Systems Engineering in Environmental and Energie Systems HSLU, Semester 1

Matteo Frongillo

October 15, 2024

Contents

Part I

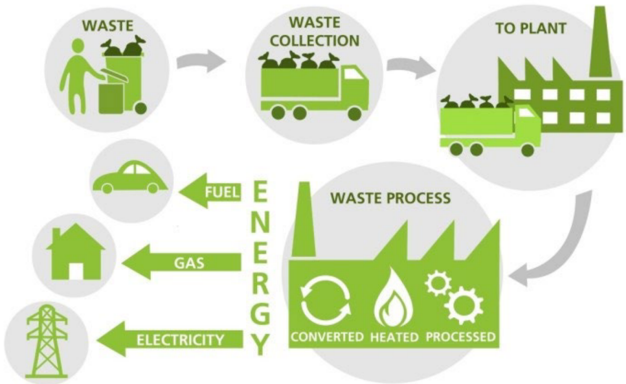
Week 1

1 Waste to energy (WtE)

Waste to energy refers to a variety of treatment technologies that convert waste to electricity, heat, fuel or other usable materials, as well as a range of residues.

WtE can occur through a number of processes such as:

- incineration;
- gasification;
- pyrolysis;
- anaerobic digestion;
- landfill gas recovery.



1.1 Incineration plants

Thermal waste to energy, also known as incineration with energy recovery, is a major waste treatment method and the most widely adopted technology that dominates the global WtE market.

An incineration plant is a waste management facility designed to burn solid waste at high temperatures, converting in into ash, gases and heat.

Incineration plays a crucial role in modern waste management strategies, contibuting to environmental protection and resource recovery.

- Volume reduction of waste (90%);
- Energy production: waste has the same energy value as wood chips or lignite;
- Reduction of contaminant spectrum: bacteria, viruses and problematic organic compounds are destroyed at or over 1'000 °C;
- Low pollutant emissions (modern incineration plants);
- Avoidance of methane emissions that results from direct deposition of organic waste in landfills;
- Chemical stability of residues/slag (compared to biological processes);
- Possibility of recovering metals from slag (80kg of iron, 20kg of aluminium and 2kg of copper are recovered per each tonne of slag).

1.1.1 Incineration plants vs. Landfills

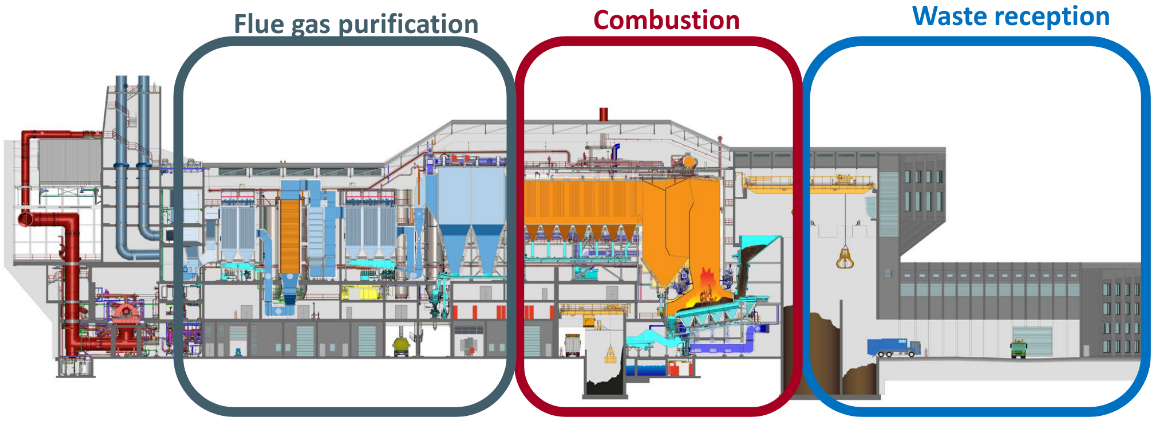
Incinerators can generate more CO_2 than landfills for every unit of electricity. Landfills, on the other hand, produce energy more effectively. However, while they don't make as much CO_2 as waste to energy incineration, they produce methane, which is stronger greenhouse gas.

Incineration plants are preferred over landfills because incineration can reduce the amount of waste which must be diverted to landfill by as much as 95%, which is an efficient method of dealing with the issue. Incineration alto eliminates the need to transport the waste to other locations or countries, thus cutting down on the emissions involved in that stage of the proces.

1.1.2 4-key Components of an incineration plant

1. Waste handling system: responsible for loading, sorting and feeding waste into the combustion chamber;
2. Combustion chamber: primary unit where waste is incinerated at temperature between 800 and 1'200 °C;
3. Air pollution control system: filters and scrubbers to minimize harmful emissions and comply with environmental regulations;
4. Energy recovery system: utilizes the generated heat to produce electricity or heat for district heating.

1.1.3 Incineration plant scheme



1.1.4 Waste incineration plants in Switzerland

There are around 30 incineration plants across Switzerland.

About four million tonnes of combustible waste from Switzerland and abroad is incinderated to generate thermal energy in municipal incinerators. The heat generated during combustion is used to produce electricity, operate district heating networks or as process heat in industrial plants.

In 2017, the 30 municipal incinerators produced a record amount of energy totalling 4'036 GWh of heat and 2'338 GWh of electricity.

They thus contribute around 2.5% of Switzerland's total energy requirements and just under 4% of the country's overall electricity production.

1.2 Types of wastes that can be converted into energy

1.2.1 Municipal Solid Waste (MSW)

Municipal wastes can be converted into energy by thermochemical or biological technologies.

At the landfill sites, gasses produced by the natural decomposition of MSW can be collected, scrubbed and cleaned before feeding into internal combustion engines or gas turbines to generate heat and power.

The organic fraction of MSW can be biochemically stabilizen in an anaerobic digester to obtain biogas (for heating and power) as well as fertilizer.

1.2.2 Wood wastes

Wood processing industries primarly include sawmilling, plywood, wood panel, furniture, building component, flooring, particle board, moulding, jointing and craft industries.

Wood wastes generally are concentrated at processing factories (e.g. plywood mills and sawmills). In general, processing 1'000 kg of wood in the furniture industries, will lead to waste generation of 45%.

Similarly, when processing 1'000 kg of wood in sawmill, the waste will amount to more than half (52%).

Wood wastes has high calorific value and can be efficiency converted into energy by thermal technologies, like combustion and gasification.

1.2.3 Agricultural wastes

Agricultural wastes include encompasses all kind of crop residues, such as bagasse, straw, stem, stalk, leaves, hush, shell, peel, pulp, stubble, ...

Large quantities of crop residues are produced annually in the MENA region, and are vastly underutilised. Dates, wheat and barley are the major staple crops grown in the Middle East region. In addition, the region has witnessed very rapid growth in the poultry sector.

1.2.4 Industrial wastes

The food processing industry in MENA produces a large number of organic wastes and by-products that can be used as biomass energy sources.

These waste materials are generated from all sectors of the food industry with everything from meat production to confectionery producing waste that can be utilised as an energy source. In the recent decades, the fast-growing food and beverage industry has remarkably increased in importance in major countries of the region.

1.2.5 Animal wastes

The MENA countries have strng animal population. The livestock sector, in particular sheep, goats and camels, plays an important role in the national economy of respective coutries.

Many millions of live ruminants are imported each year from around the world. In addition, the region has witnessed very rapid growth in the poultry sector.

1.2.6 Hazardous waste

Waste containing toxic chemicals, radioactive materials, or heavy metals can pose serious environmental and health risks. Burning or processing these materials can release harmful pollutants.

1.2.7 Non-combustible materials

Materials like glass, metals, and ceramics cannot be used for combustion-based energy recovery, since they don't burn or provide calorific value.

1.2.8 Electronic wastes (E-waste)

While some components of e-waste (like plastic) may be combustible, burning electronic waste can release toxic fumes and should instead be recycled to recover valuable materials like metals.

1.2.9 Inert construction and demolition waste

Items like concrete, bricks, and stones are not suitable for energy recovery, since they do not contain combustible materials.

1.3 Current status of waste to energy

IMMAGINE

1.3.1 Waste production per person in CH

In Switzerland, people produce 700kg of waste per person per year.

1.4 Waste hierarchy

The hierarchy helps us rethink our relationship with waste based on five priorities ranked in terms of what is best for the environment:

1. Produc prevention;
2. Preparing for re-use;
3. Recycle;
4. Recovery;
5. Waste disposal.

1.5 Advantages and disadvantages of the Swiss system

1.5.1 Advantages

...

1.5.2 Disadvantages

...

2 System thinking

2.1 Benefits

Rigorous way of integrating: people, purposes, process and performance and:

- ...

2.2 Feedback loops

...

3 Case study part 1

...

Part II

Week 2

Goal of the week:

- understand what is a system engineer's approach to structure a new task;
- know what a situation analysis consists.

4 Situation analysis and system thinking

4.1 System thinking

System thinking is a method of understanding how different elements of an intricate scenario interact and influence one another over time. It allows you to see the big picture, discover patterns and trends, and predict the outcomes of your actions.

- Enables better understanding and designing of complex phenomena;
- Lessens danger of forgetting something important.

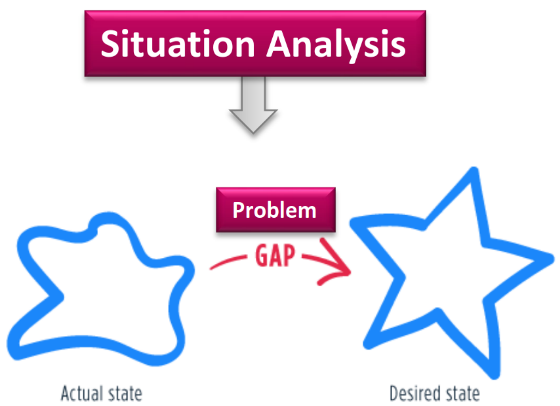
4.2 Content of a situation analysis

Situation analysis is important because permits you to:

- save a significant amount of time throughout the project's duration;
- have a clear view of complex structures;
- create overviews of communication channels, stakeholders, and resource flows, all while being user-friendly.

4.2.1 Difference between actual and desired state

A trigger to initiate the project is typically an unstructured detection of a problem, an appearance of an idea, decision to act, ...



- What is the actual state?
  Investigations and surveys are needed to find out the actual state;
- What is the desired state?
  Elaboration of desired states based on:
  - New laws and regulations;
  - Technology advances;
  - Societal changes;
- **Problem**: what are the difficulties or unused changes?

4.2.2 Task 1

The starting point of a situation analysis is based on two questions:

1. How is the actual state working today, what is happening there?
2. What are the difficulties or the unused chances?

4.2.3 Task 2

The purpose of a situation analysis is:

- to make the situation you are facing easier to understand and handle;
- to recognize the aims, tasks, and their initial situation;
- to structure and design the problem or the area under examination;
- to set out the invention and design area for the solution search;
- to create an information base for the subsequent steps of defining objectives and searching solutions.