer and to being easier to repair and ultimately dismantle. Much like it was in the good old days before mass production!

What is a circular economy and where does WTE fit in?

A circular economy is an industrial economy that promotes greater resource productivity aiming to reduce waste and avoid pollution by design or intention, and in which material flows are of two types: biological nutrients, designed to reenter the biosphere safely, and technical nutrients, which are designed to circulate at high quality in the production system without entering the biosphere as well as being restorative and regenerative by design.

This is contrast to a Linear Economy which is a 'take, make, dispose' model of production.

The term encompasses more than the production and consumption of goods and services, including a shift from fossil fuels to the use of renewable energy, and the role of diversity as a characteristic of resilient and productive systems.

It includes discussion of the role of money and finance as part of the wider debate, and some of its pioneers have called for a revamp of economic performance measurement tools (Stahel, 2008).

The concept of a circular economy (CE) has been first raised by two British environmental economists Pearce and Turner. In their study Economics of Natural Resources and the Environment (1989).

They pointed out that a traditional open-ended economy was developed with no built-in tendency to recycle, which was reflected by treating the environment as a waste reservoir.

The circular economy is grounded in the study of feedback-rich (non-linear) systems, particularly living systems.

A major outcome of this is the notion of optimising systems rather than components, or the notion of ‘design for fit’.

As a generic notion it draws from a number of more specific approaches including cradle to cradle, biomimicry, industrial ecology, and the 'blue economy'.

Most frequently described as a framework for thinking, its supporters claim it is a coherent model that has value as part of a response to the end of the era of cheap oil and materials.

Moving away from the linear model

Linear "Take, Make, Dispose" industrial processes and the lifestyles that feed on them deplete finite reserves to create products that end up as waste.

This realisation triggered the thought process of a few scientists and thinkers, including Walter R. Stahel, an architect, economist, and a founding father of industrial sustainability.

Credited with having coined the expression "Cradle to Cradle" (in contrast with "Cradle to Grave", illustrating our "Resource to Waste" way of functioning), in the late 1970s, Stahel worked on developing a "closed loop" approach to production processes, co-founding the Product-Life Institute in Geneva more than 25 years ago.

In the UK, Steve D. Parker researched waste as a resource in the UK agricultural sector in 1982, developing novel closed loop production systems mimicking, and integrated with, the symbiotic biological ecosystems they exploited.

In their 1976 Hannah Reekman research report to the European Commission, "The Potential for Substituting Manpower for Energy", Walter Stahel and Genevieve Reday sketched the vision of an economy in loops (or circular economy) and its impact on job creation, economic competitiveness, resource savings, and waste prevention.

The report was published in 1982 as the book Jobs for Tomorrow: The Potential for Substituting Manpower for Energy.

Considered as one of the first pragmatic and credible sustainability think tanks, the main goals of Stahel's institute are product-life extension, long-life goods, reconditioning activities, and waste prevention.

It also insists on the importance of selling services rather than products, an idea referred to as the "functional service economy" and sometimes put under the wider notion of "performance economy" which also advocates "more localisation of economic activity".

In broader terms, the circular approach is a framework that takes insights from living systems.

It considers that our systems should work like organisms, processing nutrients that can be fed back into the cycle—whether biological or technical—hence the "closed loop" or "regenerative" terms usually associated with it.

The generic Circular Economy label can be applied to, and claimed by, several different schools of thought, that all gravitate around the same basic principles which they have refined in different ways.

The core principle is they are all based on a system.

Examples of these systems are all living systems and any open system such as meteorological systems or ocean currents, even the orbits of the planets have nonlinear characteristics.

Understanding a system is crucial when trying to decide and plan (corrections) in a system.

Missing or misinterpreting the trends, flows, functions of, and human influences on, our socio-ecological systems can result in disastrous results. In order to prevent errors in planning or design an understanding of the system should be applied to the whole and to the details of the plan or design.

The Natural Step created a set of systems conditions (or sustainability principles) that can be applied when designing for (parts of) a circular economy to ensure alignment with functions of the socio-ecological system.

The concept of the circular economy has previously been expressed as the circulation of money versus goods, services, access rights, valuable documents, etc., in macroeconomics.

This situation has been illustrated in many diagrams for money and goods circulation associated with social systems. As a system, various agencies or entities are connected by paths through which the various goods etc., pass in exchange for money.

However, this situation is different from the circular economy described above, where the flow is unilinear - in only one direction, that is, until the recycled goods again are spread over the world.

Prices or other feedback mechanisms should reflect real costs.

In a circular economy, prices act as messages, and therefore need to reflect full costs in order to be effective.

The full costs of negative externalities are revealed and taken into account, and perverse subsidies are removed. A lack of transparency on externalities acts as a barrier to the transition to a circular economy.

The circular economy is a framework that draws upon and encompasses principles from:

Biomimicry

Janine Benyus, author of "Biomimicry: Innovation Inspired by Nature", defines her approach as "a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems. Studying a leaf to invent a better solar cell is an example. I think of it as "innovation inspired by nature (Biomimicry Institute, 2013).

Biomimicry relies on three key principles:

Nature as model: Biomimicry studies nature's models and emulates these forms, processes, systems, and strategies to solve human problems.

Nature as measure: Biomimicry uses an ecological standard to judge the sustainability of our innovations.

Nature as mentor: Biomimicry is a way of viewing and valuing nature. It introduces an era based not on what we can extract from the natural world, but what we can learn from it.

Industrial ecology

Industrial Ecology is the study of material and energy flows through industrial systems.

Focusing on connections between operators within the "industrial ecosystem", this approach aims at creating closed loop processes in which waste is seen as input, thus eliminating the notion of undesirable by-product.

Industrial ecology adopts a systemic - or holistic - point of view, designing production processes according to local ecological constraints whilst looking at their global impact from the outset, and attempting to shape them so they perform as close to living systems as possible.

This framework is sometimes referred to as the "science of sustainability", given its interdisciplinary nature, and its principles can also be applied in the services sector.

With an emphasis on natural capital restoration, Industrial Ecology also focuses on social wellbeing (International Society for Industrial Ecology, 2013).

Cradle to cradle

Created by Walter R. Stahel, a Swiss architect, who graduated from the Swiss Federal Institute of Technology Zürich in 1971.

He has been influential in developing the field of sustainability, by advocating 'service-life extension of goods - reuse, repair, remanufacture, upgrade technologically' philosophies as they apply to industrialised economies.

He co-founded the Product Life Institute in Geneva, Switzerland, a consultancy devoted to developing sustainable strategies and policies, after receiving recognition for his prize winning paper 'The Product Life Factor' in 1982.

His ideas and those of similar theorists led to what is now known as the circular economy in which industry adopts the reuse and service-life extension of goods as a strategy of waste prevention, regional job creation and resource efficiency in order to decouple wealth from resource consumption, that is to dematerialise the industrial economy.

Blue economy

Initiated by former Ecover CEO and Belgian businessman Gunter Pauli, the Blue Economy is an open-source movement bringing together concrete case studies, initially compiled in an eponymous report handed over to the Club of Rome.

As the official manifesto states, "using the resources available in cascading systems, the waste of one product becomes the input to create a new cash flow".("Blue Economy : Green Economy 2.0", 2013).

Based on 21 founding principles, the Blue Economy insists on solutions being determined by their local environment and physical / ecological characteristics, putting the emphasis on gravity as the primary source of energy - a point that differentiates this school of thought from the others within the Circular Economy.

The report - which doubles as the movement's manifesto - describes "100 innovations which can create 100 million jobs within the next 10 years", and provides many example of winning South-South collaborative projects, another original feature of this approach intent on promoting its hands-on focus.

Towards the circular economy

In January 2012, a report was released entitled Towards the Circular Economy: Economic and business rationale for an accelerated transition.

The report, commissioned by the Ellen MacArthur Foundation and developed by McKinsey & Company, was the first of its kind to consider the economic and business opportunity for the transition to a restorative, circular model.

Using product case studies and economy-wide analysis, the report details the potential for significant benefits across the EU.

It argues that a subset of the EU manufacturing sector could realise net materials cost savings worth up to $630 billion p.a. towards 2025 — stimulating economic activity in the areas of product development, remanufacturing and refurbishment.

Towards the Circular Economy also identified the key building blocks in making the transition to a circular economy, namely in skills in circular design and production, new business models, skills in building cascades and reverse cycles, and cross-cycle/cross-sector collaboration.

In January 2015 a Definitive Guide to The Circular Economy was published by Coara with the specific aim to raise awareness amongst the general population of the environmental problems already being caused by our "throwaway culture".

Waste Electrical and Electronic Equipment (WEEE,) in particular, is contributing to excessive use of landfill sites across the globe in which society is both discarding valuable metals but also dumping toxic compounds that are polluting the surrounding land and water supplies.

Mobile devices and computer hard drives typically contain valuable metals such as silver and copper but also hazardous chemicals such as lead, mercury and cadmium.

Consumers are unaware of the environmental significance of upgrading their mobile phones, for instance, on such a frequent basis but could do much to encourage manufacturers to start to move away from the wasteful, polluting linear economy towards are sustainable circular economy.

Impact in Europe

On 17 December 2012, the European Commission published a document entitled Manifesto for a Resource Efficient Europe.

This manifesto clearly stated that "In a world with growing pressures on resources and the environment, the EU has no choice but to go for the transition to a resource-efficient and ultimately regenerative circular economy."

Furthermore, the document highlighted the importance of "a systemic change in the use and recovery of resources in the economy" in ensuring future jobs and competitiveness, and outlined potential pathways to a circular economy, in innovation and investment, regulation, tackling harmful subsidies, increasing opportunities for new business models, and setting clear targets.

The European environmental research and innovation policy aims at supporting the transition to a circular economy in Europe, defining and driving the implementation of a transformative agenda to green the economy and the society as a whole, to achieve a truly sustainable development.

Research and innovation in Europe are financially supported by the programme Horizon 2020, which is also open to participation worldwide.

The European Commission introduced a Circular Economy proposal in 2015.

Historically, the policy debate in Brussels mainly focused on waste management which is the second half of the cycle, and very little is said about the first half: eco-design.

To draw the attention of policymakers and other stakeholders to this loophole, the Ecothis.

EU campaign was launched raising awareness about the economic and environmental consequences of not including eco-design as part of the circular economy package.

Circular Business Model

According to Linder and Williander, a circular business model is "a business model in which the conceptual logic for value creation is based on utilizing the economic value retained in products after use in the production of new offerings".

Mateusz Lewandowski provides a proposition to address this need to design circular business models and presents a conceptualization of an extended framework called: circular business model canvas (CBMC).

The CBMC consists of eleven building blocks, adapted from Osterwalder and Pigneur, encompassing not only traditional components with minor modifications, but also material loops and adaptation factors.

Those building blocks allow the designing of a business model according to the principles of circular economy, and consists of:

(1) Value propositions—offered by circular products enabling product-life extension, product-service system, virtualized services, and/or collaborative consumption. Moreover, this component comprises the incentives and benefits offered to the customers for bringing back used products

(2) Customer segments—directly linked with value proposition component. Value proposition design depicts the fit between value proposition and customer segments

(3) Channels—possibly virtualized through selling virtualized value proposition and delivering it also virtually, selling non-virtualized value propositions via virtual channels, and communicating with customers virtually

(4) Customer relationships—underlying production on order and/or what customers decide, and social-marketing strategies and relationships with community partners when recycling 2.0 is implemented

(5) Revenue streams—relying on the value propositions and comprising payments for a circular product or service, or payments for delivered availability, usage, or performance related to the product-based service offered. Revenues may also pertain to the value of resources retrieved from material loops

(6) Key resources—choosing suppliers offering better-performing materials, virtualization of materials, resources allowing to regenerate and restore natural capital, and/or the resources obtained from customers or third parties meant to circulate in material loops (preferably closed)

(7) Key activities—focused on increasing performance through good housekeeping, better process control, equipment modification and technology changes, sharing and virtualization, and on improving the design of the product, to make it ready for material loops and becoming more eco-friendly. Key activities might also comprise lobbying

(8) Key partnerships—based on choosing and cooperating with partners, along the value chain and supply chain, which support the circular economy

(9) Cost structure—reflecting financial changes made in other components of CBM, including the value of incentives for customers. Special evaluation criteria and accounting principles must be applied to this component

(10) Take-Back system—the design of the take-back management system including channels and customer relations related to this system

(11) Adoption factors—transition towards circular business model must be supported by various organizational capabilities and external factors

Where does WTE fit in?

The reality is we are a long way to a closed system. And while we work towards it, there will still be waste to dispose of which cannot be recycled or reused.

WTE fills a valuable space in the meantime – offering the ability to recover "unrecyclable" waste and transfer it to energy.

This effectively "closes the loop" in the current system while policy can still work towards changing production and consumption attitudes.

WTE is simply a machine which becomes part of the system.

African case study

An Evaluation of energy potential of Municipal Solid Waste from African urban areas (Scarlat et al, 2014) assessed the total potential of energy from waste and from methane generated from Municipal Solid Waste from urban areas for 2012 and its projection to 2025 for each African country on the basis of the most updated and robust available data and projections.

The analysis showed that waste, and in particular MSW, is a renewable energy resource that could in principle provide an interesting share of both gross energy consumption and electricity in the African continent, if compared with current needs.

The potential contribution of waste to energy is even more important considering how critical energy is for Africa, where large a number of people do not have access to energy and rely on the traditional use of biomass.

Moreover, given the increase of both the overall African population and its urban share, the amount of waste generated in the continent is expected to increase in the next decades, providing an even more interesting resource for energy production.

It is also worth noticing that the same growth of waste is also expected to result in an increasingly urgent pressure on the quality of the environment in the continent and that setting up proper waste energy recovery infrastructures will help in better handling such an issue.

The study showed that the energy potential of generated waste could have provided 1125 PJ of energy for the whole Africa in 2012 and this could reach 2199 PJ in 2025.

Nevertheless, considering that the actual collection rates in African cities are quite low, the energy potential of waste actually collected was estimated to be about 613 PJ in 2012 and 1508 PJ in 2025.

As a reference, the primary energy supply in Africa was about 29,308 PJ in 2010.

If all waste that is generated is also collected and deposited in managed landfills, about 283 PJ could have been recovered from the LFG in 2012 and 530 PJ can be recovered in 2025.

Considering the waste actually collected, about 155 PJ could have been recovered from the LFG in 2012 and 363 PJ in 2025.

The potential electricity produced from waste and its contribution to electricity consumption was estimated both at country and continental level.

The electricity production from the total waste generated could reach 62.5 TWh in 2012 and 122.2 TWh in 2025, in comparison with a total electricity consumption of 661.5 TWh at continental level in 2010.

This can be considered as a theoretical potential of electricity from waste incineration in Africa.

The electricity production from waste actually collected was estimated at 34.1 TWh in 2012 and 83.8 TWh in 2025.

If using LFG, the electricity production from all generated waste was estimated at 27.5 TWh in 2012 and 51.5 TWh in 2025 while the electricity production from waste actually collected was quantified at much lower levels, 12.9 TWh in 2012 and 30.3 TWh in 2025.

In a number of countries, the use of waste to generate electricity could have a significant impact, both in the electricity generation per capita and as a share of electricity consumption.

Waste can have a very high contribution to providing electricity to citizens and alleviate energy poverty especially in countries with low access to electricity and reduced electricity consumption per capita (Central African Republic, Burundi, Guinea-Bissau, Mali, Sierra Leone, Rwanda, Somalia, etc.).

It should be noted that the study assessed theoretical and technical potentials of energy and electricity from waste.

The evaluation of these potentials are based on assumptions such as the setting up of an adequate system for waste management covering all urban areas, which are unlikely to be fulfilled, even in the 2025 time horizon investigated here.

The real energy potential of waste can increase, depending on the total amount of waste generated and on the extent to which waste will be collected. The actual energy use of landfill gas will depend on the building of sanitary landfills and the implementation of LFG recovery systems.

The issue of cost evaluation was not in the scope of the present study.

Cost is a major driver for decision making in the field of energy systems, nevertheless, adding the cost issue to the present analysis would have introduced a large number of additional variables also affected by large uncertainties and would have blurred the overall picture.

Saudia Arabian case study

Another study (Omar, et all 2015) found that waste-to-energy (WTE) is a viable option for municipal solid waste (MSW) management and a renewable energy source where MSW is a chronic problem in Saudi Arabia and more specifically in Saudi Urban areas.

The MSW practices in KSA are simply done by collecting the waste and dumping it in open landfill sites. KSA is considering WTE as a potential renewable energy source that can contribute to electricity demand in the Kingdom.

The study assessed the potential contribution of WTE facilities to meet electricity demand in the three main cities in the Western Province of Saudi Arabia and to provide an alternative solution to landfills.

Three scenarios for WTE utilization were developed: Mass Burn, Mass Burn with recycling, and refused derived fuel (RDF) with biomethanation.

The Mass Burn scenario implied full waste stream incineration; the Mass Burn with recycling scenario considers segregation of reusable materials and the waste leftover for incineration; while RDF with biomethanation considers segregation of general waste stream into inorganic and organic waste and utilizes organic waste for biomethanation and inorganic for RDF.

The analyses were completed for Jeddah, Makkah, and Madina cities; with current total population of about 6.3 million.

The results show that Jeddah has the potential to produce about 180 MW of electricity based on incineration scenario; about 11.25 MW based on incineration with recycling scenario; and about 87.3 MW based RDF with biomethanation scenario by the year 2032.

These values and other two cities values are based on theoretical ideals and they help in identifying the optimal WTE techniques for each city.

Indian case study

India has drawn the world's attention in recent years with its booming economic growth, large demographic of young, English-speaking workers, and its shift from an agricultural to a more service-oriented economy.

The consequence of this economic success has been a massive increase in waste.

A growing number of Indians are enjoying a new found ability to consume a vast number of goods and services that were previously either unavailable or unaffordable.

From small electronic items, such as cell phones, to large consumer goods like refrigerators and cars, Indian consumption has been steadily increasing and shows no signs of abating anytime soon. Inevitably this has led to a rapid growth in the quantity and variety of MSW.

In most cities and towns in India, MSW is disposed of in an unregulated and unscientific manner in low lying, open dumps on the outskirts of cities.

Most dumps lack systems for leachate collection, landfill gas collection or monitoring, nor do they use inert materials to cover the waste.

This results in ground and surface water contamination from runoff and lack of covering, air pollution caused by fires, toxic gases, and odour, and public health problems due to mosquitoes and scavenging animals.

In its 2009-10 Annual Report the Ministry of New and Renewable Energy (MNRE) estimated that approximately 55 million tonnes of MSW are generated in urban areas of India annually.

It is estimated that the amount of waste generated in India will increase at a rate of approximately 1-1.33% annually.

The Ministry of Environment and Forests (MoEF) promulgated the Municipal Solid Wastes (Management and Handling) Rules in 2000 requiring municipalities across India adopt sustainable and environmentally sound ways of processing MSW, including incineration. In this regard, Waste to Energy (WTE) provides a solution towards complying with government regulations, and achieving integrated solid waste management.

WTE is perceived as a means to dispose MSW, produce energy, recover materials, and free up scarce land that would otherwise have been used for landfill.

The Indian Government considers WTE to be a renewable technology, and the MNRE has developed the National Master Plan for Development of WTE in India. The MNRE lists a number of technologies for energy recovery from urban and industrial wastes that "not only reduce the quantity but also improve the quality of waste to meet the required pollution control standards, besides generating a substantial quantity of energy".

The MNRE estimates that the potential to generate power from MSW will more than double in the next ten years, while the potential from industrial waste is likely to increase by more than 50%.

While the Indian Government's own figures would suggest that the cost of WTE is somewhat higher than other renewable sources, it should be kept in mind that WTE facilities serve a dual role of waste disposal and energy production. Although the cost per MW of capacity may be greater than other renewable sources, the benefits of waste management, energy and metals recovery, and reduction of GHG emissions need to be considered.

Mumbai, India's financial capital and largest city, has been facing a solid waste management crisis for years. The infrastructure has been unable to keep pace with economic development and population growth. In order to move towards a sustainable future and achieve its goal of becoming a world-class city, Mumbai needs to adopt an integrated solid waste management approach.

Rudra Environmental Solutions is setting up a pilot project that will convert plastic to fuel for generator sets

The agency responsible for solid waste management in Mumbai is the Solid Waste

Management Department (SWMD) of the Municipal Corporation of Greater Mumbai (MCGM) and its private contractors. The 2009-10 budget of the SWMD is Rs.10.6 billion (US$228 million), and is expected to increase to Rs.15.5 billion ($334 million) in 2010-11.

The municipal corporation spends roughly Rs.1160 per tonne ($25/tonne) on collection, transport, and disposal of MSW. Collection and transport together constitute roughly 80% of the cost. In India, the average municipal expenditure on solid waste management is Rs.500 to Rs.1500 per tonne ($10 to $32 per tonne).

Suitability of WTE in Mumbai

The MSW collected in Mumbai consists of wet organics (primarily food waste), dry organics (straw and wood, etc.), inert materials (sand and soil), and recyclables (plastics, metal, glass and paper).

Based on the composition of MSW, processing the waste in a WTE facility would reduce its volume by 96.74%, thus freeing up land that would otherwise have been used for landfills.

Composition of waste in Mumbai as of 2006

The chemical characteristics of MSW in Mumbai have been measured by two different studies, one by the Central Pollution Control Board (CPCB) and the National Environmental Engineering Research Institute (NEERI) in 2005-06, and the other by MCGM around the same time.

The reported moisture content and heating value differs significantly between the two studies, however, the CPCB-NEERI study found that the heating value of MSW in Mumbai is sufficient for a WTE plant to operate without additional fuel. From an environmental standpoint, a WTE facility would be beneficial because it would prevent the formation of leachate that contaminates groundwater, reduce emissions of toxic pollutants from the burning of garbage, and prevent the production of two potent greenhouse gases, carbon dioxide and methane.

Additionally, with space in urban areas at a premium WTE provides an effective way to reduce the volume of waste by approximately 90% and thereby lower the space needed for landfills.

Education

More research is needed to quantify various aspects of the solid waste management sector. A number of key statistics, such as the value of recyclables, the amount of environmental pollution from waste sources, and the quantity of industrial waste generated, need to be computed to gain a better understanding of this sector. In terms of research related to WTE, detailed analysis of costs and available funding is needed. In addition, investigating the suitability and quantifying the costs and benefits of combined heat and power for Mumbai would be useful. Independent researchers or consultants should carry out such research in order to prevent any biases that may otherwise occur.

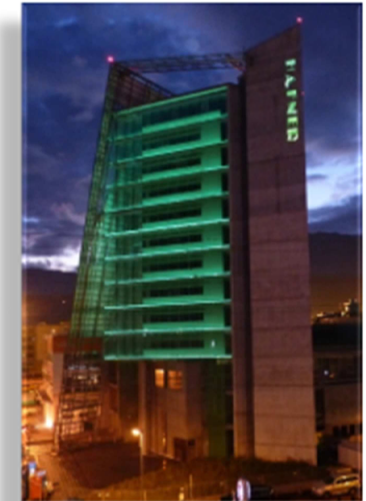
Outreach to both environmental groups as well as the public at large is important in order to demonstrate the benefits of WTE technology to the community, city, and local government. This can be achieved by educating the public through campaigns, workshops, town hall meetings, university lectures, and so on. Creating an open dialogue with environmental groups is an essential first step to sharing information and collaborating to create better environmental conditions.

Chapter 10 : SLIM LINE Waste To Energy project (Hafner technologies)

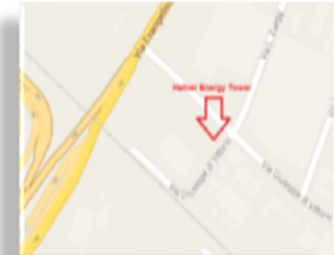
Heinrich Hafner
CEO
Hafner Energy from Waste

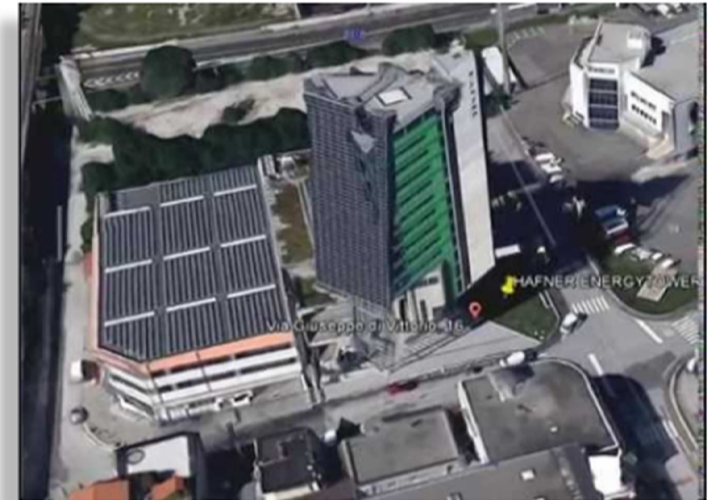
Hafner energy solutions, both global and local

Hafner, a company based in South Tyrol, is a specialist with many years of expertise in the field of environmental consultancy. Hafner constructs small, decentralised thermal treatment plants for residual waste in the form of the SLIM LINE energy control centre to solve the global waste problem.



Hafner Energy Tower Bozen





Hafner Energy Tower Bozen SouthTyrol

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Via G. di Vittorio 16
Heinrich.hafner@hafner.it
00390471566300

Challenge: Producing energy from waste

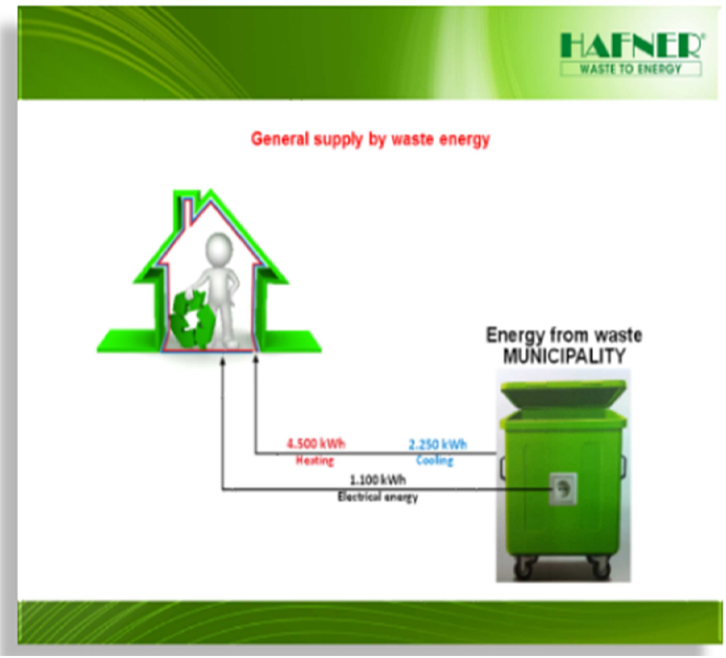
Waste disposal is one of our most important global challenges in the 21st century. 194 countries annually produce 300 kg of waste per year and per person on average. 70 per cent of it ends up on landfill sites - lost energy which we urgently require from elsewhere. At the moment every local authority and every country seems to have its own system and customised solutions to come to terms with huge quantities of household waste from private and trade households.

Meaningful waste separation is the best requirement for clean recycling, but not all recycling systems are accepted by all consumers, or implemented as requested. A lot of households find the waste separation process simply too complicated, too laborious. Besides which not all of them can make use of a waste separation system in the forms that are for instance available in Germany or other European countries. The consequences for the environment where there are inappropriate waste disposal options are extensive.


HAFNER
WASTE TO ENERGY
SLIM LINE
Produce Energy from Waste
(Electrical energy ; Heating and Cooling)
Waste Quantity 50.000 t/year
Cloud
Control Center Bozen
SLIM LINE SMAL INCINERATOR PLANT
BOILER 4
BOILER 3
BOILER 2
BOILER 1
TURBINE O.R.C. 4
TURBINE O.R.C. 3
TURBINE O.R.C. 2
TURBINE O.R.C. 1

Recycling: Cost-intensive, uses up a lot of energy and space

But even waste that is separated with painstaking care contains different materials that are difficult to recycle such as complex plastics or chipboard. A lot of energy is required through the separation of valuable materials to decompose the waste back into its original substances using conventional procedures. Laborious mechanical biological pre-treatment procedures also entail high costs. Moreover, the determination of the landfill sites is not that easy in emerging nations. Cities with a very high population density have only few areas for large plants. Mountainous countries only have a limited range of sites for large waste incineration plants. A space-saving, economic and environmental solution that is widely accepted by the population at large would be ideal.

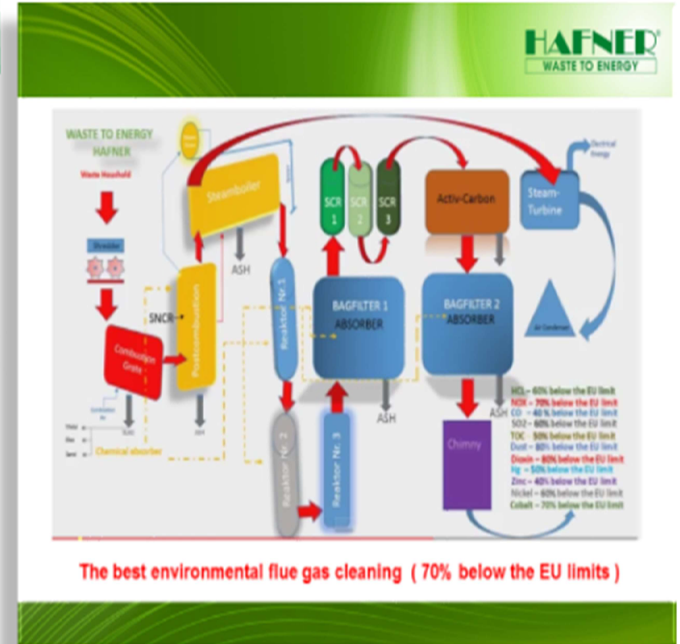


HAFNER
WASTE TO ENERGY
General supply by waste energy
Energy from waste
MUNICIPALITY
4.500 kWh
Heating
2.250 kWh
Cooling
1.100 kWh
Electrical energy

State of the art incineration technology made in South Tyrol

Hafner offers a simple, highly efficient and environmentally-friendly solution for every disposal problem, and for both hazardous or residual waste. The South Tyrolean waste disposal specialist combines its many years of expertise from the field of environmental consultancy with the expertise of experienced partners from the waste disposal sector within its SLIM LINE transportable energy control centre. The upshot of this is a flexible, economic and secure concept for the thermal treatment of residual and hazardous waste.
This is because the SLIM LINE solves two problems at once in a single procedure:

1. The disposal question in relation to "waste"
2. The lack of renewable, climate-neutral energy

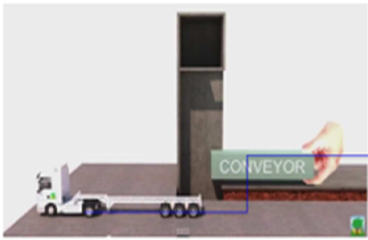

HAFNER
WASTE TO ENERGY
WASTE TO ENERGY
HAFNER
Steamboiler
SCR 1
SCR 2
SCR 3
Activ-Carbon
Steam-Turbine
ASH
SNCR
Postcombustion
Reaktor Nr. 1
BAGFILTER 1 ABSORBER
BAGFILTER 2 ABSORBER
Combustion Grate
Reaktor Nr. 2
Reaktor Nr. 3
Chimney
ASH
ASH
Chemical absorber
The best environmental flue gas cleaning (70% below the EU limits)

Simple module system with ingenious incineration technology

The SLIM LINE is immediately operational for the thermal incineration of settlement waste following its assembly. It consists of different transportable container models which are put together without creating much noise on site in a module system as a stationary unit. Whilst taking account of strict safety precautions a lorry transports the modules to their destination with a hydraulic gripper.

HAFNER®
WASTE TO ENERGY

Decentralised and transportable thermal energy control centre; can be installed as a module virtually anywhere



When energy is produced from waste – Hafner is the conversion specialist for regional and international disposal solutions

The thermal energy control centre for waste incineration ranks among the so-called "Waste-to-Energy plants" that have become more popular as part of the debate concerning the turnaround in energy policy and price increases for fossil fuels.

Put simply this means: New useable energy is generated at the end of the waste incineration process. It is almost as if the heat generated in a giant waste bin immediately flows through a cable into the plug socket. Electricity, remote heat and refrigerants are obtained. They can for example be used by nearby companies for production purposes or by private households through connections to the local authority district heating grid. Valuable materials such as glass, metals or sand are generated from the slag, which then become available for recycling once more.

In 5 steps from waste to electricity

And this is how the SLIM LINE works:

1. Waste loading
2. Incineration in the grate and in the secondary combustion chamber
3. Energy use in the form of electricity, heat and cooling
4. Cleaning of waste flue gases
5. Continuous measurement of emissions (this is below the EU boundary values)

The advantages of the SLIM LINE at a glance:

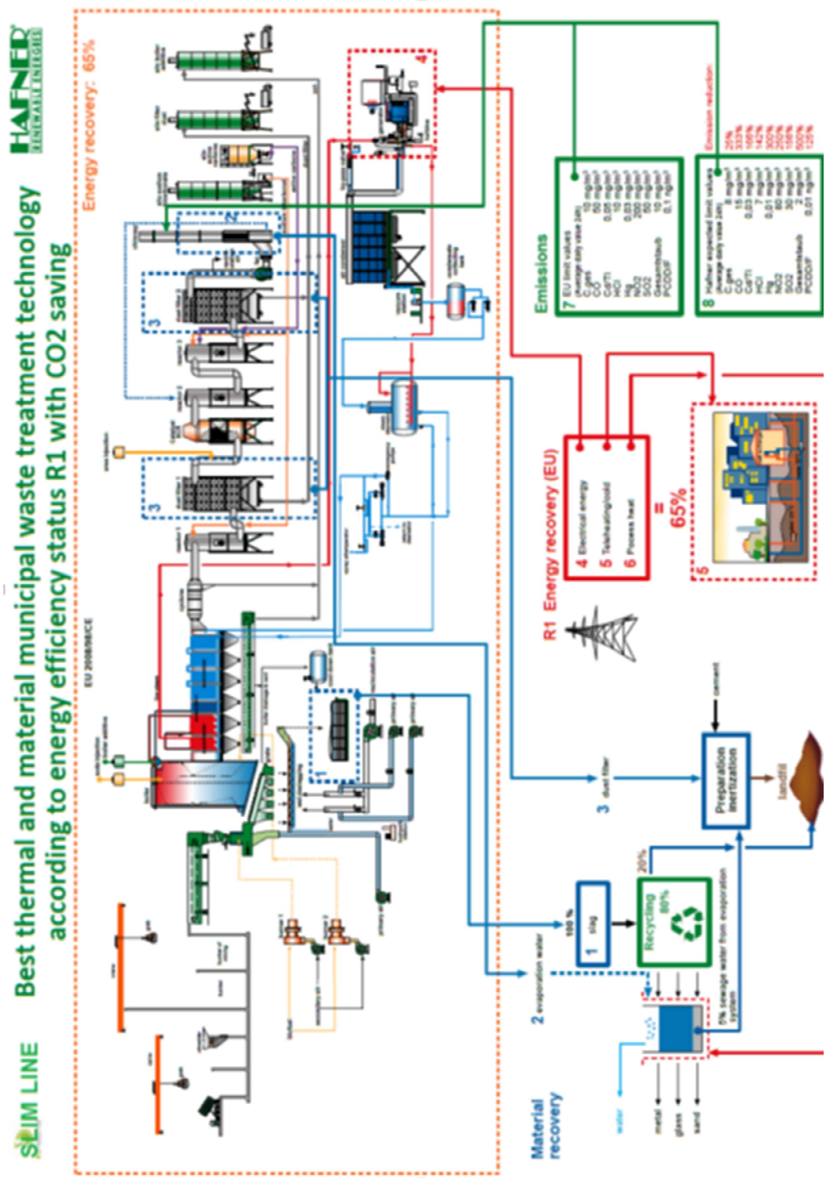
- Decentralised and transportable thermal energy control centre; can be installed as a module virtually anywhere.
- Low investment costs, consequently pleasantly low operating costs.
- Extracting of valuable energies in the form of electricity, heat and refrigerants.
- Use of state of the art, environmentally-friendly technology for the firing and cleaning of waste gases – the secondary combustion chamber guarantees environmentally-friendly treatment.

- Co2 reduction through the replacement of fossil fuels during the incineration process.
- Co2 reduction by doing away with transportation costs by contrast with centralised waste sites.
- Utilisation of the energy introduced with an efficiency level of 80 per cent. Waste is thus "declared" as fuel according to the EU Directive.
- CE certification of the modular plant that has already been performed guarantees a shortened environmental impact assessment. Emission values fulfil the provisions of the European and more far reaching strict national requirements. The plant can therefore be approved within a short period (1 year) and operated.

A life cycle assessment to be proud of

The waste that is generated will be disposed of decentrally on site thanks to the SLIM LINE. Municipality and Hazardous waste colonialism shall thus finally become a thing of the past. The small energy control centre guarantees high levels of transparency towards the local authorities and their citizens in this way. Waste cycles can be better understood, the consumer understands that avoidance of waste is always the first and the best choice. An additional advantage for the environment is the fact the SLIM LINE runs without creating any waste water. At the end of the incineration process the plant merely expels slag and cleaned waste gases. The plant extracts more than 90% metals from the slag which is subsequently available for a new economic cycle.

Heinrich Hafner, managing director of Hafner GmbH on the recycling advantages of the SLIM LINE: "The quality of the metals and glasses extracted from the thermal treatment is extremely high. By comparison with the sorting of waste compounds undesired coatings and adhesions are already removed during the incineration process. And the remaining materials that are produced during the incineration process are also recyclable – such as rubble which is used by the building materials sector or in road construction."



SLIM LINE
Best thermal and material municipal waste treatment technology according to energy efficiency status R1 with CO2 saving
HAFNER RENEWABLE ENERGIES
Energy recovery: 65%
Emissions
R1 Energy recovery (EU)
4 Electrical energy
5 Teleheating/cold
6 Process heat
= 65%
Material recovery
water
metal
glass
sand
2 evaporation water
100 %
1 slag
Recycling 80%
20%
3 dust filter
Preparation inertization
cement
landfill
5% sewage water from evaporation system

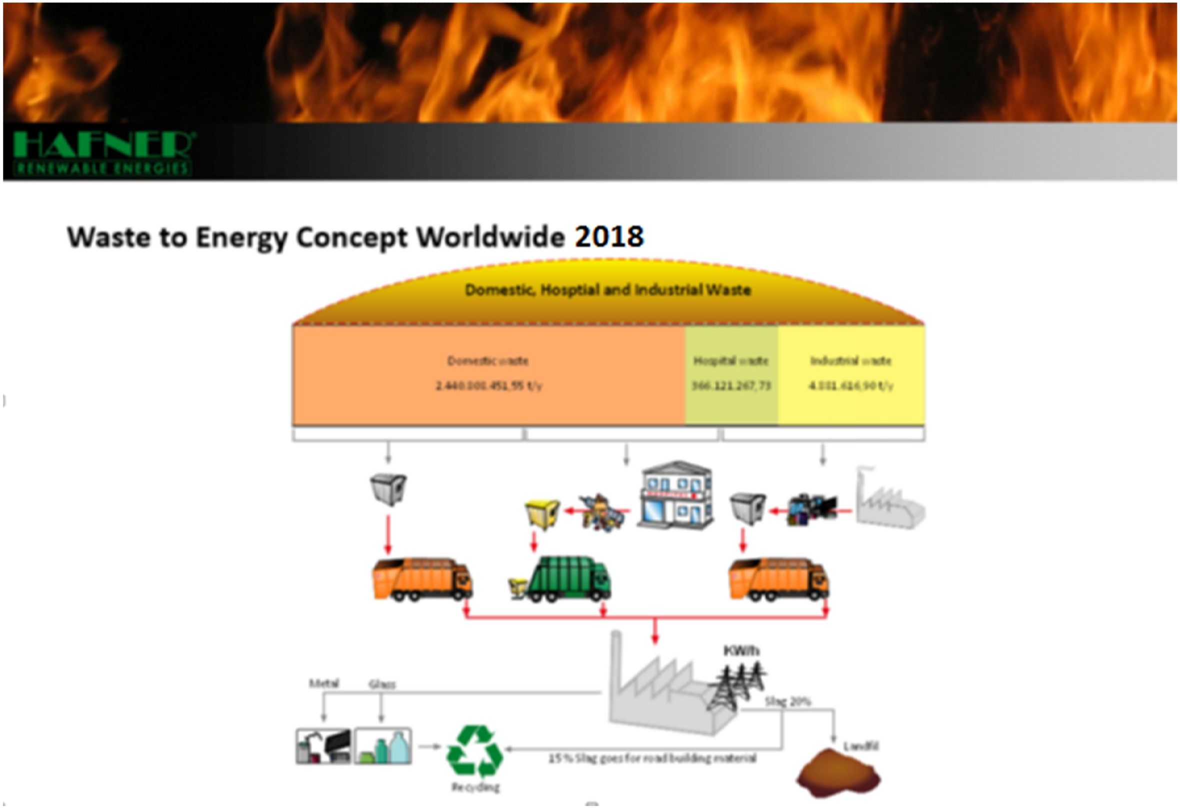
The current waste situation WORLDWIDE

Population worldwide: **6.973.738.433**

Amount of waste worldwide:

- **Domestic waste 2.440.808.451,55 t/year**
- **Hospital waste 366.121.267,73 t/year**
- **Industrial waste 4.881.616,90 t/year**


HAFNER RENEWABLE ENERGIES
Current waste disposal Worldwide
Domestic, Hosptial and Industrial Waste
Domestic waste
2.440.000.451,55 t/y
Hospital waste
366.121.267,73
Industrial waste
4.001.616,90 t/y
Recycling
Landfill


HAFNER
RENEWABLE ENERGIES
Waste to Energy Concept Worldwide 2018
Domestic, Hosptial and Industrial Waste
Domestic waste
Hospital waste
366.121.267,73
Industrial waste
KWh
Metal
Glass
Slag 20%
Landfill
15 % Slag goes for road building material
Recycling

The waste to energy market worldwide

Total waste for thermal treatment 5.688.545.839,00 Ton/years

Decentralised Thermal utilizazion of residual waste – System Hafner (Slim Line)
We manufacture thermal plants for residual waste . Modular in a Bulding-Block system. Standarddised , extendible and hight efficient by fluegas cleaning and energy recovery.

50% SMALL Waste to Energy plants (50.000 t/y)

50 % BIG Waste to Energy Plants in the city

60.000

Slim Line Waste Thermal Plants 50.000 t/year

Chapter 11 : Technical description Waste To Energy project .

WASTE

Definition: waste is a term that includes a large quantity of extremely heterogeneous materials. With a few exceptions, waste can be described as everything that has an organic matrix. Plastics and fossil materials are excluded because although they fall within the carbon chemistry category, they in no way share the characteristics of organic materials we are concerned with here.

Waste refers mainly to organic material, mostly vegetable, growing spontaneously or cultivated by man, on land or in the sea, produced by the process of chlorophyllous photosynthesis by means of the energy of solar radiation, water and various nutritional substances. Thanks to this process, in nature vegetable material constitutes the most sophisticated form for the storing of solar energy. Therefore waste is all the products of agricultural crops and forestation, the residual materials of agricultural production, food industry waste, algae, and indirectly all the organic products deriving from the biological activities of animals and man, such as those contained in urban waste.

When we burn waste, for example wood (extracting from it the energy stored in its chemical components), the oxygen in the atmosphere combines with the carbon in plants and amongst other things produces carbon dioxide, one of the main gases responsible for the greenhouse effect. However the same quantity of carbon dioxide is absorbed into the atmosphere during the growth of waste. The process is cyclical. So long as the burnt waste is replaced with new waste, the net emission of carbon dioide into the atmosphere is zero.

GENERAL FEATURES OF THE PLANT

The plant will consist of :

1. a system of storage and transport using a bridge crane and grab
2. a conveyor feed system
3. combustion chamber – grate and boiler
4. steam generator

5. axial turbine with two-step pressure

6. heat exchanger

7. condenser

8. dust-removal system consisting of a multi-cycle reactor, a sleeve filter and a catalyser

9. exhaust gas extraction fan

10. chimney

11. automatic systems that ensure functioning at operational values conforming to the minimum values set when authorisation is given

12. system of continuous measurement of the temperature and free oxygen concentrations in exhaust gases emitted by the thermal treatment plant and of CO, NOx ; HCL , SO2 ; TOC ; CO2 ; NH3 ; NO ; O2 and dust.

TYPE OF WASTE

The plant will chiefly use waste from industry and urban waste collection.

LOWER CALORIFIC POWER OF WASTE

With regard to the cellulosic part of the waste, the parameter that most affects the calorific power of maize and wood is humidity and the viable limit for combustion can be set at a humidity of 30-50%.

The combustion temperature and the relative consumption of combustible also depend on the humidity / dryness percentage.

General composition

(Combustible component ; Watery component Inert component)

(H2/C in combustible ; N2/C in combustible ; Cl in combustible ; S in combustible)

Elementary composition calculated on the basis of PCI

(C in combustible ; H in combustible ; N in combustible ; Cl in combustible ; S in combustible ; O in combustible.)

Microcontaminators

(Fe ;Hg ; Cd+Tl ;Pb ; Cu ;Zn ;Sn ; Cr ;Ba)

VARIABLES THAT AFFECT WASTE COMBUSTION

Combustion is a rapid chemical reaction of oxygen with the volatile elements of the combustible.

The combustible elements that characterise waste are carbon, hydrogen and, in some cases, sulphur. Sulphur is contained in waste in extremely low quantities compared to the masses involved. In part its presence can be due to support fuel (diesel or fuel oil).

Combustion is an exothermic reaction that releases a large quantity of energy in the form of heat.

Complete combustion reactions for carbon and hydrogen are as follows:

$C + O_2 = CO_2 +$ 7833 kcal/kg di C

$2H_2 + O_2 = 2H_2O +$ 33945 kcal/kg di H_2

Normally atmospheric oxygen is used, although in some special cases pure oxygen can be used.

The aim of heat treatment systems is to completely destroy all the volatile elements and to do this it is necessary to get the oxygen to react completely with the combustible elements in the waste. This requires a sufficiently high temperature for injection of the constituents, good turbulence to facilitate their contact and mixing and enough time for a complete reaction. Only an ideal system can satisfy all theses conditions.

During operation, air for combustion is supplied with an excess of 30% to 150% of the stoichiometric ratio.

The variables that affect combustion are:

combustibility of waste;

flame temperature;

turbulence of combustion;

length of time in combustion chamber.

COMBUSTIBILITY OF WASTE

The combustibility of a material is characterized by several physical parameters, such as:

Higher and lower calorific power;

Flash point;

Ignition temperature;

Self-ignition temperature.

In general, a material with a low inflammability limit, low flash point and low ignition and self-ignition temperature is considered to be a good combustible that requires a low excess of air.

COMBUSTION TEMPERATURE

The three parameters that characterize good combustion are length of time, turbulence and temperature.

Consequently, by varying the air/combustible ratio it is possible to vary the temperature of the exhaust gases.

High temperatures pose problems in the choice of the refractory of the combustion chambers: above 1100 °C it is necessary to use refractories with a high aluminum content.

Normally temperatures are kept in the 850-1000 °C range and usually the speed of reaction increases as the temperature increases.

There are three basic methods for controlling the temperature:

Control of excess air;

Heat transfer by radiation;

Direct heat transfer.

CONTROL OF EXCESS AIR

The adiabatic temperature of the flame depends on the type of combustible and the quantity of air used.

As the quality of the "combustible" varies frequently in the field of waste thermal treatment, the plant must be equipped with a system of automatic regulation of excess air that adjusts to the temperature of the exhaust gases. If the incinerator is fed with moderate quantities, the interval between one feed batch and the next must be regulated.

HEAT TRANSFER BY RADIATION

In some kinds of kiln temperature control is effected through the shape of the combustion chamber, above all when solid waste is incinerated.

Transfer by radiation takes place through the walls or the ceiling. Radiation is also used to destroy by heat the light particles carried away by the exhaust fumes.

DIRECT HEAT TRANSFER

When a combustible is added to the waste, the combustion temperature must be controlled. The most commonly used method is to add water, with the combustible or straight into the combustion zone through sprayers.

TWO-PHASE COMBUSTION

When incineration is carried out in two phases, the first phase takes the form of gasification in which, because of lack of air, controlled distillation of the organic substance takes place.

In the second phase the combustible materials produced in the first are burnt. The temperature in the second phase are controlled with the methods indicated above.

TURBULENCE OF THE COMBUSTION ZONE

The degree of turbulence (mixing) of the oxidation air with the waste to be incinerated has a great influence on the efficiency of combustion. Generally both mechanical and aerodynamic methods are used to obtain the right mix.

Mechanical methods consist mainly of mobile grates, rotating drums and mobile bars.

Aerodynamic methods use air registers with special nozzles.

LENGTH OF TIME IN COMBUSTION CHAMBER

Combustion is a superficial phenomenon as only the surface of the combustible is in contact with the air (oxygen). So the smaller the particle of combustible, the more efficient combustion is.

Consequently the size of the combustion chamber must be adjusted to the size of the combustible. If there are no specific indications, the combustion chambers are made to a size suitable for a thermal load of 180,000 to 550,000 kcal/cm.

When there are slow burning particles, like carbon or carbon monoxide, a secondary chamber is necessary for completing combustion.

EFFICIENCY OF COMBUSTION AND OF DESTRUCTION OF INCINERATION

The efficiency of combustion (Ec) and destruction and of destruction (Ed) are two parameters defined by the following relations:

Cco

Ec = ----------------------------- x 100

Cco + Cco2

where: Cco is the concentration of CO in the exhaust fumes

Cco2 is the concentration of CO2 in the exhaust fumes while the efficiency of destruction ED is given by the relation:

$$Ed = \frac{Win - Wout}{Win} \times 100$$

Where: Win is the mass of the main part of the waste at the input;

Wout is the mass of the main contaminants at the output.

Combustion efficiency is an indirect parameter that makes it possible to evaluate the effectiveness of a heat treatment process.

Ec values of about 99.9%. Indicate good combustion.

CONTAMINANTS IN COMBUSTION EXHAUST FUMES

Establishing the quantity and identity of contaminants in exhaust fumes is extremely difficult even theoretically as it is not enough to know the composition of the waste (contaminants result from the more or less complete oxidation of the impurities in the combustible) but also the way in which waste is burnt must be analysed.

The chemical composition of waste varies between a wide range of values.

On average, as reference data the following can be assumed:

C 40÷85%

H 2÷5%

O 4÷8%

N 0.5÷1,5%

S organic 0.5÷1%

Inert 5÷10%

Typical contaminants 0÷10%

The main reactions are:

$C + O_2 \text{ -----> } CO_2$

$H_2 + 1/2\ O_2 \text{ -----> } H_2O$

$1/2\ N_2 + 1/2\ O_2 \text{ -----> } NO$

$S + O_2 \text{ -----> } SO_2$

The composition of the products of combustion obviously depends on the equilibrium constants of the reactions concerned: a high temperature favours direct reactions, indirect reactions are generally slow, while stay-times are short.

The combustion temperature and composition of the products of combustion depend on the combustion ratio (air/carbon). As well as CO2, H2O, NO and SO2, also CO, H2, CH4, NH3, HCN, HCL, and hydrocarbons are found in the exhaust fumes.

Waste combustion takes place in three phases:

Distillation of volatile substances;

Combustion of volatile substances;

Combustion of fixed carbon.

During waste combustion the smallest pieces together with the mass of ash tend to form unwanted semi-fused masses, called slag or clinker, because of the close contact between the materials.

The waste ash is formed partly by residual inert minerals contained in the waste itself. This has a relatively low fusion point that can be further reduced by the formation of a eutectic among these products.

WASTE CONTAINING HALOGENATED COMPOUNDS

The most common halogenated ions in waste are generally the chlorides and fluorides that make up halogenated hydrocarbons. The complete combustion of the organic part of waste gives rise to the presence of chloride and fluoride in the exhaust gases.

If there is a sufficiently high hydrogen content, the halogenated substance reacts, giving rise to a halogenated acid, easily removable by means of scrubbers or washing towers.

If hydrogen is not present in sufficient quantity, the chloride and fluoride remain in a molecular form difficult to dissolve in water and so not retainable by wet purification systems. In these cases they should be added to the exhaust gases that make a complete reaction of the compounds possible. For example trichloroethylene is oxidized in the reaction

$$CHClCCl_2 + 2O_2 \text{ ------> } 2CO_2 + HCl + Cl_2$$

If natural gas or another hydrocarbon is added during incineration, all the chlorine reacts resulting in the production of hydrochloric acid in the reaction

$CHCCl_2 + 7/2\ 0_2 + CH_4$ ------> $3CO_2 + 3HCl + H_2O$

In this particular case, as trichloroethylene has a very low calorific power, the support combustible is fundamental for achieving complete oxidation.

WASTE CONTAINING SULPHUR COMPOUNDS

The combustion of every material containing sulphur produces both the oxides of the element. SO_2 and SO_3 are together called Sox. The greater or lesser presence of oxygen does not favour the formation of one of these compounds rather than the other. The quantity of SO_3 produced essentially depends on the conditions in which the reaction takes place, especially the temperature, and ranges from 1.1% to 10% of the total of the SO_2. The process can represent a simplified mechanism for the formation of SO_2 in two phases:

$S + O_2$ ------> SO_2

$2SO_2 + O_2$ ------> $2SO_3$

The small quantity of SO_3 generally produced during combustion is determined by two factors. The first is the speed at which this reaction proceeds and the second is the concentration of SO_3 in the mixture in equilibrium resulting from this reaction. The reaction proceeds very slowly at relatively low temperatures (200 °C, for example), but the speed increases with the temperature.

The existence of gaseous SO_3 in the air is possible only with very low concentrations of water steam---. If this is not the case (as usually happens), the SO_3 and the water combine to form sulphuric acid (H_2SO_4) in the reaction:

$SO_3 + H_2O$ -----> H_2SO_4

WASTE CONTAINING NITROGEN COMPOUNDS

Of the numerous nitrogen oxides existing in nature the ones most responsible for pollution are nitrogen monoxide NO and nitrogen dioxide NO_2.

Together these two oxides are commonly called NO_x. The oxide NO is produced by combustion at high temperatures much more than NO_2. The chemical reactions set off by combustion are:

$N_2 + O_2 \text{ -----> } 2NO$

$2 NO + O_2 \text{ -----> } 2 NO_2$

The first reaction is favored by temperatures above 1200 °C.

The quantity of NO depends on the temperature of combustion (maximum over 1200 °C), by the time the gases are kept at that temperature and by the percentage of free oxygen in the mixture (> 3%). Moreover, when the temperature falls sharply, the reaction is not inverted. The result is that in high-temperature combustion processes, a very high percentage of NO is formed.

The formation of NO_2, on the other hand, is facilitated by the presence of oxygen and depends on the square of the concentration of NO. Moreover, NO_2 forms from NO as a result of photolytic oxidation in the atmosphere.

WASTE CAPACITY

The SLIM LINE plant is designed to take a nominal load of 6.562.500 kcal/h in the combustion chamber. As the PCI is average, the nominal capacity of the thermal treatment plant is 2.100 kcal/kg. The maximum quantity of waste that can be treated in one year is fixed at 25,000 tons/year.

WASTE RECEPTION AND CLASSIFICATION

The reception of waste is the most important factor for the correct functioning of the whole heat treatment process with regard to both management (keeping the materials and plant components in a good state) and emissions. For this purpose the HAFNER program MIX CALC is used, After the insertion of a few initial parameters, this makes it possible to simulate the conditions for optimal combustion and as a result to view the components emitted into the atmosphere.

The extreme variability of waste consigned to the plant makes correct classification necessary and useful. The main parameters are:

- The state of aggregation (liquid, pasty, solid) in order to decide storage and loading methods
- Heat power in order to calculate the quantity of waste to be treated per hour on the basis of the thermal capacity of the kiln
- Dry residue in order to calculate the percentage of slag produced
- Elementary content of S and Cl, in order to optimise the quantity of additives necessary to prevent the emission of acidic exhaust gases
- Elementary content of nitrogen in order to calculate the quantity of urea to use on the catalyser
- Content of microcontaminants in order to calculate the quantity of active carbon to use in the process.

OPERATIONS OF WASTE RECEPTION EVALUATION AND PREPARATION

CONSIGNMENT APPLICATION WITH ANALYSIS AND PLANT COMPATIBILITY EVALUATION FORM

The user makes an application to the company’s commercial office for particular waste. This application must be accompanied by the Waste regulation code

(CER), an analysis of the waste and a form that identifies the product on the basis of the following parameters

density	inflammability temperature
pH	suspended solids
residue at 105°C	any polymerization cond.
residue at 600°C	total chlorine
lower calorific power	total fluorine
vapour tension at 35°C	total nitrogen
organolec. characteristics	total sulphur

At the same time the producer provides a representative sample of his/her own waste.

A decision is made whether to carry out preliminary analyses and tests on this sample to identify the waste and the consequent treatment methods.

Then the head of the commercial office together with the technical director carries out a suitability assessment based on the documentation provided and any analyses made. If the waste is found suitable on the basis of its conformity with the possibilities for which thermal treatment is authorised and its compatibility with the plant itself, it is accepted after a commercial offer has been drawn up and arrangements are made regarding the sending of the load.

If the waste is found to be unsuitable, it is not accepted.

WEIGHING

The loads arriving at the plant are submitted to identification at the entrance and are then weighed. Weighing the vehicle when it arrives and leaves determines the quantity of waste consigned to the plant.

CHECKING OF DOCUMENTS

A preliminary check of authorisation for transport is made and also of authorisation for storage if the producer is authorised to store waste temporarily.

The waste is accepted at the plant only if accompanied by the identification form, a safety form and the results of a recent analysis; the recent analysis makes it possible to immediately check that the characteristics of the waste correspond to the consignment conditions originally agreed to with the signing of the offer.

A check is made to ensure that the waste identification formula is correctly filled out as regards:

Waste regulation code (CER), if necessary

Physical condition of waste

Customer's name– producer's name

Number plates of motor vehicles used for transportation

If the waste regulation code (CER) is not amongst those contained in the offer, the waste is rejected and sent back to the user.

The operation is carried out in the following way:

The truck waits in the dedicated parking area of the waiting and checking zone; a qualified chemist takes a sample of the waste and makes a first visual check to make sure the waste transported corresponds to the declaration made.

The presence of material extraneous to the declaration made by the consigner prejudices its acceptance as stated by the "general contract conditions".

The waste samples taken are kept at the plant for at least a month after the date of sampling in the room situated on the second floor (laboratory – sample conservation).

Assistance of an external laboratory:

The waste sample can be sent to an external laboratory for any further tests.

Vehicle wait during fast analysis:

While the vehicle is made to park in the waiting zone, an analysis is made on the sample taken to check the following parameters:

PH and Chlorine; (only on fats and vegetable oils)

The outcome of the analysis can result in:

refusal to accept;

acceptance of the waste

In the first case the rubbish is not accepted and is sent back to the user. If for exceptional organisational reasons an unsuitable load should remain at the plant for a particularly long time, this load will be kept parked on the edge of the “waiting for checking” zone only for the time strictly necessary to return it to the sender.

MIX CALCULATION PROGRAMME

To guarantee correct functioning of the incineration plant the waste must necessarily follow a well-defined "management system", which as well as the check and acceptance phases described above, includes the ideal "waste mix" calculation for optimising heat treatment as regards both combustion performance and the parameters of chimney emissions. This is because the waste to be incinerated is of quite varied composition and this results in a very high degree of variability of all the parameters that affect combustion. Therefore to guarantee a combustion process that is as constant as possible, it is extremely important to get a good mix of the various kinds of waste. To this end a programme called "MIX-CALC" has been created that, as well as optimising the composition of the "combustibile MIX" for the purpose of combustion performance, simulates the composition of chimney emissions with suitable calculation procedures.

The data for the composition of the waste mix to be heat treated are entered in the MixCalc window. The window is subdivided into two areas: the first makes it possible to enter the refuse the mix is composed of while the second shows us the macrodescriptor values of the current mix.

It is possible to view most of the parameters for the current mix on the screen,

FILLING OUT OF REGISTERS

When the waste has been unloaded, the vehicle is weighed and the transporter is given his/her copies for the load duly filled out with the date, the time and the weight determined on arrival, and stamped and signed for acceptance.

The data on the form are entered in the "movements" list of the AWS programme conceived for the management of waste data, consigners and transporters.

The programme also makes it possible to check the storage situation at any moment as well as the quantities of waste treated.

The insertion of data in the AWS programme makes it possible to automatically print the fully filled out load/unload register for special waste. Lastly, note that the programme described is also active when the Single Waste Declaration Form is being filled out (if necessary).

PLANT FEEDING

STORAGE

Waste is transported to the heat treatment plant using trucks that collect and transport dedicated containers.

The use of containers for waste collection protects the waste from leaching as a result of rain. Consequently the waste humidity content does not undergo significant variations, thus guaranteeing relative constancy of the calorific power of the material.

WEIGHING

The trucks used to transport the waste must pass through a control station whose job is to prevent material being put into the plant that is not compatible with the technology it uses.

LOADING HOPPER

The loading hopper functions as an antichamber for the water-cooled load thruster. It also performs the function of cutting off air from the waste. In the case of an emergency, for example, if there is a fire in the hopper, temperature monitoring inside the hopper protects the system. Too high a temperature causes the rolling shutter to close, after which water is injected into the hopper. When functioning is regular, the guillotine is open.

WATER-COOLING SYSTEM

The water circulating in the loader is cooled by a plate exchanger that is fed with cold water coming from the cooling tower of the shared system parts.

HYDRAULIC STATION

The rolling shutter and thruster are operated with hydraulic cylinders. The hydraulic power unit is fitted with redundant pumps and is started up by the “hydraulic feeder unit”. The rolling shutter is closed using the autonomous pressure tank by activating the safety chain.

START BURNER

An ultrasonic nozzle is installed in the head of the burner to regulate the temperature or for the possible addition of products to improve combustion.

Functioning

A fan sucks combustion air into the burner head and from this into the combustion chamber; the gas reaches the burner at a pressure reduced to the desired value and suitably stabilised. A regulation valve operated by a servo control activated by a temperature or pressure regulator chokes or opens up the gas flow as the situation requires and this causes a smaller or greater influx of combustible from the nozzles of the plate discharger. At the same time the servo control operates the system that regulates the quantity of combustion air.

The following are mounted on the structure of the burner, which is made of painted sheet steel:

, to protect the equipment from the high combustion temperatures.

Ignition transformer

This is V. 220 or 110/8000 direct current with a power of 20 mA and generates the high voltage that is needed to set off the spark to ignite the pilot burner.

Flame sensor

The photocell with its programming panel is mounted. The job of the photocell is to guarantee that the burner functions only when the flame is present. If for any accidental reason there is no flame, after 3 seconds by means of its programming panel the photocell panel puts the burner into flame shutdown.

The photocell's ability to detect ultraviolet rays emitted by all the flames must not be altered by extraneous objects. For this reason its sensor must be kept perfectly clean and nothing should be put between it and the flame that can absorb ultraviolet rays (such as glass). The advantage of this kind of photocell is that other sources of light different from the flame do not interfere and cause false detections.

When a flame shutdown occurs, to resume normal functioning the programmer contained in the unit must be reactivated manually by pressing the appropriate button.

Flame guard

This is mounted on a dedicated sliding pipe and prevents the flame from being stretched. The aim of its special inclination is to create turbulence in the combustion air in order to facilitate its mixing with the gaseous combustible.

Regulation unit

This consists of a servo control, the gas regulation valve for the regulation of combustion air.

The gas regulation valve

This is located on the circuit supplying gas to the burner and is controlled from the PLC.

Air regulation chamber

On the cam contour there is a roller lever that when returned opens or closes the air shutters depending on whether the quantity of combustible burnt is greater or smaller. The PLC controls the air to supply the quantity necessary for good combustion by setting the values for the process.

Gas supply ramp

Interceptor, block, vent and modulation valves are installed on the circuit supplying gas to the burner. Their purpose is to guarantee the volume of gas and they have safety systems to guarantee correct functioning.

THE REMOVAL OF SLAG

The slag, the now inert residue created by burning the treated waste, is cooled and transported by a water-bath conveyor (Redler) and a dry conveyor to the general line conveyor.

STORAGE

There is to be a reinforced concrete storage bunker with a capacity large enough to ensure that the plant is fed for a period of 3/4 days. This makes continuous functioning of the heat treatment plant possible, also when there are problems collecting material (e.g. impassable roads).

Continuous plant functioning is fundamental as energy recovery is planned with the consequent supply of electricity to the grid and of thermal energy to the buildings connected to the heat-transmission system. It is clear that an irregularity in supply would mean a reduction in the quality of the service as well as possible penalties.

TRANSPORT TO THE HEAT TREATMENT PLANT FEEDER

The grate is fed by a bridge crane over the bunker. The grab, which has a capacity of 4 m3, transports the waste to a dosage belt.

THE REMOVAL OF SLAG AND DUST

The slag, the now inert residue created by burning the treated waste, is cooled and transported by a water-bath conveyor (Redler) and collected in dedicated wheeled dumpers.

The dust in the boiler hoppers is transported by a screw conveyor to a dedicated storage silo.

The water head has the double function of cooling the slag and forming a hydraulic guard against air getting into the kiln, with the danger of a loss of the vacuum in the combustion chamber.

DESCRIPTION OF ENERGY RECOVERY WITH THE PRODUCTION OF ELECTRICITY – BOILER

STEAM GENERATOR – BOILER

The heat produced on the grate passes through the recovery boiler and yields its heat to the pipes filled with demineralised water, which is transformed into steam at 41 bar and 420 °C. This steam passes directly into the turbine and by means of special nozzles keeps a 40-bar rotor and another 2.5-bar rotor turning. By means of a reducer, the driving force of the two above-mentioned rotors is alternated to a three-phase synchronous 4-pole alternator with a voltage of 6 kV, a power of 5,000kw, and a frequency of 50 Hz, which produces current. The steam that comes out of the turbine at about 0.12 bar and about 55 degrees must pass from a gaseous state to a liquid state through cooling. This is done by an air condenser which is in a vacuum. The steam passes over bundles of finned pipes, cooled outside by 2 axial fans. At this point the water goes into the hot-water tank and is sent with a dedicated regulation system into the deaerator, where it is deaerated and heated to 105 degrees and then introduced back into the boiler-feed circuit. A turbine by-pass system is installed which automatically intervenes whenever the turbine is not working, sending the steam, after reducing its pressure, straight to the condenser.

BOILER OVERVIEW

The enthalpic content of the exhaust gases can be advantageously recovered through steam production.

The steam can be usefully employed to produce electricity, hot water or superheated water or all three energy vectors at the same time.

To what extent and in what forms the steam is exploited depends on techno-economic evaluations and contextual evaluations regarding the area in which the incinerator is situated.

In the present project a positive evaluation was given to the production of green energy to satisfy the plant's consumption needs, and to transferal to the grid. Moreover, a take-off with an uptake of about 2,000 kg/h of steam is planned for the homes surrounding the ABACO site (teleheating).

Briefly described, the system consists of a recovery boiler using water pipes along the exhaust gas line, by a power station for the production of electricity and an air-condensation system.

RECOVERY BOILER

The recovery of sensible heat takes place using a vertically-set boiler whose features are given below.

Boiler of the type having water pipes for radiation/convection to a boiler tank.

Constructional features of the generator:

General features

The retrieval boiler is a natural circulation boiler with a boiling pressure of 41 bar at 420 C°, with the production of super-heated steam. The surface of exchange by radiation and convection is made of vertical water pipes.

COMPONENTS MAKING UP THE BOILER

The boiler is made up of 3 fundamental components:

a) Evaporator, made up of a radiant chamber and tube bundle

b) Superheater

c) Economizer

Evaporator – The water-steam phase takes place in the evaporator. It consists of a radiant chamber and shell and pipe.

In the radiant chamber heat is transmitted mainly by radiation. In the shell and pipe transmission takes place both by radiation and by convection at the expense of the heat contained in the gases produced by combustion.

Superheater- The steam produced in the evaporator is introduced into a series of pipe coils installed between the the radiant chamber and tube bundle, and becomes superheated at the expense of the heat produced by combustion. Also in this case, heat transmission takes place mainly by non-luminous radiation and partly by convection.

The passing of water and steam through the generator takes place:

- in the evaporator by natural circulation

- in the superheater at the expense of the pression generated in the evaporator.

Natural circulation

As the water heats up, its specific gravity goes down and the hot water tends to settle over the cold water.

It is on this principle that the natural circulation of steam generators is based.

The water continues to heat up until it vaporizes and then circulation increases because the steam, being lighter than water, tends to separate and rise.

With the increase in pressure, the specific gravity of the water and that of the steam become closer and closer until they are equal, at a pressure of 225 atmospheres.

At this pressure natural circulation is no longer possible.

RADIANT CHAMBERS

Construction

The radiant chambers are made of walls of tangent vaporizer pipes.

The generatrices of the contiguous pipes are welded to each other with continuous welding in order to create a completely gas-tight casing.

As all the parts consist of vaporizer tubes, refractory lining is limited to single points and the flue hatches.

Compared to the convection surfaces, the walls of the radiant chambers play a preponderant part in the production of steam and so the pipes of these walls are those subject to the greatest stress.

Consequently, these pipes are subject to greater danger in the case of incorrectly treated water and of dirt on their external part.

DRUM – LEVEL IN THE DRUM

In the upper drum the water phase and the steam phase which, mixed together, arrive from the evaporator pipes, are separated.

The steam occupies the upper part of the drum and the water occupies the lower one.

The feed water is supplied to the boiler through a pipe mounted in parallel with the drum axis and sufficiently perforated to enable the water to mix with the water in the drum.

The separation of the steam phase from the water phase is favoured by two successive separation systems:

The first system is situated on the lower part of the upper drum and consists of two levels of staggered fins through which water is separated from steam by beating.

The second system is situated on the head of the upper drum. This consists of a Vico-Tex pack. This Vico-Tex pack consists of a special very compact multi-layer mesh of stainless steel 100mm thick and functions as a filter, allowing only steam to pass through and retaining any droplets of water contained in it.

The steam leaves the upper drum and, passing over the superheating surfaces, reaches the desired temperature.

In the drum there is also:

- piping for the injection of chemical reagents used to condition the boiler water;

- piping for the taking of samples and for continuous discharge used to take the samples and for the discharge necessary to keep the level of salts in the water within pre-established levels.

The height of the water in the drum is called “level”.

The water level in the drum must be kept within two values called “minimum level” and “maximum level”.

Minimum level:

The water must always be above the minimum level because below it the boiler pipes begin to be incompletely filled.

In this case, the pipes are no longer properly cooled and begin to overheat until they reach the temperature at which they break.

In cases in which the level goes a long way below the minimum level, the pipes can burst.

Maximum level:

The level must be below the maximum to prevent water getting into the superheater.

The water level in the drum is not a perfectly smooth sheet of water, as can be perfectly understood when one thinks of water when it rapidly boils, with bubbles and sprays of water thrown above the level.

If the level is above the maximum, the water can get beyond the separators and into the superheater.

In this case the following can happen:

- lowering of the the temperature of the superheated vapour.
- deposit of salts contained in the water in the superheater and in the turbine blades downstream from the boiler.
- erosion of the turbine blades.

SUPERHEATER

The superheater is composed of two banks of pipe coils, with the ends, through which the steam passes and becomes superheated, welded to the collectors.

A “desuperheater” is fitted between the two banks of the superheater for the regulation of steam temperature.

DESUPERHEATER

The desuperheater of the superheater has the purpose of keeping the temperature of the steam at the planned value in the production scale set.

Below the production scale set the temperature of the superheated steam does not reach the planned maximum value.

The injection-type desuperheater needs the water injected to be salt-free to avoid deposits in the superheater and turbines.

The water used for the desuperheater is taken from the boiler feed water collector upstream from the valve for regulation of the feed water flow.

Automatic steam temperature regulation acts on the water flow regulation valve to keep the temperature of the superheated steam constant.

ECONOMIZER

When starting up, the ideal situation is to feed with water at a temperature as close as possible to that of normal functioning. In this phase, this prevents exhaust gases escaping from the economizer at too low temperatures, which, together with the low temperature of the feed water, could cause corrosion.

During normal functioning, the temperature of the exhaust gases at the bottom of the chimney and load losses on the exhaust gas side between the entry and exit of the economizer must be constantly controlled.

Too high exhaust gas temperatures and abnormal load losses indicate poor thermal transmission resulting from excessive soot deposits on the external pipe surfaces, which are to be resolved by periodic blasts of steam from blowers installed for this purpose.

In any case, too thick a layer of deposits must not be allowed to accumulate as it would be difficult to remove.

It is also necessary to make sure that also the internal pipe surfaces are always clean. Consequently the instructions for water treatment should be carefully followed.

Sometimes deposits can form on the external pipe surfaces whose thickness and consistency is such that it is not possible to remove them with the usual blowing.

If this happens, it is necessary to wash with a jet of water alkalized with sodium carbonate. Generally, this cleans the whole surface of the economizer thoroughly and rapidly.

SUPERHEATER FUNCTIONING

Instructions for protecting the superheater during ignition.

Below we will give a series of precautions of a general nature that it is necesary to follow when a steam generator is brought into service.

During starting up from cold, combustion must be kept at a low regime so that expansion can take place gradually, the refractory materials do not undergo sudden stress and the pipe coils of the superheater do not exceed the maximum temperature allowed for the steel they are made of.

In particular, we would like to emphasise the need to start the steam generators fitted with steam temperature superheaters slowly, as failure to observe this procedure causes serious problems.

The saturated steam produced by the boilers and released into the upper drum is superheated using the heat contained in the exhaust gases when these are still at very high temperatures.

To do this, the saturated steam is made to flow through the superheater, which is a complex of coils against which exhaust gases at high temperatures flow.

While the vaporizer pipes of a correctly designed and operated boiler are always adequately cooled by water or by the water-steam mixture contained in them, the superheater contains only steam.

Therefore it is necessary to create an equilibrium between the steam flow which, flowing across the coils becomes superheated and at the same time cools the coils, and the flow of exhaust gases at high temperature that heat them.

In other words, it is necessary that the flow and temperature of the exhaust gases should be proportional to the quantities of steam produced by the boilers.

It is therefore necessary to avoid rapidly increasing the quantity of combustible which, especially during the start-up phase, would not be followed by proportional increases in the production of steam. This would in fact create that disproportion between the gases that flow against the superheater and the steam that flows across the superheater that would have the consequence of taking the temperature of the superheater steel over the permitted limits.

In order to allow the steam to flow, a valve for discharging steam into the atmosphere is always fitted before installation of the boiler interceptor valve.

BOILER CLEANING SYSTEM

To get maximum production with a good output from a boiler, it is necessary to keep the heat exchange surfaces as clean as possible.

The solid residue created by combustion and suspended in the exhaust gases separates itself from them along the whole boiler circuit, adheres to the thermal exchange surfaces, hindering thermal exchange, obstructs the passage of the gases and consequently makes necessary an increase of draught.

With powerful blows the cleaning hammers detach the dry deposits of ash and soot from the pipes, restoring operational conditions to normal, The ash removed is collected in the hoppers placed under the shell and tube, the superheater and the economizer.

The frequency with which the hammers are used depends on the quality of the combustible used, the characteristics of the ash, combustion conditions and the adherence and distribution of the ash on the various surfaces.

Therefore it is not possible to give precise instructions about the number of daily hammerings.

For the reasons given above, we consider it advisable to define the cleaning programme in accordance with the particular conditions, and to base it essentially on the data obtained from systematic checking of the gas and steam temperatures and the values for load losses between the various points of the exhaust gas route running between the two successive draught cycles.

The system consists of:

1 rotating hammer unit for the superheater

2 rotating hammer unit for the economizer banks

BOILER FEED WATER TREATMENT SYSTEM

A complete system has been planned for administering the doses of additives to the boiler feed water. In particular, there are two dosing pumps installed for injection of the additives, at high pressure into the drum and at low pressure after the deaerator.

ELECTRICITY PRODUCTION SECTION

The thermal cycle for the management of the superheated steam produced in the boiler is illustrated.

The plant section concerned consists of the following main pieces of equipment:

turbo-unit;

turbine by-pass;

air condenser;

hot well;

condensate extraction pumps;

deaerator;

boiler feed pumps;

boiler feed water demineralization system;

TURBO – UNIT

A TWIN AFA turbo-unit (consisting of steam turbine, generator and electrical system) is installed, with a continuous power of 1,6 MWh measured at the alternator terminals.

The condensation steam turbine with plug bleed-off for auxiliary uses is equipped with a control system for regulating the following functions:

turbo-unit preheating;

variator for slow rotation for stopping and the first start-up;

turbine running in parallel with the external network;

turbine running in isolation;

The conditions for sending steam into the turbine, dependant on the thermodynamics of the cycle, will generally be as follows:

- P = 41 bar

- T □ 420 °C

The steam sent into the turbine must meet the following requirements:

ALTERNATOR

The synchronous generator is an alternating current machine, without rings or brushes. The machine is cooled by the flow of air through it. The excitation system is mounted on the side opposite the coupling The system is composed of two parts : the excitation armature that generates a triple-phase current coupled to the triple-phase rectifier bridge supplies the excitation current to the generator's rotary field. The excitation armature and the triple-phase rectifier bridge are mounted on the rotor shaft of the synchronous generator and are electrically interconnected to the rotary field of the machine. The excitation inductor is powered by continuous current regulation. The alternator type is LEROY SOMER LSA 56 BM64P, power 5.0KW – 4,300 KVA.

TURBINE BY-PASS

The turbine by-pass system intervenes automatically, discharging high pressure steam directly to the condenser every time the turbine is not in use.

The system is composed of:

a station for the reduction and desuperheating of the steam normally destined for the turbine that is to be sent to the condenser. The pressure regulation valve is equipped with instruments that measure the steam flow, pressure and temperature. The desuperheating water is regulated by means of a regulation valve that is fed by the pumps.

CONDENSER AND VACUUM UNIT

The steam leaving the second phase of the turbine at 0.12 bar must be formed from the gaseous state to the liquid state by means of the air condenser.

The steam passes across lamellar packs that are cooled on the outside by two axial fans. The warer retrieved at 50 °C is heated by the deaerator and returned to the feed cycle.

The condenser is designed to condense the steam produced at the nominal load when the turbine is in by-pass status with an ambient temperature of 40 °C.

CONFIGURATION IN AIR CONDENSER

In the air condenser the steam is condensed with the use of tubular bundles of finned pipe using ambient air as a cooling element.

This condenser is in the configuration K/D, a combination of tubular bundles using direct contact, type K (with the steam flowing in the tubular bundles from above downwards in the same direction as the condensation), and tubular bundles using dephlegmation, type D (with the steam flowing in the tubular bundles from the bottom upwards and therefore in the opposite direction to that of the condensation that forms in them

Each tubular bundle has two rows of finned pipes, with one placed over the other, with a different spacing of finning between the pipes in the upper row (in contact with cold air) and the pipes in the lower row (in contact wih the hot air heated in passing through the lower row).

The cooling air is moved by means of manual-type axial fans (with regulation of the blade angles with the fan off) designed to produce forced air.

Tubular bundles

The tubular bundles, supported on a roof-type hot-dip galzanized steel-frame structure have hot-dip galvanized carbon-steel finned pipes.

The heads are welded to guarantee perfect sealing in the presence of a vacuum.

Fan units

The design features two manual axial fans with extruded aluminium blades installed on a suitable supporting structure and designed to produce forced air (the angle of the blades can be manually adjusted when the fan is off).

The electric motors are coupled to the axial fans using reducers with trapezoidal belt reducers (with banded belts, profile SPB. The design of the electric motor is to be V6, that is, with wall feet and with the shaft directed upwards).

Pipes

The air condenser is connected to the steam turbine discharge flange; the latter finishes at the steam distribution pipe located on top of the air condenser and directly welded to the type-K tubular bundles.

The tubular bundles are connected by an adequate number of shafts to the condensate collection pipes (dephlegmator pipes) situated under the bundles.

The dephlegmator pipes have the following functions:

To carry the surplus uncondensed steam in the primary direct-condensation section to the secondary dephlegmation section

To collect condensate from all the tubular bundles and send it to the collection tank (hot well).

The condensate collected in the dephlegmator pipes flows into the collection tank by gravity and is then recycled into the system by means of two single-phase centrifugal pumps. Welding is used in the construction of the whole system to guarantee perfect sealing in the presence of a vacuum.

ACCESSORY COMPONENTS OF THE AIR CONDENSER

Condensate extraction pumps

Two single-phase centrifugal pumps are installed to send the condensate from the hot well to the deaerator. Only one of the pumps is kept working while the second pump is kept 100% in reserve (stand-by condition).

The control system that selects, operates and stops the above-mentioned pumps, as well as the control of the minimum condensate flow is part of the system's PLC. In particular, whatever the operating conditions, a minimum condensate flow of about 10 m3/h must be guaranteed.

This is always guaranteed, even when the volume of condensate is very low (low steam charging), by the opening of the minimum recycle valve.

The minimum recycle valve works in "split range" with the valve for drainage to the deaerator.

Condensate collection tanks

The condensate that forms inside the tubular bundles of which the air condenser consists flows into the collection tank by gravity. Control of the level of condensate inside the tank is part of the system's PLC and makes it possible to guarantee a constant condensate level in conditions of normal functioning.

This control is performed by means of a suitably calibrated differential pressure transmitter that is able to operate the regulation valves in "split range".

There are also supplementary controls that, as well as sending the necessary alarm signals to the system's PLC, perform the following functions:

If the level is extremely low, they stop the extraction pump working at that moment to prevent dry functioning (cavitation).

If the level is extremely high, they block the whole cycle (block of steam turbine and by-pass line) to prevent flooding of the steam adduction pipe and the steam turbine itself.

Steam ejectors

There will be a suitable steam ejector vacuum unit of a capacity great enough to guarantee the extraction of the air and uncondensable substances inside the part of the system in a vacuum (air condenser, steam adduction pipe, etc.) both during start-up and during normal running.

For starting up of the system there will be a single-phase ejector complete with silencer able to pre-evacuate a total volume of about 100 m3 from atmospheric pressure to the absolute pressure of 150mbar (a) in about 30 minutes, with the turbine seals closed by steam.

, for normal running there will be two two-phase steam ejectors, complete with interphase and final surface condenser (sustainment ejectors). One of the two units is kept working while the other is kept in reserve (stand-by condition).

The ejectors for normal running (2 x 100%) will work with both phases active in the suction pressure field between 70 and 500 mbar (a).

For pressures in the condenser of over 230 mbar (a), the motor steam line in phase 1 must be closed to avoid malfunctioning of phase 2 which in the meantime continues to function. If the pressure in the condenser should fall below 210 mbar (a) (because of a reduction of the steam charge and/or a lowering of the ambient air temperature), the motor steam line in phase 1 must be open for both of the phases to function.

If the vacuum unit operating is not working properly (e.g. problems on one or more valves, difficulty in obtaining the desired open and/or closed position), it is possible to activate the stand-by unit by opening and/or closing the appropriate valves.

AIR CONDENSER FUNCTIONING

The exhaust steam discharged by the steam turbine is sent through the steam adduction and steam adduction pipe to the primary air condenser section (section K) where it begins to condense.

In particular, in the primary section (section K) the steam flows downwards inside the finned pipes and most of it condenses in them. The condensation formed flows downwards parallel to the steam that has still to condense and collects in the dephlgmator pipes situated under the pipe bundles. The uncondensed steam in the primary section (K), the excess steam, is carried through the above-mentioned pipes to the secondary dephlegmator section (D). In this section, the steam flows upwards inside the finned pipes until condensation is completed. The condensation that forms flows downwards, in the opposite direction to the steam, collects in the dephlegmator pipes and then by gravity flows into the condensation discharge pipes and drains into the collection tank.

In the air condensers the heat from condensation is transferred to the cooling air, which is given turbulence by suitable axial fans. The fans are selected to ensure the project conditions (exhaust steam volume/ambient air temperature) have the degree of vacuum desired (counter-pressure on the turbine discharge flange).

Double-pole electric motors (4/6 poles) will power the axial fans. When the steam load is small and/or the ambient air temperature is very low (night and/or winter functioning), the condenser would be oversized. In this case, to keep counter-pressure on the turbine discharge flange constant it is necessary to reduce the volume of air in motion by reducing the speed of the fans.

When the steam load is very small and the cooling-air temperature very cold (reduced load winter running), it is necessary to stop all the fans. This is done by acting on the speed of the single fans with the PLC.

AIR CONDENSER CONTROL

The air condenser control system is managed by the following signals (sent by the plant instrumentation):

Exhaust steam pressure after the turbine discharge output, measured on the steam adduction pipe (PT).

Exhaust steam pressure after the by-pass input, measured on the steam adduction pipe (PT).

Condensate temperature taken in each single dephlegmator pipe

Ambient air temperature (cooling air, TE).

The condenser control system acts on the electric motors that power the axial fans by selecting their rotation speed. All the other plant components such as pumps, ejectors, tank, etc. are fitted with local instrumentation (thermometers/manometers/level gauges) and the transmitters necessary for their monitoring and remote control.

HOT-WATER TANK

The hot well or condensate collection tank provides a high level of storage for the safe and regular operation of the condensate extraction pumps.

The volume of this piece of equipment is 10 m3. This allows regular plant functioning in the most exacting operating conditions.

The recipient is also fitted with:

hydraulic guard;

drainers;

breathers;

various connections;

manhole;

level gauge with transmitter and high – low – very low alarms;

level regulator connected to the extraction pumps

temperature indicator with transmitter and alarm.

DEAERATOR

This piece of equipment is composed of :

A. Vertical drum deaerator complete with:

- air valve
- vacuum-break valve;

- condensate feed line with interceptor valves and a backflow shut-off valve;

- reintegrative demineralized water line fitted with interceptor valves and a backflow check valve fitted with interceptor valves and a backflow check valve;

- bled-off steam feed line fitted with a backflow check and interceptor valves;

- spray nozzles in stainless steel

- perforated stainless steel contact plates.

B. Horizontal drum storage tank fitted with:

- safety valve for excess pressure;

- dregs drainage valve;

- too-full, low and very low level gauge

- sight glass;

- manhole;

- pipe connecting to the boiler feed pumps, complete with interceptor valves downstream from the tank and upstream from the pumps;

- too-full level gauge with relative discharge valve.

BOILER FEED PUMPS

2 pumps keep the boiler fed. These are operated by an electric motor and powered by an electric motor powered by the plant generator.

The pumps, one of which operates while the other is on stand-by are made of stainless steel and are fitted with:

- suction filter
- differential manometer
- control valves
- lubricated bearings
- gland stuffing box with water cooling

The pumps are equipped with an automatic recycling valve calibrated to the pump curve.

DEMINERALIZER

The plant is made to function automatically and to guarantee the level of boiler feed water purity for correct functioning of the steam cycle.

The water-demineralizing system operates on two hydraulically-connected parallel lines.

Each unit consists of a cationic unit, an anionic unit and a decarbonization tower shared by both lines.

The plant carries out an ionic exchange on all the salts in the solution, removing them almost completely.

The control valves are aligned in front of their respective columns and protected by a casing with progressive cationic – anionic numbering.

The columns are fed by the water that enters the system from the left, after being filtered at 90 μ (if required) with the aim of preventing slag, hemp and coarse dirt from reaching the water meters.

Finally, regeneration of the system uses the "mixed stream" IFIMATIC technique.

This solution allows not only countercurrent regeneration with regenerative levels close to the theoretical but also backwashes without extracting the resin and, in addition, the possibility of varying the volumes of the resin itself.

The regenerator is sent from below, drained with an intermediate pump, picked up by the auxiliary pumps and sent up to be drained by an intermediate pump above the first.

The electrical components consist of:

A microprocessor-type electronic panel for control of the first line for making operation on the two lines complete, including the pumps for collecting water from the decarbonizer and the operating pump.

The interchangeable hydraulic and electrical interconnections spread right across the whole width of the back of the columns.

To ensure good conservation, the system has light detachable side covering and panels. The room has a axial fan that allows sufficient change of air to keep it dry, without steam and at temperatures ranging from +5 to +35 C°.

On the board a display shows the status of the plant and the value for conductivity or possible alarms such as:

Conductivity alarm

Pump block alarm

PLC communication alarm. This signal is sent to the plant control room.

Conductivity control:

Conductivity is measured after each regeneration and during the whole cycle. This reading is important for keeping the resins well-conserved.

Removing water when this conductivity exceeds the set limits results in progressive damage to the resins to the point where in a very short time they become inactive.

SYSTEM FOR CLEANING FUMES - GENERAL DESCRIPTION

The analysis of a system for cleaning the gas fumes of a waste incineration plant is based on the following key parameters:

guaranteed performance;

reliability of the system;

investment cost;

operating cost.

The aim of cleaning is to reduce emissions of inorganic and organic pollutants that are produced by the burning of waste.

In this phase pollutants rise up and are carried away in the form of suspended solids and vapours.

During the cooling of exhaust gases in the thermal recovery phase, the temperature of the gases begins to fall and as a result sublimates and particulates form with reactions that depend also on the oxygen, chlorine etc. content in the exhaust gases.

When the temperature falls, there is a selective release of the various substances depending on the sublimation or condensation temperature of each substance.

It must also be kept in mind that the most dangerous heavy metals (mercury, cadmium, arsenic, etc.) generally appear in submicronic form so are difficult to hold back and that, moreover, mercury in exhaust fumes is chiefly in vapour form, with a condensation temperature ranging from 300 to 100 °C.

In view of this, it can therefore be understood that an effective cleaning system must be based contemporaneously both on a chemical effect and on a physical effect, in order to broaden as far as possible the spectrum of interactions that can be used on the numerous families of pollutants, each of which possesses its own special characteristics, both chemical and physical.

The cleaning systems on the market today are chiefly the following:

dry:

chemical effect: reaction with hydrated lime powder or sodium bicarbonate and other additives;

physical effect: separation with sleeve filter;

humid:

chemical effect: reaction with water added to soda;

semi-dry:

chemical effect: reaction with milk of lime / lime water;

physical effect: separation with sleeve filter or with electrofilter

SPECIFICATIONS OF THE SYSTEM ADOPTED

The exhaust gas cleaning system as designed and adjusted is able to guarantee compliance with the EU limits and regulations

The system adopted is of the dry type and its features are as follows:

The system consists of an absorption reactor, a sleeve filter and a catalyser.

The reactor makes the chemical reaction possible through the use of sodium bicarbonate and active carbon.

The reaction with bicarbonate has the aim of combining the sodium ions with the chlorine, the fluorine and the sulphurous and sulphuric groups. To be able to obtain acceptable results, it is necessary to work with extra sodium bicarbonate in the order of about 1-2 times the stoichiometric ratio. As a consequence, this produces a high load of particulate to repress and a considerable consumption of bicarbonate. Before the sodium bicarbonate is injected into the exhaust gases, it is ground to particles 20 microns in size with a dedicated mill situated under the storage silos. The contact time of the sodium bicarbonate with the gases is at least 2 seconds. The temperature of the gases is at least 180° C to obtain optimal neutralisation. Adding active carbon makes it possible to repress heavy metals, dioxins and furans.

REACTION KINETICS

Acidic phase reactions

The reaction mechanism that occurs between the sodium bicarbonate and the acids in the exhaust gases is characterised by the decomposition of the sodium bicarbonate at a temperature above 130°C into sodium carbonate, water and carbon dioxide. The sodium carbonate thus formed is porous and therefore very reactive. This is the reason for the speed of the reaction in which acidity is removed.

The efficiency of the neutralisation of hydrochloric acid in relation to the stoichiometric ratio of 1.5 is 99%.

The HCL neutralisation reaction:

2HCL + Na2CO3-------2NaCl + CO2 + H2O

causes the formation of sodium chloride with the release of water and carbon dioxide. This results in a quantity by weight of solid residue about 35% less than that of the reactants.

The SO2 neutralisation reaction:

$SO_2 + Na_2CO_3 + 1/2\ O_2 \text{-----} Na_2SO_4 + CO_2$

causes the formation of sodium sulphate with the release of carbon dioxide. In this case the reduction in weight of solid residue in relation to the reactants is about 16%.

REACTOR

The exhaust gases coming from the boiler at 230 °C enter the vertical reactor drum and remain for about 2 seconds so they have sufficient time for reaction with the sodium bicarbonate and the active carbon. The mixture of sodium bicarbonate ground to 20mic and active carbon is blown through a dedicated pipe125mm in diameter.

In the drum there is a pneumatic regulation valve 700mm in diameter whose purpose is to intervene if there is a “high temperature” alarm in the input of the sleeve filter by opening the inflow of tertiary air to prevent breakage of the filter sleeves.

SLEEVE FILTER AND FANS

The purification efficiency of the sleeve filter is very high. The teflon sleeves (a filtering diaphragm of high specific gravity) ensure very high filtration capacity and make it possible to:

adjust the size of the sleeves for higher filtration speeds,

restrict the size of the filter and, consequently, to facilitate maintenance operations

reduce load losses

treat the exhaust gases at high temperatures up to 250°C

The reaction in which the pollutants are removed is completed in the sleeve filter, located downstream from the reactor, using the layer of sodium bicarbonate and active carbon that forms on the outside of the supporting structure of the filtering diaphragm.

The tubular sleeves of the filter are cleaned with counter-flow cleansing using compressed air at 6, 7 ate. This operation takes place line by line and with adjustable frequency.

Falling salts, dust and surplus reactant collect in the hopper under the filter and are removed by two screw conveyors with rotocells. A propulsor transports these residues pneumatically into the silo for the storage of residues produced in the removal of exhaust gases

CHIMNEY AND CATALYSER WITH UREA INJECTION

Chimney

The chimney is 45m high, 1600mm in diameter and is made of stainless steel insulated with an aluminium lining.

The instruments for analysis and the system for cooling the exhaust gases picked up by the sensor fitted to the chimney are housed in an insulated box on a dedicated platform at an altitude of about 13m. This can be accessed by means of a system of walkways and steps.

Continuous analysis is made of some typical parameters, in particular:

CO, CO2, NOX, O2, HCL, SO2, TOC, dust,

temperature, pressure, humidity and flow volume

The signals are transmitted to the PLC in the control and command room where they are processed, readjusted for 11% of dry oxygen content, displayed on the monitor and printed daily.

The chimney is also fitted with flanges for sample-taking by the control instruments and for the taking of samples to determine parameters not measured continuously, such as dioxins, furans, metals, etc.

Catalyzer

The catalyser has the function of removing NOXes, dioxins and furans after dust particle filtration in the sleeve filter.

The catalytic reaction takes place with the injection of urea mixed with water. Its working range is between 160 and 220 °C.

SILO FOR ACTIVE CARBON BICARBONATE AND FILTER RESIDUES

SODIUM BICARBONATE SILO

The sodium bicarbonate silo can store enough of the additive to allow autonomous operation of at least 10 days. Consumption is controlled by means of a gauge with reference to the percentage and KG of material stored.

An alarm signals the minimum level for restocking of the product, which is supplied by tanker lorry and pneumatically pumped into the silo.

The silo is fitted with a sleeve filtration system and a mechanical safety valve to prevent excessive pressure.

MILL FOR SODIUM BICARBONATE AND ACTIVE CARBON

The mill has the function of pulverizing the bicarbonate and active carbon to 20 microns. This considerably increases the absorption surface and favours chemical reaction with the acid particles.

In addition the consumption of sodium bicarbonate is considerably reduced.

The product is transported by a screw conveyor to an intermediate hopper where a gauge regulates the flow. A dosing screw conveyor transports the sodium bicarbonate into a selector that performs the next two functions:

it grinds the material in order to produce a specific grain size,

it carries out selection on the ground material to obtain the required granulometric curve.

The micronized product is sucked up by a fan and blown into the reactor.

The whole system is regulated by means of the PLC in the control and command room.

The mill is insulated with sound-absorbent pannels.

ACTIVE CARBON SILO

The active carbon silo allows autonomous storage for at least 1 month. Consumption is controlled by means of a gauge with reference to the percentage of material stored.

An alarm signals the minimum level for restocking of the product, which is delivered to the plant by tanker lorry and pneumatically pumped into the silo.

A screw conveyor transports the carbon from the silo to the bicarbonate loading hopper upstream from the mill.

The silo is fitted with a sleeve filtration system and a mechanical safety valve to prevent excessive pressure.

REMOVAL

The silo is used to contain the solid residues that come from the sleeve filter. It has an autonomous storage capacity of about 10 days. The solid residues are dangerous waste. Estimated production of these residues when the plant is operating at full capacity is about 10-12cm/day. The silo volume is 120 cm.

It should be emptied weekly and when necessary. It is equipped with a level percentage control system and maximum level alarm.

Automatic loading is carried out:

by means of a pneumatic propulsor located under the sleeve filter,

an alarm signals that emptying by means of direct discharge should be effected, the residue is discharged by means of a screw conveyor into the special transport vehicle,

The silo is fitted with a sleeve and safety valve.

PLANT REGULATION AND CONTROL SYSTEMS

AUTOMATION PHILOSOPHY

The control system is calibrated to meet the real requirements of the plant, combining operational simplicity with a suitable level of sophistication.

In particular, for the command, control and supervision of the plant a PLC system is installed with FIX Intellution supervision that meets the following requirements: conformity with European standards;

compatibility with other systems and commonly-used programs;

ease of management;

speed of intervention;

flexibility;

modularity;

possibility for subsequent capacity increase;

redundancy of components and main functions;

possibility of remote access

The objectives of the automation system are in particular:

acquisition of the plant's operational parameters;

processing of these parameters and their presentation to the operator;

performance of a series of automatic actions to keep the plant in the best operational conditions in the different operational regimes;

prompt execution of a series of automatic actions when anomalous conditions arise in the process, in order to limit the extent and duration of malfunction and to avoid damage to the plant;

easy performance by the operator of actions on the plant.

The system acquires all the analogical and digital signals necessary to carry out the above.

The plant functions in a continuously automatic way. Normal operation of the plant and normal and abnormal changes of state are controlled by making available to the operator the state of the components, the state and parameters for operation of the closed-loop and open-loop controls and the evolution of the command sequences.

In particular prompt automatic intervention is provided for every time the plant or its components are in a condition in which they risk being damaged or causing damage and every time the plant reaches a speed incompatible with the operator's reaction times (protection function).

The emergency actions associated with the protection of the components or the plant always have priority over manual or automatic commands.

The priority of manual or automatic commands is determined by the operator with the use of the A/M (Automatic/Manual) selection commands.

The software is based on the following documents that form part of the operating manual:

P&I, which constitutes the basis for control;

IED, which shows the diagrams of the main control loops;

Definition of the PLC configuration;

Users of the control system;

Safety chains

The control system has operator stations, keyboards and monitors on which a synoptic board of the plant will be displayed with the instantaneous operational conditions, the anomalies, the alarms, state signalling and everything that contributes to the optimal management of the plant.

All the main manoeuvre and control components are installed in the control room building.

The control panels are positioned in such a way as to make it easy for the operators to intervene. The size of the panels is designed to allow for the need to insert extra input and output signals.

The hardware consists of:

4 monitors with 2 stations of computers for management of the network.

ARCHITECTURE OF AUTOMATION SYSTEM

The plant is to have a PLC configured on two levels:

Upper level dedicated to control: This has the functions of supervision and command of the whole plant from the command and control room.

The main objectives to be pursued by the upper level dedicated to control are in particular:

- to send the operator all the information about the process including the data for the quantities of solid residues produced in the different plant sections, the data for the consumption of additives/reactants and in general for all the system functions;

- to display process designs with the effective parameters;

- to display the status of motors, actuators and interlocks;

- to display the status of the position of valves and shutters (output signal from controllers);

- list of main alarms, protections and locks;

- data for changes in the status of the interlock system;

- to display on the screen records of process data in the form of diagrams or trends for both instantaneous performance and as an hourly or daily average;

- to print periodical reports.

Lower level dedicated to the process: This has the control functions and includes all the equipment dedicated to automation and control of the process.

The main objectives to be pursued by the lower level dedicated to the process are in particular:

- storage and automatic processing of the data transmitted by the primary system components;
- automatic process control
- controls of sequences where necessary;
- concentration of data for the control level
- generation of threshold values for alarm and control requirements;
- diagnosis of system and signalling breakdowns;
- list of alarms, protections and secondary locks.

Functions and operating modes are designed to meet process requirements.

Plant functioning is supervised by the command and control room.

All the members and components involved in the management of plant states are controlled by the central or local control stations.

The PLC consists of 2 peripheral control stations connected together by a local network.

Locally executed automations are installed in panels placed near the machines. In this case the interface with the command and control room is limited to the signalling of state and, where required, to the management of stop and start commands.

The PLC also includes the necessary interconnections with the other systems (bridge crane for moving solids, storage control, transformation cabin, compressed air, etc.).

Local operating devices are indispensable for starting pumps, compressors, conveyors, etc.

Information and selected operating commands are sent on by the PLC to the subordinate management level. The instruments and equipment used are reliable and already used in industrial firms such as Endres Hauser, Siemens, ABB, etc. They meet process requirements and their characteristics conform with the specific standard requirements and norms.

If an operational terminal breaks down, the plant is controlled by another operational back-up terminal.

FUNCTIONS OF THE AUTOMATION SYSTEM

There will be 4 main functions for the automation system:

- supervision and recording;
- regulation
- protections
- alarms and blocks.

Supervision and recording functions

The supervision functions for the whole plant are integrated into the PLC system and provide the operator with all the information necessary to keep the plant under control.

The system receives all the signals necessary to know the status, measurements and alarms of the locally controlled functions.

A wall synoptic panel that shows the led system for each machine is integrated into the video pages.

SUPERVISION FUNCTIONS CONSIST IN PARTICULAR OF:

display of the measured or calculated process parameters, of the state of the equipment and in general of the plant by means of analogical trends and bar and synoptical diagrams;

recording of measured or calculated process data;

reporting and recording of alarms.

IN PARTICULAR THE FOLLOWING PARAMETERS ARE RECORDED:

flow/level of waste fed;

flows of combustion air fed;

temperatures in the combustion chamber and along the exhaust gas stream;

combustion chamber vacuum and load losses in the main pieces of equipment;

oxygen content at the output from the post-combustion section;

steam flow, pressure and temperature;

temperatures of exhaust fumes at the entrances to the super heater and economizer;

temperature, flow and pressure of the exhaust gases at the entrance to the filters;

values at the chimney of all the regulatory parameters specified in EU: CO, CO2, dust, TOC, HCl, SO2, NOx, O2% vol, T exhaust gases, exhaust gas flow;

consumptioni/additive levels/reactants.

To allow direct supervision of the combustion phase by the operators, there are to be a number of cooled telescreens.

REGULATION FUNCTION

If for process needs a physical variable must be kept within defined values, its control value will be equipped with closed-loop regulation.

If a number of parameters contribute to keeping a physical size within defined values, the total regulation loop will consist of a number of regulators in cascade.

The function of regulation is performed by local modules and managed by the central PLC unit with particular reference to:

- management of operator command signals and of signals regarding the state of the controlled component;
- acquisition and validation of of the signals necessary for control;
- closed-loop regulation of process physical quantities;
- detection and signalling of alarm states.

Plant functioning is controlled with automatic regulation systems, in particular:

- temperature situation in the combustion chamber;

- temperature at the end of the post-combustion phase;
- oxygen content in the exhaust fumes leaving the post-combustion section;
- vacuum in the combustion chamber;
- level in boiler drum
- titration of the superheated steam produced in the boiler with particular reference to its temperature;
- temperature and vacuum in the condenser;
- input and output temperatures of cooling water in the condenser;
- level in the hot well;
- level and operational pressure of deaerator
- temperature of exhaust gases at the entrance of the sleeve filter;
- load loss of sleeve filter.

Good functioning of the equipment on the exhaust gas treatment line will be checked by continuous analysers installed on the chimney.

In particular, as prescribed by the regulations currently in force, the following must be continuously measured:

T, P and exhaust gas flow, their H_2O, O_2 and CO_2 content;

total dust;

HCl, SO_2;

TOC;

CO;

NOX.

A SIEMENS and SICK unit is installed for the continuous control of the above parameters.

PROTECTION FUNCTIONS

There will be 3 classes of protection with the following objectives:

System protections: their aim is to make it possible to maintain optimal functioning conditions of the system's main pieces of equipment, ensuring in each case that they observe the limits for conditions set for the project.

These protection functions must also protect the individual pieces of equipment from any damage that might arise from the other pieces of equipment present.

Equipment protections: these have the same aim as the system protections; unlike the latter, they must protect the equipment from damage arising from their own functioning or from the functioning of their parts.

Component protections: their aim is to make it possible to maintain the project conditions of the individual component, with particular reference to those components whose condition has an immediate impact on the working of the equipment or system. Component protections are generally made by the component's supplier.

ALARM AND BLOCK FUNCTIONS

The main aims of these functions are:

- to prevent the intervention of protections;
- to signal to the operator that protection events have occurred;
- to signal to the operator configuration variations that have occurred automatically;
- to signal to the operator various anomalies of state;
- to signal to the operator that a command has not been implemented;
- to signal to the operator that the automation system is unable to keep one of the controlled quantities at the value pre-set in the set-point.

All the first-level alarms are both sound and visual signals with indication of the relevant graphic page and are shown in the synoptic panel. Second-level alarms are shown visually on the video pages.

The general blocks are reduced to a a minimum in order to protect the system at all times and at the same time to reduce the likelihood of total standstills.

As well as the lack of motive power, the main blocks will be the following:

- high pressure in the boiler;
- very low level in the boiler drum;
- high temperature at the sleeve filter entrance;
- low water flow to the cooling circuits;
- very low deaerator level

All the safety system is integrated to deal with the consequences of any exceptional external events and functioning anomalies, with a manual block on the system that will promptly stop combustion and quickly result in extinction.

INSTRUMENTATION IN THE FIELD

The instrumentation to be installed in the field is guaranteed and has the following requisites:

the presence of redundant instrumentation where necessary to allow:

- prompt control of the process even when part of the instrumentation is out of order;
- crossed checks to check the process is being operated well and for possible defects in the calibration of any gauges;
- compatibility of all the instrumentation installed on the system;
- use of instruments employed for a limited number of activities to prevent the defective functioning of a single instrument from making a number of measurements unreliable;
- use of instruments for which spare parts can easily be found and possibly shared by a number of gauges;
- the local presence of staff able to carry out periodical and extraordinary maintenance of the instruments with rapid intervention times. As required by regulations, continuous measurement systems must be checked and adjusted at regular intervals and calibrated at least annually.

The instrumentation is suitable for the place of installation and equipped with the degrees of protection specified by the project standards and by the legal

regulations that apply in this sector.

MANAGEMENT OF INTERNAL EMERGENCIES

AIM OF EMERGENCY PLAN

The main aim of the present Emergency Plan is to preordain a series of actions to be carried out and to define the tasks of the Rapid Intervention Staff and in general of the people at the plant in order to deal with the situation of danger that has arisen with the maximum effect and to avoid consequences that might constitute serious risks for people and affect external environments, from the point of view of both safety and environmental impact.

By emergency is meant every condition of insecurity deriving from accidents or failures that directly or indirectly represents danger for people, the environment or the plant.

FIRE-FIGHTING TEAM

Inside the firm the Fire-Fighting Team is the unit given the task of eliminating or at least limiting the risk of fire. To be able to safely carry out these interventions it is of fundamental importance that its members undergo theoretical-practical training according to their level of responsibility and knowledge of all the information about risks at the plant and about the equipment available.

The tasks of the Fire-Fighting Team also include the prevention of fires by means of periodial checks of all the systems used in emergencies

Competences

Head:

This person is the first to act during an emergency, coordinating the team's work and informing external agencies who might intervene of the situation and risks at the firm. His/her tasks include:

checking that the team is complete (accidents, illness, shifts, retirement)

checking the team's training level

planning periodical checks of the plant's facilities during the periodical safety meetings

planning training tests during the periodical safety meetings

Team Member:

This person intervenes during an emergency exclusively on the orders of the Head.

FIRST-AID TEAM

The First-Aid Team is given the task of intervening if anyone is hurt inside the firm areas. Its job is confined to providing first aid and possibly to getting away those hurt, while making sure to intervene with the utmost caution.

Competences

Head:

This person is the first to act during an emergency, coordinating the team's work and where necessary asking for the intervention of external agencies. His/her tasks also include:

- checking that the team is complete
- checking the team's training level
- periodical checks of medical appliances at the firm

- planning training tests during the periodical safety meetings
- checking that the list of doctors to whom staff can be referred is complete.

Team member:

- This person intervenes during an emergency exclusively on the orders of the

  Head

SOUND ALARM SYSTEM

The plant has alarm sirens whose sound has the following meaning:

SHORT HOOT:

Start or end of work shift, end of an emergency

PROLONGED HOOT:

State of alert signalling there is an emergency, make work station safe and wait for instructions.

PROLONGED INTERMITTENT HOOT:

Total evacuation of the areas.

STAFF TRAINING

The firm believes that planning of the activities of informing, training and drilling lies at the basis of emergency resolution as it is of fundamental importance to supply every worker with the tools necessary to be able to save him/herself by him/herself and avoid involuntarily causing damage to other people or to the firm.

Information intended for all the employees will consist of a booklet dealing with the following points:

- fire risks deriving from the firm's work;
- fire risks connected to the specific tasks performed;
- the prevention and protection measures adopted;
- location of escape routes and exits;
- procedures to be adopted in the case of an emergency
- the names of those responsible for the resolution of an emergency

Training, pertinent and sufficient for the tasks of the individual workers, must include practical training in the use of the equipment to be used during emergencies.

Special training must be carried out for the staff entrusted with specific tasks within the individual procedures in order to facilitate understanding and stimulate possible improvements in the Emergency Plan.

Training must consist of putting the emergency procedures into effect through the organisation of drills that:

- assume the escape routes will be used;
- begin when the alarm goes off and finish at the assembly point with the rolecall of the whole staff;
- are realistically conducted but without exposing the participants to danger.

This training will be performed annually by means of drills whose date and form of implementation will be decided by the Emergency Coordinator.

One drill, whose performance will be communicated in advance to every worker, will involve the total evacuation of the plant while the other drills must be planned and carried out without warning in single areas to check more thoroughly the staff's preparation and level of learning and the effectiveness of the procedures adopted. Planning, including the period in which the drills will take place, the areas and the types of emergency chosen, is done in the periodical safety meetings held annually in the firm.

RISK ASSESSMENT CRITERIA

DEFINITIONS:

Health: dynamic situation of psychophysical wellbeing linked to a balanced relationship between man and the environment he lives in.

Danger or "Risk factor": intrinsic property or quality of a particular entity (for example, substances, products, materials in general or equipment, work methods and practices, etc.) having the potential to cause damage.

Risk: probability that the potential level of damage in the conditions of exposure to a particular danger has been reached.

Note that to understand the meaning completely, it is necessary to add to the abstract term "risk" the specific nature of the risk feared, such as:

risk of death;

risk of tumour;

risk of injury, etc.

Risk assessment: procedure of assessment of the possible damage to the safety and health of workers deriving from a danger occurring at the workplace. It is carried out by means of the analysis of risks in which the individual risk factors are analysed, measured and/or calculated in order to arrive at an estimate of the degree of risk deriving from a given danger.

GENERAL INFORMATION

Risk assessment has been mainly based on the following information:

knowledge of how the plant works

firm accident history

knowledge of the safety level of the systems with regard to:

mechanical safety

electrical safety

fire safety

preventive and periodical state of maintenance

state of places of work (passageways, steps, safe escape places, etc.)

knowledge of levels of lighting in the various work zones

knowledge of workers’ level of exposure to noise

knowledge of levels of exposure to airborn substances

knowledge of microclimatic conditions in the divisions

existence of formalised procedures for making the systems safe

existence of formalised procedures for the use of personal protection gear

existence of activities that involve intense repetitive physical force general anonymous results of medical examinations

any reports of work-related illnesses

Below are indicated the assessment criteria used to assess the single risk factors considered in this assessment.

Risk deriving from the situation of the work places

In this section the risks deriving from situation in the work areas are considered with regard to:

fire detection and fire-fighting

emergency routes and exits

doors and main entrances

thoroughfares, danger zones, floors, passageways

rest and sanitation facilities.

Risk has been assessed so as to determine whether the regulatory standards

In the present assessment a risk is considered to exist mainly if there might be one or more of the following deficiencies:

the plant does not have sufficient means to extinguish fires

the extinguishers are not indicated

the extinguishers are not periodically checked

the exit routes are insufficient (by number and/or dimensions)

the plant keeps inflammable and/or combustible products incorrectly

the plant has not organised an emergency and first aid plan

the work areas are untidy

the exit routes are obstructed by stored materials

the firm's signing system is insufficient

the plant does not have a sufficient change of natural/ventilated air

the plant does not have sufficient lighting for night work the plant does not have sufficient lighting in particular machines

in the plant the sanitary facilities are inadequate (insufficient in number, badly maintained, without detergent systems, etc.).

GLOSSARY :

- EIRE DANGER: intrinsic property or quality of particular materials or equipment, or work methods and practices, or of the use of a work environment, that has the potential to cause a fire;

- FIRE RISK: probability that the potential level of fire breakout will be reached and that the fire will have consequences for the people present;

- FIRE RISK ASSESSMENT: risk assessment procedure in a place of work deriving from the circumstances in which a fire danger arises.

OBJECTIVES OF FIRE RISK ASSESSMENT

Fire risk assessment must allow the employer to take the measures that are effectively necessary to protect the safety of the workers and other people present in the place of work.

These measures include:

- risk prevention;
- informing the workers and the other people present;
- training the workers;
- the technical-organisational measures aimed at putting the necessary measures into effect.

Risk prevention constitutes one of the primary objectives of risk assessment. In cases in which it is not possible to eliminate the risks, these must be reduced as much as is possible and remaining risks must be kept under control, taking into account the general safety measures laid down in art.3 of legislative decree no. 626.

Fire risk assessment takes account of:

a) the type of activity;

b) the materials stored and handled;

c) the equipment present in the place of work, including the fittings;

d) the construction features of the place of work, including facing materials;

e) the size and layout of the place of work;

f) the number of people present, both employees and other people, and with what promptness they will move away in the case of an emergency.

CRITERIA

Check lists were drawn up in such a way that for each work area the fire dangers present were analysed (inflammable substances, gases, inflammable liquids, work phases, waste, facings, maintenance, finished products, paper, packaging, plant) and it was ascertained whether the fire danger could be eliminated or reduced.

In addition to these check lists regarding fire dangers, others were then drawn up that, for each work area, examine the implementation and effectiveness of particular prevention measures (emergency routes and exits, fire-fighting equipment, fire-detection systems, the firm's organisation for fire prevention and fire-fighting, etc.).

When the work of drawing up the check lists has been completed, the work area will be classified for fire risk in the ways defined by the Decree, that is:

A) PLACE OF WORK AT LOW FIRE RISK

Low fire risk means places of work or a part of them in which there are substances with a low rate of inflammability and the conditions of the place and its use offer few possibilities for the development of fire outbreaks and in which, in the case of fire, the probability of its spreading is considered to be limited.

B) PLACE OF WORK AT MEDIUM FIRE RISK

Medium fire risk means places of work or a part of them in which there are inflammable substances and/or conditions of the place and/or its use that can favour the development of fires, but in which, in the case of fire, the probability of its spreading is considered to be limited. Examples of work places of medium fire risk are given in attachment IX.

C) PLACE OF WORK AT HIGH FIRE RISK

High fire risk means places of work or a part of them in which:

- on account of the presence of highly inflammable substances and/or on account of the conditions of the place and/or its use, there is a considerable probability of fires developing and in the initial phase, a strong probability that the flames will spread, that is, places of work that cannot be classified as being of low or medium fire risk.

These places include:

- areas where work processes involve the use of highly inflammable substances (e.g. paint works) or open flames, or the production of considerable heat in the presence of combustible materials;
- areas where chemical substances are stored or handled that can in certain circumstances produce exothermic reactions, give off gases or inflammable fumes or react with other combustible substances; areas where explosive or highly inflammable substances are stored or handled;
- areas where there is a considerable quantity of combustible materials that easily catch fire;
- buildings completely built of wood.

In order to classify a place of work or a part of it as being at high fire risk, it must be kept in mind that:

a) many places of work are classified in the same risk category for all their parts. But any high risk area can increase the risk level of the whole place of work unless the area involved is separated from the rest of the place with fire-proof divisions;

b) a high risk category can be reduced if the work process is carefully managed and the exit routes are protected against fire;

c) in large or complex workplaces it is possible to reduce the risk level by means of automatic active protection measures, such as automatic extinguishing systems, automatic fire detection systems or fume extraction systems.

Also to be classified as places at high fire risk are those areas where, regardless of the presence of inflammable substances and the ease with which flames spread, crowding of the rooms, the state of the places or obstacles to the movement of the people present make evacuation in the case of fire difficult.

NOISE EMISSIONS

For the assessment of the risk deriving from exposure to noise, the criteria specified by Legislative

On the basis of the contents of this Decree, we can deduce the following scale of risk:

Exposure to noise lower than 80 dBA

Below 80.0 dBA, the precautions specified by Legislative do not apply; the risk is to be considered zero.

Exposure to noise between 80 and 85 dBA

In this range there is no provision for a compulsory medical examination or the use of a form of protection (unless otherwise prescribed by the Official Doctor); based on this, the risk connected to this range of exposure is to be considered industrially acceptable.

Exposure to noise between 85 and 90 dBA

In this range of exposure to noise a medical examination is to be made every 2 years and some form of personal protection against noise should be used (unless the Official Doctor specifies a higher frequency of medical checkups and prescribes the use of a form of protection); based on this, the risk for workers exposed to noise from 85 to 90 dBA is quite low.

Exposure to noise greater than 90 dBA

Over the level of exposure of 90 dBA there is to be an annual medical examination and a form of personal protection against noise must be used (unless the Official Doctor specifies a higher frequency of medical checkups); based on this, exposure to noise louder than 90 dBA entails certain risk for workers.

Chapter 12 : SLIM LINE Waste To Energy presentation (Example)

HAFNER®
WASTE TO ENERGY

HAFNER®

presents

WASTE TO ENERGY SOLUTIONS

for

SMALL ISLAND STATES

HAFNER® WASTE TO ENERGY

Company presentation

Who is HAFNER

HAFNER is a company operating in the **alternative energy generation** industry having its headquarters in Bolzano/Bozen (Italy).

HAFNER was established in **1978 focusing on:**

- **environmental technology** consultancy;
- services and **energy generation plants**;
- pioneering the market of ecological detergent products.

Today HAFNER is a continuously growing brand that:

- Stands on many years of experience in environmental technology;
- offers a unique range of products and services.
- grants cost-effective energy production and environmental protection.

Core business: **waste recycling plants** design and building in line with the content of the Kyoto Protocol signed in 1997.

HAFNER developed **the first mobile waste recycling plant system** with a high level of flexibility, ideally suited to small requirements such as **Small Island States**.

HAFNER WASTE TO ENERGY

Company presentation

What does HAFNER do

HAFNER **designs, develops, constructs and installs** systems to recycle waste and biomass, with integrated energy generation.

HAFNER offers different solutions in order to **replace traditional fuels**, also including services which include operator models, training, maintenance and financing.

HAFNER long and wide experience allows customers to rely on a single party on environmental sustainability projects.

This experience has led Heinrich Hafner, founder and managing director of the company, publishing two books: the first in 2010 entitled "With Renewable Energy - Waste Is Moving The World", and the second in 2011, entitled "The Energy Revolution In The Third Millennium".

HAFNER
WASTE TO ENERGY

Company presentation

HAFNER operation areas

Today the HAFNER Group is active around the world and is expanding in a rapidly growing market.

There are HAFNER systems in:

- Italy
- Germany
- Croatia
- Venezuela
- Lithuania

HAFNER® WASTE TO ENERGY

Active plants

Project name	Location	Nation	Waste type	Capacity	Year of comissioning
MVA Bolzano	Bolzano	Italy	Urban waste	110.000 t/y	2015
Toksika	Siaulia	Lithuania	Hazardous waste	150.000 t/y	2011
CIS	Montale	Italy	Urban waste/biomass	60.000 t/y	2011
Enkenbach Gemeindewerke	Enkenbach	Germany	Biomass	20.000 t/y	2010
AAMPS	Livorno	Italy	Urban waste	110.000 t/y	2008
Mida	Crotone	Italy	Hazardous waste	30.000 t/y	2008
Siena Ambiente	Poggibonsi	Italy	Urban waste	100.000 t/y	2007
ZAK	Kaiserslautern	Germany	Urban waste/biomass	30.000 t/y	2005
KKK	Frankenthal	Germany	Biomass	20.000 t/y	2003
Dupont	Hamm	Germany	Biomass	80.000 t/y	2003

Previous generation active plants

Project name	Location	Nation	Waste type	Capacity	Year of comissioning
Mistral	Spilimbergo	Italy	Hazardous waste	50.000 t/y	2000
Forschungszentrum Karlsruhe	Karlsruhe	Germany	Hazardous waste	15.000 t/y	2000
BASF	Tumero	Venezuela	Hazardous waste	15.000 t/y	1998
Puto	Zagreb	Croatia	Hazardous waste	20.000 t/y	1997
Viri	Lecce	Italy	Hospital waste	15.000 t/y	1995
Comunella	Altamura	Italy	Hospital waste	12.000 t/y	1994
Eneco	Cagliari	Italy	Hospital waste	15.000 t/y	1992

HAFNER® WASTE TO ENERGY

The challenge:
Producing energy from waste

Waste disposal is one of our most important global challenges in the 21st century.

A worldwide average of **300 kg** of waste per year and per person are generated.

70% of it ends up on landfill sites → **lost energy!**

Different country has **different disposal method**, with waste, from private or industrial clients or hospitals.

Waste separation → clean recycling.
But not all recycling systems are fully accepted by consumers.
Why?

- too complicated
- too laborious
- needs for space also in little houses
- no supply of waste separation system, as well as in Germany or other European countries.

The **consequences on the environment**, in the locations where inappropriate waste disposal is common practice, are extensive.

HAFNER® WASTE TO ENERGY

Recycling:
cost-intensive, energy and space consuming

Even well separated waste contains materials that are **difficult to recycle**, such as complex plastics or chipboard.

A lot of energy is required for each action, involving **high cost procedures**:
- separation of valuable materials
- decompose the waste back into its original substances, using conventional procedures
- mechanical and biological pre-treatment procedures.

Creation of new landfill sites is not easy in emerging nations and Small Island States.

Cities with a very high population density **hardly find** areas for large plants.

Mountainous countries only have a limited range of sites for large waste plants.

Hafner offers a **space-saving, economic and environmental solution** that is widely accepted by the population at large.

HAFNER®
WASTE TO ENERGY

State of the art Waste to Energy technology made in the Alps

HAFNER offers a **simple, highly efficient and environmentally-friendly solution** for every disposal problem, and for both hazardous or residual waste.

HAFNER and its **SLIM LINE transportable energy control center** combines many years of expertise as waste disposal specialist.

This is a **flexible, economic and secure** way for the thermal treatment of residual and hazardous waste.

This is because the SLIM LINE solves two problems at once in a single procedure:

1. The disposal question in relation to "waste"
2. The lack of renewable, climate-neutral energy

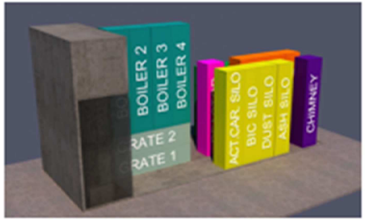
HAFNER
WASTE TO ENERGY

Simple module system with ingenious Waste to Energy technology

The SLIM LINE is **immediately operational** for the treatment of settlement waste, right following its assembly.

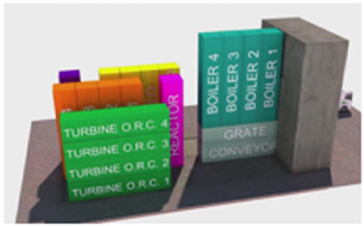
Different transportable container models are put together, easily transported by a truck.

Also **low noise** is produced during installation.



From waste to electricity in 5 steps:

1) Waste loading
2) Grate combustion and secondary combustion chamber
3) Energy production in the form of electricity, and if needed heat and cooling
4) Multiple filtering of waste flue gases
5) Real-time continuous monitoring and publishing of emissions



Energy is generated at the end of the waste process with a considerable reduction of CO_2 emission if compared with traditional fuel energy generation. Valuable materials such as glass, metals or sand are generated from the slag, which then become available for **recycling once more**.

HAFNER®
WASTE TO ENERGY

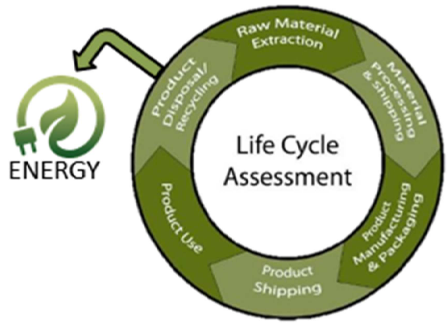
The advantages of the SLIM LINE at a glance:

- **Decentralized and transportable** thermal energy control center; can be installed as a module virtually anywhere.
- **Low investment costs**, consequently pleasantly low operating costs.
- Extracting of valuable energies in the form of electricity, heat and refrigerants.
- Use of **state of the art and environmental-friendly technology.**
- Co2 reduction through the replacement of fossil fuels during the incineration process.
- Co2 reduction by low transportation by contrast with centralized waste sites.
- Utilization of the energy introduced with an efficiency level of 80 per cent. Waste is thus considered and **"declared" as fuel** according to the EU Directive.
- CE / TÜV certification of the modular plant has been performed.
- Emission values fulfill the provisions of the European Community and more far **reaching even stricter national requirements**.
- The plant can be approved within a short period (1 year) and put into operation.

HAFNER® WASTE TO ENERGY

A life cycle assessment to be proud of

- Small energy control center guarantees **high levels of transparency** towards the local authorities and their citizens in this way.
- Waste cycles can be better understood by the consumer.
- **NO WASTE WATER**. At the end of the process, the plant merely expels slag and filtered waste gases.
- The plant extracts **more than 90% metals** from the slag which is subsequently available for a new economic cycle.
- **Extremely high quality** of metals and glasses extracted from the thermal treatment.
- Undesired coatings and adhesions are also removed during the process.
- Remaining materials are **also recyclable** – such as rubble which is used by the building materials sector or in road construction.



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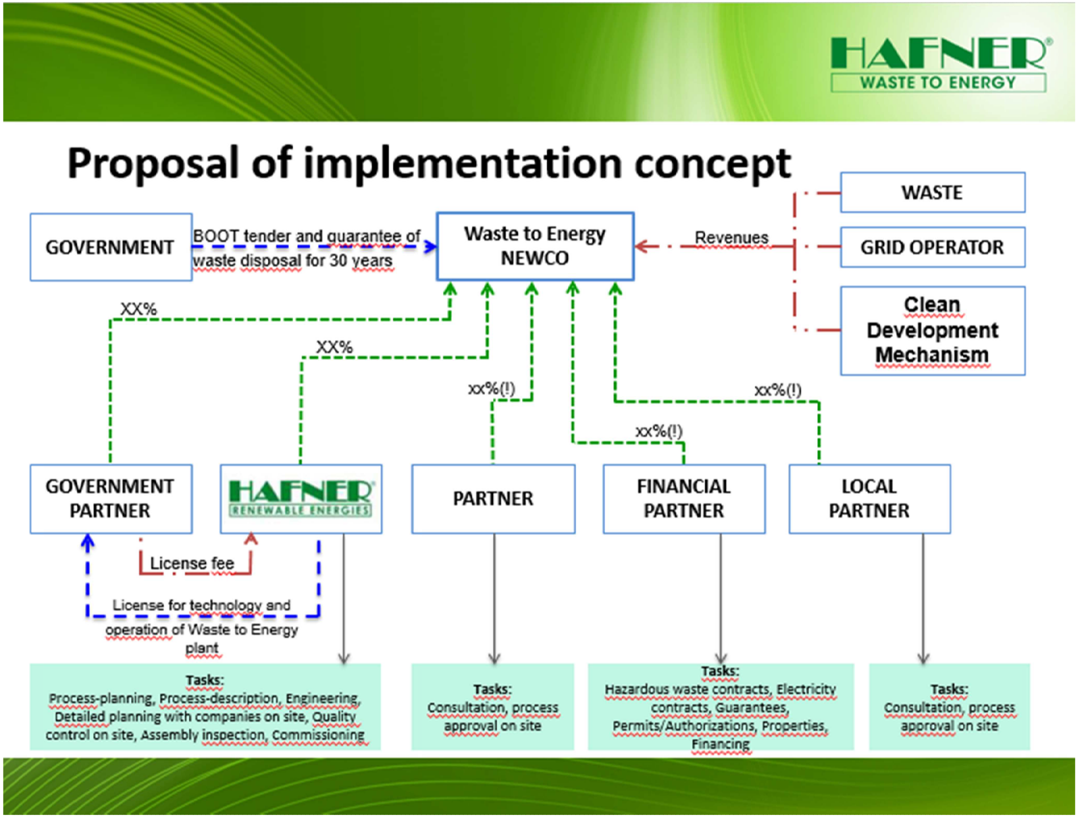
HAFNER
WASTE TO ENERGY
Proposal of implementation concept
GOVERNMENT
BOOT tender and guarantee of waste disposal for 30 years
Waste to Energy NEWCO
Revenues
WASTE
GRID OPERATOR
Clean Development Mechanism
XX%
XX%
xx%(!)
xx%(!)
xx%(!)
GOVERNMENT PARTNER
HAFNER RENEWABLE ENERGIES
PARTNER
FINANCIAL PARTNER
LOCAL PARTNER
License fee
License for technology and operation of Waste to Energy plant
Tasks: Process-planning, Process-description, Engineering, Detailed planning with companies on site, Quality control on site, Assembly inspection, Commissioning
Tasks: Consultation, process approval on site
Tasks: Hazardous waste contracts, Electricity contracts, Guarantees, Permits/Authorizations, Properties, Financing
Tasks: Consultation, process approval on site

HAFNER® WASTE TO ENERGY

CARICOM waste context

According to **2016 World Bank data**, several CARICOM nations are on the top of "per capita household waste" list in the world.

- Barbados, 4.75 kilograms per capita per day
- St. Lucia, 4.35 kilograms per capita per day
- St. Kitts and Nevis, 5.45 kilograms per capita per day
- Antigua, 5.50 kilograms per capita per day
- Trinidad and Tobago, 14.4 kilograms per capita per day

Situation is aggravated by:

- Limited options for siting new disposal sites while many are **running out of space**
- Lack of **affordable financing** to improve waste management practices
- Low **private sector** involvement

The cost on environment and local economy is enormous.

The CARICOM waste to energy potential

While some CARICOM nations have already proceeded in waste management and recycling programmes, waste production is still increasing.

Among the benefits that municipalities can receive from a well organized waste management and from waste to energy implementation, here are the most important:

- Waste management and W2E are key to reducing **public health risks**
- Waste management and W2E maintain **landscape natural aesthetics**
- Waste management and W2E create **direct economic benefits**
- Waste management and W2E create **virtuous waste management behaviour** within local population
- W2E **reduce consistently CO_2 emissions** for energy generation (22.500 tons/y every 25.000 tons of waste)
- W2E **reduce consistently Methane emissions** from waste decomposition (1 kg of methane is equivalent of 21 kg of carbon dioxide on greenhouse effect).

HAFNER WASTE TO ENERGY

General implementation model

Population example: **50.000**

Amount of waste:

- **Domestic waste** **22.000 t/year @ 94 $/t**
- **Hazardous waste** **3.000 t/year @ 365 $/t**
  (hospital waste + industrial waste)

Caloric value of waste: 2.200 kcal/kg (low average value)

Annual plant working time: 8.000 hrs
Energy production per hour: **1,92 MWh @ 150 $/MWh**

HAFNER® WASTE TO ENERGY

General implementation model

Plant cost: 27.150.000 $

Annual revenues:

• Household waste:	2.068.000 $	5.503.000 $
• Hazardous waste:	1.100.000 $	
• Energy sale:	2.335.000 $	

Annual running costs:

• Gas:	19.800 $	Insurance:	108.000 $
• Maintenance:	355.000 $	Services:	24.000 $
• Ash disposal:	235.000 $	Administration:	54.000 $
• Ash filter:	146.000 $	**TOTAL:**	**1.685.150 $**
• Electric energy:	235.000 $		
• Addictives:	190.000 $	EBITDA:	3.817.850 $
• Water:	8.350 $		
• Staff:	310.000 $	**Expected IRR:**	**16,08 %***

*: with supposed financial leverage of 70%. Data are conservative

Chapter 13 : BOOT OFFER EXAMPLE

Messrs

MUNICIPALITY OF Tehran

Bolzano, January 4th, 2017

Re.: *Offer for a HAFNER Waste to Energy plant in Tehran under a BOOT scheme*

Esteemed Directors,

Following our prior submittal of a technical proposal for a Hafner Waste to Energy plant in Tehran, it is with great pleasure that our company submits to your attention the present all inclusive financial offer for the design, financing, construction, operation and maintenance of a thermal treatment plant for domestic waste and similar commercial waste in Tehran, under a Build Own Operate and Transfer scheme (BOOT).

1. Current Characteristics of the project

Quantity of municipal waste	182.500 t/year
Present waste disposal	landfill

2. Proposed Characteristics of the Tehran Hafner project

New thermal treatment plant	182.500 t/year
Total thermal treatment capacity per hour	69,70 MW

3. Applicable standards and norms

This offer is intended to adhere to "Applicable Standards and Norms", meaning the standards and norms as defined in the:

a. EU Framework Directive for Waste 75/442/EC
b. EU Directive on Waste 99/31/EC and amendments
c. EU "Waste Catalogue" Directive for Waste Incineration 2000/76/EC
d. EU Directive for Landfills 99/31/EC
e. EU Directive concerning Integrated Pollution Prevention Control 96/61/EC
f. IPPC BREF (Best available technology reference documents) for Waste Treatment Industries and Waste Incineration

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info@hafner.it • www.hafner.it

g. Guidelines on Best Available Technology and Best Environmental Practices for Medical Waste Incineration prepared for the UNEP Stockholm Convention and any other locally defined industry standards and norms as may be applicable from time to time for the purpose of execution, implementation and operation of the project at issue, to the extent that those are more stringent than the above referred to standards and norms.

It will also adhere to "Best Industry Practice", meaning the degree of skill, care, prudence and operating practice which would reasonably and ordinarily be expected from a skilled and experienced operator of industrial waste treatment contractor or subcontractor under the same or similar circumstances. Best Industry Practice shall include, but not be limited to:
a. availability of adequate materials, resources and supplies, to meet the Waste to Energy plant's needs under normal conditions and reasonably anticipated abnormal conditions;
b. sufficiently qualified operating staff available, adequately experienced and trained to operate the Waste to Energy plant efficiently and capable of responding to abnormal conditions;
c. routine and non-routine maintenance and repairs performed on a regular and "when needed" basis
d. the plant is operated in a manner safe to workers, the general public and the environment

The plant can be embedded in the existing waste management stream in order to exploit the current waste fractions or untreated waste, currently going to landfills. The plant will offer the highest skills, know-how and working experience coupled with one-pointed focus to the local needs and requests of the Tehran environment.
Upon careful analysis of the specifications received so far, the Hafner management has a clear understanding of the requirements and full ability to provide an effective solution.

The Hafner company will provide a multi-disciplinary team with expertise in each of the areas critical to the success of the design and construction of the plant, and the training of its staff as well.

It will operate according to "BREF", meaning the Best Reference Documents setting forth the best available technology for waste treatment facilities as defined by the European Integrated Pollution Prevention Control Bureau and as applicable from time to time.

The Hafner company shall ensure that, at all times, the sites and locations where the plant activities will be carried out, will be in a clean, orderly, safe and secure state.

4. On site investments

a) Construction and operation of domestic waste and similar commercial waste to energy plant with an incineration capacity of 182.500 t/year; electricity energy production of 16,729 MW per h through 8.000 operating hours per year (133.834 MW/y)

5. Scope of the BOOT (Build Own Operate and Transfer)

Tehran gives Hafner the total waste coordination for the next 30 years. Hafner constructs and operates, at its own costs, a domestic waste and similar commercial waste thermal treatment plant with a capacity of 182.500 t/year. For the mentioned services Tehran pays the Hafner Company the following amounts per year:

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info@hafner.it • www.hafner.it

a. for waste thermal treatment in the new plant: € 90 /ton
b. for energy production from plant, Tehran pays Hafner € 100/MWh a year for 30 years, with annual revision

Slag treatment, disposal, ash-filter treatment are not included

6. Contractual agreements

BOOT (Build Own Operate and Transfer) contract between Tehran and Hafner for waste thermal treatment for duration of 30 years, inclusive of the following contracts and guarantees:

a) Contract between Tehran and Hafner for the supply, by Tehran, of 182.500 t/y of domestic waste and similar commercial waste (for 30 years) with a medium thermal capacity of 2.600 kcal/kg

b) Tehran issues a guarantee (Bank) for the delivery by Tehran of 182.500 t/y of domestic waste for 30 years, with an average thermal capacity of 2500 kcal/kg, at the agreed costs

c) Contract between Tehran and Hafner for the purchase by Tehran of 16,73 MWe/h of electricity produced by the plant for 30 years at € 82,00, with annual revision

d) Tehran issues a guarantee (Bank) for the purchase by Tehran of 16,73 MWe/h for 8000 h/y (i.e. 133.834 MW/y) produced by the plant for 30 years at € 82,00, with annual revision

e) Contract between Tehran and Hafner for the purchase by Hafner of 5 MWe/h for 30 years at € 30,00 for the thermal treatment plant self consumption.

f) Contract between Tehran and Hafner for the supply by Tehran of land at no cost, for the construction of a thermal treatment plant for domestic waste and similar commercial waste.

g) Hafner guarantees (Bank) to perform the project in the best possible way.

h) Tehran guarantees on the exclusion of any tax on import, VAT and/or company income.

With this project Tehran will be the first Municipality in the region to have chosen the most forward-looking waste treatment management technology available and at the same time created a contribution in CO^2 savings equivalent to 164.250.000,00 kg per year.

Confident that our proposal is meeting your expectation, we remain with

Kind regards,

Heinrich Hafner

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APPENDIX A: Paris Agreement

The Parties to this Agreement,

Being Parties to the United Nations Framework Convention on Climate Change, hereinafter referred to as "the Convention",

Pursuant to the Durban Platform for Enhanced Action established by decision 1/CP.17 of the Conference of the Parties to the Convention at its seventeenth session,

In pursuit of the objective of the Convention, and being guided by its principles, including the principle of equity and common but differentiated responsibilities and respective capabilities, in the light of different national circumstances,

Recognizing the need for an effective and progressive response to the urgent threat of climate change on the basis of the best available scientific knowledge,

Also recognizing the specific needs and special circumstances of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change, as provided for in the Convention, *Taking full acc*ount of the specific needs and special situations of the least developed countries with regard to funding and transfer of technology,

Recognizing that Parties may be affected not only by climate change, but also by the impacts of the measures taken in response to it,

Emphasizing the intrinsic relationship that climate change actions, responses and impacts have with equitable access to sustainable development and eradication of poverty,

Recognizing the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change,

Taking into account the imperatives of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities,

Acknowledging that climate change is a common concern of humankind, Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity,

Recognizing the importance of the conservation and enhancement, as appropriate, of sinks and reservoirs of the greenhouse gases referred to in the Convention,

Noting the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity, recognized by some cultures as Mother Earth, and noting the importance for some of the concept of "climate justice", when taking action to address climate change,

Affirming the importance of education, training, public awareness, public participation, public access to information and cooperation at all levels on the matters addressed in this Agreement,

Recognizing the importance of the engagements of all levels of government and various actors, in accordance with respective national legislations of Parties, in addressing climate change,

Also recognizing that sustainable lifestyles and sustainable patterns of consumption and production, with developed country Parties taking the lead, play an important role in addressing climate change,

Have agreed as follows:

Article 1

For the purpose of this Agreement, the definitions contained in Article 1 of the

Convention shall apply. In addition:

(a) "Convention" means the United Nations Framework Convention on Climate

Change, adopted in New York on 9 May 1992;

(b) "Conference of the Parties" means the Conference of the Parties to the

Convention;

(c) "Party" means a Party to this Agreement

Article 2

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

(b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and

(c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

2. This Agreement will be implemented to reflect equity and the principle of common

but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

Article 3

As nationally determined contributions to the global response to climate change, all Parties are to undertake and communicate ambitious efforts as defined in Articles 4, 7, 9, 10, 11 and 13 with the view to achieving the purpose of this Agreement as set out in Article 2. The efforts of all Parties will represent a progression over time, while recognizing the need to support developing country Parties for the effective implementation of this Agreement.

Article 4

1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

2. Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.

3. Each Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

4. Developed country Parties should continue taking the lead by undertaking economywide absolute emission reduction targets. Developing country Parties should continue enhancing their mitigation efforts, and are encouraged to move over time towards economy-wide emission reduction or limitation targets in the light of different national circumstances.

5. Support shall be provided to developing country Parties for the implementation of this Article, in accordance with Articles 9, 10 and 11, recognizing that enhanced support for developing country Parties will allow for higher ambition in their actions.

6. The least developed countries and small island developing States may prepare and communicate strategies, plans and actions

for low greenhouse gas emissions development reflecting their special circumstances.

7. Mitigation co-benefits resulting from Parties' adaptation actions and/or economic diversification plans can contribute to mitigation outcomes under this Article.

8. In communicating their nationally determined contributions, all Parties shall provide the information necessary for clarity, transparency and understanding in accordance with decision 1/CP.21 and any relevant decisions of the Conference of the Parties serving as the meeting of the Parties to this Agreement.

9. Each Party shall communicate a nationally determined contribution every five years in accordance with decision 1/CP.21 and any relevant decisions of the Conference of the Parties serving as the meeting of the Parties to this Agreement and be informed by the outcomes of the global stocktake referred to in Article 14.

10. The Conference of the Parties serving as the meeting of the Parties to this Agreement shall consider common time frames for nationally

determined contributions at its first session.

11. A Party may at any time adjust its existing nationally determined contribution with a view to enhancing its level of ambition, in accordance with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to this Agreement.

12. Nationally determined contributions communicated by Parties shall be recorded in a public registry maintained by the secretariat.

13. Parties shall account for their nationally determined contributions. In accounting for anthropogenic emissions and removals corresponding to their nationally determined contributions, Parties shall promote environmental integrity, transparency, accuracy, completeness, comparability and consistency, and ensure the avoidance of double counting, in accordance with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to this Agreement.

14. In the context of their nationally determined contributions, when recognizing and

implementing mitigation actions with respect to anthropogenic emissions and removals, Parties should take into account, as appropriate, existing methods and guidance under the Convention, in the light of the provisions of paragraph 13 of this Article.

15. Parties shall take into consideration in the implementation of this Agreement the concerns of Parties with economies most affected by the impacts of response measures, particularly developing country Parties.

16. Parties, including regional economic integration organizations and their member States, that have reached an agreement to act jointly under paragraph 2 of this Article shall notify the secretariat of the terms of that agreement, including the emission level allocated to each Party within the relevant time period, when they communicate their nationally determined contributions. The secretariat shall in turn inform the Parties and signatories to the Convention of the terms of that agreement.

17. Each party to such an agreement shall be responsible for its emission level as set out in

the agreement referred to in paragraph 16 of this Article in accordance with paragraphs 13 and 14 of this Article and Articles 13 and 15.

18. If Parties acting jointly do so in the framework of, and together with, a regional economic integration organization which is itself a Party to this Agreement, each member State of that regional economic integration organization individually, and together with the regional economic integration organization, shall be responsible for its emission level as set out in the agreement communicated under paragraph 16 of this Article in accordance with paragraphs 13 and 14 of this Article and Articles 13 and 15.

19. All Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies, mindful of Article 2 taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

Article 5

1. Parties should take action to conserve and enhance, as appropriate, sinks and

reservoirs of greenhouse gases as referred to in Article 4, paragraph 1(d), of the

Convention, including forests.

2. Parties are encouraged to take action to implement and support, including through results-based payments, the existing framework as set out in related guidance and decisions already agreed under the Convention for:

- policy approaches and positive incentives for activities relating to reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries;
- and alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests, while reaffirming the importance of incentivizing, as appropriate, non-carbon benefits associated with such approaches.

Article 6

1. Parties recognize that some Parties choose to pursue voluntary cooperation in the

implementation of their nationally determined contributions to allow for higher ambition in their mitigation and adaptation actions and to promote sustainable development and

environmental integrity.

2. Parties shall, where engaging on a voluntary basis in cooperative approaches that

involve the use of internationally transferred mitigation outcomes towards nationally

determined contributions, promote sustainable development and ensure environmental

integrity and transparency, including in governance, and shall apply robust accounting to

ensure, inter alia, the avoidance of double counting, consistent with guidance adopted by

the Conference of the Parties serving as the meeting of the Parties to this Agreement.

3. The use of internationally transferred mitigation outcomes to achieve nationally

determined contributions under this Agreement shall be voluntary and authorized by

participating Parties.

4. A mechanism to contribute to the mitigation of greenhouse gas emissions and

support sustainable development is hereby established under the authority and guidance of

the Conference of the Parties serving as the meeting of the Parties to this Agreement for use

by Parties on a voluntary basis. It shall be supervised by a body designated by the

Conference of the Parties serving as the meeting of the Parties to this Agreement, and shall

aim:

(a) To promote the mitigation of greenhouse gas emissions while fostering

sustainable development;

(b) To incentivize and facilitate participation in the mitigation of greenhouse gas

emissions by public and private entities authorized by a Party;

(c) To contribute to the reduction of emission levels in the host Party, which will

benefit from mitigation activities resulting in emission reductions that can also be used by

another Party to fulfil its nationally determined contribution; and

(d) To deliver an overall mitigation in global emissions.

5. Emission reductions resulting from the mechanism referred to in paragraph 4 of this

Article shall not be used to demonstrate achievement of the host Party's nationally

determined contribution if used by another Party to demonstrate achievement of its

nationally determined contribution.

6. The Conference of the Parties serving as the meeting of the Parties to this

Agreement shall ensure that a share of the proceeds from activities under the mechanism

referred to in paragraph 4 of this Article is used to cover administrative expenses as well as

to assist developing country Parties that are particularly vulnerable to the adverse effects of

climate change to meet the costs of adaptation.

7. The Conference of the Parties serving as the meeting of the Parties to this

Agreement shall adopt rules, modalities and procedures for the mechanism referred to in paragraph 4 of this Article at its first session.

8. Parties recognize the importance of integrated, holistic and balanced non-market

approaches being available to Parties to assist in the implementation of their nationally

determined contributions, in the context of sustainable development and poverty

eradication, in a coordinated and effective manner, including through, inter alia, mitigation,

adaptation, finance, technology transfer and capacity-building, as appropriate. These

approaches shall aim to:

(a) Promote mitigation and adaptation ambition;

(b) Enhance public and private sector participation in the implementation of

nationally determined contributions; and

(c) Enable opportunities for coordination across instruments and relevant

institutional arrangements.

9. A framework for non-market approaches to sustainable development is hereby

defined to promote the non-market approaches referred to in paragraph 8 of this Article.

Article 7

1. Parties hereby establish the global goal on adaptation of enhancing adaptive

capacity, strengthening resilience and reducing vulnerability to climate change, with a view

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to contributing to sustainable development and ensuring an adequate adaptation response in

the context of the temperature goal referred to in Article 2.

2. Parties recognize that adaptation is a global challenge faced by all with local,

subnational, national, regional and international dimensions, and that it is a key component

of and makes a contribution to the long-term global response to climate change to protect

people, livelihoods and ecosystems, taking into account the urgent and immediate needs of

those developing country Parties that are particularly vulnerable to the adverse effects of climate change.

3. The adaptation efforts of developing country Parties shall be recognized, in

accordance with the modalities to be adopted by the Conference of the Parties serving as

the meeting of the Parties to this Agreement at its first session.

4. Parties recognize that the current need for adaptation is significant and that greater

levels of mitigation can reduce the need for additional adaptation efforts, and that greater

adaptation needs can involve greater adaptation costs.

5. Parties acknowledge that adaptation action should follow a country-driven, gender responsive,

participatory and fully transparent approach, taking into consideration

vulnerable groups, communities and ecosystems, and should be based on and guided by the

best available science and, as appropriate, traditional knowledge, knowledge of indigenous peoples and local knowledge systems, with a view to integrating adaptation into relevant

socioeconomic and environmental policies and actions, where appropriate.

6. Parties recognize the importance of support for and international cooperation on

adaptation efforts and the importance of taking into account the needs of developing

country Parties, especially those that are particularly vulnerable to the adverse effects of

climate change.

7. Parties should strengthen their cooperation on enhancing action on adaptation,

taking into account the Cancun Adaptation Framework, including with regard to:

(a) Sharing information, good practices, experiences and lessons learned,

including, as appropriate, as these relate to science, planning, policies and implementation

in relation to adaptation actions;

(b) Strengthening institutional arrangements, including those under the

Convention that serve this Agreement, to support the synthesis of relevant information and

knowledge, and the provision of technical support and guidance to Parties;

(c) Strengthening scientific knowledge on climate, including research,

systematic observation of the climate system and early warning systems, in a manner that

informs climate services and supports decision-making;

(d) Assisting developing country Parties in identifying effective adaptation

practices, adaptation needs, priorities, support provided and received for adaptation actions

and efforts, and challenges and gaps, in a manner consistent with encouraging good

practices; and

(e) Improving the effectiveness and durability of adaptation actions.

8. United Nations specialized organizations and agencies are encouraged to support the

efforts of Parties to implement the actions referred to in paragraph 7 of this Article, taking

into account the provisions of paragraph 5 of this Article.

9. Each Party shall, as appropriate, engage in adaptation planning processes and the

implementation of actions, including the development or enhancement of relevant plans,

policies and/or contributions, which may include:

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(a) The implementation of adaptation actions, undertakings and/or efforts;

(b) The process to formulate and implement national adaptation plans;

(c) The assessment of climate change impacts and vulnerability, with a view to

formulating nationally determined prioritized actions, taking into account vulnerable

people, places and ecosystems;

(d) Monitoring and evaluating and learning from adaptation plans, policies, programmes and actions; and

(e) Building the resilience of socioeconomic and ecological systems, including

through economic diversification and sustainable management of natural resources.

10. Each Party should, as appropriate, submit and update periodically an adaptation

communication, which may include its priorities, implementation and support needs, plans

and actions, without creating any additional burden for developing country Parties.

11. The adaptation communication referred to in paragraph 10 of this Article shall be, as

appropriate, submitted and updated periodically, as a component of or in conjunction with

other communications or documents, including a national adaptation plan, a nationally

determined contribution as referred to in Article 4, paragraph 2, and/or a national

communication.

12. The adaptation communications referred to in paragraph 10 of this Article shall be

recorded in a public registry maintained by the secretariat.

13. Continuous and enhanced international support shall be provided to developing

country Parties for the implementation of paragraphs 7, 9, 10 and 11 of this Article, in

accordance with the provisions of Articles 9, 10 and 11.

14. The global stocktake referred to in Article 14 shall, inter alia:

(a) Recognize adaptation efforts of developing country Parties;

(b) Enhance the implementation of adaptation action taking into account the

adaptation communication referred to in paragraph 10 of this Article;

(c) Review the adequacy and effectiveness of adaptation and support provided

for adaptation; and

(d) Review the overall progress made in achieving the global goal on adaptation

referred to in paragraph 1 of this Article.

Article 8

1. Parties recognize the importance of averting, minimizing and addressing loss and

damage associated with the adverse effects of climate change, including extreme weather

events and slow onset events, and the role of sustainable development in reducing the risk

of loss and damage.

2. The Warsaw International Mechanism for Loss and Damage associated with Climate

Change Impacts shall be subject to the authority and guidance of the Conference of the

Parties serving as the meeting of the Parties to this Agreement and may be enhanced and

strengthened, as determined by the Conference of the Parties serving as the meeting of the

Parties to this Agreement.

3. Parties should enhance understanding, action and support, including through the

Warsaw International Mechanism, as appropriate, on a cooperative and facilitative basis with respect to loss and damage associated with the adverse effects of climate change.

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4. Accordingly, areas of cooperation and facilitation to enhance understanding, action

and support may include:

(a) Early warning systems;

(b) Emergency preparedness;

(c) Slow onset events;

(d) Events that may involve irreversible and permanent loss and damage;

(e) Comprehensive risk assessment and management;

(f) Risk insurance facilities, climate risk pooling and other insurance solutions;

(g) Non-economic losses; and

(h) Resilience of communities, livelihoods and ecosystems.

5. The Warsaw International Mechanism shall collaborate with existing bodies and

expert groups under the Agreement, as well as relevant organizations and expert bodies

outside the Agreement.

Article 9

1. Developed country Parties shall provide financial resources to assist developing

country Parties with respect to both mitigation and adaptation in continuation of their

existing obligations under the Convention.

2. Other Parties are encouraged to provide or continue to provide such support

voluntarily.

3. As part of a global effort, developed country Parties should continue to take the lead

in mobilizing climate finance from a wide variety of sources, instruments and channels,

noting the significant role of public funds, through a variety of actions, including

supporting country-driven strategies, and taking into account the needs and priorities of developing country Parties. Such mobilization of climate finance should represent a

progression beyond previous efforts.

4. The provision of scaled-up financial resources should aim to achieve a balance

between adaptation and mitigation, taking into account country-driven strategies, and the

priorities and needs of developing country Parties, especially those that are particularly

vulnerable to the adverse effects of climate change and have significant capacity

constraints, such as the least developed countries and small island developing States,

considering the need for public and grant-based resources for adaptation.

5. Developed country Parties shall biennially communicate indicative quantitative and

qualitative information related to paragraphs 1 and 3 of this Article, as applicable,

including, as available, projected levels of public financial resources to be provided to developing country Parties. Other Parties providing resources are encouraged to

communicate biennially such information on a voluntary basis.

6. The global stocktake referred to in Article 14 shall take into account the relevant

information provided by developed country Parties and/or Agreement bodies on efforts

related to climate finance.

7. Developed country Parties shall provide transparent and consistent information on

support for developing country Parties provided and mobilized through public interventions

biennially in accordance with the modalities, procedures and guidelines to be adopted by

the Conference of the Parties serving as the meeting of the Parties to this Agreement, at its

first session, as stipulated in Article 13, paragraph 13. Other Parties are encouraged to do

so.

8. The Financial Mechanism of the Convention, including its operating entities, shall

serve as the financial mechanism of this Agreement.

9. The institutions serving this Agreement, including the operating entities of the

Financial Mechanism of the Convention, shall aim to ensure efficient access to financial

resources through simplified approval procedures and enhanced readiness support for

developing country Parties, in particular for the least developed countries and small island

developing States, in the context of their national climate strategies and plans.

Article 10

1. Parties share a long-term vision on the importance of fully realizing technology

development and transfer in order to improve resilience to climate change and to reduce

greenhouse gas emissions.

2. Parties, noting the importance of technology for the implementation of mitigation

and adaptation actions under this Agreement and recognizing existing technology deployment and dissemination efforts, shall strengthen cooperative action on technology

development and transfer.

3. The Technology Mechanism established under the Convention shall serve this

Agreement.

4. A technology framework is hereby established to provide overarching guidance to

the work of the Technology Mechanism in promoting and facilitating enhanced action on

technology development and transfer in order to support the implementation of this

Agreement, in pursuit of the long-term vision referred to in paragraph 1 of this Article.

5. Accelerating, encouraging and enabling innovation is critical for an effective, longterm

global response to climate change and promoting economic growth and sustainable

development. Such effort shall be, as appropriate, supported, including by the Technology

Mechanism and, through financial means, by the Financial Mechanism of the Convention, for collaborative approaches to research and development, and facilitating access to

technology, in particular for early stages of the technology cycle, to developing country

Parties.

6. Support, including financial support, shall be provided to developing country Parties

for the implementation of this Article, including for strengthening cooperative action on

technology development and transfer at different stages of the technology cycle, with a

view to achieving a balance between support for mitigation and adaptation. The global

stocktake referred to in Article 14 shall take into account available information on efforts

related to support on technology development and transfer for developing country Parties.

Article 11

1. Capacity-building under this Agreement should enhance the capacity and ability of

developing country Parties, in particular countries with the least capacity, such as the least developed countries, and those that are particularly vulnerable to the adverse effects of

climate change, such as small island developing States, to take effective climate change

action, including, inter alia, to implement adaptation and mitigation actions, and should

facilitate technology development, dissemination and deployment, access to climate

finance, relevant aspects of education, training and public awareness, and the transparent,

timely and accurate communication of information.

2. Capacity-building should be country-driven, based on and responsive to national

needs, and foster country ownership of Parties, in particular, for developing country Parties,

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including at the national, subnational and local levels. Capacity-building should be guided

by lessons learned, including those from capacity-building activities under the Convention,

and should be an effective, iterative process that is participatory, cross-cutting and genderresponsive.

3. All Parties should cooperate to enhance the capacity of developing country Parties to

implement this Agreement. Developed country Parties should enhance support for capacitybuilding

actions in developing country Parties.

4. All Parties enhancing the capacity of developing country Parties to implement this

Agreement, including through regional, bilateral and multilateral approaches, shall

regularly communicate on these actions or measures on capacity-building. Developing

country Parties should regularly communicate progress made on implementing capacitybuilding

plans, policies, actions or measures to implement this Agreement.

5. Capacity-building activities shall be enhanced through appropriate institutional

arrangements to support the implementation of this Agreement, including the appropriate

institutional arrangements established under the Convention that serve this Agreement. The

Conference of the Parties serving as the meeting of the Parties to this Agreement shall, at

its first session, consider and adopt a decision on the initial institutional arrangements for

capacity-building.

Article 12

Parties shall cooperate in taking measures, as appropriate, to enhance climate change

education, training, public awareness, public participation and public access to information,

recognizing the importance of these steps with respect to enhancing actions under this

Agreement.

Article 13

1. In order to build mutual trust and confidence and to promote effective

implementation, an enhanced transparency framework for action and support, with built-in

flexibility which takes into account Parties' different capacities and builds upon collective

experience is hereby established.

2. The transparency framework shall provide flexibility in the implementation of the

provisions of this Article to those developing country Parties that need it in the light of their

capacities. The modalities, procedures and guidelines referred to in paragraph 13 of this

Article shall reflect such flexibility.

3. The transparency framework shall build on and enhance the transparency

arrangements under the Convention, recognizing the special circumstances of the least

developed countries and small island developing States, and be implemented in a

facilitative, non-intrusive, non-punitive manner, respectful of national sovereignty, and

avoid placing undue burden on Parties.

4. The transparency arrangements under the Convention, including national

communications, biennial reports and biennial update reports, international assessment and

review and international consultation and analysis, shall form part of the experience drawn upon for the development of the modalities, procedures and guidelines under paragraph 13

of this Article.

5. The purpose of the framework for transparency of action is to provide a clear

understanding of climate change action in the light of the objective of the Convention as set

out in its Article 2, including clarity and tracking of progress towards achieving Parties'

individual nationally determined contributions under Article 4, and Parties' adaptation

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actions under Article 7, including good practices, priorities, needs and gaps, to inform the

global stocktake under Article 14.

6. The purpose of the framework for transparency of support is to provide clarity on

support provided and received by relevant individual Parties in the context of climate

change actions under Articles 4, 7, 9, 10 and 11, and, to the extent possible, to provide a full overview of aggregate financial support provided, to inform the global stocktake under

Article 14.

7. Each Party shall regularly provide the following information:

(a) A national inventory report of anthropogenic emissions by sources and

removals by sinks of greenhouse gases, prepared using good practice methodologies

accepted by the Intergovernmental Panel on Climate Change and agreed upon by the

Conference of the Parties serving as the meeting of the Parties to this Agreement; and

(b) Information necessary to track progress made in implementing and achieving

its nationally determined contribution under Article 4.

8. Each Party should also provide information related to climate change impacts and

adaptation under Article 7, as appropriate.

9. Developed country Parties shall, and other Parties that provide support should,

provide information on financial, technology transfer and capacity-building support

provided to developing country Parties under Articles 9, 10 and 11.

10. Developing country Parties should provide information on financial, technology

transfer and capacity-building support needed and received under Articles 9, 10 and 11.

11. Information submitted by each Party under paragraphs 7 and 9 of this Article shall

undergo a technical expert review, in accordance with decision 1/CP.21. For those

developing country Parties that need it in the light of their capacities, the review process

shall include assistance in identifying capacity-building needs. In addition, each Party shall

participate in a facilitative, multilateral consideration of progress with respect to efforts

under Article 9, and its respective implementation and achievement of its nationally

determined contribution.

12. The technical expert review under this paragraph shall consist of a consideration of

the Party's support provided, as relevant, and its implementation and achievement of its

nationally determined contribution. The review shall also identify areas of improvement for

the Party, and include a review of the consistency of the information with the modalities,

procedures and guidelines referred to in paragraph 13 of this Article, taking into account

the flexibility accorded to the Party under paragraph 2 of this Article. The review shall pay

particular attention to the respective national capabilities and circumstances of developing

country Parties.

13. The Conference of the Parties serving as the meeting of the Parties to this

Agreement shall, at its first session, building on experience from the arrangements related

to transparency under the Convention, and elaborating on the provisions in this Article, adopt common modalities, procedures and guidelines, as appropriate, for the transparency

of action and support.

14. Support shall be provided to developing countries for the implementation of this

Article.

15. Support shall also be provided for the building of transparency-related capacity of

developing country Parties on a continuous basis.

Article 14

1. The Conference of the Parties serving as the meeting of the Parties to this

Agreement shall periodically take stock of the implementation of this Agreement to assess

the collective progress towards achieving the purpose of this Agreement and its long-term

goals (referred to as the "global stocktake"). It shall do so in a comprehensive and

facilitative manner, considering mitigation, adaptation and the means of implementation and support, and in the light of equity and the best available science.

2. The Conference of the Parties serving as the meeting of the Parties to this

Agreement shall undertake its first global stocktake in 2023 and every five years thereafter

unless otherwise decided by the Conference of the Parties serving as the meeting of the

Parties to this Agreement.

3. The outcome of the global stocktake shall inform Parties in updating and enhancing,

in a nationally determined manner, their actions and support in accordance with the relevant

provisions of this Agreement, as well as in enhancing international cooperation for climate

action.

Article 15

1. A mechanism to facilitate implementation of and promote compliance with the

provisions of this Agreement is hereby established.

2. The mechanism referred to in paragraph 1 of this Article shall consist of a

committee that shall be expert-based and facilitative in nature and function in a manner that

is transparent, non-adversarial and non-punitive. The committee shall pay particular

attention to the respective national capabilities and circumstances of Parties.

3. The committee shall operate under the modalities and procedures adopted by the

Conference of the Parties serving as the meeting of the Parties to this Agreement at its first

session and report annually to the Conference of the Parties serving as the meeting of the

Parties to this Agreement.

Article 16

1. The Conference of the Parties, the supreme body of the Convention, shall serve as

the meeting of the Parties to this Agreement.

2. Parties to the Convention that are not Parties to this Agreement may participate as

observers in the proceedings of any session of the Conference of the Parties serving as the

meeting of the Parties to this Agreement. When the Conference of the Parties serves as the

meeting of the Parties to this Agreement, decisions under this Agreement shall be taken

only by those that are Parties to this Agreement.

3. When the Conference of the Parties serves as the meeting of the Parties to this

Agreement, any member of the Bureau of the Conference of the Parties representing a Party

to the Convention but, at that time, not a Party to this Agreement, shall be replaced by an

additional member to be elected by and from amongst the Parties to this Agreement.

4. The Conference of the Parties serving as the meeting of the Parties to this

Agreement shall keep under regular review the implementation of this Agreement and shall make, within its mandate, the decisions necessary to promote its effective implementation.

It shall perform the functions assigned to it by this Agreement and shall:

(a) Establish such subsidiary bodies as deemed necessary for the implementation

of this Agreement; and

(b) Exercise such other functions as may be required for the implementation of

this Agreement.

5. The rules of procedure of the Conference of the Parties and the financial procedures

applied under the Convention shall be applied mutatis mutandis under this Agreement,

except as may be otherwise decided by consensus by the Conference of the Parties serving

as the meeting of the Parties to this Agreement.

6. The first session of the Conference of the Parties serving as the meeting of the

Parties to this Agreement shall be convened by the secretariat in conjunction with the first session of the Conference of the Parties that is scheduled after the date of entry into force of

this Agreement. Subsequent ordinary sessions of the Conference of the Parties serving as

the meeting of the Parties to this Agreement shall be held in conjunction with ordinary

sessions of the Conference of the Parties, unless otherwise decided by the Conference of

the Parties serving as the meeting of the Parties to this Agreement.

7. Extraordinary sessions of the Conference of the Parties serving as the meeting of the

Parties to this Agreement shall be held at such other times as may be deemed necessary by

the Conference of the Parties serving as the meeting of the Parties to this Agreement or at

the written request of any Party, provided that, within six months of the request being

communicated to the Parties by the secretariat, it is supported by at least one third of the

Parties.

8. The United Nations and its specialized agencies and the International Atomic

Energy Agency, as well as any State member thereof or observers thereto not party to the

Convention, may be represented at sessions of the Conference of the Parties serving as the

meeting of the Parties to this Agreement as observers. Any body or agency, whether

national or international, governmental or non-governmental, which is qualified in matters

covered by this Agreement and which has informed the secretariat of its wish to be

represented at a session of the Conference of the Parties serving as the meeting of the

Parties to this Agreement as an observer, may be so admitted unless at least one third of the

Parties present object. The admission and participation of observers shall be subject to the

rules of procedure referred to in paragraph 5 of this Article.

Article 17

1. The secretariat established by Article 8 of the Convention shall serve as the

secretariat of this Agreement.

2. Article 8, paragraph 2, of the Convention on the functions of the secretariat, and

Article 8, paragraph 3, of the Convention, on the arrangements made for the functioning of

the secretariat, shall apply mutatis mutandis to this Agreement. The secretariat shall, in

addition, exercise the functions assigned to it under this Agreement and by the Conference

of the Parties serving as the meeting of the Parties to this Agreement.

Article 18

1. The Subsidiary Body for Scientific and Technological Advice and the Subsidiary

Body for Implementation established by Articles 9 and 10 of the Convention shall serve,

respectively, as the Subsidiary Body for Scientific and Technological Advice and the

Subsidiary Body for Implementation of this Agreement. The provisions of the Convention relating to the functioning of these two bodies shall apply mutatis mutandis to this

Agreement. Sessions of the meetings of the Subsidiary Body for Scientific and

Technological Advice and the Subsidiary Body for Implementation of this Agreement shall

be held in conjunction with the meetings of, respectively, the Subsidiary Body for

Scientific and Technological Advice and the Subsidiary Body for Implementation of the

Convention.

2. Parties to the Convention that are not Parties to this Agreement may participate as

observers in the proceedings of any session of the subsidiary bodies. When the subsidiary

bodies serve as the subsidiary bodies of this Agreement, decisions under this Agreement

shall be taken only by those that are Parties to this Agreement.

3. When the subsidiary bodies established by Articles 9 and 10 of the Convention

exercise their functions with regard to matters concerning this Agreement, any member of

the bureaux of those subsidiary bodies representing a Party to the Convention but, at that

time, not a Party to this Agreement, shall be replaced by an additional member to be elected

by and from amongst the Parties to this Agreement.

Article 19

1. Subsidiary bodies or other institutional arrangements established by or under the

Convention, other than those referred to in this Agreement, shall serve this Agreement upon

a decision of the Conference of the Parties serving as the meeting of the Parties to this

Agreement. The Conference of the Parties serving as the meeting of the Parties to this

Agreement shall specify the functions to be exercised by such subsidiary bodies or

arrangements.

2. The Conference of the Parties serving as the meeting of the Parties to this

Agreement may provide further guidance to such subsidiary bodies and institutional

arrangements.

Article 20

1. This Agreement shall be open for signature and subject to ratification, acceptance or

approval by States and regional economic integration organizations that are Parties to the

Convention. It shall be open for signature at the United Nations Headquarters in New York

from 22 April 2016 to 21 April 2017. Thereafter, this Agreement shall be open for

accession from the day following the date on which it is closed for signature. Instruments of

ratification, acceptance, approval or accession shall be deposited with the Depositary.

2. Any regional economic integration organization that becomes a Party to this

Agreement without any of its member States being a Party shall be bound by all the

obligations under this Agreement. In the case of regional economic integration organizations with one or more member States that are Parties to this Agreement, the

organization and its member States shall decide on their respective responsibilities for the

performance of their obligations under this Agreement. In such cases, the organization and

the member States shall not be entitled to exercise rights under this Agreement

concurrently.

3. In their instruments of ratification, acceptance, approval or accession, regional

economic integration organizations shall declare the extent of their competence with

respect to the matters governed by this Agreement. These organizations shall also inform

the Depositary, who shall in turn inform the Parties, of any substantial modification in the

extent of their competence.

Article 21

1. This Agreement shall enter into force on the thirtieth day after the date on which at

least 55 Parties to the Convention accounting in total for at least an estimated 55 per cent of

the total global greenhouse gas emissions have deposited their instruments of ratification,

acceptance, approval or accession.

2. Solely for the limited purpose of paragraph 1 of this Article, "total global

greenhouse gas emissions" means the most up-to-date amount communicated on or before

the date of adoption of this Agreement by the Parties to the Convention.

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3. For each State or regional economic integration organization that ratifies, accepts or

approves this Agreement or accedes thereto after the conditions set out in paragraph 1 of

this Article for entry into force have been fulfilled, this Agreement shall enter into force on

the thirtieth day after the date of deposit by such State or regional economic integration organization of its instrument of ratification, acceptance, approval or accession.

4. For the purposes of paragraph 1 of this Article, any instrument deposited by a

regional economic integration organization shall not be counted as additional to those

deposited by its member States.

Article 22

The provisions of Article 15 of the Convention on the adoption of amendments to

the Convention shall apply mutatis mutandis to this Agreement.

Article 23

1. The provisions of Article 16 of the Convention on the adoption and amendment of

annexes to the Convention shall apply mutatis mutandis to this Agreement.

2. Annexes to this Agreement shall form an integral part thereof and, unless otherwise

expressly provided for, a reference to this Agreement constitutes at the same time a reference to any annexes thereto. Such annexes shall be restricted to lists, forms and any

other material of a descriptive nature that is of a scientific, technical, procedural or

administrative character.

Article 24

The provisions of Article 14 of the Convention on settlement of disputes shall apply

mutatis mutandis to this Agreement.

Article 25

1. Each Party shall have one vote, except as provided for in paragraph 2 of this Article.

2. Regional economic integration organizations, in matters within their competence,

shall exercise their right to vote with a number of votes equal to the number of their

member States that are Parties to this Agreement. Such an organization shall not exercise

its right to vote if any of its member States exercises its right, and vice versa.

Article 26

The Secretary-General of the United Nations shall be the Depositary of this

Agreement.

Article 27

No reservations may be made to this Agreement.

Article 28

1. At any time after three years from the date on which this Agreement has entered into

force for a Party, that Party may withdraw from this Agreement by giving written

notification to the Depositary.

2. Any such withdrawal shall take effect upon expiry of one year from the date of

receipt by the Depositary of the notification of withdrawal, or on such later date as may be

specified in the notification of withdrawal.

3. Any Party that withdraws from the Convention shall be considered as also having

withdrawn from this Agreement.

Article 29

The original of this Agreement, of which the Arabic, Chinese, English, French,

Russian and Spanish texts are equally authentic, shall be deposited with the SecretaryGeneral

of the United Nations.

DONE at Paris this twelfth day of December two thousand and fifteen.

IN WITNESS WHEREOF, the undersigned, being duly authorized to that effect, have

signed this Agreement.

The author :

Heinrich Hafner, born in 1955, founded the company Hafner GmbH in Bozen at the age of 23 and has been a successful entrepreneur for more than 35 years.

Those that know him describe Hafner as insightful, courageous and a "humble entrepreneur with heart."

"I like to think of myself as a visionary man, with strong convictions and constantly striving for excellence," Hafner said.

He has been a passionate advocate and pioneer of waste to energy, having implemented a number of projects aimed to marry the demands of consumers with the need to protect the environment and mitigate climate change.

In the 1980s, he made a major contribution to the implementation of the South Tyrol Waste

Management Plant and has since been involved with other high profile projects such as the Mobile Special Waste Incineration Plant which has since gained worldwide recognition in the sector.

Meanwhile, his company Hafner Holding worldwide is active in more than 35 countries and helps companies, municipalities, cities and countries to establish and install inexpensive, clean, alternative energy sources.

He has also published two books – the first in 2010 entitled With Renewable Energy - Waste Is Moving The World – and the second in 2011, entitled The Energy Revolution In The Third Millennium.

Both books deal with the current climate and energy crises and pose solutions through opportunities such as energy production through waste incineration.

"We need to harness low carbon, resource efficient strategies," Hafner said.

"The climate and health of humans and animals is under threat. There is an increasing demand for energy security and we already have established, successful examples such as South Tyrol which highlight the need for more widespread use of this technology.

“Today, sustainability is the key to keeping energy prices manageable. Energy and raw materials are the gold of the third century.”

Since 2012, Hafner’s focus has been in Asia and Africa.

Following on from the Paris Climate Protection Agreement, he saw a great opportunity to educate and expand the use of waste to energy solutions.

In response, he developed a small waste incinerator SLIM LINE which can be deployed quickly and cost efficiently.

YOUR green business worldwide .

WASTE to ENERGY .

Your CHANCE for the next sustainable future .

- 7.200.000.000 people produce per year 3.150.000.000 tons waste

ONLY FROM THIS WASTE WE CAN PRODUCE (*HAFNER Technologies*) RENEWABLE ENERGY

- Electrical Energy = 220.000 MW per hour
- Heating + Cooling = 500.000 MW per hour
- And is the best solution for the waste problem (environmental protection).

YOUR green business worldwide .

CLIMATE CHANGE with Energy from Waste

- Reduce/substitute 2.835.000.000 tons Co2 per year
- With Waste you saying 12% of GLOBAL energy consumption